ISSN 0711-6659

canadian acoustics
acoustique canadienne

Journal of the Canadian Acoustical Association - Revue de l'Association canadienne d'acoustique

DECEMBER 2021 DÉCEMBRE 2021
Volume 49 - - Number 4 Volume 49 - - Numéro 4

Guest Editorial - Éditorial invité 3

Engineering Acoustics / Noise Control - Génie acoustique / Contrôle du bruit 5

Musical Acoustics / Electroacoustics - Acoustique musicale / Électroacoustique 27

Psychological Acoustics - Psycho-acoustique 41

Speech Sciences - Sciences de la parole 49

Proceedings of the Acoustics Week in Canada - Actes du congrès de la Semaine canadienne d'acoustique 59

Other Features - Autres rubriques 65

Canadian Acoustical Association/Association Canadienne d'Acoustique P.B. 74068 Ottawa, Ontario, K1M 2H9

Association canadienne d'acoustique B.P. 74068 Ottawa, Ontario, K1M 2H9

Canadian Acoustics publishes refereed articles and news items on all aspects of acoustics and vibration. Articles reporting new research or applications, as well as review or tutorial papers and shorter technical notes are welcomed, in English or in French. Submissions should be sent only through the journal online submission system. Complete instructions to authors concerning the required "camera-ready" manuscript are provided within the journal online submission system.

L'**Acoustique Canadienne** publie des articles arbitrés et des informations sur tous les aspects de l'acoustique et des vibrations. Les informations portent sur la recherche, les ouvrages sous forme de revues, les nouvelles, l'emploi, les nouveaux produits, les activités, etc. Des articles concernant des résultats inédits ou des applications ainsi que les articles de synthèse ou d'initiation, en français ou en anglais, sont les bienvenus.

Canadian Acoustics is published four times a year - in March, June, September and December. This quarterly journal is free to individual members of the Canadian Acoustical Association (CAA) and institutional subscribers. **Canadian Acoustics** publishes refereed articles and news items on all aspects of acoustics and vibration. It also includes information on research, reviews, news, employment, new products, activities, discussions, etc. Papers reporting new results and applications, as well as review or tutorial papers and shorter research notes are welcomed, in English or in French. The Canadian Acoustical Association selected **Paypal** as its **preferred system** for the online payment of your subscription fees. Paypal supports a wide range of payment methods (Visa, Mastercard, Amex, Bank account, etc.) and does not requires you to have already an account with them. If you still want to proceed with a manual payment of your subscription fee, please Membership form and send it to the Executive Secretary of the Association (see address above). - - Dr. Roberto Racca - Canadian Acoustical Association/Association Canadienne d'Acoustique c/o JASCO Applied Sciences 2305–4464 Markham Street Victoria, BC V8Z 7X8 - - secretary@caa-aca.ca

Acoustique canadienne est publié quantre fois par an, en mars, juin, septembre et décembre. Cette revue trimestrielle est envoyée gratuitement aux membres individuels de l'Association canadienne d'acoustique (ACA) et aux abonnés institutionnels. L'**Acoustique canadienne** publie des articles arbitrés et des rubriques sur tous les aspects de l'acoustique et des vibrations. Ceci comprend la recherche, les recensions des travaux, les nouvelles, les offres d'emploi, les nouveaux produits, les activités, etc. Les articles concernant les résultats inédits ou les applications de l'acoustique ainsi que les articles de synthèse, les tutoriels et les exposées techniques, en français ou en anglais, sont les bienvenus. L'Association canadienne d'acoustique a sélectionné **Paypal** comme solution pratique pour le paiement en ligne de vos frais d'abonnement. Paypal prend en charge un large éventail de méthodes de paiement (Visa, Mastercard, Amex, compte bancaire, etc) et ne nécessite pas que vous ayez déjà un compte avec eux. Si vous désirez procéder à un paiement par chèque de votre abonnement, merci de remplir le formulaire d'inscription et de l'envoyer au secrétaire exécutif de l'association (voir adresse ci-dessus). - - Dr. Roberto Racca - Canadian Acoustical Association/Association Canadienne d'Acoustique c/o JASCO Applied Sciences 2305–4464 Markham Street Victoria, BC V8Z 7X8 - - secretary@caa-aca.ca

Contents - Table des matières

Guest Editorial - Éditorial invité **3**

Fighting the machines

Jérémie Voix 3

Engineering Acoustics / Noise Control - Génie acoustique / Contrôle du bruit **5**

Determination of Acoustic Characteristics of Melamine Foam with Experimental Validation

Dr. Behzad Ahmed Zai, Saad Sami, Majid Shahzad, Rashid Ali 5

Subjective Analysis Of Soundscape In Three Areas In The Brazilian City In The Legal Amazon Region

Lucas Rafael Ferreira, Erika Fernanda Toledo Borges, Giane de Campos Grigoletti 15

Musical Acoustics / Electroacoustics - Acoustique musicale / Électroacoustique **27**

A Review Of Automatic Musical Instrument Classification Based On Sound Recognition System

Wong Tee Hao, Rahizar Ramli , Ahmad Saifizul , Soong Ming Foong 27

Psychological Acoustics - Psycho-acoustique **41**

Crowdsourcing listening tests using an audio polling station

Olivier Robin, Abdelghani Benghanem, Philippe Gournay, Olivier Valentin, Philippe-Aubert Gauthier, Roch Lefebvre, Alain Berry 41

Speech Sciences - Sciences de la parole **49**

An Acoustic Analysis of Oromo and Amharic Ejective Stops

Feda Negesse 49

Proceedings of the Acoustics Week in Canada - Actes du congrès de la Semaine canadienne d'acoustique **59**

Acoustics of infrasound and audible noise inside homes near wind turbines using multichannel spectral processing

Andy Metelka 59

Other Features - Autres rubriques **65**

Acoustics Week in Canada 2021 - Post Conference Report - Semaine canadienne de l'acoustique 2021 - Rapport post-conférence 65

2021 CAA Awards Winners - Récipiendaires des prix ACA 2021 68

2022 CAA Prizes Announcement - Annonce des Prix ACA 2022 70

Acoustic Week in Canada 2022 Newfoundland Conference Announcement - Appel à communication - Semaine canadienne de l'acoustique 2022 à Terre-Neuve 71

Minutes of the 2021 CAA Board of Directors Meeting - Compte rendu de la réunion du Conseil d'administration 2021 de l'ACA 75

Minutes of 2021 CAA Annual General Meeting - Compte rendu de l'assemblée générale annuelle 2021 de l'ACA 80

CAA Announcements - Annonces de l'ACA 84

Le combat contre les machines

L'année écoulée a certainement été un défi pour nous tous, et certainement pour les bénévoles de l'Association canadienne d'acoustique qui ont dû se battre “contre les machines" ! Les serveurs qui hébergent notre journal ont été migrés vers un autre hôte après de lourdes attaques signalées par notre fournisseur de services, tout en migrant vers une toute nouvelle version de Open Journal System (OJS 3.3). Les répercussions furent nombreuses, puisque tous les scripts d'automatisation de la CAA ont été rendus inefficaces pendant un certain temps (rappels automatiques par courriel, pages web pour les abonnés de soutien et les membres du conseil d'administration, etc.), ce qui a aussi rendu la préparation du journal plus pénible, entraînant même la désindexation temporaire du journal de Google Scholar ! La situation est à nouveau sous contrôle et je suis très reconnaissant à tous les membres de la CAA pour leur patience, en particulier à Cécile Le Cocq, notre administratrice système et responsable du journal, pour son aide dans la correction des nombreux scripts et routines SQL.

En raison du contexte de la pandémie de COVID-19, notre conférence annuelle 2021 de la Semaine canadienne d'acoustique s'est tenue entièrement en ligne. Vous trouverez à la page 65, un résumé de la conférence écrit par l'équipe organisatrice de Sherbrooke, dirigée par le professeur Olivier Robin. J'aimerais profiter de cette occasion pour le remercier, ainsi que ses collègues, le Dr Sebastian Ghinet et le professeur Patrice Masson, pour leur excellent travail et pour une conférence très bien accueillie, malgré sa tenue en ligne. Je suis également heureux que cette proposition - attendue depuis longtemps - d'adhésion à tarif réduit pour les membres retraités ait finalement été approuvée lors de notre dernière assemblée générale des membres de la CAA et mise en application sur les serveurs de la CAA depuis lors.

Vous trouverez à la page 80 le procès-verbal de cette assemblée générale des membres et à la page 75 le procès-verbal du dernier conseil d'administration, tel que préparé par notre secrétaire exécutif, Roberto Racca. Dans ces procès-verbaux, vous trouverez, entre autres, les initiatives auxquelles votre conseil d'administration s’est engagées, dont :

- La mise en place d'un inventaire des programmes de forma-

Fighting the machines

This year has certainly been challenging for all of us, and it has certainly been challenging for the volunteers of the Canadian Acoustical Association who had to “fight against the machines”! The servers that were hosting our journal were migrated to a different host after a series of heavy attacks reported by our professional service providers, and at the same time the journal migrated to a brand-new version of Open Journal System (OJS 3.3) over the summer. The ripple effects were far-reaching as all the CAA’s automation scripts were ineffective for a time (automated email reminders, support webpages for subscribers and board members, etc.). This also resulted in making the journal preparation more difficult and at one point, the journal was even de-indexed from Google Scholar! The situation is back under control, and I am very grateful to all CAA members for their patience and understanding, and particularly to Cécile Le Cocq, our system administrator and journal manager, for her assistance in fixing our many SQL scripts and routines.

Due to the current context of the COVID-19 pandemic, our annual 2021 Acoustics Week in Canada Conference was held entirely online. You will find on page 65, a summary of the conference by the organizing committee from Sherbrooke, led by Professor Olivier Robin. I would like to take this opportunity to thank him and his colleagues Dr. Sebastian Ghinet and Professor Patrice Masson, for their excellent work and for a very well received conference, despite its online modality. I am also happy to announce that the – long-awaited proposal – of a reduced-fee membership for retired members was approved during our last CAA’s Member General Assembly. Please note that this change has since been implemented on the CAA’s servers.

You will find on page 80 the minutes of the Member’s General Assembly and on page 75 the minutes of our last Board of Directors meeting, as prepared by our Executive Secretary, Roberto Racca. In these minutes you will find, among other things, the initiatives that your board has committed to, including:

- The creation of an Inventory of Acoustical Training Programs across Canada, intended to become an online repository of all the professional, undergraduate, and graduate courses /t rainings offered through universities, colleges, associations, etc.

tion en acoustique à travers le Canada, visant la création d'un annuaire en ligne de tous les cours et formations professionnelles, de premier cycle et de deuxième cycle offerts par les universités, collèges, associations, etc.

- Une mise à jour de nos procédures, afin de refléter l'évolution des rôles clés au fil du temps (rédacteur en chef, responsable des médias, etc.) et afin d'être mis à la disposition de tous les membres via un wiki.
- Une section "Practitioners' Corner" rajeunie dans notre journal, avec certains de nos directeurs qui battent le tambour et sollicitent davantage d'articles auprès des membres industriels.
- Un pack linguistique mis à jour pour le site de la revue Acoustique canadienne, afin de refléter le langage spécifique de notre association (par exemple, OJS parle nativement d'un "abonnement" alors que nous voulons vraiment dire "adhésion").
- Une adaptation de ce clip vidéo français sur "Qu'est-ce qu'un acousticien?" (https://www.youtube.com/watch?v=AjUNHyM_BNk) à la réalité canadienne.
- Le déploiement d'un système de gestion des annonces qui simplifierait le travail de notre responsable de la publicité et qui informerait automatiquement les annonceurs de la CAA de l'expiration imminente de leur " forfait " tout en leur permettant d'accéder au journal.

La CAA est entièrement gérée par des bénévoles et tous les membres sont les bienvenus. À ce propos, j'aimerais souhaiter la bienvenue à la professeure Victoria Duda qui a été nommée coordinatrice des prix. Elle remplace la professeure Joana Rocha, que je remercie pour les excellents services qu'elle a rendus ces dernières années à ce poste. Entre-temps, nous avons toujours besoin d'aide pour la migration de notre site web principal vers WordPress ainsi que pour le développement d'un kit de démarrage pour les sections locales de la CAA... si vous connaissez quelqu'un qui pourrait être intéressé! ;-)

Mais je ne veux pas vous empêcher de vous plonger dans ce numéro du journal, alors sur ce, je vous souhaite de très bonnes fêtes de fin d'année.

Jérémie Voix
Président

- An update of our Operations and Procedures Manual, to reflect the evolution of key roles over time (Editor in Chief, Media Manager, etc.). This will be available to all members through a wiki page.
- A refreshed "Practitioners' Corner" section in our journal Canadian Acoustics, and some beating of the drum to solicit more papers from industrial members.
- A special section in the Canadian Acoustics journal website, to clarify the semantics of our association (for example, OJS speaks of "subscription" when we really mean "membership").
- The adaptation of this video clip from France on "What's an acoustician" to reflect our Canadian reality (https://www.youtube.com/watch?v=AjUNHyM_BNk)
- The deployment of an Ad Management System to simplify the tasks related to advertising. This system will automatically notify CAA advertisers that their "package" is about to expire and also enable them to access the journal.

The CAA is entirely run by volunteers and all members are welcome to join forces. On that note, I would like to extend a warm welcome to Professor Victoria Duda who has been appointed as our Award Coordinator. She is replacing Professor Joana Rocha, who I thank for her great service over the last years. Meanwhile, we still need help for our core website migration into WordPress as well as for the development of some starter kits for CAA Local Chapters... if you know anyone who could be interested! ;-)

But I don't want to keep you any further from digging into this journal issue, so I'll simply wish you all a very happy holiday season.

Jérémie Voix
President

Determination of Acoustic Characteristics of Melamine Foam with Experimental Validation

Behzad Ahmed Zai*[1], Saad Sami†[1], Majid Shahzad‡[1], Rashid Ali♦[2]
[1]Space and upper atmosphere research commission, Pakistan
[2]Materials and chemical engineering, Ghulam Ishaq Khan institute of engineering sciences and technology, Pakistan

Résumé

Les lanceurs spatiaux subissent des charges dynamiques sévères tout au long du vol. Les charges acoustiques sont l'une de ces charges qui sont très critiques pour le lanceur au moment de l'allumage et du décollage. Les amplitudes des charges acoustiques sont généralement très élevées et doivent être diminuées pour économiser les composants électroniques. En règle générale, l'un des matériaux isolants les plus courants et les plus efficaces est la mousse de mélamine (MF). Dans cet article, les panneaux MF de réduction du bruit acoustique et environnemental d'épaisseurs variables (25, 50 et 75 mm) sont analysés. Un logiciel commercial FEA est utilisé pour estimer les paramètres acoustiques qui sont validés expérimentalement à l'aide d'un tube d'impédance, basé sur la méthode des matrices de transfert. Le tube d'impédance peut mesurer le coefficient d'absorption acoustique incident normal et la perte de transmission pour la gamme de fréquences de 64 Hz à 6,2 kHz. Un tube d'impédance classique à deux microphones est connecté à un porte-échantillon en aval de la première paire de microphones et à une section en aval du porte-échantillon qui accueille une seconde paire de microphones. Deux agencements séparés de tube d'impédance sont utilisés pour mesurer le coefficient d'absorption et la perte de transmission. La FEA et les résultats expérimentaux sont comparés et trouvés dans de bons accords. De plus, l'épaisseur de mousse d'isolation optimisée est obtenue en fonction des paramètres acoustiques requis.

Mots clefs : Mousse de mélamine, coefficient d'absorption, perte de transmission, niveau de pression acoustique, tube d'impédance

Abstract

Space launch vehicles experience severe dynamic loadings throughout the flight. Acoustic loads are one such load which are very critical to the launch vehicle at the time of ignition and take off. The amplitudes of acoustic loadings are generally very high and required to be diminished to save electronic components. Typically, one of the most common and efficient insulating material is Melamine Foam (MF). In this paper, the acoustic and environmental noise reduction MF panels of variable thicknesses (25, 50 and 75mm) are analyzed. Commercial FEA software is used to estimate the acoustic parameters which are experimentally validated using impedance tube based on transfer matrix method. The impedance tube can measure the normal incident sound absorption coefficient and transmission loss for frequency range of 64 Hz to 6.2 kHz. A conventional, two-microphone impedance tube, is connected to a sample holder downstream of the first microphone pair and a section downstream of the sample holder that accommodates a second pair of microphones. Two separate arrangements of impedance tube are used to measure the absorption coefficient and transmission loss. The FEA and experimental results are compared and found in good agreements Furthermore, the optimized insulation foam thickness is obtained based on required acoustic parameters.

Keywords: Melamine foam, absorption coefficient, transmission loss, sound pressure level, impedance tube

1 Introduction

In space missions, satellite launch system encounters a wide range of broadband noise loads. Therefore, acoustic emission and transmission must be studied during critical instants of a launch system including maximum dynamic pressure condition, transonic flight condition and lift off.

The upper stages of launch system are subjected to extreme broad band and random acoustic excitation. The high velocity jet noise emitted from the rocket boosters is reflected back to payload from the launching platform at the time of lift-off, consequently compromising the entire mission. Sound pressure level (SPL) inside a fairing cavity could reach to 120–140 dB which can cause significant damage to sensitive elements (e.g. solar panel and power supply). For the determination of SPL inside fairing, a vibro-acoustic environmental analysis must be carried out. Numerical prediction of vibro-acoustic response of satellite launch vehicle is a prerequisite so that the noise control engineer could effectively optimize the vehicle system [1-3]. Therefore, it is a standard operating procedure to qualify payloads under launch environment response conditions before flight [4].

While designing for acoustic noise attenuation, the upper parts of the launchers such as payload fairing and bays have

* behzad_zai@pnec.nust.edu.pk
† saadme79@gmail.com
‡ dr_majid@engineer.com
♦ rashidali@giki.edu.pk

the prime importance. Passive techniques with acoustic blankets were used by Glaese and Anderson [5], they presented structural-acoustic modeling for a full-scale composite launch vehicle payload fairing. The purpose of these analyses and experimental efforts was to provide data and valid models that will be used for active acoustic control for payload fairing. Furthermore, they implemented a closed-loop acoustic transmission reduction that was measured on a full-scale composite payload fairing. There are two approaches which are adopted to reduce SPL in fairing. The first is by increasing the transmission loss along the fairing's wall, this approach will increase the design cost and reduce mass ratio of optimized design. Thus, the second approach is more commonly used to absorb the acoustic load. It is achieved with the help of an acoustic blanket of optimized thickness. For this purpose, the most commonly used porous material is MF.

Among commonly used porous materials, MF was characterized by its light weight, high flexibility and high sound absorption coefficient within a mid-high frequency noise range [6, 7]. Moreover, MF was experimentally demonstrated by National Aeronautics and Space Administration (NASA) to have superior noise attenuation performance as traditional acoustic blankets [8-10]. Li et al [11] paid great efforts to investigate noise reduction in a cylindrical cavity with MF lining within the low-medium frequency range (100–400 Hz). They derived natural frequencies of the cylindrical cavity with presence of locally and non-locally reacting liners from theories of the cylindrical cavity lining. They demonstrated that MF lining could achieve noise reduction by up to 4–8 dB within the low and medium-frequency range. Furthermore, different porous material was used by many other researchers as noise attenuation blankets to attenuate sound energy by trapping and dissipating it in the form of heat [12-18].

The acoustical performance of blanket materials can be characterized in many ways, since knowledge of different parameters, such as Biot´s parameters, are significant when acoustic noise control treatment designs are specified. Biot´s parameters include physical properties such as porosity, density, resistivity, tortuosity, thermal characteristic lengths and viscosity of the material being used. These parameters are necessary in the computation of absorption and transmission loss of the acoustic foam and are usually provided by the material manufacturer, if not can be measured experimentally as presented by Lauriks [19].

In recent years, the advancement in the utilization of MF along with other material is being carried out by different researchers. Ji et. al [20] investigated a porous labyrinthine type of acoustic metamaterials (LAMs), a sort of acoustic meta surface, analytically, numerically, and in laboratory tests. The LAMs are composed of a series of porous elements, where stainless steel plates with various lengths are inserted into the MF. Moreover, Yang et al. [21] explored the physical properties and corresponding mechanism of MF which was modified by phenolic resin. They found out that this phenomenon had a significant effect on the pore size of MF. There was a remarkable improvement in sound transmission loss (STL) compared to that without phenolic resin. However, STLs did not increase monotonically.

The acoustic properties of a porous material are first estimated analytically. Therefore, Finite Element Techniques are extensively useful in resolving problems arising in different industrial sector. COMSOL is one such software being used for solving complex acoustic problems which basically revolve around pressure waves in a fluid. The acoustics mode provides two types of analysis; Time-Harmonic and Eigen-Value [22]. Zheng et al. [23] utilized COMSOL to develop acoustic models for high frequency resonators of a Turbo charged internal combustion engine. Using the software, the realistic flow patterns of the possible 3D effects were observed for losses incurred during combustion. Another experimental work was presented using two-source location technique to obtain two-port matrices and transmission losses of four sample resonator with varying the mean flow speeds. Tomasz [24], presented a numerical method for the calculation of frequency dependent sound transmission loss within a reflective pipe with outlet to acoustic-free space using COMSOL.

For experimental validation of results obtained using Finite Element Analysis (FEA), the impedance tube method is commonly used to measure the normal incident sound absorption coefficient and transmission loss for different materials [25]. Bolton et al. [26] described a method for measuring the normal incidence transmission loss and related acoustical properties of a sample placed in a four-microphone standing wave tube. The similar work was presented by Hua and Herrin [27], they used the two-load method to determine the transmission loss of a muffler or silencer. Several practical measurement considerations were examined. The use of the impedance tube is not only limited to measure the acoustic parameter of porous material but also used in variety of applications such as fluid and soil transmission loss measurements [28-30].

Berardi considered natural fibers as a valid raw material for producing sound absorbing panels at a reduced cost. Moreover, these fibers often have good thermal insulation properties [31]. Similar research on natural fiber and nano fiber is presented by Iannace et al. [32, 33]. They characterized natural materials as an alternative to traditional synthetic materials in the fields of acoustic treatments and energy saving. Furthermore, researcher used artificial intelligence for acoustic characterization of different material [34]. These researchers performed very useful research in the field of acoustic and presented different alternatives which can be used as an effective acoustic material.

In this paper, the theory underlying the transfer matrix approach is described first, then followed by a description of the experimental setup using impedance tube. Various results, including the normal incidence transmission loss and absorption coefficients are then presented for an acoustic insulation of variable thickness MF both numerically and experimentally. The working frequency range is described with the placement of small and large diameter tubes. The resonance features are obtained due to sample constraint around its edges for both absorption coefficient and transmission loss. The acoustic characteristics at different thicknesses of

MF are presented for estimation of required insulation blanket within payload fairing to protect satellite and other electronic components from harmful noise effect.

2 Analytical relation

The material absorption coefficient is an important parameter which is characterized by its normal or random incidence characteristics. The ISO standard 10534-2-(1998) illustrates the well-known process to determine the absorption and impedance characteristics of noise insulating materials through "two microphones" or "transfer-function" method for as shown in Figure 1.

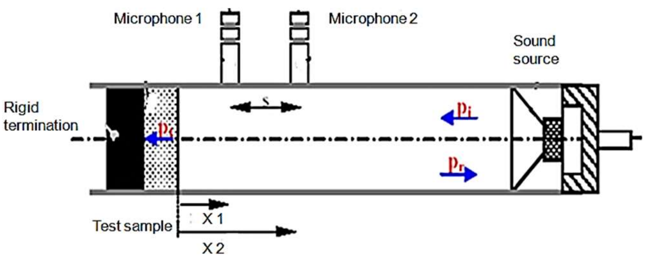


Figure 1: Two microphone impedance tube for the measurement of absorption coefficient

The transfer function method mainly relied upon the ratio of the sound pressures of the reflected and the incident wave at termination (at x = 0), given by Eq. (1) [35]. The absorption coefficient relation for materials is given in Eq. (2).

$$R = [(H_{12} - e^{-jks})/(e^{jks} - H_{12})](e^{j2ki}) \quad (1)$$

$$\alpha = 1 - |R^2| \quad (2)$$

Absorption coefficient for random incidence can also be measured in a reverberant room, where the acoustic diffuse fields can be simulated with approximation. The transmission loss computation of noise absorbent materials is essential in building acoustic and environmental noise reduction studies. Internationally, impedance tube method is widely adopted for determining the sound absorption coefficient, [36]. However, there is no international standard procedure of measuring sound transmission loss when used in conjunction with the impedance tubes. Bolton et al. [37] modified a sound absorption measurement impedance tube so that it could be used in measuring the sound transmission loss of automotive sealant materials. Ho et al. [38] measured the sound transmission of perforated panels with an impedance tube somewhat similar to Bolton's measurement system, the differences among two is the type of sample holder and a monotonic wave. More recently, a commercial sound transmission measuring system, proposed by Ryu (2000), has become available i.e., the B&K 4206T transmission loss tube kit. Generally sound transmission loss measurement tubes comprise of three parts: the upstream tube, the sample holder and the downstream tube. They implemented enclosed boundary conditions in the downstream tube with a semi-anechoic termination whereas Ryu [39] tested with both open and closed boundary conditions during his work.

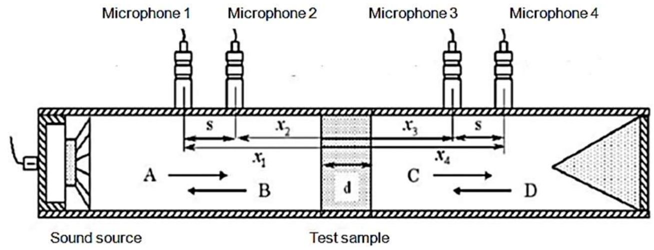


Figure 2: Four microphone impedance tube for the measurement of transmission loss

The impedance tube used for computation of transmission loss is shown in Figure 2. A set of two microphones (MP1 & MP2) are mounted in the up-stream tube, similarly two microphones (MP3 & MP4) are mounted in the downstream tube to measure both incident and reflected waves. The reference position (x = 0) is given as the front surface of a sample: x_1, x_2, x_3, x_4 denote each microphone's position. If a one-dimensional plane wave in the tube is assumed to be $pe^{j(wt-kx)}$ then the Fourier components of the sound pressure at micro-phone placed at positions 1, 2, 3 and 4, after eliminating the time-dependent term, can be expressed by the following equations [40].

$$p_1 = Ae^{-jkx_1} + Be^{jkx_1} \quad (3)$$

$$p_2 = Ae^{-jkx_2} + Be^{jkx_2} \quad (4)$$

$$p_3 = Ae^{-jkx_3} + Be^{jkx_3} \quad (5)$$

$$p_4 = Ae^{-jkx_4} + Be^{jkx_4} \quad (6)$$

Eq. (3) - (6) can be rearranged to solve for the coefficients A to D as shown in Eq. (7) - (10)

$$A = [j(p_1 e^{jkx_2} - p_2 e^{-jkx_2})/2 \sin k(x_1 - x_2)] \quad (7)$$

$$B = [j(p_1 e^{jkx_2} - p_2 e^{-jkx_2})/2 \sin k(x_1 - x_2)] \quad (8)$$

$$C = [j(p_1 e^{jkx_2} - p_2 e^{-jkx_2})/2 \sin k(x_1 - x_2)] \quad (9)$$

$$D = [j(p_1 e^{jkx_2} - p_2 e^{-jkx_2})/2 \sin k(x_1 - x_2)] \quad (10)$$

In order to simplify the equation, the two microphones were placed at an equal distance. The transmission coefficient (*T*) is defined by the ratio *C/A* and the transmission loss (*TL*) equals$-20 \log|H_t|$:

$$TL = 20 \log|(e^{jks} - H_{12})/(e^{jks} - H_{34})| - 20 \log|H_t| \quad (11)$$

Where, $s = |x_1 - x_2| = |x_3 - x_4|$, $H_{12} = p_2/p_1$ is the transfer function, which is the ratio of the Fourier-transform component between the sound pressures at positions 1 and 2 and $H_{34} = p_4/p_3$ is the transfer function, which is the ratio of the Fourier-transform component between the sound pressures at positions 3 and 4. $H_t = \sqrt{|S_d/S_u|}$. White noise was generated by the spectrum analyzer and the noise signal was simultaneously measured using all 4 microphones.

3 Acoustic analysis

3.1 Absorption coefficient

Absorption properties of open cell and acoustic proofing foam is computed using pressure acoustic model of analytical software. In porous materials, acoustic wave travels through a complex arrangement of small interconnected pores. Since the pores are small, losses usually arise due to heat conduction and friction. Porous foams are not only used in the sound proofing of rooms and ducts but also to mitigate reverberation problems in closed spaces. The aim of this model is to distinguish the absorption properties more specifically, the surface impedance and the absorption coefficient of a layer of acoustic foam in terms of frequency. A 2D model is employed to simulate the absorption behavior of the porous material over a wide range of frequency band.

Figure 3 depicts the schematic and simulation results for the measurement of absorption coefficient. It is shown that an incident sound wave strikes the surface of the porous MF at an angle of 90 degrees. Only a small portion of domain width is modeled and the periodic Floquet conditions are applied on the left and right boundary to extend the domain to infinity. A plane wave radiation condition is applied at the top of the domain. MF is modeled as a rigid porous elastic material and the material parameters used in the simulation model are listed in Table 1. A rigid surface is used at the bottom to eliminate further transmission of the incident wave. The surrounding fluid domain consists of air. Sound wave are travelling from top to bottom and subsequent acoustic energy suppressions are encountered in MF.

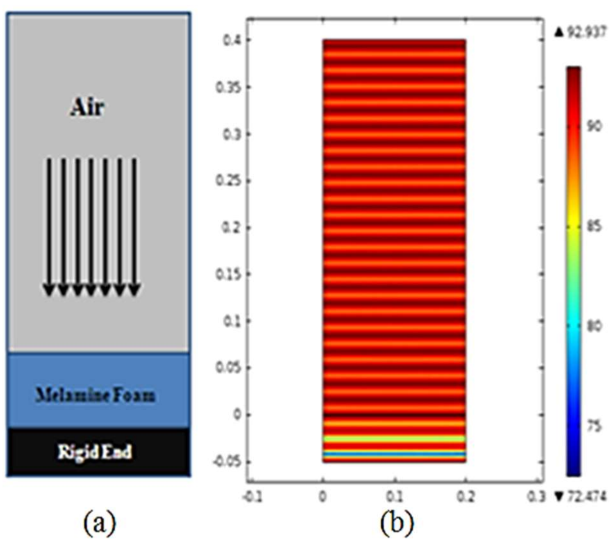


Figure 3: (a) Schematics for absorption coefficient, (b) numerical simulation results for absorption coefficient

Table 1: Melamine material parameters for absorption coefficient Computation

Quantity	Unit	Value
Porosity	-	0.995
Flow resistivity	Pa·s/m^2	10,500
Viscous characteristic length parameter	-	0.49
Thermal characteristic length	μm	470
Viscous characteristic length	μm	240
Tortuosity factor	-	1.0059

3.2 Transmission loss

The Poro-elastic waves interface method is utilized to compute the transmission losses. The Poro-elastic wave model describes as the small deformation elastic waves propagating in a porous material coupled to waves in a fluid. The model accounts for the coupled displacement of the fluid/structure making it a fluid-structure interaction problem. The 2D axisymmetric geometry is shown in Figure 5. The central portion contains MF, acting as acoustic insulation material and air in the rest of the system. The porous material is assumed to be isotropic with parameters as listed in Table 2. The acoustic pressure level throughout the domain is also shown in Figure 4. Sound wave travelling from bottom to top and subsequent acoustic energy suppression is encountered in MF.

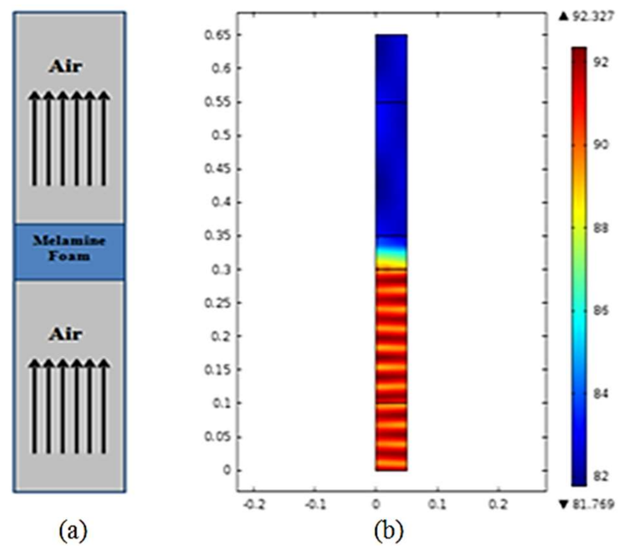


Figure 4: (a) Schematics for transmission loss, (b) numerical simulation results for transmission loss

Table 2: Melamine material parameters for transmission loss computation

Quantity	Unit	Value
Density	kg/m^3	9
Young's modulus	kPa	180
Poisson's ratio	-	0.46
Biot-Willis coefficient	-	1
Porosity	-	0.995
Permeability of porous matrix	m^2	1.5e-9

4 Experimental setup

4.1 Introduction

VA-Lab2 IMP is the software code used for the computation of absorption coefficient and transmission loss. The hardware comprises of impedance tube setup and data acquisition system. The Transfer function method uses a set of two microphones to acquire pressure level by a sound generating source near the sample. VA-Lab IMP can accurately separate the incident wave from reflecting wave to measure absorption coefficient. An extended frequency range can be obtained from the combination of measurement results gained from the tubes of different diameters. VA-Lab2 IMP supports the 2-channel hardware to measure absorption coefficient and VA-Lab4

IMP supports four microphones transfer function method to measure transmission loss [41].

4.2 Sample Type

MF is selected porous material for this study of sound attenuation. It is an open cell foam made from melamine resin which is a thermoset polymer. This foam comprises of three-dimensional network structures consisting of slender and easily shaped filaments. Key characteristics of this foam are:

- Low density and high acoustic absorption capacity
- Good heat insulation properties
- Can withstand temperature up to 240° C

Foam samples of two different diameters (100mm & 30mm) are used to measure transmission losses and absorption coefficients for two different sizes of impedance tube. Test samples are shown in Figure 5

Figure 5: Testing samples of melamine foam (100 mm & 30 mm diameters)

4.3 Testing Setup

Setup of absorption coefficient testing system is shown in Figure 6. To measure the absorption coefficient of material, Source tube and Sample holder are necessary. The sound will be generated via loudspeaker located at the extreme left side and sample holder is located at extreme right of the tube. Two microphones are used to capture the sound energy level before and after absorption. Data acquisition board & a Lab VIEW system are used to gather and process the data. Microphones are positioned in such a way that all the frequency range of interest (64 Hz to 6.3 kHz) should easily be captured.

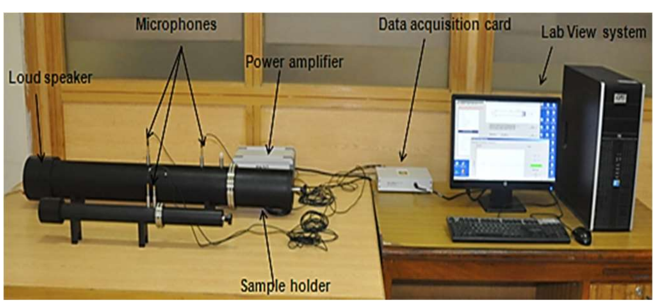


Figure 6: Complete experimental setup for the measurement of absorption coefficient**.**

Setup for measurement of transmission loss is shown in Figure 7. To measure transmission loss, sample holder is replaced by extension tube. The sound will be generated via loudspeaker from the extreme left position; extension tube is attached with the source tube at extreme right, and sample is placed between source tube and extension tube. Two microphones are positioned on the upstream and two are placed on the downstream region. Four microphones are used to measure the sound energy level before and after transmission. Data acquisition system processes these energy levels and provides the transmission loss. Microphones are positioned to capture desired range of frequency from 64 Hz to 6.3 kHz.

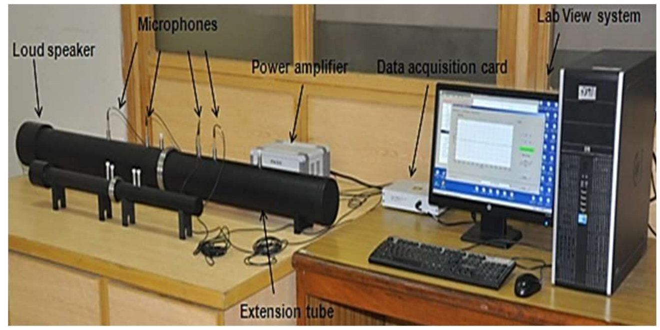


Figure 7: Complete experimental setup for the measurement of transmission loss

For both absorption coefficient and transmission loss, the parameters including tube diameter, distance between two microphones and the distance from the sample to the nearest microphone decide the working frequency range. The data out of this pre-defined range of frequency will be inaccurate. The environmental conditions such as atmospheric pressure, temperature, humidity, velocity and characteristic impedance should be accurately defined.

As per testing standard, the loudspeaker should work at least 10 minutes before testing. The different positions of microphones work in different effectual frequency range, curves out of the range will be random. For both type of testing, the test sample shall fit snugly in the holder. However, it shall not be compressed unduly nor fitted so tightly that it bulges. It is recommended to fill in the interspaces by using Vaseline or Plasticine between the sample and the tube. The test sample can be held firmly, if necessary, by adhesive tape or grease. For example, samples such as carpet material should be firmly attached to the back plate using double-sided adhesive tape to avoid vibration and unwanted air gaps. Most of the specimen, even the uniform one, should be tested repeatedly. Absorption coefficient of the same sample in different diameter tubes will be dissimilar mostly because of the dimension of the specimens and the situation of specimens' edge. Uncertainties to the determined acoustic material properties would come from material samples and placement, bias errors and reference plane definition.

5 Result and Discussion

5.1 Absorption coefficient

The absorption coefficients of the three samples (25mm, 50mm and 75mm) is measured using both the small and large tubes as shown in Figure 8 to Figure 12 for working frequency range of 64 Hz to 6.3 kHz. This range is achieved with three arrangements. First is from 63 Hz to 500 Hz with wide spacing of microphones. Second is from 400 Hz to 1600 Hz with normal spacing. The third arrangement is from 1600 Hz to 6.3 kHz with small diameter tube and normal spacing of microphones. The flow resistance of the material under test is relatively low, and because the sample is effectively anechoically-terminated, most of the incident energy is either transmitted through the sample or is dissipated within it. As a result, the magnitude of the reflection is relatively low consequently having higher absorption coefficient except at the lower frequencies where the sample is stiffened by the effect of the edge constraint. It may be seen, as expected, that the absorption coefficients are nearly unity, except at the lower frequencies.

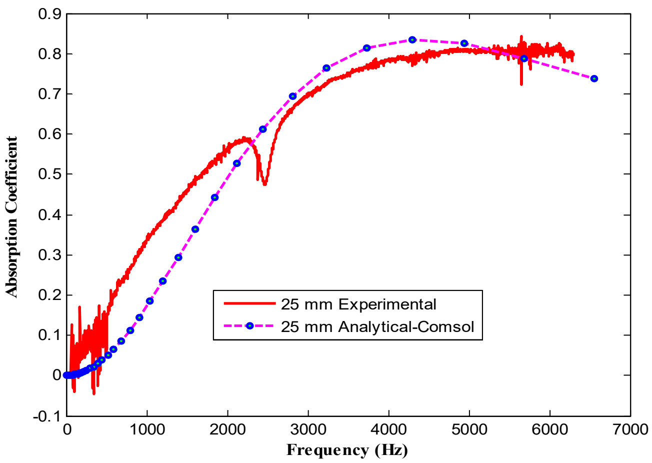


Figure 8: Absorption coefficient for 25 mm thick melamine foam

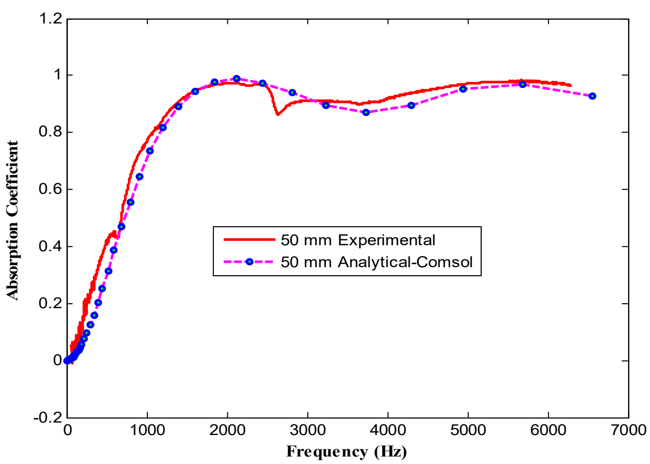


Figure 9: Absorption coefficient for 50 mm thick melamine foam

Note also that there are resonance features at two different locations of all three samples. This behaviour is typical of the effect of sample edge constraint on the normal incidence absorption loss of an elastic porous material [42]. The two features represent the effects of the first two diaphragm-like modes of the samples in which the sample experiences a pure shearing motion. The frequencies at which these features occur are inversely proportional to the sample diameter and are directly proportional to the square root of the ratio of the shear modulus and density of the sample. Thus, the first resonance in the large tube case occurs at approximately one-quarter of the resonance frequency observed in the small tube. The similar relation exists in the difference of diameter of the impedance tube (100 mm & 30 mm). These features are not visible in FEA results because the acoustic analysis is performed on infinite plate sheet where the sample edge constraint effect does not exist.

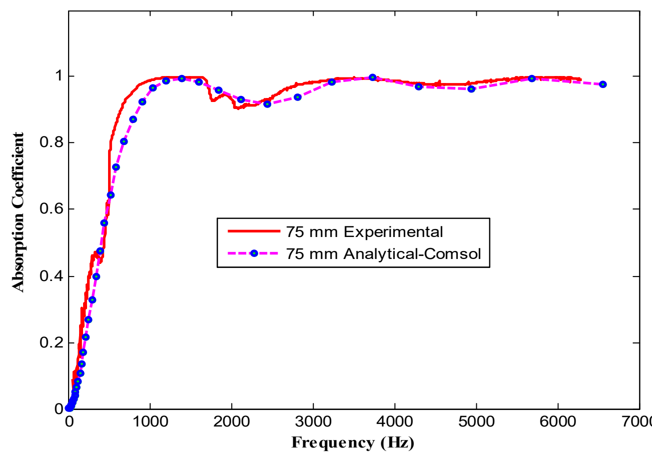


Figure 10: Absorption coefficient for 75 mm thick melamine foam

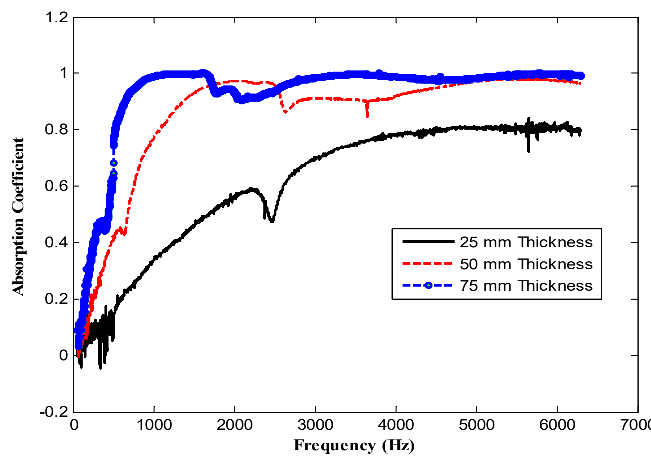


Figure 11: Combined absorption coefficient plot for three thicknesses (Experimental)

Figure 8 – Figure 10, show that the numerical and experimental results are in good agreement. The saturation in absorption coefficient is achieved at lower frequencies as the thickness of the sample is increased. For 25mm thickness sample, total absorption is achieved in between 4,000-5,000 Hz, for 50 mm sample around 2,000 Hz and for 75mm thickness around 1,000 Hz. Combined absorption coefficient plot for three different thickness samples is shown in Figure 11. It can be observed that the absorption coefficient is increasing with the frequency and maximum value of 0.8 is achieved at 4,200Hz for 25mm thickness. Saturation in absorption coefficient is achieved much earlier for higher thickness samples.

These results are compared with other published research as shown in Figure 12. Doutres et al. (2010) used the similar setup and found out acoustic properties of a porous material. The trend and magnitude of absorption coefficient are similar to present research. The saturation of absorption coefficient at the value of 1.0 is achieved at almost same frequency resulting that the properties of the material are almost similar to the MF. However, the slight variation could be because of variation in thickness and change of material properties of test samples. Furthermore, in published research the resonance features are not evident which are highlighted in present research. The prior information of these features can be extremely useful for design and to avoid any possible failure at these critical frequencies.

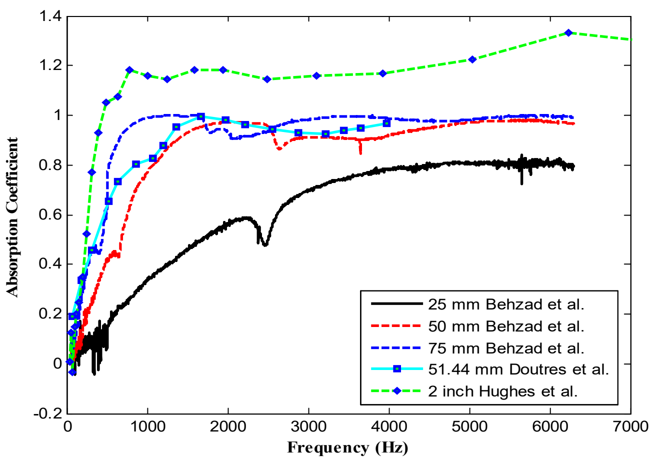


Figure 12: Result comparison for absorption coefficient with published research

Another researcher Hughes et al. (2014) from NASA carried out similar research on variety of test samples including 2 in MF for absorption coefficient only. However, the boundary conditions were different. They used a flat panel rather a cylindrical tube type boundary conditions. They used a higher quality of MF, thus, having better material properties. The active frequency range is same which suggest that both material have a tendency to attenuate the sound wave for a wide frequency range.

5.2 Transmission loss

Transmission loss of all three samples (25mm, 50mm and 75mm) is estimated first through FEA and later validated with both large and small diameter impedance tube as shown in Figure 13 to Figure 16. It is shown that the transmission loss increases monotonically with increasing frequency as expected for a porous layer. The working frequency range is from 64 Hz to 6.3 kHz. Note also that there are resonance features at approximately 450 Hz and 1800 Hz appears in the large and small tube results respectively. This behaviour is typical of the effect of sample edge constraint on the normal incidence transmission loss of an elastic porous material. The similar features are observed in the measured absorption coefficient. Thus, the first resonance in the large tube case occurs at approximately one-quarter of the resonance frequency observed in the small tube. The similar relation exists in the difference of impedance tube diameters (100 mm & 30 mm). These features are not visible in FEA results because the acoustic analysis is performed on infinite plate sheet where the sample edge constraint effect does not exist.

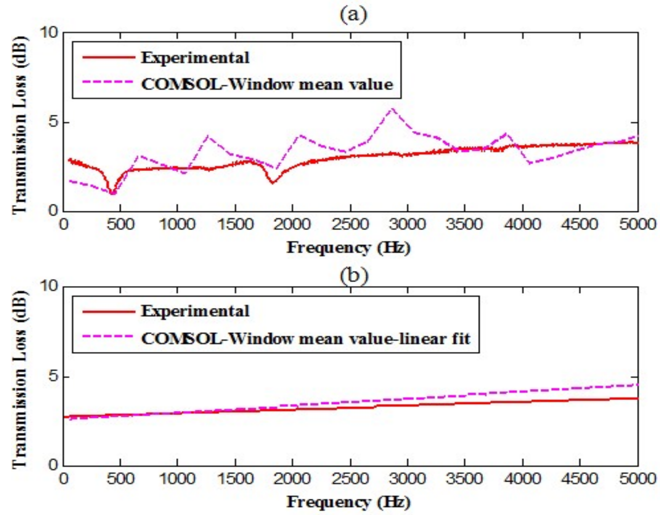


Figure 13: Transmission loss for 25 mm thick melamine foam

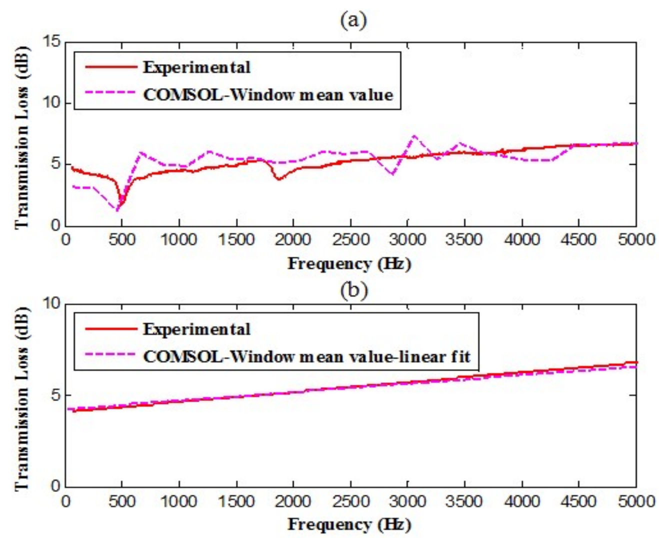


Figure 14: Transmission loss for 50 mm thick melamine foam

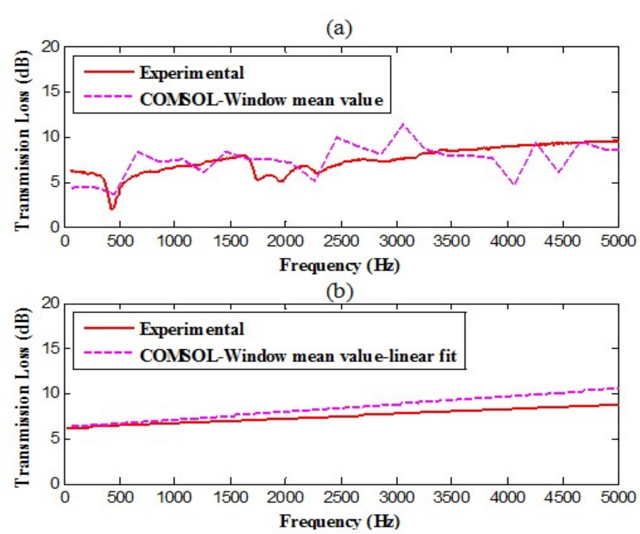


Figure 15: Transmission loss for 75 mm thick melamine foam

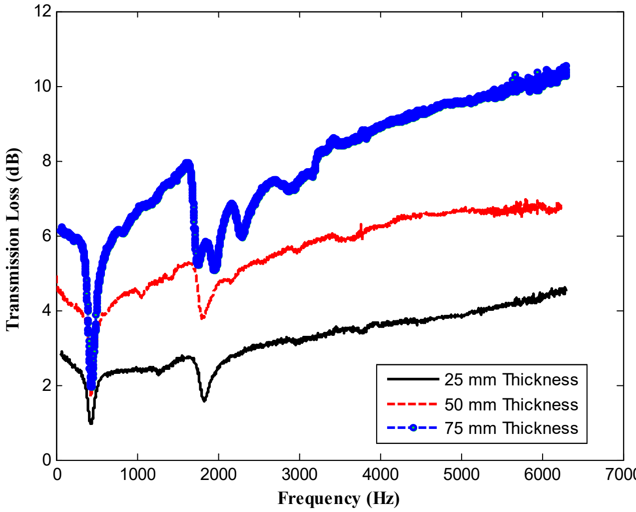


Figure 16: Combined transmission loss plot for three thicknesses (Experimental)

Nonetheless, a close examination of the data shows that the transmission loss does increase with decreasing frequency below the first resonance in both the large and small tube results. Thus, at low frequencies the sample edge constraint causes the normal incidence transmission loss of a porous sample measured in a tube to differ from that of a laterally infinite plane sheet of the same material as depicts in FEA results. This effect becomes more significant as the flow resistivity of the samples increases (therein increasing the strength of the coupling between the solid and fluid phases of the material) and the shear stiffness of the sample increases in proportion to its bulk density (increasing the frequency of the diaphragm-like resonances).

Figure 13 (a) - Figure 15 (a), show that the analytical results obtained via commercial FEA software and experimental results are in good agreement. It is observed that the trend of both approaches are same, however there is larger variation in analytical results around the experimental value. Therefore, a mean window operation is applied to the data. In this approach the mean of five consecutive values are computed and plotted against the mean frequency. An additional processing in the analytical data is performed with the assumption that the data acquired from experimental setup is being processed. Figure 13 (b) – Figure 15 (b) show the linear fit plot for both analytical and experimental results, these plots follow each other and are in good agreement.

Combined transmission loss plot for three different thickness samples is shown in Figure 16. It is observed that the transmission losses are increasing with the frequency except for ~ 450Hz & ~1,800 Hz, where a resonance effect is evident. Furthermore, an appreciable increase in transmission losses is observed with the increasing foam thickness. Similar to absorption coefficient, the results of transmission loss are compared with other published research as shown in Figure 17. Doutres et al. (2010) used the similar setup and found out acoustic properties of a porous material. The trend and magnitude of transmission loss are similar to present research. Like the absorption coefficient, the magnitude of transmission loss is higher compared to 50 mm MF because of higher thickness and better physical properties. In published research, the resonance features are evident similar to present research at displaced frequencies. Another researcher Hughes et al. (2014) from NASA carried out similar research on variety of test samples for transmission loss. However, the sample configuration was different from the present research.

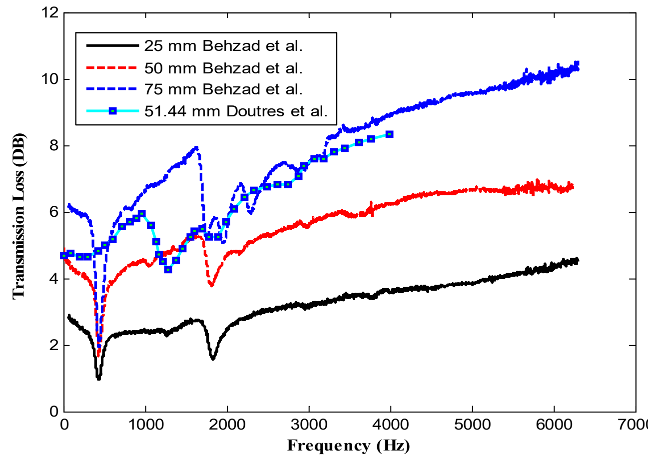


Figure 17: Result comparison for transmission loss with other published research

6 Conclusion

The acoustic parameters including transmission loss and absorption coefficient are investigated both numerically and experimentally with working frequency range of 64 Hz to 6.2 kHz using melamine foam (MF). Three different sample thicknesses are employed to have better correlation of the acoustic parameters with respect to frequency and thickness. The resonance features are identified in both absorption coefficient and transmission loss measurements. The saturation level for absorption coefficients is achieved earlier for higher thickness compared to lower thickness of MF lining. The transmission loss of 2-4 dB (25mm), 4-6 dB (50mm) and 6-8 dB (75mm) is achieved for variable thickness samples. Numerically computed parameters are validated using impedance tube setup and are found in good agreement. These results are very useful to estimate the acoustic characteristics for designing insulation blanket of different structure which are vulnerable against acoustic loading.

References

[1] T. Do. 1999. "Vibroacoustic Modeling Study of the Delta II 10-Foot Composite Fairing." *Journal of the IEST* 42 (6): 26-33.

[2] H. Defosse and M.A. Hamdi. 2000. "Vibro-acoustic study of Ariane V launcher during lift-off." *The 29th International exhibition on noise control engineering, France.*

[3] D. Bianco, P. Francesco, M. Barbarin, P. Vitiello, D. Bartoccini, L. Federico and Citarella Roberto. 2018. "Integrated Aero–Vibroacoustic: The Design Verification Process of Vega-C Launcher." *Applied Sciences* 8(88).

[4] J.M. Scott, B.G. Jay and C.B. Robert. 1996. "General Environmental specification for STS and ELV – Payloads, Subsystems and Components. GEVS-SE." Rev. June, NASA Goddard Space Flight Center, Greenbelt, Maryland, 20771.

[5] R.M. Glaese, E.H. Anderson. 2003. "Initial Structural-Acoustic Modeling and Control Results for a Full-Scale Composite Payload Fairing for Acoustic Launch Load Alleviation." CSA Engineering,2565 Leghorn Street, Mountain View, CA,94043.

[6] G.H. Yuan, X.C. Wang, P.Z. Hou and C.L. Li. 2007. "Absorbing Property of Open-Cell Melamine Foam." *Material Mechanical Engineering* 31(9): 55–57.

[7] J.P. Arenas and M.J Crocker. 2010. "Recent Trends in Porous Sound Absorbing Materials." *Sound and Vibration* 44 (7): 12–17.

[8] A.M. McNelis, W.O. Hughes and M.E. McNelis. 2014. "NASA Engineering and Safety Center (NESC) Enhanced Melamine (ML) Foam Acoustic Test (NEMFAT)." Hampton, VA, USA: National Aeronautics and Space Administration, Langley Research Center.

[9] M. McNelis and W.O. Hughes. 2015. "Effect of Coversheet Materials on the Acoustic Performance of Melamine Foam." NASA Glenn Research Center at Lewis Field.

[10] W.O. Hughes, A.M. McNelis and M. Emcnelis M. 2014. "Acoustic Test Characterization of Melamine Foam for Usage in NASA's Payload Fairing Acoustic Attenuation Systems." Cleveland, OH, USA: Glenn Research Center.

[11] Bin Li, Xiangyu Chen, Wenjie Yan, Shilin Yan and Xu He. 2019. "Theoretical and Experimental Study On Effect of Melamine Foam Lining on Acoustic Characteristics of a Cylindrical Cavity." *Results in Physics* 13.

[12] J.S. Bolton. 2005. "Porous Materials for Sound Absorption and Transmission Control." *Proceedings of Congress and Exposition on Noise Control Engineering*, Brazil.

[13] Olivier Doutres, Yacoubou Salissou, Noureddine Atalla and Raymond Panneton. 2010. "Evaluation of The Acoustic and Non-Acoustic Properties of Sound Absorbing Materials Using a Three-Microphone Impedance Tube." *Applied Acoustics* 71 (6): 506-509.

[14] R. Wijntjes, F. Simon, T. Haase, O. Unruh and E. Tijs. 2016. "Benchmark for Experimentation of Acoustic Transmission Loss Applied to Helicopter Trim Panels." *ERF 2016 42nd European Rotocraft Forum, France*.

[15] Marius Deaconu and Laurentiu Cristea, 2016. "Sound Transmission Loss in Porous and Isotropic Materials. Comparative Analysis Between Impedance Tube and FEM Results." *Proceedings of the Annual Symposium of the Institute of Solid Mechanics and Session of the Commission of Acoustics, SISOM 2016 Bucharest 12-13 May*.

[16] Yacoubou Salissou and Raymond Panneton. 2009. "A General Wave Decomposition Formula for The Measurement of Normal Incidence Sound Transmission Loss in Impedance Tube." *The Journal of the Acoustical Society of America* 125(4): 2083.

[17] Abhishek Kundu and Alain Berry. 2011. "Active Sound Control with Smart Foams Using Piezoelectric Sensoriactuator." *Journal of Intelligent Material Systems and Structures* 22 (16): 1771-1787.

[18] Olivier Doutres and Noureddine Atalla. 2011. "Experimental Estimation of the Transmission Loss Contributions of a Sound Package Placed in a Double Wall Structure." *Applied Acoustics* 22(6): 372-379.

[19] W. Lauriks. 2005. "Characterization of Porous Acoustic Materials. Symposium on the Acoustics of Poro-Elastic Materials." France.

[20] Guosheng Ji, Yi Fang, Jie Zhou and Xun Huang. 2019. "Porous Labyrinthine Acoustic Metamaterials with High Transmission Loss Property." *Journal of Applied Physics* 125(21).

[21] Yong Yang, Zhou Chen, Tengzhou Xu, Ruonan Han and Desire Emefa Awuye. 2019. "Sound Insulation and Hydrophobic Properties of Phenolic Resin Modified Melamine Foam: Role of Micro-Morphology, Materials Research Express."

[22] COMSOL Multiphysics modeling Guide.

[23] W. Zheng. 2011. "Development of Acoustic Models for High Frequency Resonators for Turbocharged IC-Engines." MS thesis in Sound & Vibration Stockholm, Sweden.

[24] S. Tomasz. 2010. "Finite Element Modeling of Sound Transmission Loss in Reflective Pipe." Poznan University of Technology Institute of Applied Mechanics, Poland.

[25] Hiroshi Nakagawa and Kunikazu Hirosawa. 2018. "Development of A Narrow Impedance Tube to Measure Normal Absorption Coefficient and Transmission Loss at High Frequencies Around 10 kHz." Acoustic Science & Technology 39 (6).

[26] J. Stuart Bolton, Taewook Yoo and Oliviero Olivieri. 2007. "Measurement of Normal Incidence Transmission Loss and Other Acoustical Properties of Materials Placed in a Standing Wave Tube." *Technical Review, Brüel& Kjær Sound & Vibration Measurement A/S.*

[27] X. Hua and D. Herrin. 2013. "Practical Considerations when using the Two-Load Method to Determine the Transmission Loss of Mufflers and Silencers." *SAE International Journal of Passenger Cars – Mechanical System* 6(2).

[28] Miša Oblak, Miha Pirnat and Miha Boltežar. 2018. "An Impedance Tube Submerged in A Liquid for The Low-Frequency Transmission-Loss Measurement of a Porous Material." *Applied Acoustics* 139: 203-212.

[29] Behrooz Yousefzadeh. 2008. "An Experimental Study of Sound Transmission Loss (STL) Measurement Techniques using an Impedance Tube." *The Journal of the Acoustical Society of America* 123.

[30] Martin Wolkesson. 2012. "Evaluation of Impedance Tube Methods a Two Microphone In-Situ Method for Road Surfaces and The Three Microphone Transfer Function Method for Porous Materials." MS Thesis, Department of Civil and Environmental Engineering Division of Applied Acoustics, Chalmers University of Technology, Sweden.

[31] U. Berardi, G. Iannace. 2015. "Acoustic characterization of natural fibers for sound absorption applications. " Building and Environment 94(2): 840-852.

[32] G. Iannace.. 2014. "Acoustic Properties of Nanofibers." Noise & Vibration Worldwide https://doi.org/10.1260/0957-4565.45.10.29

[33] G. Iannace.. 2017. "The acoustic characterization of green materials." Noise & Vibration Worldwide https://doi.org/10.1177/1351010X17704624

[34] G. Ciaburro, G. Iannace. 2021. "Acoustic Characterization of Rooms Using Reverberation Time Estimation Based on Supervised Learning Algorithm." *Appl. Sci. 11*(4), 1661; https://doi.org/10.3390/app11041661

[35] A.F. Seybert and D.F. Ross. 1997. "Experimental Determination of Acoustic Properties Using a Two-Microphone Random-Excitation Technique." *The Journal of the Acoustical Society of America* 61(5): 1362-1370.

[36] ISO 10534-2. 1998. "Acoustics – determination of sound absorption coefficient and impedance in impedance tubes – part 2: transfer-function method", ISO 10534-2.

[37] J.S. Bolton, N.M. Shiau and Y.J. Kang. 1996. "Sound Transmission Through Multi-Panel Structures Lined with Elastic Porous Materials." *Journal of Sound and Vibration* (191): 317–347.

[38] K.N. Ho, Z. Yang, X.X. Zhang and P. Sheng. 2005. "Measurements of Sound Transmission Through Panels of Locally Resonant Materials Between Impedance Tubes." *Applied Acoustics* 66: 751–765.

[39] Y. Ryu. 2000. "The acoustic impedance measurement system using two microphones, Bruel & Kjaer sound & vibration measurement a/s, Denmark."

[40] S.S. Jung, Y.T. Kim, Y.B. Lee. 2008. "Measurement of Sound Transmission Loss by Using Impedance Tubes." *Journal of the Korean Physical Society* 53 (2): 596-600.

[41] User's Manual "Impedance Tube Test System" No: BSWA-III-C021-03-0027-IMP Ver.: V1.03 Release Data: Mar./09/2010 BSWA TECH.

[42] L.L. Beranek. 1947. "Some notes on the measurement of acoustic impedance." *Journal of Acoustic Soc. Am.* 19: 420-427.

SUBJECTIVE ANALYSIS OF SOUNDSCAPE IN THREE AREAS IN THE BRAZILIAN CITY IN THE LEGAL AMAZON REGION.

Lucas Rafael Ferreira *[1], Érika Borges †[2] et Giane Grigoletti‡[1]
[1]Federal University of Santa Maria, Santa Maria, Brazil.
[2]Universidade do Estado de Mato Grosso, Mato Grosso, Brazil.

Résumé

La ville de Sinop compte environ 143 000 habitants et est située au nord du Mato Grosso dans la région de l'Amazonie légale. La ville possède de grands espaces verts et certains d'entre eux subissent des altérations du paysage sonore à cause de l'urbanisation, comme le quartier Aquarela do Brasil, le Parque Florestal et l'avenue Tarumãs. Les paysages sonores de ces trois endroits ont été définis comme objets d'étude car ils présentent des typologies et des utilisations différentes, deux d'entre eux étant boisés et un autre avec peu de végétation situé au centre de la ville. L'objectif de la recherche est d'identifier les points de préservation du paysage sonore et de définir ceux qui interfèrent dans la sensation de confort des personnes à partir d'une analyse subjective. Les utilisateurs ont répondu à des questionnaires pour comprendre les paysages sonores et la relation de confort dans l'environnement qu'ils ont avec l'identification des différents sons du paysage sonore. Les résultats subjectifs impliquent des variables physiques, sensibles et psychologiques, qui sont présentées et revendiquées dans cet article. Il a été vérifié que les niveaux sonores existants dans les lieux analysés sont supérieurs à la limite imposée par la réglementation brésilienne, cependant, il existe une satisfaction de confort définie par la plupart des utilisateurs de ces espaces urbains.

Mots clefs : paysage sonore, bruit urbain, acoustique urbaine, confort environnemental

Abstract

The Sinop city has about 143,000 inhabitants and is located in the north of Mato Grosso in the Legal Amazon region. The city has large green areas and some of them are suffering alterations in the soundscape through urbanization, such as the Aquarela do Brasil neighborhood, Parque Florestal, and Tarumãs Avenue. The soundscapes in these three locations were defined as objects of study because they have different typologies and uses, two of them wooded and another with little vegetation located in the center of the city. The objective of the research is to identify the preservation points of the soundscape and to define which of them interfere in the feeling of comfort of people from a subjective analysis. Questionnaires were answered by users to understand the soundscapes and the relation of comfort within the environment they have with the identification of different sounds of the soundscape. The subjective results involve physical, sensitive, and psychological variables, which are presented and claimed in this article. It was verified that the existing sound levels in the analyzed locations are above the limit imposed by the Brazilian regulation, however, there is a satisfaction of comfort defined by most users of these urban spaces.

Keywords: soundscape, urban noise, urban acoustics, environmental comfort.

1 Introduction

With the advent of the industrial revolution, new technologies have emerged that not only bring benefits, but also deterioration of the environment. On the other hand, with access to these facilities and modernity, there was an intensification of the growth in the number of pollution sources. The increase in the means of transport was evident, contributing to the increase in noise within cities [1].

Giunta et al. state that noise pollution is one of the negative consequences of human development [2], which influences the quality of life and health of the population, becoming one of the most frequent environmental problems in large and medium-sized cities.

* lucasrafael2209@gmail.com
† erikafernanda@gmail.com
‡ ggrigoletti@gmail.com

These noise-related health problems are in part due to adaptation. People get used to the sounds generated inside cities, however, even if they do not notice their effects, the noises are still harmful to health [3].

The disorderly growth of cities, coupled with the increase in the number of urban roads, has resulted in the appearance of noise sources capable of generating great damage to the population. These sources, when in excess, result in the appearance of so-called noise pollution [4].

Medium and large cities have an intense flow of cars, which leads to an increase in noise levels, which are considered to be responsible for hearing loss. The excessive sound caused by traffic, industries, recreation areas, people talking and airplanes are part of those responsible for noise pollution [5].

Exposure to noise daily can lead to health problems, such as loss of sleep, heart rate modification, insomnia, contraction of blood vessels, among others [6].

Currently, noise pollution is already considered by the World Health Organization (WHO) as the second-largest type of pollution in the world, losing only to air pollution [7]. However, it is the one that presents the greatest danger, due to its difficulty of perception and immediate acceptance of its effects, and can thus interfere with human health [8].

Brazil, within the scope of development to which it has been passing, is affected by this sudden change in the quality of sounds in its cities. This advent of intensification of sounds interferes directly and indirectly in the quality of life of people and may influence the state of mind or conduct our behavior [9]. Noise is associated with human activities resulting from urbanization and industrial development and is considered a pollutant [10].

These changes within the cities consequently bring about a change in the soundscape, which is nothing more than an acoustic environment as perceived or experienced and/or understood by a person or people, in a given context [11].

The urban soundscape contributes to the perceived quality of the urban environment and brings an identity to each place seen in Figure 1. Cities are composed of a junction of distinct soundscapes, each outdoor space has unique urban characteristics.

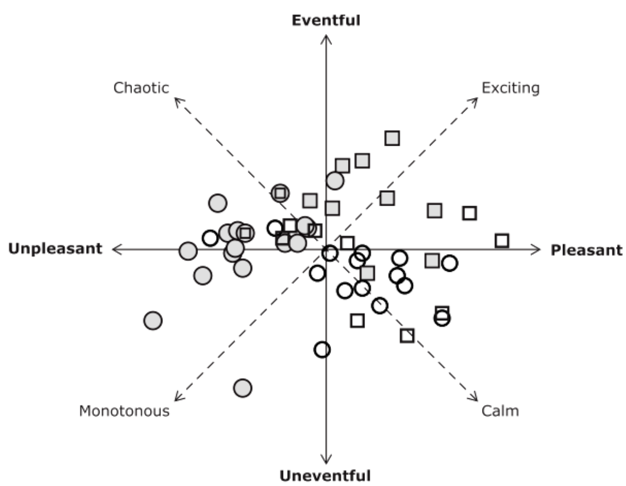


Figure 1: Example of a sound landscape classification [12]

Sound beyond the negative effects can provide positive effects, improving mood, bringing an affective memory to mind, or bringing relaxation [13].

Just pleasant sounds are not enough to bring well-being. The context in which the person is inserted is a fundamental part of the interpretation of the soundscape. The visual characteristics, infrastructure, and activities that are being performed have a great influence on this interpretation.
Currently, the soundscape cannot be considered in a categorization only acoustic, its evaluation must consider a range of factors beyond the acoustic [14], such as the visual context [15], as the social context [16] and the individual interpretations [17], and can be seen in the diagram in Figure 2.

This study was conducted in the Legal Amazon region in Sinop city, which is located in the north of the state of Mato Grosso, is an agro-industrial hub and has been expanding gradually and rapidly, standing out for its economic strength

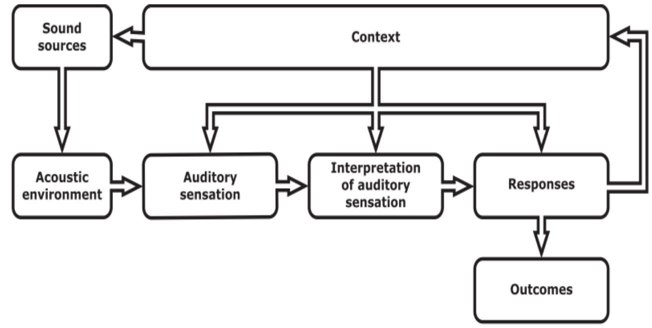


Figure 2: Elements in the perceptual construct of soundscape [14].

and attracting new companies and residents, growing about 10% per year [18].

The increase in population, homes, commerce, vehicle traffic, night noises, promotes an acoustic environment different from the initial one. In this context, the change in the landscape of Sinop brought with it new visual and sound characteristics.

At the same time that it has transformed in its urban context in which it has also modified its original sound environment, the city of Sinop still has quiet areas of significant environmental value for the preservation and contemplation of nature.

The concern with the well-being of the human being has increased, consequently, the search for laws and guidelines, to guide the management of urban spaces and identify how the characteristics of the environment influence the quality of life of people, end up appearing, such as those used for noise management through the European Directive 2002/49/EC [19].

More current standards, to bring a congruence of existing approaches, such as ISO/BS 12.913-1:2014 [15], ISO/TS 12.913-2:2018 [20] and ABNT NBR 10.151:2019 [21] provide, the first two guidelines to be followed in the study of sound landscape and the third the instructions for measurements in external areas.

Since Sinop city has spaces with distinct characteristics, the need to qualify them was seen.

Based on the above considerations, it became essential to carry out specific studies to identify and describe the impact on the soundscape traces and its consequences for individuals. In this article, the proposed classification (subjective) will be operated employing questionnaires applied to the users of the studied sites. This study will serve to identify areas where there is still a sound landscape suitable for preservation, in addition to highlighting critical areas.

Objective

The main objective of this study is to subjectively characterize the soundscape of three areas within the urban environment of a medium-sized Brazilian city within the region of the Legal Amazon to point out the area that should be preserved and/or that requires adaptation and structural interventions.

2 Standards

Holtz claims that until the beginning of the 20th-century countries created their laws and guidelines for noise management [22], but with the digital era reaching the 1990s there was a process of global integration, so some countries began to share the same norms.

European countries made strong progress in noise studies through legislative initiatives and multinational efforts. This led them to be a reference in the subject.

As the years went by, standards emerged, improving the methods and approach of research/studies in this area.

2.1 Green paper

The Green Paper was a document drawn up in Brussels in 1996 by the Commission of the European Communities and initiated the study of acoustics within cities on the European continent.

The document reveals the low relevance of noise pollution to the detriment of other types of pollution. The main objective of the document was to encourage an open debate on public policies concerning noise control, to exchange knowledge, bring more relevant information and attitudes seen as beneficial to the population.

This document was the initial stimulus for the first steps to be taken regarding noise management in cities.

2.2 European directive

After the first steps to be taken in 1996, in 2002 the European Parliament together with the Council of the European Union published Directive 2002/49/EC [19]. This Directive aims at defining a common approach to avoid, prevent or reduce, as a matter of priority, the harmful effects of exposure to environmental noise, including annoyance.

According to Directive 2002/49/EC protection against noise, part of Community policy, aims at increasing the level of protection of health and the environment. There was a need for research with criteria that would enable concrete measures and actions to be taken to guide the development and assist in the directives that were already in force, for this Directive/49/EC came to light.

This directive has an objective character, without spaces for dubious interpretations, facilitating research in general, since all studies governed by it offer only one type of approach.

2.3 International Organization for Standardization: ISO 12.913-1:2014 and ISO/TS 12.913-2:2018

The field of study on the sound landscape has evolved to include several aspects around the world. There is a multiplicity of opinions about its definition and purpose. For this reason, there was a need for a norm that could serve as a congruence between all lines of studies on the subject.

In this context, the ISO 12.913-1:2014 standard [15] aims to provide a basis for communication between disciplines and professions involving the soundscape. According to the standard, the soundscape is based on people's perception, so it works with perceptual construction, related to a physical phenomenon.

Furthermore, in part two ISO/TS 12.913-2:2018 [20], it explains the pertinent factors for the measurement and reporting in studies about soundscape, as well as for the planning, design, and management of the soundscape.

This standard has the requirements and supporting information for data collection and reporting with the bias in the study and investigation of the soundscape, harmonizing data collection.

It also has explanations of the descriptors, such as soundwalk, questionnaire, interview guide, the taxonomy of sound sources, and binaural measurements. It is necessary to clarify that these descriptors need to follow some normative frameworks.

2.4 Brazilian Association of Technical Standards: ABNT NBR 10151:2019

The NBR 10151:2019 standard [21] establishes the conditions for conducting studies on external and internal noise, being holistic.

As the present study focuses on external noise, the standard exposes specifications of the noise measurement method, application of corrections in the measured levels.

It is worth mentioning that this standard establishes the procedure for measuring and assessing sound pressure levels in external and internal environments for inhabited areas; procedure for assessing total, specific and residual sound; procedure for assessing tonal, impulsive, intermittent and continuous sound; limits of sound pressure levels for environments outside buildings, in areas of human occupation.

3 Method

Methods of studying the soundscape are under development. Accordingly, this study was based on ISO 12913-1:2014, ISO/TS 12.913-2:2018, and ABNT NBR 15151:2019 [15, 20, 21].

The study had a subjective approach with the application of questionnaires to the users of the sites and for comparison with the current standard was made the measurements in situ.

3.1 Object of study

The survey was conducted in the Sinop city, located north of Mato Grosso (11º 51' 51" S, 55º 30' 09" W) in the region of Legal Amazon. According to Ferreira [23], the city was founded in the 1970s, when Colonizadora Sinop S.A. acquired approximately 500,000 hectares of land, located 500 km from Cuiabá on the BR 163 highway (Cuiabá-Santarém), and created Gleba Celeste.

Due to the great demand and migration to the west of the country, in less than seven years Governor Frederico Campos signed Law 4.156/79, which elevated Sinop to the category of municipality.

Currently, it has an estimated population of 142,996, according to IBGE [24]. Despite being young, the city is in constant development, going through great urban changes.

Within the urban sound landscape of the city, significant changes were observed such as the decrease of green and silent areas seen in the case of Avenida Tarumãs, formerly one of the most forested in the city which underwent a reform that extracted much of the vegetation, as shown in Figure 3.

The areas where the study was conducted are green reserve R-11 (Parque Florestal); the green area in the neighborhood Aquarela do Brasil; and Tarumãs Avenue. These areas are shown in Figure 4.

Figure 3: Tarumãs Avenue, before and after (NORTÃO NOTÍCIAS, 2014) (1 e 2); (SKYSCRAPERCITY, 2010) (3); (ANÚNCIOSABZ,2017) (4).

Figure 4: Locations of the study areas.

3.2 Soundwalk

In the spaces defined for the study, walks were carried out to identify the residual noise that attracted more attention according to ISO/TS 12913-2:2018 [20]. The entire accessible area of the environments was covered, without or with the minimum interference in people's behavior.

The measured points were chosen as they presented interesting characteristics analyzed during the soundwalk in the environment.

Each environment had some points needed for the assessment. The Aquarela Brasil neighborhood had five points (Figure 5), Forest Park and Tarumãs Avenue had six points (Figure 6 and 7).

Figure 5: Positioning of measuring points in the Aquarela Brazil neighborhood.

Figure 6: Positioning of acoustic measurement points in the Parque Florestal.

Figure 7: Positioning of the acoustic measurement points on Tarumãs Avenue.

3.3 Equipment

For the acoustic measurements of the studied sites, the sound pressure levels (Leq) were measured, and the weighted sound pressure level (LAeq) was calculated using the sound level meter model G4, Type 2270, from the company Brüel & Kjær (Figure 8), installed 1.5 m from the ground, with the aid of a tripod, because according to Rodrigues (2015) this is the average height of the human ear, following the recommendations established by NBR 10.151:2019 [21].

Figure 8: B&K 2270 Sonometer.

The duration of the measurements at each point was ten minutes (Laeq, 10 min), measuring traffic noise where necessary, with these data a noisy assessment of the acoustical environment was made concerning what the standard establishes.

The measurements were performed on weather-friendly days, avoiding precipitation that could interfere with the final result.

3.4 Data collection

Along with measurements, behavioral notes of people were taken, as well as photographic surveys and filming of the environment in question according to ISO/TS 12913-2:2018 [20].

The notes also included the sound events heard during the measurements and the characteristics of the landscapes in different environments.

To understand the influence of urban aspects on the quality of the sound landscape of these environments, points were measured in regions where the sound of traffic could directly interfere with the sound quality of the environment.

To assess the quality of the environment or the soundscape two types of subjective assessments were performed, one by the researcher and the other by the user.

Behavioral observation of the users who were inserted in the acoustic environment, the activities they performed, in addition to observing the time of execution of such activity, was performed.

The classification of the soundscape was obtained utilizing a questionnaire to obtain an understanding of their relationship with the sound environment according to ISO 12913-2:2018 [20]. There were a total of 180 questionnaires, sixty in each place studied.

The understanding and perception of the soundscape, the motivation of the visit, length of stay, neighborhoods of origin, and how often they attended the site were addressed in their surveys.

The questionnaires applied had open and objective questions. The objective answer questions limit the respondent to a set of answers provided, while the open-ended questions allow the respondent freedom of response, without influence from the researcher [25].

The closed-ended questions present greater objectivity and ease in systematizing the collected information [26], but to have greater reliability regarding the quality of the sound environment, the open-ended questions are necessary because spontaneous answers are obtained from users.

3.5 Measurements

The measurements were carried out, together with the application of the questionnaires, on different days of the week (Table 1) targeting the days with user flow.

Table 1. Dias de medições realizadas.

Place	Day 1	Day 2	Day 3	Day 4
Aquarela do Brasil	21/04/18	22/04/18	28/04/18	29/04/18
Parque Florestal	23/04/18	25/04/18	28/04/18	29/04/18
Avenida Tarumãs	21/04/18	22/04/18	28/04/18	29/04/18

The measurements were taken at the points defined during the exploratory walk of the environment.

3.6 Analysis of the results

The values obtained in the measurements were compared with the values recommended in ABNT NBR 10151:2019 [21] for the comfort of individuals (Table 2). It is worth noting that the Aquarela do Brasil neighborhood and the Forest Park fall into category 2 (Daytime 50 dB and Night 45 dB) while Avenida Tarumãs fall into category 4 (Daytime 60 dB and Night 55 dB).

The subjective data were carefully analyzed and interpreted, establishing the characterization of the soundscape users of each environment studied.

Through this description obtained through the responses of the individuals, the subjective judgment of the Soundscape was established.

4 Results

The results were analyzed separately. The data collected with the measurements were used to identify whether or not the guidelines of the NBR 10.151:2019 standard was framed. The data obtained through the questionnaires were analyzed to define the soundscape users' understanding of each environment studied.

4.1 Acoustics characterization

The acoustic characterization of the study sites was based on the results obtained from measurements at the points chosen through the exploratory walk.

Table 2. Limits of sound pressure levels according to the types of inhabited areas and the period.

Tipes of Areas	Daytime	Night
1- Area of rural residences	40 dB	35 dB
2- Strictly residential urban or hospital or school area	50 dB	45 dB
3- Predominantly residential mixed área	55 dB	50 dB
4- Mixed area with predominance of commercial and/or administrative activities	60 dB	55 dB
5- Mixed area with predominance of cultural activities, leisure and tourism	65 dB	55 dB
6- Predominantly industrial area	70 dB	60 dB

For the Aquarela do Brasil neighborhood, data were obtained at five points within the limits of the green recreation and leisure area (Fig. 5). In the Parque Florestal (reserve R-11) six points were evaluated (Fig. 6), of which five were located on the trails and one on the access road. In Tarumãs Avenue, data collection was performed in six points (Fig. 7) distributed in the spaces where there is recreation during the weekends.

The land occupation around the Aquarela do Brasil neighborhood and the Parque Florestal is exclusively residential, while on Tarumãs Avenue it is a mixed area (commercial and residential use) [27].

It was found that the roads around the two green areas have a relatively low traffic density, while on Tarumãs Avenue the flow is very high being responsible for the high sound levels.

When comparing the measured data with the values that ABNT NBR 10151:2019 recommends [21], only the Parque Florestal fits, whereas Tarumãs Avenue exceeds 15 dB(A) of the standard value.

4.2 Subjective anaysis

During the measurements, the researcher took notes of the sounds perceived.

In the Aquarela do Brasil neighborhood the sounds identified were: birds singing, people talking, children shouting, sounds of playground toys, waterfall sounds and traffic sounds (light); in the Forest Park the predominant sounds were those of nature: sounds of birds, sounds of wild animals, wind beating on leaves, people chatting low and traffic sounds (light); on Tarumãs Avenue the sound of traffic completely dominates the soundscape along with sounds of music, sound cars, and people chatting.

Sixty questionnaires were applied to each study site, totaling 180 surveys conducted, to have a more accurate sample.

The amount concerning the total number between men and women had little difference, 97 females (53.8%) and 83 (46.2%) males. It was noted that in the watercolor neighborhood and Tarumãs Avenue there were mostly female visitors (58.3% and 63.3% respectively) and in the Parque Florestal mostly male (60%) as shown in Figure 9.

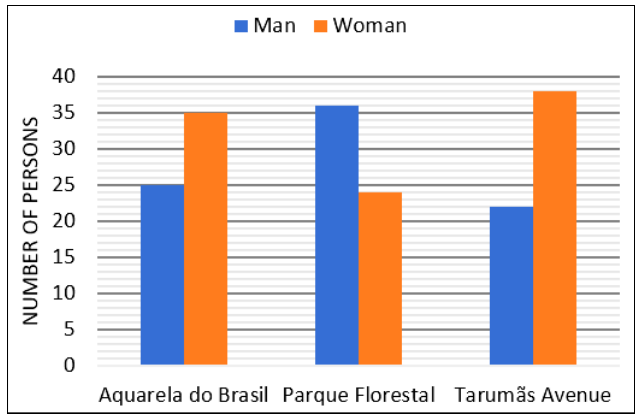


Figure 9: Gender of visitors in research places.

Concerning age groups, it was found that the majority of the visitors interviewed were young people between 15 and 29 years of age, as can be seen in Figure 10, showing us that the search for leisure, entertainment, or tranquility is, for the most part, among young people.

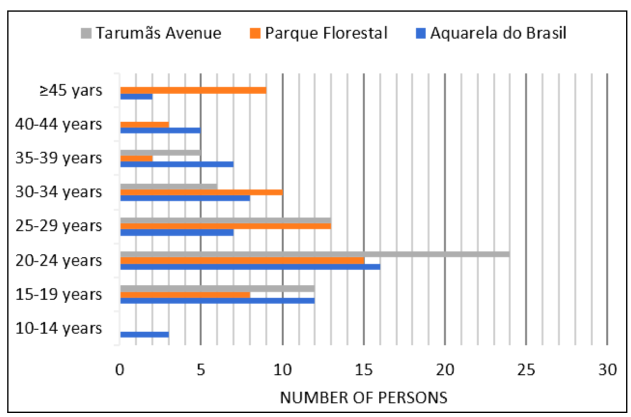


Figure 10: Age range of visitors.

The users of the places when asked about the frequency with which they visit the place, in their majority answered go at least once a month, 37 (61.7%) questioned in Parque Florestal and Tarumãs Avenue, as well as 46 (76.7%) in Aquarela do Brasil, as we can see in Figure 11.

The time in a certain place tends to be relevant when it comes to sound perception and when questioned about the length of stay in the place, most of them remain between one and two hours in the three places studied, is shown in Figure 12.

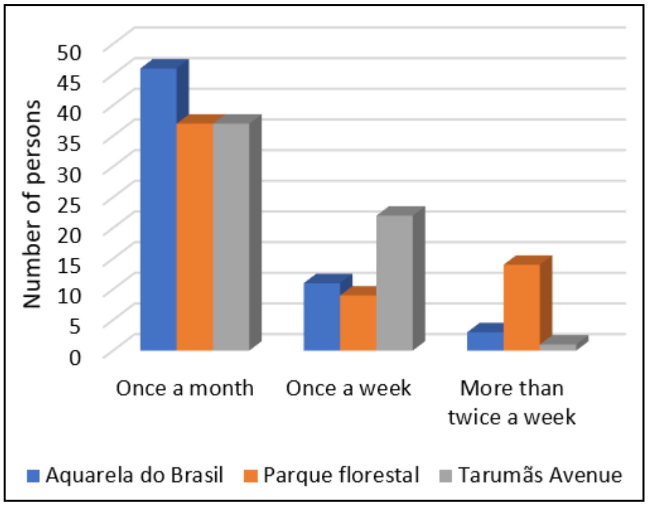


Figure 11: Frequency of visits.

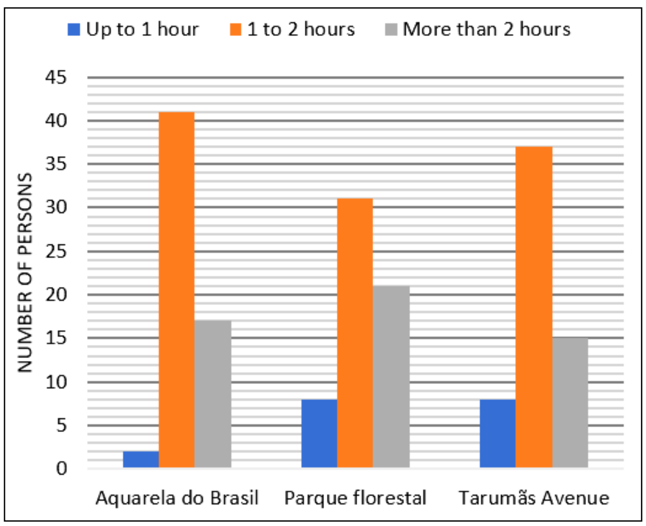


Figure 12: Time spent in place.

Regarding the quality of the infrastructure of the site (Figure 13) and the visual beauty (Figure 14), most of the interviewees were satisfied, however, there was a drop in satisfaction concerning Tarumãs Avenue.

They were asked to assess the volume of sound in the environment. The Tarumãs Avenue was the worst evaluated in this sense, having been considered by 29 people (48.3%) as the place with high volume. While the other two areas studied were characterized by low or normal volume, shown in Figure 15.

There was the questioning as to the inconvenience generated by the sound of the environment, the numbers showed that 55 people (91.7%) do not suffer any inconvenience in the Forest Park, in the neighborhood Aquarela do Brasil this number already drops to 38 people (63.3%) and last and most discrepant, on Avenida Tarumãs, 24 individuals (40%) of those interviewed say they are not disturbed by the volume of the sound as can be seen in Fig. 16.

Through the analysis of open-ended questions that aimed to understand the perception of sound quality and the degree of enjoyability by individuals, it was found that 54 respon-

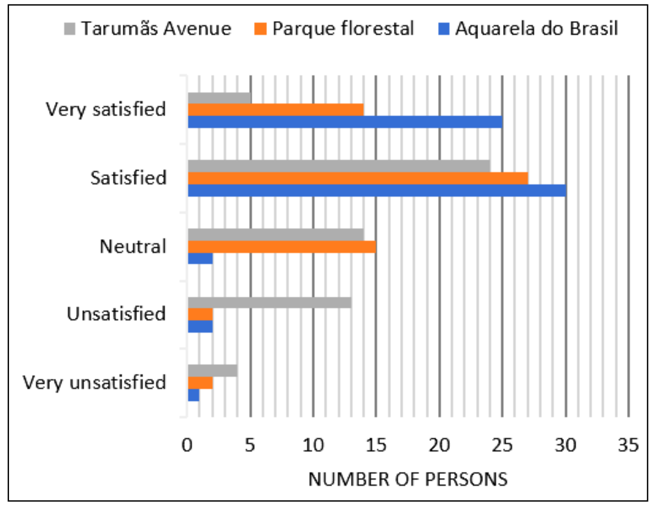


Figure 13: Level of satisfaction with the infrastructure of the place.

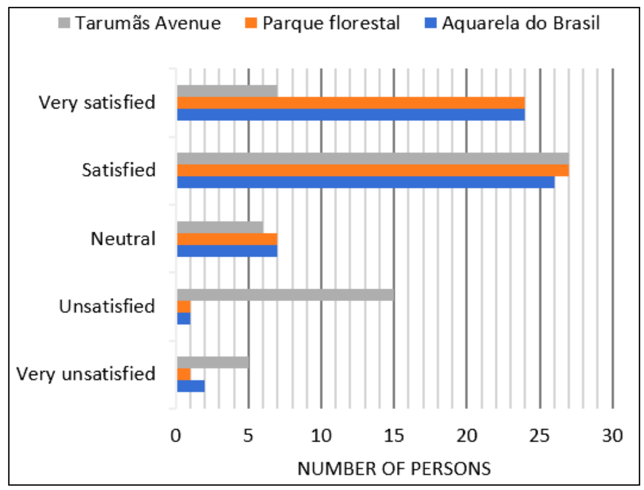


Figure 14: Level of satisfaction with the aesthetic beauty of the place.

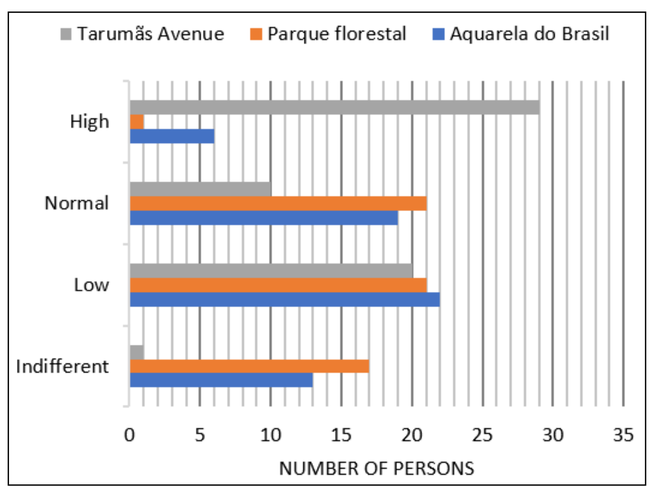


Figure 15: Sound perception of the place.

dents (90%) in the Forest Park, 32 visitors (53%) in the neighborhood Aquarela do Brasil and 29 individuals (48.3%) on

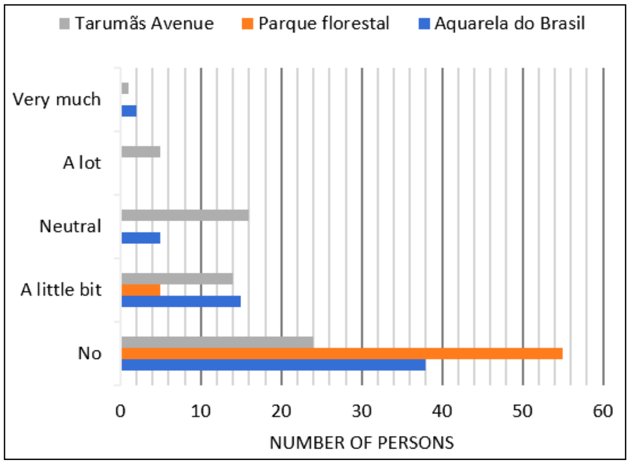


Figure 16: Nuisance from the sound of the place.

Tarumãs Avenue felt an improvement in the sound environment compared to urban sounds. However, 31 of the 60 interviewees (51.7%) on Tarumãs Avenue said that the sound was a little or very exaggerated.

Through the analysis of open-ended questions that aimed to understand the perception of sound quality and the degree of enjoyability by individuals, it was found that 54 respondents (90%) in the Forest Park, 32 visitors (53%) in the neighborhood Aquarela do Brasil and 29 individuals (48.3%) on Tarumãs Avenue felt an improvement in the sound environment compared to urban sounds. However, 31 of the 60 interviewees (51.7%) on Tarumãs Avenue said that the sound was a little or very exaggerated.

4.3 Discussion

The background sounds that make up the soundscape do not contribute to the overall experience of the environment. Therefore, if these sounds are not perceived by the people in the environment, this will not provide a bad understanding of the sound environment. These background sounds do not attract the attention of individuals and are not taken into account in their assessment of the environment, obviously, in some circumstances.

When the sound landscape prevents activities within the environment, such as communication, having a disturbance profile, it causes a bad understanding, consequently, a negative assessment will be made.

Soothing soundscapes contribute to a positive overall experience but must meet the expectations created by individuals. The context in which this soundscape appears will determine whether the person will have positive impressions. However, the soothing soundscape is influenced by the background sounds and is capable of turning an initial positive understanding into a negative one.

The soothing soundscape can be stimulating as well as calming. When these stimuli can awaken good feelings, understanding becomes positive.

Perceptions are individuals. At the same time that the soundscape can bring about good stimuli or relaxation, it is also capable of causing the opposite effect.

Through this understanding, when subjectively evaluating the soundscape, the responses will not always be those initially foreseen. The perception of the soundscape is fluid and can change all the time.

The three soundscapes studied have distinct characteristics.

- Aquarela do Brasil: has green areas, sounds of nature, good infrastructure for leisure, children screaming, people talking, traffic sounds, noises of playground toys;
- Tarumãs Avenue: intense traffic sounds, a lot of music with high sound level, the sound car passing by, horns, people talking and little infrastructure;
- Parque Florestal (reserve R-11): dense green area inside the city, sounds of nature, people talking low, background sounds of light traffic, has good infrastructure, leisure areas, wild animals.

Taking into account that 53.8% of the answers obtained through the questionnaires were female and 46.2% male, besides, the vast majority of the respondents were young people between 15 and 29 years old. Consequently, the profile was drawn and it can be stated that the answers were mostly obtained by young women between 15 and 29 years old.

The frequency of visits and stays at the study sites becomes relevant so that we can determine from the answers whether people are getting used to the noises and disregarding their influence on their evaluation to the detriment of the activities carried out. The result of the study shows that the minimum stay by most visitors is two hours in both quieter environments (Parque Florestal) and noisier environments (Tarumãs Avenue).

It is necessary to highlight that the soundscape is something beyond objective measurements and framing in a certain classification. The infrastructure and visual beauty of the places are parameters that play a very important role in the perception of the sound environment.

The results show that most visitors are satisfied with what they are offered in the environments. However, Tarumãs Avenue has up to 33.3% disapproval in these matters.

Analyzing the results of the evaluation of the sound perception of the environment, interesting results were obtained, mainly concerning Tarumãs Avenue.

As expected, the Forest Park offers a very attractive infrastructure and visual aspect, and still has a place with little noise from the urban environment.

The Aquarela do Brasil neighborhood because it is a planned neighborhood, offers a good infrastructure and attractive visual aspect, having, in general, a positive evaluation in this aspect, which also contributed concerning the nuisance most say not to feel or a little, even their sound levels are high.

When evaluating the answers obtained on Tarumãs Avenue, which does not have an adequate infrastructure to attend visitors and a visual aspect that does not please 33.3% of visitors, it was concluded that only 20 people (33.3%) also feel uncomfortable with the noise in this environment. Of the total 60 interviewees, 24 (40%) do not feel uncomfortable at all. Reflecting what encompasses the soundscape (social and visual context, feelings, activities, and individual interpretations).

5 Conclusion

This study was based on a subjective analysis of soundscapes, based on the subjectivity of the general understanding of the environment.

The values obtained in the measurements at the different measurement points in the study place show that most of them are in disagreement with what ABNT NBR 10.151:2019 determines [21] and also with what WHO determines.

The place with the highest disagreement is Tarumãs Avenue which has 67 dB (A), due to the high level of traffic besides the music of the vehicles. This shows that the hypothesis that urban development effectively influences in the deterioration of the urban sound environment of the places studied is a fact. However, the results assume that the soundscape would have a negative impression on individuals, but it was the other way around.

The low influence of urban sounds inside the Parque Florestal reflects in the good evaluation of the users regarding the discomfort inside the environment, which in turn has large green belts helping in the sound attenuation and the perception of sounds from nature.

The Aquarela do Brasil neighborhood suffers the influence of urban sounds, at the same time that it has green areas, these do not have a high density not directly influencing the decrease of the sound intensity, however, it helps in the visual improvement and consequently in the positive interpretation of the environment by the great majority of the visitors.

The large amount of noise generated in Tarumãs Avenue was not able to reveal this environment as a negative sound landscape, however, its high sound levels resulted in a bad evaluation by 1/3 of users. The context of fun and entertainment had in this environment overcame the nuisance generated by the noise and also the lack of infrastructure and visual aesthetics.

It is worth noting that even in most places being judged as pleasant in sound aspects, the attention must be maintained. People can get used to the noise and stop taking it into account in their judgments of the environment, however, the negative influence on health remains active.

The only soundscape, taking into account the permitted levels and individual assessments, that should be preserved would be the Parque Florestal.

The other two (Aquarela do Brasil and Tarumãs Avenue) would require public policies, in addition to structural interventions, which would enable the adaptation of the sound environment to the values standardized by NBR 10151:2019.

References

[1] B. Berglund, B, T. Lindvall, D. H. Schwela. Guidelines of Community Noise. World Health Organization, 1999.

[2] M. B. Giunta, L. C. L. Souza, E. Viviani. Ruído ambiental em cidades de médio porte. Estudo de caso: São Carlos e Bauru SP. In: XXIV ENCONTRO SOBRAC, 2012, Belém. Anais Sobrac, 2012.

[3] C. M. Yorg, P.H. T. Zannin. Noise evaluation in the Itaipu Binacional Hydroelectric Power. 27º International Congress on Occupational Health. Iguassu Falls, Brazil, 2003.

[4] I. Guedes. Influência da Forma Urbana em Ambiente Sonoro: Um estudo no bairro de Jardins em Aracajú (SE). Dissertação (Mestrado em Engenharia Civil, Arquitetura e Urbanismo) – Programa de Pós-Graduação em Arquitetura e Urbanismo, Universidade Estadual de Campinas, Campinas, 2005.

[5] A. Kwitko. Coletânea n.1: PAIR, PAIRO, EPI, EPC, PCA, CAT, PERÍCIAS, REPARAÇÃO e outros tópicos sobre audiologia ocupacional. São Paulo: LTr, 2001.

[6] S. N. Y. Gerges. Ruído: fundamentos e controle. 2a ed. Florianópolis: S.N.Y.Gerges, 2000.

[7] WHO – WORLD HEALTH ORGANIZATION. Guidelines for community noise, 2017. Disponível em: <http://www.who.int/docstore/peh/noise/gu> Acesso em: jan. 2017.

[8] P. Silva. Acústica Arquitetônica & Condicionamento de Ar. 6ª ed. Belo Horizonte: Empresa Termo Acústica LTDA, 2011.

[9] K. Sun, B. De Coensel, K Filipan, F. Aletta, T. Van Renterghem, T. De Pessemier, W. Joseph, D. Botteldooren. Classification of soundscapes of urban public open spaces. Landscape and Urban Planning, v. 189, n. July 2018, p. 139–155, 2019.

[10] N. Singh, S. C. Davar. Noise Pollution-Sources, Effects and control. Journal of Human Ecology, v. 16, n. 3, p. 181–187, 24 nov. 2004.

[11] ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO-12913-1 - Acoustics — Soundscape — Part 1: Definition and conceptual framework. 2014.

[12] Ö. Axelsson, M. E. Nilsson, B. A. Berglund. A principal components model of soundscape perception. The Journal of the Acoustical Society of America, v. 128, n. 5, p. 2836–2846, 2010.

[13] S. R. Payne. The production of a perceived restorativeness sounscape scale, 2013.

[14] A. Zannin, A. Calixto, F. B. Diniz, J. A. C. Ferreira. A survey of urban noise annoyance in a large Brazilian city: The importance of a subjective analysis in conjunction with an objective analysis, 2003.

[15] K. Sun, B. De Coensel, G. N. Echevarria Sanchez, T. Van Renterghem, D. Botteldooren. Effect of interaction between attention focusing capability and visual factors on road traffic noise annoyance, 2018.

[16] E. Maris, P. J. Stalen, R. Vermunt, H. Steensma. Noise within the social contexto: Annoyance reduction through fair procedures, 2007.

[17] D. Dubois, C. Guastavino, M. Raimbault. A cognitive approach to soundscapes: using verbal data to access auditory categories. 2006.

[18] K. Werneck. Sinop completa 41 anos de fundação e já projeta mais de 200 mil habitantes. Disponível em: <http://www.reportermt.com.br/geral/sinop-completa- 41-anos-de-fundacao-e-ja-projeta-mais-de-200-mil-habitantes/45420>. Acessed: April 13, 2019.

[19] EUROPEAN PARLIAMENT - European directive 2002/49/CE. 2002.

[20] ISO - INTERNATIONAL ORGANIZATION FOR STANDARDIZATION. ISO-12913-2 - Acoustics — Soundscape — Part 2: Data collection and reporting requirements. 2018.

[21] ABNT - Associação Brasileira de Normas Técnicas. NBR 10151:2019 – Acústica – Medição e avaliação de níveis de pressão

sonora em áreas habitadas – Aplicação de uso geral, Rio de Janeiro, 2019.

[22] M. C. B. Holtz. Avaliação qualitative da paisagem Sonora de parques urbanos. Estudo de caso: Parque Villa Lobos, em São Paulo, São Paulo, 2012.

[23] J. C. V. Ferreira. História de Sinop: saiba sobre o surgimento da cidade de Sinop. 2017. Disponível em: <http://portalmatogrosso.com.br/municipios/historia- de-sinop/570>. Acesso em 17 de Junho de 2017.

[24] IBGE – INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2020. Cidades. Disponível em: < https://www.ibge.gov.br/cidades-e-estados/mt/sinop.html>. Acessed: July 10, 2020.

[25] U. Reja, K. Manfreda, V. Vehovar. Open-ended vs. Close-ended Questions in Web Questionnaires. Faculty of Social Sciences. University of Ljubljana. Ljubljana, 2003.

[26] A. Chagas. O questionário na pesquisa científica. Revista Administração On Line, 2000.

[27] PREFEITURA DE SINOP. Plano diretor participativo, Sinop, Mato Grosso, 2009.

A REVIEW OF AUTOMATIC MUSICAL INSTRUMENT CLASSIFICATION BASED ON SOUND RECOGNITION SYSTEM

Tee Hao Wong *[1,2], **Rahizar Ramli** †[2], **Ahmad Saifizul** ‡[2], **Ming Foong Soong** ♦[2]
[1]School of Foundation Studies, University College of Technology Sarawak, Sibu, Sarawak, Malaysia
[2] Department of Mechanical Engineering, University of Malaya, 50603, Kuala Lumpur, Malaysia

Résumé

Cet article présente une revue des recherches sur la classification des instruments de musique qui ont utilisé le système d'apprentissage automatique. Les deux principales étapes de la tâche de classification automatique sont discutées, l'extraction des caractéristiques et la classification. La classification des instruments de musique suit le système Hornbostel-Sachs. Dans l'extraction de caractéristiques, les caractéristiques pertinentes couramment utilisées dans la littérature sont répertoriées et organisées dans une taxonomie qui est divisée en fonction du domaine de calcul. Différentes techniques de classification largement utilisées par les chercheurs sont également présentées et passées en revue.

Mots clefs : classification des instruments de musique, apprentissage automatique, extraction de caractéristiques, classification automatique

Abstract

This paper presents a review of research on musical instrument classification which employed the machine learning system. The two main steps in the automatic classification task are discussed: feature extraction and classification. The musical instrument classification follows the Hornbostel-Sachs system. In the feature extraction, the relevant features that are commonly used in the literature are listed and organized in a taxonomy which is divided according to the domain of computation. Different classification techniques that are widely used by the researchers are also presented and reviewed.

Keywords: musical instrument classification, machine learning, feature extraction, automatic classification.

1 Introduction

Two of the various approaches often used in the studies on musical instruments are the acoustical characterization and sound recognition system. Scientists since many years ago started to discover the acoustical characteristics of different types of musical instruments by using various techniques. The initial techniques used are modal analysis and acoustic radiation. Over the years, there are many other new parameters developed and introduced from these fundamental techniques. The common acoustical characterization parameters are mechanical admittance and impedance, sound radiation coefficient, the intensity of the acoustic radiation, anti-vibrational, and transmission parameter to name a few.

Mechanical admittance is defined as the ratio of the velocity, v to the force, F. This characteristic is useful in understanding the body vibration of the musical instrument. The study which used admittance on musical instrument vibration measurements can refer. Reciprocal to the admittance, driving point mechanical impedance on the other hand is defined as the ratio of the applied force, F to the velocity, v produced by the instrument body. Measurement is done by applying the force to the instrument body and the resulting velocity is measured with the accelerometer [1].

Sound radiation characteristics of different musical instruments have been extensively studied as well. Sound radiation coefficient which is defined as the ratio of the material's speed of sound, c to its density, ρ describes how much the sound radiation of the musical instrument body is damped. It can be measured by the vibrational response of the instrument soundboard for a given force [1].

The intensity of the Acoustic Radiation (IAR) parameter is introduced by Tronchin in 2005 on the kettledrums. It is defined as the product between the space-averaged amplitude of the cross-spectrum sound pressure, p, and the velocity, v generated from the surface vibration. As the name suggests, it is a parameter related to acoustic intensity and acoustic radiation [2].

Studies were also carried out in determining the sound characteristics of the woods used in musical instruments. Various woods are tested, analyzed based on the anti-vibration and transmission parameters. The anti-vibration parameter is the reciprocal of the sound radiation ratio produced by the woods. It is the ratio of the longitudinal wave speed, c to the density, ρ of the wood. On the other hand, the transmission parameter is the product of the longitudinal wave speed, c, and the quality factor, Q. The results are then used in the acoustical classification and comparison of the woods used in a different category of musical instruments [3].

* andrew_wth@hotmail.com
† rahizar@um.edu.my
‡ saifizul@um.edu.my
♦ mfsoong@um.edu.my

On the other hand, sound recognition systems started to get more attention due to the growth of digital music. Music information retrieval (MIR) which is the subset of the broader field of sound recognition, is known to be the field that contributes to the solutions of the musically related task. Sound recognition is a multi-disciplinary field that includes speech recognition, information retrieval, music information retrieval, environmental sound retrieval, etc. Figure 1 below illustrates the general taxonomy of the sound classification scheme introduced by [4]. Under the field of MIR, there are various tasks. For instance, music genre recognition, song identification, mood classification, music annotation, tempo, fingerprinting, etc. One of the tasks is on musical instrument classification.

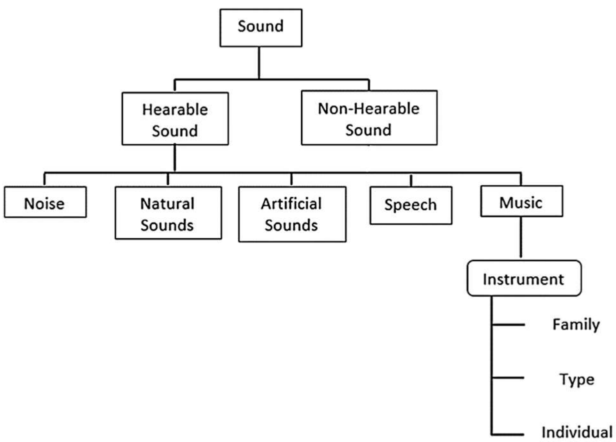


Figure 1: Taxonomy of sound [4].

The application of MIR in the musical instrument classification can help in the identification of the individual musical instrument, its type, and family. It is gaining popularity among researchers, musicians, and acousticians in the efforts of getting a better understanding of the sound produced by musical instruments. As we are currently living in the digital world, where vast amounts of musical databases are made available online. The demands are there for the development of computational tools for the analysis, summarization, classification, and indexing of those musical data [5]. These demands have inspired a growing research attempt in automatic classification of the sound produced by the different types of musical instruments.

This paper aims to review a variety of research efforts on musical instrument classification. Because of the wide variety of applications of music information retrieval as mentioned above, it is difficult to include all relevant works. This paper will only focus on the research and studies done on musical instrument classification. The rest of the paper is organized as follows. Section 2 discussed the musical instrument families and classification followed by sound recognition in Section 3. Section 4 and 5 present the features extraction and classification techniques, respectively. The conclusion is covered in Section 6.

2 Musical Instrument Classification

The globally used musical instrument classification was developed by Curt Sachs and Erich Moritz von Hornbostel in 1914. It is called the Hornbostel-Sachs system (or H-S System). Curt Sachs was a German musicologist and expert on the history of musical instruments. Erich Moritz von Hornbostel was an Austrian musicologist and expert on the history of non-European music [6]. Generally, the H-S system has five top-level classifications, which are shown in Figure 2 below. Initially, there were only four major classes excluding the electrophone. Electrophone class was introduced and added into the system by [7]. The system is then updated in 2011 by the Musical Instrument Museums Online (MIMO) project which aimed to create "a single access point to digital content and information on the collections of musical instruments held in a consortium of European museums". The system consists of several levels below those five major levels which are not shown in Figure 2. A complete list of musical instruments classification which is listed in decimal notation can refer to [8].

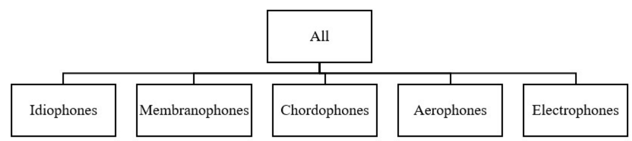


Figure 2: Hornbostel-Sachs musical instrument classification system.

The five top classes in the H-S system are idiophones, membranophones, chordophones, aerophones, and electrophones. They were divided by the primary source of sound from the musical instruments. For idiophones, the sound vibration is coming from the substance of the instrument itself, without requiring stretched membranes or strings. The sound from membranophones instruments is excited by tightly stretched membranes while chordophones instruments are by stretched string between fixed points. As for aerophones, the vibration is mainly from the air itself. Lastly, electrophones are instruments that use materials generating acoustic sound signals, electronically stored data, or electronic circuitry to generate electrical signals that are then transferred to a loudspeaker to produce sound [8].

Hornbostel-Sachs classification system is one of the various systems that have been used throughout history. Several other systems are also widely used. The western classification system is used in the west, dividing instruments into the woodwind family, string family, brass family, and percussion family. The Chinese classification system which is historically proven to be the oldest classifying scheme dates from the third millennium BC. The Chinese classification system groups the instruments according to the materials that are made of. For example, stone, wood, silk, and bamboo [9]. However, these classifying systems are not perfect in classifying all musical instruments. Certain musical instruments can be classified in more than one family. For instance, a piano that has strings, but is struck by hammers. So, it could be classified as a string instrument or percussion instrument according to the western system. The application of any classifying system is dependent on the researcher or musician and their focus or scope of research.

3 Sound Recognition System

As mentioned earlier in section 1, MIR is a subtask of the audio recognition system. The task is dealing with the automatic audio recognition of music signals which at the end will extract the information or characteristics of the music content. Musical instrument class is one of the characteristics that could be obtained by the analysis. The application of an audio recognition system in musical instrument classification is not a new thing as there are numerous attempts done by the researcher on it in recent years. Most of the research done in musical instrument classification have adopted the technique used in speech recognition and speaker identification system. This is because a few features from the speech recognition system can be directly applied to solve the musical instrument classification problem [10].

Generally, the musical instrument classification system consists of three steps, preprocessing, feature extraction, and classification as shown in Figure 3. Most of the research on musical instrument classification emphasized feature extraction which is vital in getting the correct characteristics of the sound processed.

Figure 3: Process of audio recognition system in musical instrument classification.

In the first step, the audio input that is captured by the microphone will go through a windowing process by segmenting the audio into shorter signal chunks. A musical audio signal is usually long and may contain a large number of samples given that the sampling rate is higher than 10 kHz. The audio sample is, therefore, couldn't be analyzed directly and need to go through the pre-processing step. This is because the audio signal is constantly changing. To simplify it, the audio signal is split into a continuous sequence of finite frames of samples. The frames with short scales are then assumed to be not changing much. This process converts the non-stationary audio signal into a stationary signal over a short period [11]. Typically, the segmented frame length is in between 10 to 50 milliseconds and will be overlapping with the adjacent frames for about 25 to 50% [5, 12]. This is to ensure that there are no missing signals during the segmentation process. The frame size, however, is related to the length of the processed sound signal [13].

In the pre-processing step, some research will remove the noise or silence part of the audio input before proceeding to the next step [14]. It can help in reducing the computational complexity of the recognition system. For instance, zero-crossing rate (ZCR) or the energy threshold value is used in the research done to eliminate the unwanted silence part of the audio signal. Other than that, they also applied the pre-emphasis which serves the purpose of compensating the suppressed high-frequency formants during sound production by the musical instruments [5].

The next step of sound recognition is the feature extraction of the audio signal. To classify the audio input into any musical instrument class, it is very crucial to identify the characteristics of the sound produced by each musical instrument. This process is also called parameterization that eventually will build the feature vectors that best represent the musical sound. The built feature vectors contain the most significant characteristics or parameters of the musical sound. This will then be very useful in the classification process. There are various methods to extract the characteristics or features from the audio inputs, which will be discussed in detail in section 4.

The significant parameters of the musical instruments' sound constructed in the feature extraction will be used as a descriptor to represent a similar type of musical instrument or to distinguish between different types of musical instruments. This could be done through the classification process based on various techniques or machine learning algorithms called the classifier. There are many classifiers available currently but the choice of the suitable one depends on the goal of the classification system, the accuracy of the classifier, and avoiding overfitting. In general, the classification algorithm consists of two phases: the training phase and the testing phase. In the training phase, the machine learning algorithm under supervised conditions will build representative acoustic models that best represent the sound class that the system wants to recognize. This is done by taking multiple sound samples of the same musical instrument if the musical instrument type is the goal of the machine learning system. After the algorithm is trained, it will then be tested in the testing phase. The unknown sound samples will be imported into the system for classification. The algorithm will classify the incoming sound signal into different classes based on the information acquired in the previous phase [13].

The effectiveness of the sound classification system is the main concern of the researcher. It is measured by comparing the accuracy of different features or classifiers used in the sound classification system. Until today, researchers are still trying to get the best feature set or classifier that could be used in musical instrument classification. Since 2014, there is an annual competition organized by the MIR community called Music Information Retrieval Evaluation eXchange (MIREX). This event lets the participant test their music classification system in a few categories such as genre, musical instrument, music, mood, and artist classification [11]. Other than that, the MIR community is organizing the meeting through the International Society of Music Information Retrieval Conference (ISMIR) every year since 2014.

4 Feature Extraction

Feature extraction and classifier are important components of the classification system. Feature extraction determines the features to be used for the machine learning system. The problems of classifying the sound samples into different classes based on feature vectors will be addressed. The feature vectors represent the similarities between the sound samples.

The features extracted may be redundant and irrelevant. This will cause a burden for the computation time. Therefore, some of the features will be discarded and only a subset of the features will be used at the end. This process is called feature selection. Both feature extraction and feature selection are very crucial in machine learning. It can ease the computation time by selecting only the useful and relevant features particularly when the dataset is too large [15].

There are several approaches to categorize the features extraction of the audio signal in the machine learning system. Due to the manifold nature of audio features, there is no general taxonomy that could be applied to all fields of research. Hence, it is usually designed according to the research field and purpose of the study. Fu et al. [11] unified the taxonomies of audio features by [16] into a single hierarchical taxonomy. The taxonomy consists of low-level features and mid-level features with the top-level providing the information on the human's perception towards music through the semantic labels. The low-level features in this taxonomy are divided into timbre and temporal features. As for the mid-level features, it contains information on rhythm, pitch, and harmony. The taxonomy is grouped into short-term and long-term features.

Alias et al. [13] extended the taxonomy introduced by [17] in their review on feature extraction techniques on speech, music, and environmentally sound. The taxonomy is classified into physically based and perceptually based approaches. These two approaches are then further divided into different parameterization domains such as time, frequency, wavelet, image, cepstral, etc. This is different from the taxonomy by [17] which listed the parameterization domain on the first level of taxonomy and the physically-based and perceptually based features are put under the frequency domain.

In this paper, taxonomy in Figure 4 will be adopted and the features extraction techniques in the literature for the classification of musical instruments will be reviewed. It is noted that some of the domains may not be relevant in the review of the musical instrument classification therefore it will not be covered in this paper. Only the relevant domain such as time, frequency, cepstral, wavelet domain is covered. The mathematical analysis in detail is beyond the objectives of this study and will not be covered in this paper.

4.1 Time Domain

Also called a temporal domain, the time domain is perhaps the most basic domain for audio signals. It is not complex and easy to extract audio features from. It can be displayed directly from the raw audio signal without further transformation. There are four classes of physical time-domain audio features: zero crossing-based, amplitude-based, power-based, and rhythm-based features.

4.1.1 Zero-Crossing Rate-Based Features

The technique used here is based on the analysis of the rate of change of the sound signal. It is a simple but effective method commonly used in MIR.

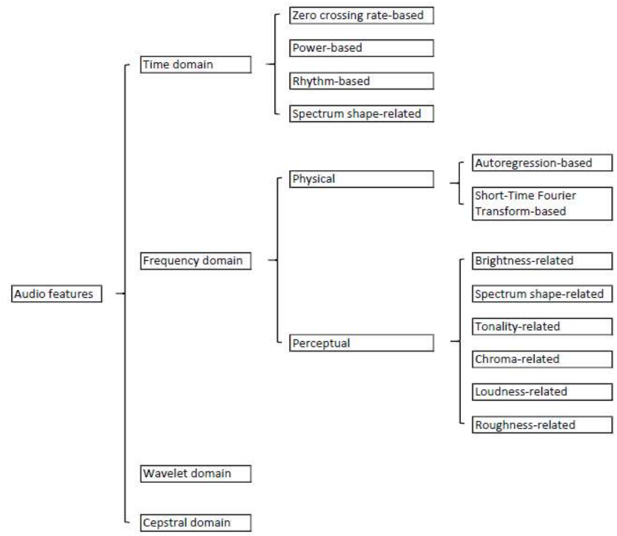


Figure 4: Taxonomy of audio features in musical instrument classification.

Zero-Crossing Rate (ZCR): Known to be one of the easiest features to get from the audio signal. The zero-crossing rate is defined as the number of times the audio signal waveform passed the zero-amplitude level within one second. This feature is widely used in audio classification and machine learning systems. It is measured based on the rate of change of the audio signal and is probably the simplest way for feature extraction. Kedem [18] and El-Maleh et al. [19] mentioned in their papers that the ZCR can provide a rough estimation of the dominant frequency and the spectral centroid in the signal. ZCR is quite popular in the musical instrument classification field.

4.1.2 Power-Based Features

Power-based features are extracted based on the audio signal power. Few relevant features are described below.

Energy: Using the frame-based procedure, the energy feature summarizes the energy distribution of each frame over time. Mitrovic et al. used the term short-time energy to represent this feature [17]. The researchers used this feature for finding the energy distribution in each frame and tried to find the differences between the instruments. Bhalke et al. [5] used time-domain energy as the feature in their musical instrument recognition paper.

Temporal Centroid: Temporal centroid gives the time average over the signal envelope in seconds. It represents the instant moment in time that containing the largest average energy of the signal. The temporal centroid has been used as a time-domain audio feature. It may also be classified as a MPEG-7 feature in the musical instrument classification field [12].

Log Attack Time (LAT): The log attack time characterizes the attack of the sound signal. Musical instruments can produce either instant or smooth transitions of musical sounds. It is computed as the logarithm of the time taken from the start to the first significant local peak [12].

Root Mean Square (RMS): Also named as the volume is the review by [17], RMS is computed by finding the root mean square of the waveform magnitude within the frame [20].

4.1.3 Rhythm-Based Features

Rhythm is a relevant characteristic of musical sound that characterizes the sonic events' structural organization [13]. Feature derived under this taxonomy is discussed here.

Periodicity: Periodicity or tempo is the measure of the rhythmic strength or repetitive structures of audio signals [21]. Periodicity is obtained by applying the autocorrelation function to acquire the mean value of the maximum peaks through all the signal frames.

4.1.4 Spectrum Shape-Related Features

The spectrum shape of the audio signal is another relevant feature that could be employed in the task of musical instrument classification. Spectrum shape-related features are described in the following paragraphs.

Attack, Decay, Sustain, and Release (ADSR) Envelope: The temporal envelope of musical instrument sounds are characterized by attack time, decay time, sustain time, and release time as shown in Figure 5. Attack time is the time taken for the sound signal to rise from zero to the peak. The decay time is the subsequent time to run down the signal level from peak to the sustained level. Sustain time is the main sequence where the signal level remained the same and lastly, the release time represents the time taken for the signal to decay back to the zero levels. ADSR combined up to form a signal envelope that could be extracted as a feature in vector form in the musical instrument classification task [5].

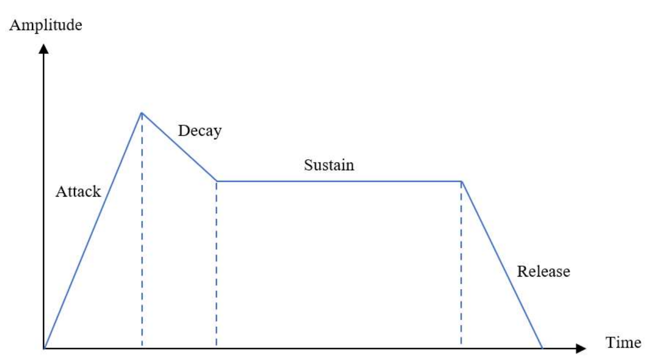


Figure 5: The ADSR envelope

Amplitude Modulation (AM): Amplitude modulation (AM) features are extracted from the audio signal for the peaks which corresponds to the frequency of amplitude modulation. AM has measured over two spectral ranges 4 to 10 Hz and 10 to 40 Hz [22].

Autocorrelation Coefficients (AC): Autocorrelation coefficients (AC) represent the overall shift of the spectrum [23]. Brown reported that AC is useful in musical instrument identifications [24].

Temporal Kurtosis: Temporal kurtosis shows the spikiness of the audio envelope. It is used in measuring the variation of the transients of the audio signal over successive frames [25].

4.2 Physical Frequency Domain

The frequency domain is also named the spectral domain. According to [17], audio features on the spectral domain form the largest set of audio features. They are acquired from autoregression analysis or Short-Time Fourier Transform (STFT). This paper employed the approach by [17] in further dividing the frequency domain into two subsets: physical features and perceptual features. In this section, features extracted in the physical frequency domain for the musical instrument classification task will be discussed first.

4.2.1 Autoregression-based

Autoregression-based features use linear prediction analysis on signal processing. The linear predictor captures the spectral predominance of audio signals [13]. Commonly used autoregression-based features are discussed below.

Linear Prediction Coefficients (LPC): Linear prediction coefficients capture the spectral envelope of the audio signal, such as formant frequencies that could be found in the vocal tract. It has been used extensively in speech recognition applications. The application of LPC in musical instrument classification could be found in the works by [14]. The prediction model used is shown in Figure 6. It consists of the input *u(n)* which is the periodical sound produced by the musical instrument, *H(z)* which represents the musical instrument system and the output *o(n)* represents the music.

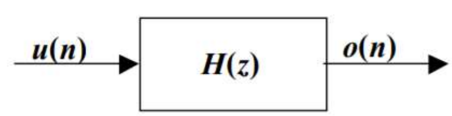


Figure 6: Linear prediction model for musical instrument sound production [14].

Line Spectral Frequencies (LSF): Line Spectral Frequencies are also called Line Spectral Pairs (LSP). It is obtained by finding the root phases of the two polynomials that are decomposed from the LPC [26]. LSF is proved to be more robust when compared to LPC as they provide statistical properties.

4.2.2 Short-Time Fourier Transform-Based Frequency Features

Short-Time Fourier Transform or STFT-based audio features are obtained from the signal spectrogram that is employed by STFT computation. According to [17], there are two ways to yielding the STFT features, either from the spectrogram envelope or from the STFT phase. The application of STFT-based features in musical instrument classification is found to be mostly, if not all, from the spectrogram envelope. These features are widely employed by researchers and are discussed below.

Spectral Flux: Spectral flux (SF) is defined as the 2-norm of the frame to frame spectral amplitude difference vector by [27]. SF measures the changes in the spectrum shape over time. Signals without much variation like noise will show low SF, while the high SF indicates sudden changes that are useful in detecting certain information like the onset of sound.

Spectral Peaks: As defined by [28], spectral peaks are the constellation maps that display the most significant local peaks in the time-frequency signal distortions. The advantage of this feature is that it is highly robust to noise since the significant peak frequencies are usually free from noise disturbance. This feature is used by [28] in the Shazam search engine.

Audio Spectrum Envelope: Audio spectrum envelope (ASE) is defined as the log-spectrum frequency power spectrum that produced a reduced spectrogram of the original audio signal. ASE consists of coefficients that describe the power spectrum density within a series of frequency bands. Categorized as a MPEG-7-based low-level descriptor, it is suitable for automatic musical sound recognition [29].

4.3 Perceptual Frequency Domain

Another division of frequency-based features is the perceptual domain. Perceptual features have a semantic meaning as the human auditory perception. In this section, several perceptual features will be included and discussed.

4.3.1 Brightness-Related Perceptual Frequency Features

The brightness of an audio signal characterizes the frequency spectrum distribution. An audio signal is considered bright when it is dominated by high frequencies. Brightness is also defined as the balancing point of the signal energy [27].

Spectral Centroid: Spectral centroid (SC) is one of the commonly used features. It describes the center of the gravity (centroid) of the spectral energy. It can also be defined as the first moment which is the frequency position of the mean value of the spectrum [30]. Deng et al. in their work on musical instrument classification defined that the SC measures the average frequency weighted by the sum of spectrum amplitude within each frame [12].

Sharpness: Even though it is often treated to be similar to the spectral centroid, sharpness is computed based on the specific loudness instead of the spectrum magnitude. The sharpness of a sound increases as the strength of the high frequencies of the spectrum increases [31].

4.3.2 Spectrum Shape-Related Perceptual Frequency Features

Spectrum shape is considered one of the popular and widely used approaches in MIR. The relevant set of spectrum-shape-related features are listed below.

Bandwidth: Bandwidth is also called a centroid width. It shows the weighted average of the deviations between the spectral components with the spectral centroid [32]. It is the second-order statistic of the spectrum which could distinguish the tonal sounds and noise-like sounds. Bandwidth can be defined from the logarithmic approach or the power spectra [20]. Alternatively, it could also be computed from the entire spectrum or within the spectrum subbands [33]. According to the MPEG-7 standard, bandwidth is defined as the audio spectrum spread (ASS) which is obtained by computing the standard deviation of the signal spectrum.

Spectral roll-off point: Spectral roll-off point is defined as the *N*% percentile of the power spectral distribution. *N* is set at the 95th percentile by [27]. It's a measurement of the skewness of the spectral shape.

Spectral flatness: Spectral flatness measures the flatness of the frequency distribution of the power spectrum. It is calculated by taking the ratio between geometric and the arithmetic mean of a subband in the power spectrum [33]. Spectral flatness can differentiate between noise-like sounds and tonal sounds. Noise-like sounds and tonal sounds are high and low in ratio, respectively. This is beneficial in the musical instrument classification task.

Spectral crest factor: This feature is the contrast of spectral flatness. The spectral crest factor measures the spikiness of the power spectrum. It can be obtained by finding the ratio of the maximum power spectrum and the mean power spectrum of a subband. Opposite to the spectral flatness, noise-like sounds will show a low spectral crest factor while tonal sounds give a higher spectral crest factor. Eronen and Klapuri applied crest factors in their research on musical instrument classification [34].

Entropy: Another measurement of spectral flatness is entropy. It is used in measuring the noisiness of the audio signal. Shannon entropy is usually computed in different subbands [33].

Spectral slope: Spectral slope is a measurement of the inclination of the spectrum shape by applying the linear regression method [35].

Spectral skewness and kurtosis: Spectral skewness is defined as the asymmetry of the spectral distribution around the spectral centroid. Spectral kurtosis, on the other hand, tells the spikiness of the frequency spectrum. The value of spectral kurtosis is high if the spectrum is spikier and low if it is flatter [25].

4.3.3 Tonality-Related Perceptual Frequency Features

The review by [13] put the features under the tonality category differently from the review by [17]. According to [13], tonality features are related to the fundamental frequency which is defined as the lowest frequency of the stationary harmonic sound signal. Tonality describes the structure of the sounds that constitute the fundamental frequency and its partials. Tonality-related features that are widely used in musical instrument classification will be listed and discussed below.

Fundamental Frequency: Denoted as "F naught" or F0, the estimation of fundamental frequency could be done with several approaches, such as spectral methods, autocorrelation methods, or cepstral methods. In the review by [17] and some other literature, the fundamental frequency is denoted as a pitch of the audio signal. Work by [22] extracted fundamental frequency as a feature in instrument recognition.

Harmonicity: Also called partials, harmonics are the integer multiples frequencies of the fundamental frequency. They are often denoted as F1, F2, F3, etc. Harmonicity features can distinguish between periodic and non-periodic sound signals and are commonly employed in recognizing musical instruments. There are two measurements of harmonicity according to the MPEG-7 standard. The first one is the Harmonic ratio which measures the proportion of harmonic components in the power spectrum. The other one measures the upper limit of harmonicity (ULH) which estimates the frequency beyond the spectrum that no longer contains harmonic structure [36].

Inharmonicity: Fundamental and its subsequent harmonics may not always show perfect harmonicity (integer multiples of F0) in the real situation. The actual location of the harmonics may deviate away from its ideal location. This is called inharmonicity and is one of the features extracted in musical instrument timbre classification [37].

MPEG-7 Spectral Timbral Descriptors: Several features are closely related to the harmonic structure of the sound according to the MPEG-7 standard. They are found to be suitable in the discrimination of musical instrument sounds. The features are harmonic centroid, harmonic deviation, harmonic spread, and harmonic variation. The harmonic centroid is the amplitude-weighted average of the harmonic frequencies which is related to the sharpness and brightness. Harmonic deviation measures the deviation of the harmonic peaks from their neighboring harmonic peaks. The harmonic spread is the power-weighted root-mean-square deviation of the harmonic peaks obtained from the harmonic centroid. It is related to the bandwidth of the harmonic frequencies. Lastly, harmonic variation describes the correlation between the two adjacent harmonic peak amplitudes. It represents the harmonic variability of the harmonic structure over time. The application of these features could be found in the work by [12].

Jitter: Jitter determines the deviations of the cycle-to-cycle fundamental frequency. Barbedo and Tzanetakis in their work on the classification of musical instruments describe jitter as the measurement of the stability of the partial over time [38].

4.3.4 Chroma-Related Perceptual Frequency Features

The chroma-related feature is considered as the perceptual feature by [17] and is mainly used in musical information retrieval as it could describe the octave invariance of the sound signal. Chroma is normally ranged to 12 pitch classes, with each class one note of the twelve-tone equal temperament [39]. Two notes with a separation of one or more octaves are said to be having the same chroma. The same chroma means that the notes will produce the same effect on human auditory perception.

Chromagram: Chromagram is computed from a logarithmic Short-Time Fourier Transform to the spectrogram that represents the energy of the 12 pitch classes. It maps all spectral audio information into one octave which results in spectral compression. This could be used in describing the harmonic musical sound signals.

4.3.5 Loudness-Related Perceptual Frequency Features

Loudness is one of the perceptual features that the human auditory system can sense in listening to the sound signal. Loudness-related perceptual features aim to simulate human hearing ability in the audio retrieval system. Peeters et al. defined loudness as the subjective impression of the sound intensity [23].

Loudness: Loudness is computed from the normalized power spectrum of the input frame which subtracts an approximation of the absolute threshold of hearing. It is then filtered by gammatone filter banks and the frequencies across are summed to obtain the power of each auditory filter. These powers which represent the internal excitations will be compressed, scaled, and summed across the filters to extract the loudness estimation [40].

Specific Loudness Sensation: Specific loudness sensation is a measurement of loudness in sone units. Sone units are defined as a perceptual scale for loudness measurement according to [23]. Pampalk et al. computed this feature by merging the spectral masking effect and the Bark-scale frequency analysis [41].

4.3.6 Roughness-Related Perceptual Frequency Features

Roughness is a fundamental hearing sensation that measures the sensory dissonance of the sound signals. According to [42], the amplitude variations which change rapidly will cause unpleasantness and reduce the noise quality, hence deducing that the sound is rough. Computation of roughness can refer to the work by [31, 40]. The application of roughness as a feature in musical instrument classification can see [38].

4.4 Wavelet Features

The application of wavelet is based on the division of the continuous-time signal or given function into different scale components [13]. Wavelet transform can extract the desired time-frequency components of the musical sound signal. The wavelet is decomposed into sub-bands which will be further analysed. The characteristics information of the particular musical sound signal can then be obtained. According to [43], comparing to Fourier transform, wavelet transform has advantages in showing the functions consisting of discontinuities and sharp peaks. It is also good in constructing and deconstructing finite non-stationary signals.

Daubechies Wavelet coefficient histogram features: Proposed by [44] in their study on music genre classification, Daubechies wavelet coefficient histogram is applied by decomposing the audio signal by Daubechies wavelet. Histograms are built from the wavelet coefficients obtained for each subband. The histograms estimate the waveform variation of each subband. Wavelet features are obtained by computing the first three statistical moments and the energy of the coefficients subband.

4.5 Cepstral Features

Introduced by [45] with the concept of "cepstrum", cepstral features represent the smoothed frequency based on the logarithmic magnitude. It was first employed in speech analysis [46] and is now widely used in various fields of audio information retrieval.

4.5.1 Perceptual Filter Bank-Based Features

Perceptual filter banks-based features are computed based on the cepstral domain. The sound signal is first Fourier transformed; the magnitude is then converted into the logarithmic scale. Discrete Cosine Transform will be performed on the previous result to decorrelate the output data.

Mel-frequency cepstral coefficients (MFCCs): Also called MFCC, this feature is very well known in automatic speech recognition and audio content classification. MFCC is designed and computed based on the human auditory model. To extract the MFCC features, the audio signal is framed into short frames and the periodogram estimate for each frame is computed. Mel frequency is then applied to the power spectra before the energy in each filter is summed. All the filterbank energies are then logarithmized and lastly, they are decorrelated by the Discrete Cosine Transform (DCT). Only 8-13 DCT coefficients will be used to represents the spectral shape of the audio signal. The first DCT coefficients represent the spectrum's mean power. The second coefficient represents the spectral centroid. Higher-order coefficients are related to spectral details like pitch [17]. Figure 7 shows the MFCCs obtained from the flute musical instrument.

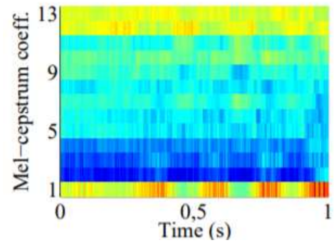


Figure 7: MFCCs for the flute musical instrument [17].

4.5.2 Autoregression-Based Features

Autoregression analysis is often used in signal processing. This technique uses linear prediction analysis that can predict the value of every signal sample by the linear combination of previous values [47].

Complex Cepstrum: According to the [48], complex cepstrum is the inverse Fourier transform of the logarithm of the signal's Fourier transform. Application of the complex cepstrum on the musical instrument recognition can read the work by [49].

Linear Prediction Cepstral Coefficients (LPCC): Linear prediction cepstral coefficients are the alternative for linear prediction coefficients (LPC) discussed earlier above. They are obtained by the inverse Fourier transform of the log magnitude frequency response of the linear prediction spectral envelope [50]. In comparison to LPC, LPCC is more robust in representing the spectral envelope.

5 Classification

After feature extraction and selection, classifiers are used in the machine learning system to classify the isolated musical sounds into the instrument and its family. In this section, several techniques commonly used in automatic musical instrument classification will be discussed. It is worth noting that the accuracy or effectiveness of the classifier is affected by many factors (number of samples, combination with different features, number of samples used in the testing phase and training phase, etc.). Therefore, the classifiers in the following paragraphs will not include the accuracy obtained by each literature reviewed in this paper.

5.1 K-Nearest Neighbours

Also denoted as KNN, this classifier is one of the popular machine learning algorithms. In the training phase, it will store the feature vectors from all the training samples and then use them in classifying the new test samples. By referring to the set of k nearest training samples in the feature set, the new sample will be assigned to the class with the most examples in the set. The system is using the Euclidean distance measurement method. Details of how the classification process goes can refer to the Figure 8 below.

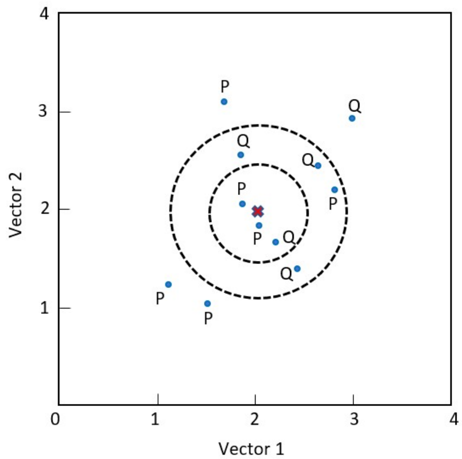


Figure 8: Design of the KNN technique.

From Figure 8 above, the cross is the target of the classification. If k=3 is selected (inner circle), then the cross would be categorized as class P as the three nearest neighbours to that cross are mostly from class P. However, if k=7 is selected (outer circle), the cross would now be categorized as class Q with Q be the majority neighbours.

k-Nearest Neighbours is a simple algorithm that is widely used in the automatic machine learning system, but some downsides are to be considered when implementing this technique. According to [51], this algorithm is lazy and requires stores all the training samples in the memory to generate a decision for the new sample. It is also highly sensitive to the irrelevant features which could dominate the distance metrics. Heavy computational load is another drawback of this algorithm.

5.2 Support Vector Machine

Another popular classifier used is the support vector machine (SVM). It is based on the statistical learning theory developed by [52]. The working principle of SVM is looking for the optimal linear hyperplane which gives the lowest generalization errors when classifying the unknown test sample. The linear hyperplane is mapped so that the margin between the different categories is separated as wide as possible. It serves as the borderline between the categories. The new test samples could be categorized based on which side they fall when they are mapped into space. The hyperplane is a linear line when the features can be separated into 2 dimensions. It will become a 2D plane when it is displayed in three-dimension space. This approach can be used when linearly hyperplane couldn't separate the data in 2-dimensional space and requires higher dimensional space to do so. This is achieved by applying the so-called "kernel trick" as illustrated in Figure 9. Kernel trick transforms the low dimensional input space to a higher dimensional space so that the segregation (hyperplane) could take place.

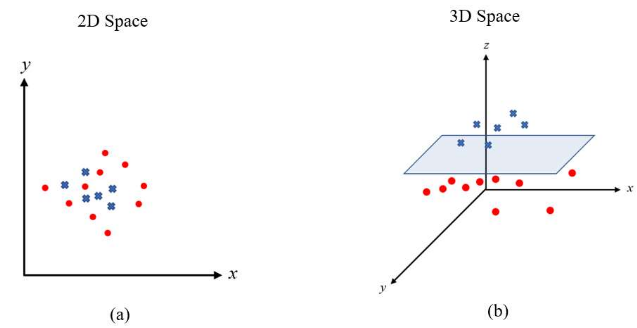


Figure 9: (a) Inseparable data in 2D space (b) Hyperplane separating the data in 3D space with the kernel trick.

Even though SVM is a popular algorithm used by many in their research, SVM does still gives some drawbacks. In the multiclassification task, SVM needs to perform a series of interconnections between the classes. Computation-wise, it is an intensive process to work on. Also, there is a risk of selecting the less optimal kernel function during the process.

5.3 Decision Trees

Decision trees have been pervasively implemented in classification tasks and machine learning systems. This technique attempts to focus on the relevant features and abandons irrelevant ones in the construction of the tree. A decision tree is built top-down that begins with the most informative root node. Usually, two branches will split from the root which represents different descriptor values or attribute. Each node in the tree represents the test of the samples' attributes, and the descendant node represents the result of the test. The complete tree is built by repeating the training process recursively with the training samples. After that, pruning work will be carried out to avoid overfitting. The decision tree is commonly used in supervised learning methods which produce high accuracy, stability, and are easy to interpret.

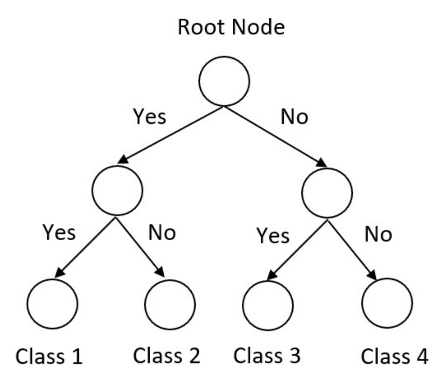


Figure 10: Decision tree in classifying 4 classes of musical instruments.

In the musical instrument classification task, the decision tree can also help in identifying the best feature in discriminating instruments. From the literature, the common decision tree algorithm used is J48 or also known as C4.5. This algorithm is also called a statistical classifier which is developed by [53].

5.4 Naive Bayesian Classifiers

Naïve Bayesian Classifier (NBC) is the classification technique based on the Bayes' Theorem. This technique uses a conditional probability model in the prediction of classes. Naïve Bayes classifier assumes that the classification features are independent, hence it is called "naïve". Like the other classifiers, NBC will be trained by collecting enough training samples. The probabilities of different classes and features will be obtained by counting the frequencies of their occurrence in the training phase. A new sample can then be classified based on conditional probabilities. BNC is one of the easy and fast algorithm one can use in the classification task. It requires less training data and is not computationally intensive. However, this algorithm is known as a bad estimator. It is also too "naïve" by assuming that the features are completely independent in real life. Deng et al., in their works on the feature analysis for musical instrument classification, used the NBC technique as one of the classifiers [12].

5.5 Artificial Neural Networks

Artificial neural networks (ANN) are inspired by biological neural networks. It is constructed based on a large collection of interconnected artificial neurons. These neurons are arranged into layers in which the transmission of signal happens from the input layer to the output layer by the connection called edges. These edges have a weight that tells the strength between the connecting layers. The weight may change during the learning process. With sufficient training samples, the network becomes capable of predicting the outcome from the input. This learning process can be done either supervised or unsupervised. The prediction accuracy of ANN is getting better when more examples are processed. It keeps on learning and refining the weight for every sample processed. Implementation of ANN in musical instrument classification can be found in [10].

5.6 Hidden Markov Models

Abbreviated as HMM, Hidden Markov Model is a statistical Markov model that contains two components. The first is a set of hidden variables that is unobservable directly from the data while the second is another set of variables that are conditional on the first set of hidden variables [54]. HMM is used in predicting a sequence of the hidden variables from a set of observed variables. This allows the model to generate a random measurement in each state from a variety of distributions.

5.7 Gaussian Mixture Models

The Gaussian mixture model is a probabilistic model to representing the subpopulation that is normally distributed within the overall population. Without needing to know which the data point belongs to, this allows GMM to automatically learn the subpopulation. This model can do the clustering of groups of data mixed. This is done by the computation of the three parameters which are the mean, covariance, and the mixing probability of the Gaussian mixture. Due to this, GMM is unsupervised learning. This classifier has been used in speech recognition, image pattern recognition, and musical instrument classification. GMM is one of the popular classifiers used intensively in instrument classification. For instance, refer to [14].

5.8 Discriminant Analysis

Discriminant analysis is a technique used in machine learning to find the linear, quadratic, or logistic functions of the features that characterize or separates samples into two or more predefined classes. Discriminant analysis is related to the multivariate analysis of variance (MANOVA) and regression analysis. This technique could determine the most discriminative features of each class and the most similar or dissimilar classes. Martin and Kim used linear discriminant analysis in their research on musical instrument identification [55].

5.9 Higher-Order Statistics

Higher-order statistics (HOS) is the technique that uses the sample function with cubic power or higher. Conventional techniques (lower-order statistics) are functions with constant, linear, or quadratic functions. Mean and variance is examples of lower-order statistics. HOS in the analysis of musical signals used skewness and kurtosis as the estimation of the shape parameters.

6 Conclusion and Future Work

In this paper, two important steps in the process which are feature extraction and classification are reviewed. The application of the MIR in classifying musical instruments into different families or individual instruments is gaining wide interest from researchers and musicians. Different approaches have been used and they harvested different results. The effort is to obtain the best feature set which contains either individual or the combination of temporal, spectral, cepstral, and other properties of sound in the classification task. Choosing a good classifier is also important in which it can better identify the subtle characteristics of different instruments or families.

From the review in this paper, we have discussed various approaches in the features and classifiers used in classifying monophonic instrumental sounds. While the coverage of this paper is not exhaustive, it is apparent that there is no specific feature or classifier which can be considered as the best in the musical instrument classification task. Most of the works by the literature reviewed in this paper are on the comparison of the accuracy obtained by the different combinations of features and classifiers. The different combination shows different accuracies and also projected both advantages and disadvantages. The selection of the appropriate features or classifier is dependent on the specific task of classification. For instance, the complexity of the learning phase, database size, real-time limitations, etc. However, it can be concluded that fewer features used in the sound recognition system will usually achieve better accuracy and also reduces the computational burden.

It can be noticed that certain literature reviewed is working on traditional musical instruments. These efforts sparked the interest of the authors in working towards the classification of the sound of the local traditional musical instruments. However, our research interest is not in the classification of the individual instrument or families. To our knowledge, an approach yet to be tested is the ability of the sound classification system in identifying the sound quality produced by the traditional musical instrument. The current work by authors or any other future efforts can be focusing on the instruments' sound quality. It is agreeable that "no instruments are 100% alike", hence the quality of each instrument might differ from one another and this is something worth study for. The subtle differences in sound quality might create another tough challenge in the MIR field, but it is worthy to explore for and it is hoped that the new exploration may produce useful knowledge in the future.

Remerciements/Acknowledgments

This paper is extracted from the Ph.D. work of the first author who is currently under the sponsorship of the University College of Technology Sarawak (UCTS). This work is also funded by UCTS under Grant No 4/2018/01.

References

[1] J. Meyer, Acoustics and the performance of music: Manual for acousticians, audio engineers, musicians, architects and musical instrument makers, Springer Science & Business Media2009.

[2] L. Tronchin, Modal analysis and intensity of acoustic radiation of the kettledrum, The Journal of the Acoustical Society of America 117(2) (2005) 926-933.

[3] S. Yoshikawa, Acoustical classification of woods for string instruments, The Journal of the Acoustical Society of America 122(1) (2007) 568-573.

[4] D. Gerhard, Audio signal classification: History and current techniques, Citeseer2003.

[5] D. Bhalke, C.R. Rao, D.S. Bormane, Automatic musical instrument classification using fractional fourier transform based-MFCC features and counter propagation neural network, Journal of Intelligent Information Systems 46(3) (2016) 425-446.

[6] E.M. Von Hornbostel, C. Sachs, Systematik der musik-instrumente. Ein versuch, Zeitschrift für Ethnologie 46(H. 4/5) (1914) 553-590.

[7] F.W. Galpin, A textbook of European musical instruments: their origin, history and character, London: Williams & Norgate1937.

[8] M. Consortium, Revision of the Hornbostel-Sachs classification of musical instruments by the MIMO Consortium, Available in:< http://network. icom. museum/cimcim/resources/classification-of-musical-instruments (2011).

[9] D.E. Hast, J.R. Cowdery, S.A. Scott, Exploring the world of music: an introduction to music from a world music perspective, Kendall Hunt1999.

[10] I. Kaminsky, A. Materka, Automatic source identification of monophonic musical instrument sounds, Proceedings of ICNN'95-International Conference on Neural Networks, IEEE, 1995, pp. 189-194.

[11] Z. Fu, G. Lu, K.M. Ting, D. Zhang, A survey of audio-based music classification and annotation, IEEE transactions on multimedia 13(2) (2010) 303-319.

[12] J.D. Deng, C. Simmermacher, S. Cranefield, A study on feature analysis for musical instrument classification, IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) 38(2) (2008) 429-438.

[13] F. Alías, J.C. Socoró, X. Sevillano, A review of physical and perceptual feature extraction techniques for speech, music and environmental sounds, Applied Sciences 6(5) (2016) 143.

[14] J. Marques, P.J. Moreno, A study of musical instrument classification using gaussian mixture models and support vector machines, Cambridge Research Laboratory Technical Report Series CRL 4 (1999) 143.

[15] M.N. Murty, V.S. Devi, Introduction to pattern recognition and machine learning, World Scientific2015.

[16] N. Scaringella, G. Zoia, D. Mlynek, Automatic genre classification of music content: a survey, IEEE Signal Processing Magazine 23(2) (2006) 133-141.

[17] D. Mitrović, M. Zeppelzauer, C. Breiteneder, Features for content-based audio retrieval, Advances in computers, Elsevier2010, pp. 71-150.

[18] B. Kedem, Spectral analysis and discrimination by zero-crossings, Proceedings of the IEEE 74(11) (1986) 1477-1493.

[19] K. El-Maleh, M. Klein, G. Petrucci, P. Kabal, Speech/music discrimination for multimedia applications, 2000 IEEE International Conference on Acoustics, Speech, and Signal Processing. Proceedings (Cat. No. 00CH37100), IEEE, 2000, pp. 2445-2448.

[20] Z. Liu, J. Huang, Y. Wang, T. Chen, Audio feature extraction and analysis for scene classification, Proceedings of First Signal Processing Society Workshop on Multimedia Signal Processing, IEEE, 1997, pp. 343-348.

[21] L. Lu, H. Jiang, H. Zhang, A robust audio classification and segmentation method, Proceedings of the ninth ACM international conference on Multimedia, 2001, pp. 203-211.

[22] A. Eronen, Comparison of features for musical instrument recognition, Proceedings of the 2001 IEEE Workshop on the Applications of Signal Processing to Audio and Acoustics (Cat. No. 01TH8575), IEEE, 2001, pp. 19-22.

[23] G. Peeters, A large set of audio features for sound description (similarity and classification) in the CUIDADO project, CUIDADO IST Project Report 54(0) (2004) 1-25.

[24] J.C. Brown, O. Houix, S. McAdams, Feature dependence in the automatic identification of musical woodwind instruments, The Journal of the Acoustical Society of America 109(3) (2001) 1064-1072.

[25] A. Klapuri, M. Davy, Signal processing methods for music transcription, Springer Science & Business Media2007.

[26] J.P. Campbell, Speaker recognition: A tutorial, Proceedings of the IEEE 85(9) (1997) 1437-1462.

[27] E. Scheirer, M. Slaney, Construction and evaluation of a robust multifeature speech/music discriminator, 1997 IEEE international conference on acoustics, speech, and signal processing, IEEE, 1997, pp. 1331-1334.

[28] A. Wang, An industrial strength audio search algorithm, Ismir, Washington, DC, 2003, pp. 7-13.

[29] H.-G. Kim, N. Moreau, T. Sikora, Audio classification based on MPEG-7 spectral basis representations, IEEE Transactions on Circuits and Systems for Video Technology 14(5) (2004) 716-725.

[30] G. Tzanetakis, P. Cook, Musical genre classification of audio signals, IEEE Transactions on speech and audio processing 10(5) (2002) 293-302.

[31] E. Zwicker, H. Fastl, Facts and Models, Springer, 1999.

[32] E. Wold, T. Blum, D. Keislar, J. Wheaten, Content-based classification, search, and retrieval of audio, IEEE multimedia 3(3) (1996) 27-36.

[33] A. Ramalingam, S. Krishnan, Gaussian mixture modeling of short-time Fourier transform features for audio fingerprinting, IEEE Transactions on Information Forensics and Security 1(4) (2006) 457-463.

[34] A. Eronen, A. Klapuri, Musical instrument recognition using cepstral coefficients and temporal features, 2000 IEEE International Conference on Acoustics, Speech, and Signal Processing. Proceedings (Cat. No. 00CH37100), IEEE, 2000, pp. II753-II756 vol. 2.

[35] F. Morchen, A. Ultsch, M. Thies, I. Lohken, Modeling timbre distance with temporal statistics from polyphonic music, IEEE Transactions on Audio, Speech, and Language Processing 14(1) (2005) 81-90.

[36] X. Zhang, W.R. Zbigniew, Analysis of sound features for music timbre recognition, 2007 International Conference on Multimedia and Ubiquitous Engineering (MUE'07), IEEE, 2007, pp. 3-8.

[37] G. Agostini, M. Longari, E. Pollastri, Musical instrument timbres classification with spectral features, EURASIP Journal on Advances in Signal Processing 2003(1) (2003) 943279.

[38] J.G.A. Barbedo, G. Tzanetakis, Musical instrument classification using individual partials, IEEE Transactions on Audio, Speech, and Language Processing 19(1) (2010) 111-122.

[39] R.N. Shepard, Circularity in judgments of relative pitch, The Journal of the Acoustical Society of America 36(12) (1964) 2346-2353.

[40] M. McKinney, J. Breebaart, Features for audio and music classification, (2003).

[41] E. Pampalk, A. Rauber, D. Merkl, Content-based organization and visualization of music archives, Proceedings of the tenth ACM international conference on Multimedia, 2002, pp. 570-579.

[42] P. Daniel, R. Weber, Psychoacoustical roughness: Implementation of an optimized model, Acta Acustica united with Acustica 83(1) (1997) 113-123.

[43] S. Mallat, A theory for multiresolution signal decomposition: The wavelet representation Fundam, Pap. Wavelet Theory 2 (2009) 494-513.

[44] T. Li, M. Ogihara, Q. Li, A comparative study on content-based music genre classification, Proceedings of the 26th annual international ACM SIGIR conference on Research and development in informaion retrieval, 2003, pp. 282-289.

[45] B.P. Bogert, The quefrency alanysis of time series for echoes; Cepstrum, pseudo-autocovariance, cross-cepstrum and saphe cracking, Time series analysis (1963) 209-243.

[46] S. Davis, P. Mermelstein, Comparison of parametric representations for monosyllabic word recognition in continuously spoken sentences, IEEE transactions on acoustics, speech, and signal processing 28(4) (1980) 357-366.

[47] T.E. Tremain, The government standard linear predictive coding algorithm: LPC-10, Speech Technology (1982) 40-49.

[48] A.v. Oppenheim, R. Schafer, T. Stockham, Nonlinear filtering of multiplied and convolved signals, IEEE transactions on audio and electroacoustics 16(3) (1968) 437-466.

[49] J.C. Brown, Computer identification of musical instruments using pattern recognition with cepstral coefficients as features, The Journal of the Acoustical Society of America 105(3) (1999) 1933-1941.

[50] Q.-Z. Wu, I.-C. Jou, S.-Y. Lee, On-line signature verification using LPC cepstrum and neural networks, IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics) 27(1) (1997) 148-153.

[51] T.M. Mitchell, Machine learning. 1997, Burr Ridge, IL: McGraw Hill 45(37) (1997) 870-877.

[52] V. Vapnik, Statistical learning theory Wiley, New York 1 (1998) 624.

[53] J. Quinlan, C4. 5: programs for machine learning, Elsevier (2014).

[54] P. Herrera-Boyer, G. Peeters, S. Dubnov, Automatic classification of musical instrument sounds, Journal of New Music Research 32(1) (2003) 3-21.

[55] K.D. Martin, Y.E. Kim, Musical instrument identification: A pattern-recognition approach, The Journal of the Acoustical Society of America 104(3) (1998) 1768-1768.


HBK
HOTTINGER BRÜEL & KJÆR
TECHNOLOGY BY
B K
Brüel & Kjær
NEED TO SIMPLIFY
NOISE MEASUREMENT
AND ANALYSIS?
JOB DONE.
No matter which profession you are in, you need a sound level meter solution that gets your job done faster, easier and problem-free. The new B&K 2245 gives you absolute confidence and control through user-friendly mobile apps and functionality tailored for your task, including on-site analysis, photo embedding, smart data handling on your PC, and more.
To simplify your job-to-do, visit www.hbkworld.com/2245
HBM
B K
Brüel & Kjær
64.5

CROWDSOURCING LISTENING TESTS USING AN AUDIO POLLING STATION

Olivier Robin*[1,2], Abdelghani Benghanem†[1,2], Philippe Gournay‡[3], Olivier Valentin§[1,2], Philippe-Aubert Gauthier¶[4,2], Roch Lefebvre‖[3], and Alain Berry[1,2]**

[1]Groupe d'Acoustique de l'Université de Sherbrooke, Université de Sherbrooke, Sherbrooke, Québec, Canada;
[2]Centre for Interdisciplinary Research in Music, Media, and Technology, McGill University, Montréal, Québec, Canada;
[3]Groupe de Recherche sur la Parole et l'Audio, Université de Sherbrooke, Université, Sherbrooke, Québec, Canada;
[4]Ecole des arts visuels et médiatiques, Université du Québec à Montréal, Montréal, Québec, Canada.

Résumé

Afin de proposer une alternative aux tests d'écoute contrôlés en laboratoire, une approche basée sur la production participative a été testée par le biais d'une station de vote audio installée dans le cadre d'une exposition sur le son. Les personnes visitant l'exposition étaient invités à donner leur avis sur la qualité sonore des véhicules et sur la qualité sonore des algorithmes de codage audio. Pour les mêmes échantillons sonores, une série de résultats a été préalablement obtenue dans des conditions de laboratoire avec un nombre limité de participants. Dans des conditions partiellement non contrôlées et avec un plus grand nombre de participants, les résultats obtenus à l'aide de la station de vote sont conformes aux résultats obtenus en laboratoire.

Mots clefs: Tests d'écoute, production participative, qualité sonore

Abstract

As an alternative to laboratory controlled listening tests, a crowd sourced approach was tested using an audio polling station installed in a sound-related exhibition. Visitors were asked to provide their opinion concerning sound quality of vehicles and sound quality of audio coding algorithms. Using the same audio samples, another series of evaluation results were obtained in laboratory conditions with a limited number of participants. With partially uncontrolled conditions and a larger number of participants, the results obtained using the audio polling station are in line with laboratory results.

Keywords: Listening tests, crowd sourcing, sound quality

1 Introduction

Formal listening tests are used in a large variety of sound-related research areas, from music perception and digital sound encoding to sound quality research [1], and generally regarded as the most reliable method for audio quality evaluation. In practical terms, such tests generally require complex and controlled protocols that involve consequent manpower and demanding preparation. These constraints often result in a reduced number of participants, and the same trained or practiced listeners might be recurrently enrolled to simplify the setup of tests but also warrant results consistency [2]. Indeed, some standards even explicitly call for experienced listeners, like the International Telecommunication Union ITU-R BS.1534 [3] which specifies the use of at least 20 expert participants. Expert listeners are usually preferred to non-expert ones for such qualifying tests because assessors should be experienced in detecting small impairments in audio signals. While tests conducted using a relatively small group of experts are expected to provide a better and quicker indication of the likely results in the long term, such expert testing might also lead to excessively refined results that are not fully representative of the target customers [4]. Indeed, products or applications will be used by a much more significant number of people with a reduced sensitivity concerning audio quality [5].

Crowdsourcing has been established as a powerful tool to collect and gather human subjective data [6, 7]. The main advantages of using crowdsourcing generally include reduced costs, improved speed and flexibility, together with the acquiring of large data sets. These aspects provide leverage for reducing the complexity of listening tests, and several solutions based on this sourcing model have been proposed including web-based tests, mobile laboratory units and smartphone applications. The latter have for example been used for the production of noise maps through a participatory approach [8, 9]. Mobile laboratory units were initially proposed for on-site hearing screening in the 1960s [10] and recently extended for on-site listening experiments including virtual acoustic environments [11]. However, the great majority of the crowdsourced approaches for listening tests have been web-based [12–15]. Web-based listening tests can be theoretically performed by everyone who has access to a computer with a compatible web browser and an Internet connection. Using web-based listening tests, the data collection pro-

*. Olivier.Robin@usherbrooke.ca
†. Abdelghani.Benghanem@usherbrooke.ca
‡. Philippe.Gournay@usherbrooke.ca
§. m.olivier.valentin@gmail.com
¶. gauthier.philippe-aubert@uqam.ca
‖. Roch.Lefebvre@usherbrooke.ca
**. Alain.Berry@usherbrooke.ca

cess can be largely sped up with reduced time and location constraints. In Cartwright et al. [13], data were collected from 530 participants in only 8.2 hours. Different quality control mechanisms have been proposed to ensure reliable results and limit potential bias sources, and the use of headphones instead of loudspeakers is especially recommended [7]. Several studies [7, 13] have shown that if the listening experiment was properly designed including quality control and limitations of possible stimuli and scenarios, minor differences exist between listening tests carried out in a laboratory environment and those carried out over the Internet.

Classically, listening tests are performed using dedicated equipment in a controlled environment where listeners have to go - whereas most of the cited crowd sourced approaches rely on tests made in uncontrolled environment using variable equipment (generally owned by listeners). The proposal of mobile laboratory units is surely unique in the sense that the laboratory environment goes to the listener. An idea that has not yet been explored in the case of listening tests is making available to the general public a given equipment in a public environment.

The main contribution of this work is thus a proof of concept for the use of an audio polling station for crowd sourcing listening tests, *i.e.* to collect the general public opinion in partially controlled conditions. Such an approach implies that no recruiting and handling of subjects is required while large group of subjects can be tested, and a specific cross-section of the general population can be reached by the placement of the polling station.

In the present work, an audio polling station was installed in an exhibition concerning sound in a science museum. Visitors were asked to provide their opinion, on a voluntary basis, concerning audio samples following a paired-comparison paradigm. The polling station design is detailed in Section 2. The considered test cases are presented in Section 3. Results obtained using a controlled laboratory experiments and the polling station are compared in Section 4, followed by concluding remarks in Section 5.

2 The polling station design and installation

Born out of a collaboration between the Sherbrooke Museum of Nature and Science and Université de Sherbrooke, the exhibition, 'Sound, only sound !', is a touring interactive exhibition that includes fourteen zones covering four different dimensions of sound (seeing, touching, feeling and hearing sound) [16]. One of the interactive zones includes a polling station for crowdsourcing listening tests which is composed of a desktop computer, a touchscreen monitor (Elo 7200), an external sound card (Audient id4) and closed headphones (dbi pro-705), see Figure 1(a). The sound pressure levels were calibrated using a binaural manikin (GRAS 45BB KEMAR Head & Torso, equipped with large ears and GRAS 40AD 1/2" microphones), and it was verified that they did not exceed the WHO recommendations (equivalent sound pressure level L_{eq} over 8 hours not exceeding 75 dB(A) [17]). The same headphones were used for all the participants, which ensured consistent audio level and quality. The background noise in the room was not measured during the museum opening hours, but its effect was estimated to be limited since exhibition areas were quiet ones. Listening using closed headphones was thus considered to provide adequate shielding against this low background noise and a sufficient signal-to-noise ratio. The user interface was developed using the AB test page of Web Audio Evaluation Tool [12], and adapted in terms of content and subject presentation, see Figure 1(b).

Every visitor of the exhibition could access the polling station. Participants were informed that these tests were part of a research project, and that adult consent was required for persons under the age of 18. The only collected information were the answers to the listening tests that followed AB tests, i.e. following a paired-comparison paradigm [18]. Therefore, no ethics approval was required by the *Comité d'éthique pour la recherche*, the internal review board at *Université de Sherbrooke* because (1) this research involved only the observation of individuals in public places, (2) did not involve planned or direct interventions by researchers with participants, and (3) the research subjects did not have a reasonable expectation of privacy and the dissemination of research results does not identify specific individuals [19].

A case-independent approach was followed, *i.e.* listening tests concerning various topics (sound quality of vehicles, music and speech audio compression quality, audio compression effect on voice, sound of backup alarms) were combined. For each test, individuals (or subjects) were asked to listen to two audio samples (A and B), and make a preference choice between A or B. The series of tests was continuously and randomly presented. Examples of icons and corresponding questions are provided in Figure 1(c). The order of presentation of the A/B pairs was also randomized. Concerning sound quality of vehicles and music and speech audio compression quality, results were also previously obtained in controlled laboratory conditions and here compared to the results obtained using the polling station during the first presentation of the exhibition at Sherbrooke (see Sections 3 and 4).

More than 4 000 opinions on the whole series of topics and tests were collected in six weeks at Sherbrooke, Québec, Canada during Summer 2019. After this first iteration, the exhibition also toured in two other locations (The Exploration Place, Prince George, British Columbia, Fall 2019 and Resurgo Place, Moncton, New Brunswick, Winter 2020), but was unfortunately stopped by the COVID-19 pandemic.

3 Considered test cases

3.1 Sound quality of vehicles

Like many attributes related to the perceived quality of a product, sound has become an important factor that influences the consumers' perception of the quality of a vehicle. Consequently, automotive manufacturers have undertaken efforts to design the acoustic signature to match the vehicle image in the customers' mind, as a way to optimize the "desire-to-buy" of their products. Unsupervised perceptive evaluations of the sound signature might be a solution to overcome the diffi-

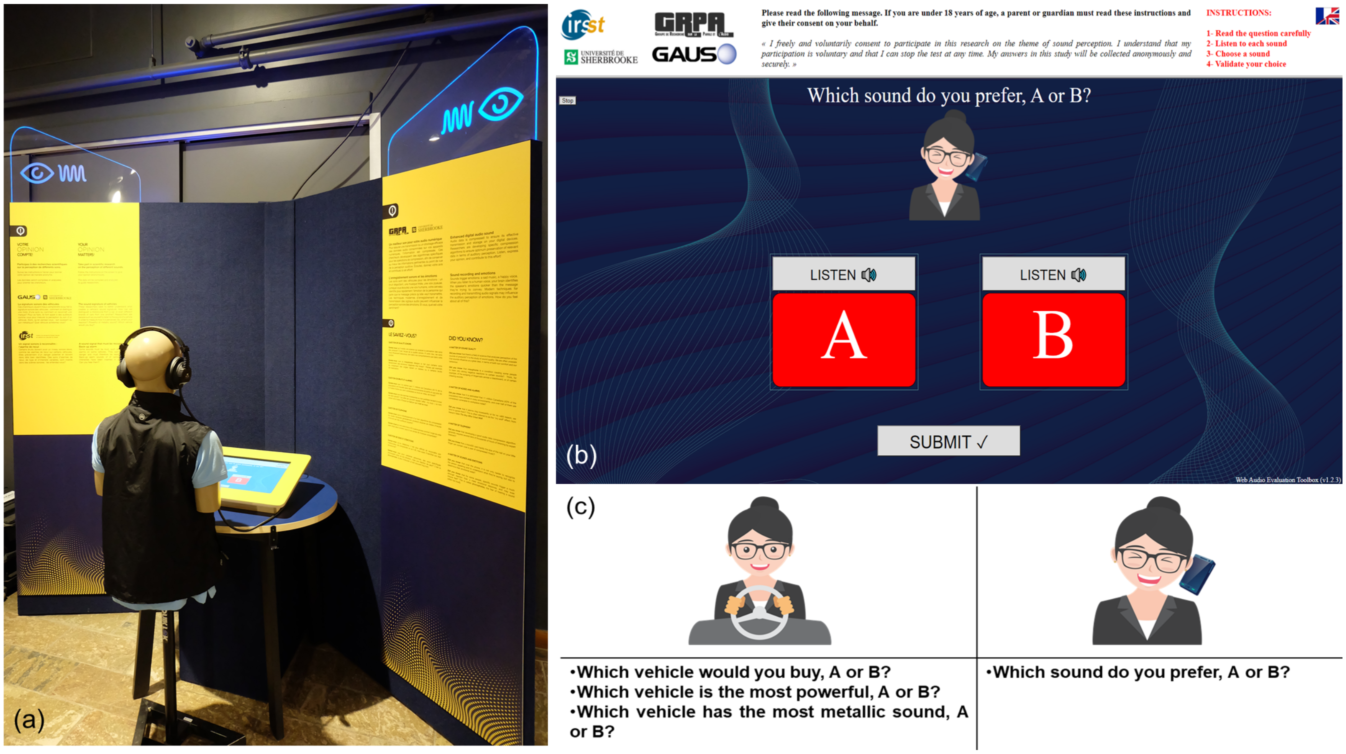


Figure 1: (a) The polling station as presented at Sherbrooke Nature and Sciences Museum - the acoustic manikin illustrates the typical positioning of a participant ; (b) Close-up view of the user interface ; (c) The presented icons and corresponding questions for sound quality of vehicles and sound quality for audio coding algorithms, respectively.

culties linked to classical perceptive measurements performed in laboratory environments (recruiting and handling subjects, providing tools and environment for performing tests), and could expand the possibilities for gathering consumers opinion. The interior sounds of seven side-by-side recreational vehicles (SSV) were recorded on the passenger side while the vehicles were rapidly accelerating on an asphalt road, from 0 to 60 km/h in a few seconds (Wide-open throttle condition). Recordings were performed using a binaural mannequin (GRAS 45BB KEMAR Head & Torso, equipped with large ears and GRAS 40AD 1/2" microphones), with a sampling rate of 48 kHz and a 24-bit resolution. Audio samples presented to the participants had a duration of 5 seconds, and short fade-ins and fade-outs were applied in the beginning and at the end of each sound sample so that they could be repeated without audible artifacts. Audio samples were also equalized to the same global loudness value and were presented to participants using Sennheiser headphones (chosen among models HD600, HD555, HD598, or HD579) [20, 21]. Each headphone was frequency-equalized by filtering each sound sample with appropriate frequency response amplitude-only for the left and right channels of each headset, using 2048-order zero-phase finite impulse response filters. This creates the same output signals from the headphones as those measured with the binaural mannequin. A validation of sound reconstruction was performed : the binaural microphones were installed on the KEMAR mannequin equipped with large artificial ears and the spectrum of the sounds recorded on the mannequin was compared with the spectrum of the original sounds measured in the interior of the vehicle cabin in operating condition.

Twenty-one pairs of sounds to be evaluated were included in the polling station. With seven recordings, all recordings were compared against all others. The A/B testing procedure was used to evaluate each pair of sounds regarding the "desire-to-buy" and two perceptual attributes ("powerful" and "metallic"), chosen among the outcomes of a rapid sensory analysis performed with a pool of consumers of recreational vehiclest [20, 21].

3.2 Sound quality for audio coding algorithms

The objective of this experiment was to compare two audio coding technologies : the xHE-AAC profile of the MPEG-D USAC standard [22], and Layer III of the MPEG-1/2 audio compression standards (MP3). The xHE-AAC codec is the high-quality codec used in the USAC verification test [23]. The MP3 codec is the LAME high quality codec version 3.99.3 operated at a constant bit rate [24].

The xHE-AAC technology is more recent (2012) and therefore in principle more efficient than the MP3 technology which was approved in 1992. Three content categories (speech, music, and speech-over-music) were considered, with two representative audio samples per category. The subjects could listen to and compare two coded versions, one with xHE-AAC and the other with MP3. The xHE-AAC encoder was forced in its linear predictive coding mode and used at a fixed bit rate (24 kbps) while MP3 was used at one of four possible bit rates (from 32 up to 96 kbps). Comparisons thus included twenty-four pairs of stereo audio samples (six different audio samples times four MP3 bit rates). Participants had then to express their preference towards one or the other. Neither the identity of the coders nor the MP3 bit rate were disclosed to the subjects. The same experiment was carried out in laboratory conditions with eight expert listeners.

4 Results

4.1 Sound quality of vehicles

Figure 2 presents the results of the listening tests obtained using the polling station, compared to the ones obtained using classical supervised listening tests performed with a panel of 17 SSV users. These supervised listening tests did not involve A/B comparisons but rather ratings of individual sounds on a 0-100 scale with respect to the various attributes. The results for the polling station correspond to the ratio between the number of times a sound was chosen and the total presentation number of that sound, while SSV users panel results are thus expressed as the median of the given ratings. To allow for direct comparison, the scores of the two panels were centered and reduced (mean was subtracted and results were divided by standard deviation).

Results from Fig. 2 indicate that unsupervised polling stations provide similar evaluations than the ones performed in controlled conditions by the users' panel. Indeed, whether it is for the "powerful" attribute, the "metallic" attribute, or the "desire-to-buy", results are consistent regardless of the evaluation method. Note that for the supervised tests, the "powerful" and "metallic" attributes were suggested by the same panel of users as a result of a preliminary sensory analysis.

Also the subjects involved in the polling-station experiment were a different cross-section of the total population, whereas the lab subjects were all SSV drivers. They may respond differently to these sounds purely due their familiarity with such vehicles in daily life, but the results obtained show that the subjects similarly react to audio samples.

Indeed, coefficients of determination (R^2), computed using Matlab R2020a, support that results obtained using the polling station are correlated with those obtained with the users' panel ("powerful" attribute : $R^2 = 0.64$; "metallic" attribute : $R^2 = 0.76$; "desire-to-buy" : $R^2 = 0.91$). The largest correlation is obtained for the "desire-to-buy" evaluation case, which is attributed to the fact that the "desire to buy" is likely less abstract than the two other perceptual attributes. R^2-related observations are confirmed by two-tailed sign test procedures which reject the null hypothesis at a 5 % significance level, corroborating that unsupervised polling stations seem to be appropriate candidates to perform sound quality assessments as they provide similar results than those obtained using users' panel ("powerful" attribute : $p = 0.0243$; "metallic" attribute : $p = 0.0087$; "desire-to-buy" : $p = 0.0009$).

4.2 Sound quality for audio coding algorithms

The results obtained show that the percentage of preference towards xHE-ACC at 24 kbps decreases when the MP3 bit rate increases (Figure 3). This confirms the statement made in section 3.2 that MP3 is less efficient than xHE-AAC and requires higher bit rate to achieve the same level of subjective quality. The results also show that the percentage of preference towards xHE-AAC is on average slightly larger for speech than for music. This is deemed normal given that the xHE-AAC encoder was forced to operate in its linear predictive coding mode, which is particularly efficient on speech signals [23].

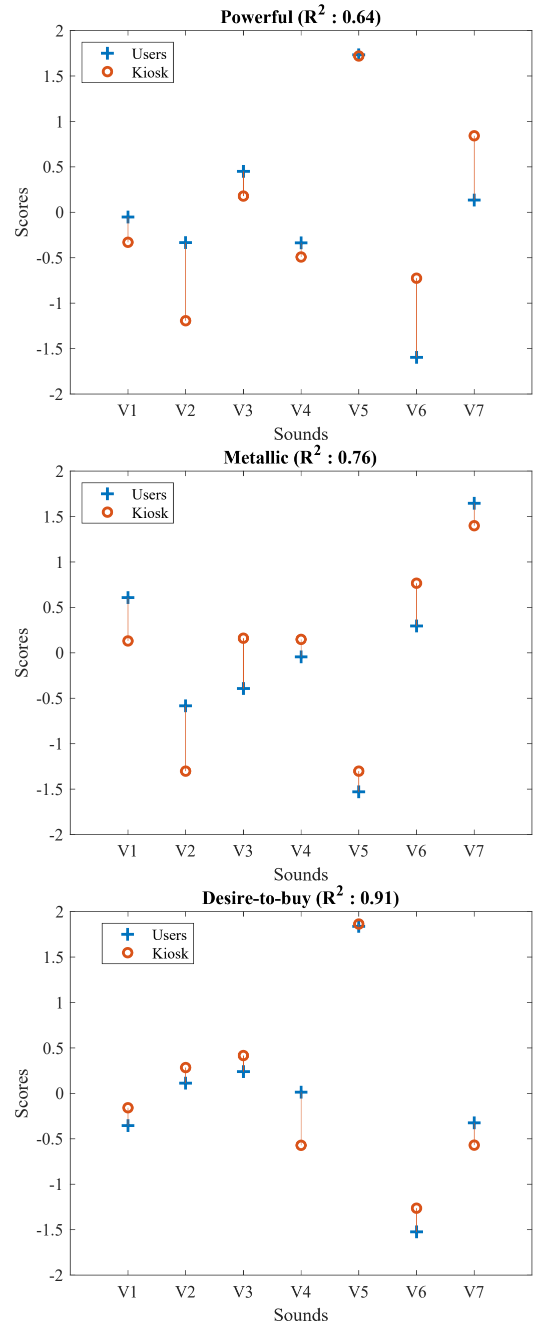


Figure 2: Perceptual evaluations obtained for the "powerful" attribute (top left), the "metallic" attribute (top right) and the "desire-to-buy" (bottom), using the polling station (○ markers, labelled as "kiosk") and a panel of users under controlled conditions (+ markers, labelled as "users"). Each evaluated vehicle is numbered from V1 to V7.

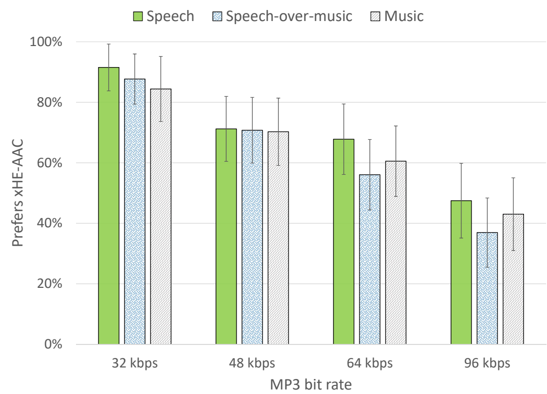


Figure 3: Percentage of preference in favor of the xHE-AAC codec as a function of the MP3 bitrate, per content type, with 95% confidence intervals. Results obtained with the polling station.

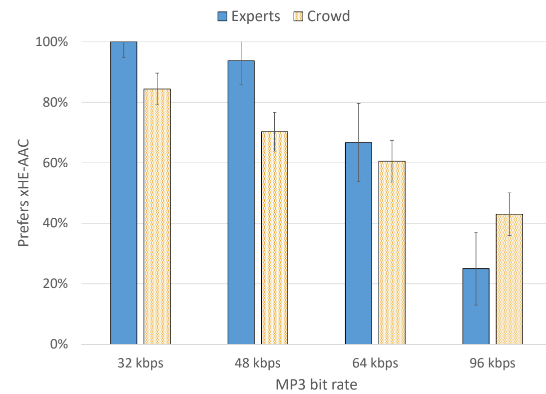


Figure 4: Percentage of preference in favor of the xHE-AAC codec as a function of the MP3 bitrate for all content types, with 95% confidence intervals. Comparison of results with experts or crowd.

Figure 4 compares the results obtained in the laboratory ("Expert" series) to those obtained with the polling station ("Crowd" series) for all content types. Both series exhibit the same downward trend, which is however more pronounced with expert listeners than with the crowd. There are two main reasons for expert listeners being more discriminatory. First, expert listeners have extensive experience in this kind of subjective assessment and are recruited for this given objective. Then, they operated in a controlled, thus presumably quieter and distraction-free, environment. Note that there are exactly 48 expressed preferences per data point for the "Experts" series compared to around 190 for the "Crowd" series in Figure 4. Overall, this experiment shows that the polling station makes it possible to reach the same conclusions as the expert auditors, at least when the differences in audio quality between conditions are relatively large.

5 Discussion

According to the results obtained, using a polling station makes it possible to reach similar conclusions as experts or trained auditors and confirms to be a possible alternative to listening tests in laboratory conditions. The trends observed in experts vs crowd evaluations are comparable, but usually less discriminatory in the case of the crowd sourced evaluation which is in line with previous works [2,4]. The number of opinions collected in six weeks together with the results obtained shows that a polling station allows quick and easy access to sound evaluations from a large panel of participants, that would have otherwise required highly time-consuming laboratory tests.

Also and compared with web-based or laboratory-based approaches, physical polling stations could be possibly installed in non usual locations (companies, stores, town halls) to attract particular group or type of subjects and to collect their opinions on various sound-related topics (sound quality of products, soundscape, environmental noise, among others). The next step of this work is to continue the analysis of gathered data, including (1) the other presented topics like perception of backup alarms and (2) to verify the geographical consistency of obtained results (*i.e.* when the exhibition toured at two other locations, did the observed trends show possible dependency on sociological and/or demographic factors ?). Indeed, the setup of the polling station after the pandemic will include simple sanitary measures. Disposable and sanitary headphone covers should be used on ear pads. The hard parts of the headphones like the headband and the touchscreen should be cleaned with adequate wipes and diluted cleaning or disinfectant solutions.

Acknowledgments

The authors would like to thank all the subjects who kindly participated in this study. The support of Sherbrooke Nature and Science Museum (MNS2) for the setup and development of the 'Sound, only sound !' exhibition has been instrumental and here acknowledged. The support from Web Audio Evaluation Tool is also here acknowledged. The authors wish to acknowledge the financial support received from the Faculty of Engineering, Université de Sherbrooke, to setup the exhibition and from the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT), Québec, Canada, to support the analysis of data.

References

[1] S. Bech and N. Zacharov, *Perceptual Audio Evaluation - Theory, Method and Application* (Wiley, 462 pages, 2006).

[2] W. Howie, D. Martin, S. Kim, T. Kamekawa, and R. King, "Effect of skill level on listener performance in 3D evaluation, " J. Audio Eng. Soc. 68 (9), 628-637 (2020).

[3] Recommendation ITU-R BS.1534-3 (10/2015), Method for the subjective assessment of intermediate quality level of audio systems

[4] N. Schinkel-Bielefeld, N. Lotze, F. Nagel, "Audio quality evaluation by experienced and inexperienced listeners, " Proc. Mtgs. Acoust. 19, 060016 (2013)

[5] M. Schoeffler and J. Herre, "The relationship between basic audio quality and overall listening experience, " J. Acoust. Soc. Am. 140, 2101 (2016).

[6] D.C. Brabham, "Crowdsourcing as a Model for Problem Solving : An Introduction and Cases," Convergence, 14(1), 75–90 (2008).

[7] T. Hoßfeld, C. Keimel, M. Hirth, B. Gardlo, J.Habigt K. Diepold and P. Tran-Gia, "Best Practices for QoE Crowdtesting : QoE Assessment With Crowdsourcing, " IEEE Trans. Multimedia, vol. 16, no. 2, pp. 541-558 (2014).

[8] J. Picaut, N. Fortin, E. Bocher, G. Petit, P. Aumond, G. Guillaume, “An open-science crowdsourcing approach for producing community noise maps using smartphones, ” Building and Environment, **148**, 20-33 (2019).

[9] A. Radicchi, D. Henckel and M. Memmel, “Citizens as smart, active sensors for a quiet and just city. The case of the ‘open source soundscapes’ approach to identify, assess and plan ‘everyday quiet areas’ in cities, ” Noise Mapping 5, 1–20 (2018).

[10] W. Taylor, W. Burns and A. Mair, “A mobile unit for the assessment of hearing, ” Ann. Occup. Hyg. 7, 343–352 (1964).

[11] F. Pausch and J. Fels, “MobiLab – A Mobile Laboratory for On-Site Listening Experiments in Virtual Acoustic Environments,” Acta Acust. united Ac., 105 (5), 875–887 (2019).

[12] N. Jillings, B. De Man, D. Moffat, and J. D. Reiss, “Web audio evaluation tool : A framework for subjective assessment of audio, ” Proc. of 2nd Web Audio Conference, April 4-6, Atlanta, USA (2016). `http://hdl.handle.net/1853/54595`, accessed 10 November 2020

[13] M. Cartwright, B. Pardo, G. J. Mysore and M. Hoffman, “Fast and easy crowdsourced perceptual audio evaluation, ” 2016 IEEE ICASSP, Shanghai, 2016, pp. 619-623.

[14] B. Pedersen, “Hi-precision audio in listening tests - also in the browser ?, ” Proc. of 3rd Web Audio Conference, August 21-23, London, UK (2017). `https://qmro.qmul.ac.uk/xmlui/handle/123456789/26144`, accessed 10 November 2020.

[15] M. Schoeffler, S. Bartoschek, F.-R. Stöter, M. Roess, S. Westphal, B. Edler and J. Herre, “webMUSHRA — A Comprehensive Framework for Web-based Listening Tests, ” Journal of Open Research Software, 6(1), 8 (2018).

[16] “SOUND, ONLY SOUND !” (2020) [Exhibition]. Musée Nature Sciences Sherbrooke (MNS2). `https://mns2.ca/en/travelling/travel-with-the-sound/`, accessed 22 May 2021.

[17] WHO (1999). Guidelines for community noise. Geneva : World Health Organization (`http://apps.who.int/iris/handle/10665/66217?show=full`, accessed 14 June 2020).

[18] J.L. Punch, B. Rakerd, and A.M. Amlani, “Paired-comparison hearing aid preferences : Evaluation of an unforced-choice paradigm, ” J. Am. Acad. Audiol., 12 : 190–201 (2001).

[19] Tri-Council Policy Statement : Ethical Conduct for Research Involving Humans – TCPS 2 (2018), Article 2.3 (`https://ethics.gc.ca/eng/policy-politique_tcps2-eptc2_2018.html`, Accessed 23 August 2021).

[20] A. Benghanem, O. Valentin, P.-A. Gauthier and A. Berry, “Sound quality evaluation of vehicles : effect of global loudness equalization on sensory profile,” Proc. of ICSV26 conference, Montréal (2019), `https://www.iiav.org/content/archives_icsv_last/2019_icsv26/index.html`, accessed 10 November 2020.

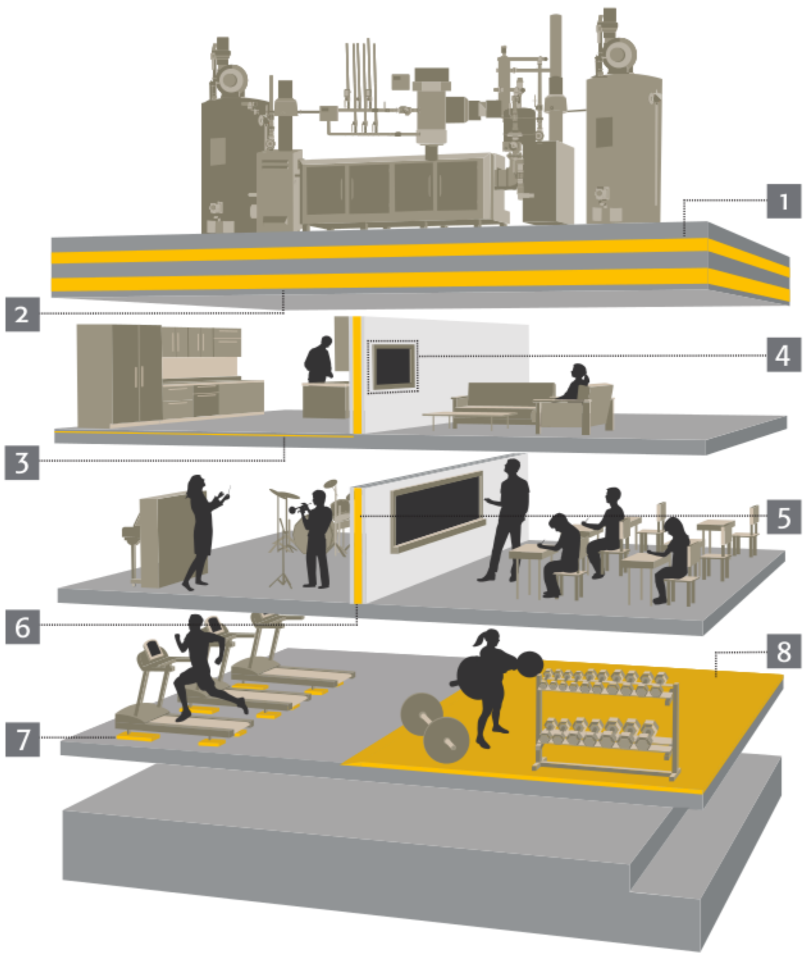
[21] A. Benghanem, O. Valentin, P.-A. Gauthier and A. Berry, “Sound quality of side-by-side vehicles : Investigation of multidimensional sensory profiles and loudness equalization in an industrial context,” Acta Acustica, 5, 1–19 (2021).

[22] M. Neuendorf et al., “MPEG Unified Speech and Audio Coding - The ISO/MPEG Standard for High-Efficiency Audio Coding of all Content Types,” J. Audio Eng. Soc., 61 (12), 956–977 (2013).

[23] S. Quackenbush and R. Lefebvre, “Performance of MPEG Unified Speech and Audio Coding,” 131th AES Convention, New York, USA, October 20-23 (2011).

[24] LAME high quality MPEG Audio Layer III (MP3) encoder, version 3.99.3, The LAME Project, `http://lame.sourceforge.io/`, accessed 10 November 2020.

CONTROL
NOISE
LOWER PROJECT COSTS
IMPROVE SPEECH PRIVACY
BOOST COMFORT
& WELLNESS
QUICK ROI
INCREASE PRODUCTIVITY
FACILITY
FLEXIBILITY
ENHANCE WORKPLACE CULTURE
SUPPORT FOCUS
LogiSon® ACOUSTIC NETWORK
SOUND.
THAT WORKS.™
Sound masking is more than a product. It's a service provided by professional technicians who know the effect isn't achieved from the moment they power the system, but by tuning the sound to an independently-proven curve. Designed right, tuned right—that's our motto. And the result is more consistent, comfortable and effective sound masking.
www.logison.com
© 2021 KR MOELLER ASSOCIATES LTD. LOGISON IS A REGISTERED TRADEMARK OF 777388 ONTARIO LIMITED. PHOTO BY VINCENT LIONS.


1
2
3
4
5
6
7
8


1 GENIEMAT® FF
2 GENIECLIP® LB
3 GENIEMAT® RST
4 GENIECLIP® MOUNT
5 GENIECLIP® RST
6 GENIEMAT® FIS
7 GENIEMAT® TMIP
8 GENIEMAT® FIT

AN ACOUSTIC ANALYSIS OF OROMO AND AMHARIC EJECTIVE STOPS

Feda Negesse [1*]
Department of Linguistics, Addis Ababa University, Addis Ababa, Ethiopia

Résumé

Les études acoustiques antérieures des éjectifs semblent s'être concentrées sur la comparaison des arrêts éjectifs avec les arrêts sans voix pulmonaires. La présente étude examine les arrêts éjectifs de l'oromo et de l'amharique afin d'examiner s'il existe des variations significatives au sein des sons et entre les deux langues. Les données audios de l'étude ont été recueillies auprès de 36 étudiants de premier cycle qui sont des locuteurs natifs de leurs langues respectives. Neuf mesures acoustiques, qui incluent des paramètres temporels et spectraux, ont été extraites des données. Une analyse statistique des mesures acoustiques révèle une variation significative au sein des arrêts d'éjection par rapport à la plupart des variables acoustiques étudiées. Il existe une variation significative entre les langues dans le seul mode de phonation tel que mesuré par h1-h2. La plupart des témoins des sons sont correctement classés avec les moments spectraux de leurs éclats de bruit. Typologiquement, les arrêts éjectifs des langues ne peuvent pas être catégoriquement classés comme faibles ou forts et diffus ou compacts en fonction de leurs propriétés acoustiques. Dans l'ensemble, il est conclu que plus de différences sont observées au sein des sons qu'entre les langues.

Mots clefs : Oromo, Amharique, éjectifs, arrêts

Abstract

Previous acoustic studies of ejectives seem to have concentrated on the comparison of ejective stops with pulmonic voiceless stops. The current study investigates ejective stops of Oromo and Amharic in order to examine if there are significant variations within the sounds and between the two languages. The audio data for the study were collected from 36 undergraduate students who are native speakers of their respective languages. Nine acoustic measures, which included temporal and spectral parameters, were extracted from the data. A statistical analysis of the acoustic measures reveals a significant variation within ejective stops with respect to most acoustic variables under investigation. There is a significant variation between languages in only mode of phonation as measured by h1-h2. Most tokens of the sounds are correctly classified with the spectral moments of their noise bursts. Typologically, ejective stops of the languages cannot be categorically classified as weak or strong and diffuse or compact based on their acoustic properties. Overall, it is concluded that more differences are observed within the sounds than between the languages.

Keywords: Oromo, Amharic, ejective, stops

1. Introduction

Ejective stops are found in the sound systems of Oromo and Amharic, Afroasiatic languages widely spoken in the Horn of Africa [1, 2]. The articulation of ejective stops is aerodynamically complex, involving oral (or pharyngeal) and glottal constrictions [3]. To describe ejective stops, various acoustic measures such as VOT, duration of closure, intensity of burst release and pitch pattern of the following vowel are often used [4]. These measures are known to vary within a class of ejective stops and across languages [5]. The survey of previous studies reveals that most of them have mainly focused on acoustic features of ejective stops of a single language or on acoustic comparison of ejective stops of a single language with their corresponding pulmonic voiceless stops [6]. The current study will examine ejective stops of Amharic and Oromo to find out if there are significant variations within the sounds and between the two languages.

* fedan2010@gmail.com

1.1. Acoustic study of ejective stops

The articulation of ejective stops is aerodynamically a complex process, involving a closure in the oral cavity and at the glottis [7]. During the process, the larynx rises, compressing the air in the oral cavity. Then, air pressure builds up in the cavity behind the closure, and ultimately, the sudden release of the oral closure produces sounds with various phonetic features [8]. Depending on the timing of the release of oral and glottal constrictions, two types of ejective stops are often identified. If the glottal closure is released before the oral closure, a strong ejective with a large burst and a long VOT will be produced. On the other hand, the simultaneous release of both closures will lead to the production of weak ejective stops with a weak burst and short VOT [3]. These cases seem to be the two possible timings for the production of the sounds as the oral closure is not expected to be released before the glottal closure.

Acoustic criteria such as total duration, burst intensity, VOT, F0, and intensity rise time are used to classify ejective stops [4]. Long duration, intense burst, long VOT, high F0 onset, modal phonation and fast intensity rise time are said to be features of strong ejective stops. On the other hand, short segmental duration, normal burst, short VOT, low F0 onset, creaky phonation and slow intensity rise, are believed to be characteristics of weak ejective stops [9, 10]. A binary division of ejective stops into strong or weak is debatable. It may be argued that the two categories represent only two ends of a continuum as ejective stops of the same language can be realised more as strong than as weak or vice-versa when one or more acoustic criteria are satisfied [11]. Other binary division of ejective stops is also possible based on their overall spectral shape of noise bursts. Past studies used standard deviation and kurtosis to classify plain stops into diffuse or compact based on place of articulation [12-15]. One of the objectives of the current study is to determine if these acoustic features could classify ejective stops into diffuse or compact.

Previous studies have largely focused on the comparison of acoustic features of ejective stops with those of pulmonic voiceless stops in a word-initial or a word-medial position [7, 9, 11, 16]. The comparison indicated that ejective stops significantly differed from pulmonic voiceless stops, having longer VOT, slower intensity rise time, and lower F0 in the following vowel [4, 9]. For instance, Georgian aspirated stops have longer VOT than ejective stops while ejective stops have shorter VOT than voiced stops [9]. The comparison also showed that acoustic properties of ejective stops exhibit variations with their place of articulation and position in a word. For example, VOT tends to decrease from anterior to posterior of the vocal tract, with velar ejective stops having the longest VOT [5, 9]. The VOT of ejective stops is longer at a word-initial position than at a word-medial position [10, 11]. Acoustic data from a study of ejective stops are useful to understand the association between a complex articulation and its acoustic correlates. However, enough published acoustic data on ejective stops of different languages seems to be lacking on ejective stops.

Similarly, enough attention does not seem to be paid to the investigation of acoustic features of ejective stops across languages. A couple of studies compared acoustic features of ejective stops in different languages, reporting significant acoustic variations cross-linguistically. One of such studies compared ejective stops in Hausa and Navajo, and reported that the sounds significantly differed in terms of total duration and closure duration ratio. Another study revealed significant contrasts between Tigrigna and Quiche ejective stops [17, 18]. Nevertheless, some other studies have compared the acoustic properties of ejective stops in their studies with published data from ejective stops of other languages [4, 10, 16]. Such comparisons may be problematic given the lack of standardisation in methods across studies. If researchers followed similar methods, valid generalisations could be drawn and such generalisations are useful for understanding ejective typology. Lack of data is also noted in the classification of ejective stops though enough data may be available on the classification of vowels and fricatives [19-21].

1.2. Amharic and Oromo ejective stops

Ethiopia is one of the linguistically diverse countries being home for speakers of over 81 languages [22]. Among these languages are Oromo and Amharic, which belong to the Cushitic and Semitic branches of the Afroasiatic language phylum respectively. These languages share many consonants, and one class of these consonants are ejective stops (TABLE 1). Oromo has ejective stops and affricate, but Amharic has an ejective fricative in addition to those which it shares with Oromo.

Table1: An inventory of Oromo and Amharic consonant phonemes [2, 1].

Manner	Voicing	Labial	Alveolar	Palatal	Velar	Glottal
Stop	Vl	P*	t		k	ʔ
	Vd	b	d		g	
	Ejective	p’	t’		k’	
Affricate		Vl		ʧ		
	Vd			ʤ		
	Ejective			ʧ’		
Fricative						
	Vl	f	s	ʃ		h
	Vd	v*	z*	ʒ*		
	Ejective		s’ *			
Nasal		m	n	ɲ		
Liquid			l r			
Glide		w		j		

*These phonemes are found only in Amharic.

The current study focuses only on ejective stops, which can be geminated in Oromo [1] and labialised in Amharic [2]. Investigating acoustic correlates of gemination and labialisation in ejective stops of different languages is an interesting area of study but geminated and labialised ejective stops lie out of the scope of the current study. It is believed that these sounds warrant a separate study, which will thoroughly investigate their acoustic properties. As far as the knowledge of the researcher is concerned, there is not enough acoustic study on ejective stops of Ethiopian languages except some on Amharic, Tigrigna and Oromo [10, 23, 24]. The number of participants in these studies is very small. The data were collected from a single speaker in [25], from five speakers in [10] and from eight speakers in [23, 24]. Similarly, the number of speakers participated in other previous studies is small, ranging from one [16] to eleven [4]. With small number of speakers, it may be difficult to capture acoustic features of speech sounds, known to be variable [4]. These studies did not set out to compare acoustic features of ejectives of two or more languages, but they focused on an acoustic description of ejectives of a single language. The current study, therefore, aims to determine (a) if there is a significant variation within ejective stops of Amharic and Oromo, and between the two languages with respect to acoustic characteristics of their ejective stops, (b) to classify ejective stops of the language using different sets of acoustic parameters and (c) to investigate how the two languages behave typologically as regards their ejective stops.

2. Method

2.1. Participants

Participants of the study are 36 speakers (Amharic=18; Oromo=18, with gender balanced in each language) who were doing their first degrees at a university at the time of the research. The Amharic speakers were born and brought up in Addis Ababa, having acquired the standard dialect of the language [26]. The Oromo speakers were born and brought up in the countryside of Wollega, where the Macha or the Western dialect of the language is spoken [1]. The Oromo speakers learned Amharic at school as a subject starting from grade five. It is assumed that their Amharic may not be good enough to qualify them as proficient bilingual speakers since Amharic is hardly used in the countryside of the region [22]. The average age of all participants was 23 years and the range was four years. None of the participants reported hearing and speech difficulties, and their consents were sought before they took part in the study.

2.2. Stimuli and procedures

The target sounds were embedded in a monosyllable (CV) and produced in a carrier phrase of each language. The syllable was used because real words which have the target sounds in the same or in even a similar phonetic environment could not be found. It was created following the syllabic structures of the languages. For example, CV forms Amharic words such as /k'ata/, which means a 'trigger'. Oromo words also have the syllable (CV) in words like / k'ara/, which means a 'sharp edge' [1]. The syllable contains the target sound at an initial position in the context of the vowel sound /a/. For instance, one of the stimuli for Amharic is /t'a bəl/, which means 'say t'a' and the Oromo version is /t'a ʤedi/, which also means 'Say t'a'. The initial position was chosen for VOT, burst release and post-burst silence are clearly exhibited at this position (See FIG. 1) though it did not allow for the measurement of closure duration and total segmental duration.

The stimuli were randomised and presented to participants of the study on a laptop's screen (MacBook Air 2017) in Keynote. Instructions were written in each language and the participants could only proceed to the recording session when they read and understood the instructions. The recording took place in a quiet room with Computerised Speech Lab (CSL, Kay 4400). The participants held a microphone (Sennheiser e865) 10 cm away from their mouths. Before the actual recording, the participants were familiarised with the recording procedures. The familiarisation session was intended to adjust the presentation pace of the stimuli so that it could match the habitual speech rate of each participant. In the actual recording session, the participants repeated each stimulus three times in a random order at their habitual speech rates, and one session produced nine stimuli (three tokens for each ejective) for one participant. All recording sessions produced (36 speakers x 3 ejective stops x 3 repetitions) 324 tokens, which means 162 tokens per language. The stimuli were sampled at 44.1k Hz and digitised at 16 bit.

2.3. Measurements

As stated earlier, this study compares Oromo and Amharic ejective stops with respect to nine acoustic measures, namely VOT, h1-h2, F0 in 30 ms into the onset of the following vowel, relative intensity, intensity rise time and four spectral moments. VOT was measured from the beginning of the burst as indicated by 'B' up to the end of the glottal closure as indicated by 'G'. It is the sum of the duration of 'B'and 'G' as indicated in Figure 1 Glottal closure duration is the length of the silent gap (a post-burst lag) between the burst release and the onset of the following vowel as indicated by 'P' [10]. A phonation pattern of the vowel onset (as measured by h1-h2) was measured over 30ms portion of the following vowel onset designated by 'P'. Fundamental frequency was computed in the 30 ms portion of the vowel onset and normalised by subtracting it from F0 at the midpoint of the vowel [13]. Maximum of intensity of ejective burst (in dB) was subtracted from maximum intensity of the following vowel (in dB) to obtain relative intensity [9]. Intensity rise time was computed by subtracting the time at the maximum intensity from the time at the onset of the vowel [27]. The spectral moments were computed from power spectra over the entire burst, which is over the portion indicated by 'B' in FIG 1 [9]. PRAAT [28] was used to extract the acoustic measures from the stimuli and the extraction was done manually.

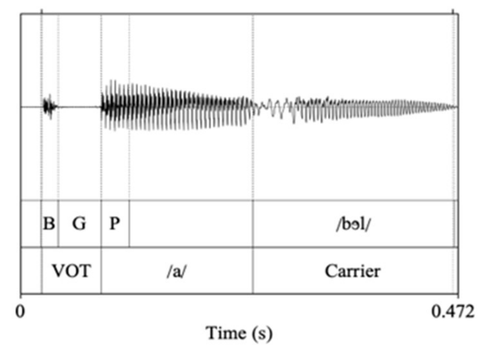


Figure 1: 'k'a bəl' (meaning 'Say k'a') as produced by an Amharic female speaker.

2.4. Statistical analysis

Linear mixed effects regression in R (R Core Team 2019), with the lme4 package [29] was used for the data analysis. Language (with two levels) and sound (with three levels) were modelled as fixed factors, and speakers as a random factor. The sounds were compared with respect to the nine acoustic measures, collapsed across languages because the study is interested in acoustic variations within stop ejective stops. Multiple contrasts were conducted using emmeans package in R [30]. The mixed function in the afex package [31] was used to conduct likelihood ratio tests for the fixed effects, with the argument method set to 'LRT'. Linear discriminant analysis was carried out with SPSS (Version 20) to classify ejective stops of the languages based on their places of articulation. The acoustic measures were entered stepwise and F0 was not included in the analysis as it was not statistically significant [21].

3. Results

3.1. VOT

The significant main effect of sound (ejective stops) is found for VOT [χ2 (2) = 28, p<0.001]. Post-hoc comparisons of mean VOT reveal that /p'/ is significantly different and /k'/ while /t'/ from (p<0.001). No significant main effect of language is observed for VOT [χ2 (1) =1.58, p= 0.21]. The interaction of language and sound is not also significant for VOT [χ2 (2) =2.33, p= 0.31].

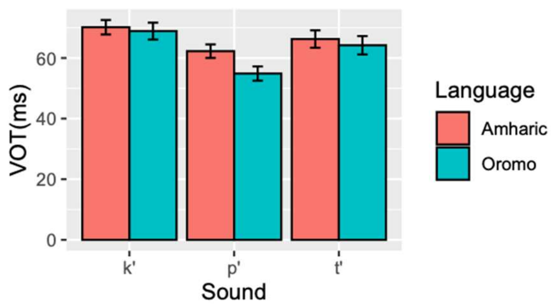


Figure 2: Mean values of VOT (ms) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

3.2. Relative burst intensity and intensity rise time

The results show that ejective stops significantly differ in their relative burst intensity (R_int), [χ2(2) = 70.75, p<0.01] and intensity rise time (Rise_time) [χ2(2) = 19.06, p<0.001]. Post-hoc comparisons of relative burst intensity indicate that /p'/ is significantly different from /k'/ and /t'/, (p<0.001) while intensity rise time significantly separates /t'/ from /k'/, (p<0.001).

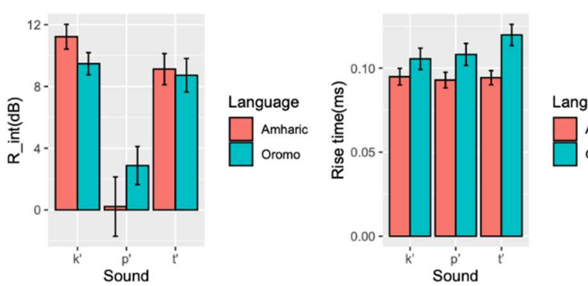


Figure 3: Mean values of relative burst intensity (dB) and intensity rise time (ms) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

However, such significant main effect of language is not found for relative burst intensity [χ2 (1) =0.02, p=0.89], and for intensity rise time [χ2 (1) =3.39, p=0.07]. In addition, no significant interaction of language and sound is found for both relative intensity, [χ2 (2) = 4.98, p=0.08]; and intensity rise time, [χ2 (2) =1.89, p= 0.39].

3.3. F0 and h1-h2

Ejective stops do not exhibit a significant variation in F0, [χ2 (2) = 13.3, p<0.001] and h1-h2, [χ2(1) = 1.4, p=0.5]. Main effect of language is only found for h1-h2 [χ2(1) = 11.79, p<0.001] but not for F0, [χ2 (1) = 0.01, p<0.91]. The ejective /k'/ is significantly different from /t'/ at p<0.001 in mean h1-h2. Significant interactions of language and sound are found for F0, [χ2(2) = 5.74, p=0.06] and for h1-h2, [χ2 (2) =1.82, p= 0.4].

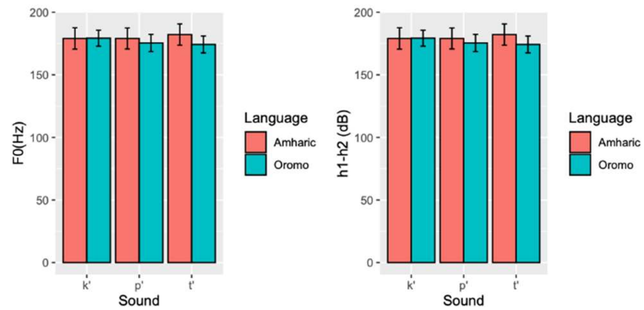


Figure 4: Mean values of F0 (Hz) and h1-h2 (dB) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

F0 and h1-h2 are used to identify the type of phonation involved in the production of the following vowel. A creaky phonation has weaker h1 and lower pitch than modal phonation [3, 32]. Thus, ejective stops in both languages seem to be followed by a vowel with modal phonation. Both languages have higher pitch at the onset than at the midpoint of the following vowels and this is more obvious in the case of Amharic (Figure 4). Higher F0 at vowel onset is arguably considered to be the feature of stiff or strong ejective stops [4], and mean h1-h2 separates ejective stops from other stops [33].

3.4. Spectral mean and standard deviation

The results show the main effect of sound for spectral mean of ejective stops, [χ2 (2) = 124.426, p<0.001]. Post-hoc tests also reveal that all possible pairwise comparisons are significantly different from each other, [p<0.001]. A significant main effect is not found for language, [χ2(2) =1.27, p=0.26]

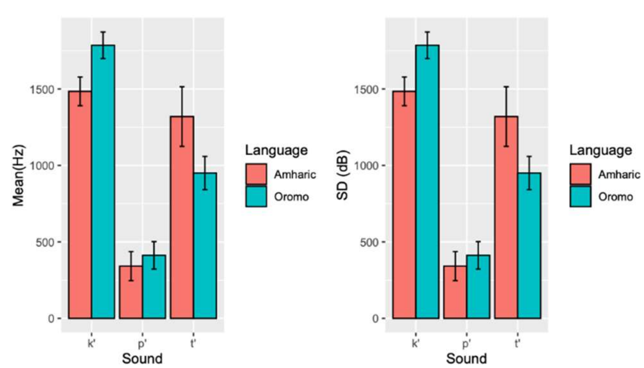


Figure 5: Mean values of spectral mean (Mean) and standard deviation (SD) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

Like spectral mean, standard deviation increases from anterior to posterior parts of the vocal tract (Figure 5). Accordingly, /p'/ is the least compact ejective stop while /k'/ is the most compact ejective stops. Standard deviation significantly varies with sound, [χ2 (2) =163.53, p<0.001] and /p'/ significantly differ from all other ejective stops [p<0.001].

However, the acoustic feature does not vary with language, [χ2 (1) = 0.05, p= 0.82]. The interaction of language and sound is not also significant, SD, [χ2 (2) = 0.97, p=0.62] while there is a significant interaction of language and sound for Mean, [χ2 (2) =12.24, p< 0.002].

3.5. Skewness and kurtosis

The sound /p'/ has the highest mean skewness while /k'/ has the lowest value for the acoustic measure and there is a significant main effect of sound on mean skewness, [χ2 (2) =165.41, p<0.001]. Post-hoc comparisons also indicate that /p'/ significantly differs from all other ejective stops [p<0.001]. Amharic has higher mean skewness for /p'/ and /t'/ but language type does not have a significant main effect on skewness of ejective stops, [χ2 (1) =1.79, p=0.18].

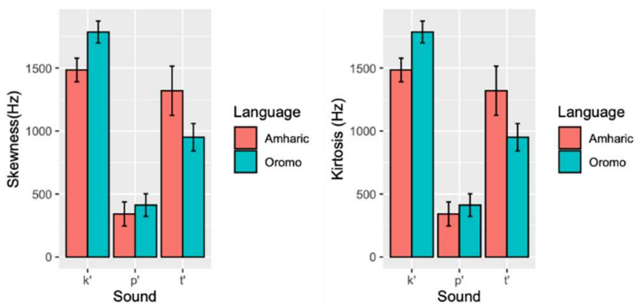


Figure 6: Mean values of skewness and kurtosis (Hz) for Amharic and Oromo ejective stops. Error bars show 95 % confidence intervals.

Kurtosis determines if spectral energy is found concentrated over small frequencies forming a sharp peak, or distributed over large frequencies forming a flat peak. The sound /p'/ has the highest mean kurtosis whereas /k'/ has the lowest mean kurtosis, suggesting a high concentration of energy over a small range of frequencies for /p'/ (FIG. 6). Ejective stops significantly vary with respect to their mean kurtosis, [χ2(2) =242.61, p<0.001]. Post-hoc comparisons show that /p'/ significantly differs from all other ejective stops [p<0.001]. The languages do not significantly differ from each other with respect to mean kurtosis of their ejective stops, [χ2 (1) =0.46, p=0.5]. The interaction of language and sound is significant for both skewness [χ2 (2) = 16, p=0.001] and kurtosis, [χ2(2) =8.3, p= 0.02].

3.6. Discriminant analysis

Linear discriminant analysis was carried out to determine to the extent to which different sets of acoustic parameters would classify ejective stops of the two languages. When VOT, intensity rise time and relative intensity were entered into the classifier, /p'/ had the highest classification with 72% and 63 % of its tokens correctly classified respective in Amharic and Oromo. The ejective /t'/ was poorly classified in both languages and the classification accuracy of this sound was rather poorer in Amharic because it was greatly confused with /k'/ and /p'/. However, the sound was better classified in Oromo with the set of acoustic parameters. The overall classification accuracy was higher for Oromo ejective stops but /p'/ was better separated in Amharic than in Oromo.

Table 2: Percentages of correct classification for ejective stops of Amharic and Oromo.

	Amharic				**Oromo**			
Parameter	p'	t'	k'	Total	p'	t'	k'	Total
VOT, Rise_time, R_int, h1-h2	72	22	57	51	63	43	61	56
Mean, SD, skewness, kurtosis	83	54	65	67	80	69	78	75
All	83	54	65	67	80	67	82	76

The ejective stops were better differentiated with mean values of the spectral moments, with 67% and 75% of the ejective tokens correctly classified in Amharic and Oromo respectively (Table 2). In both languages, the ejective /p'/ had the highest classification accuracy followed by /k'/ while /t'/ had the lowest classification accuracy but tokens of this sound were by far better classified in both languages when the spectral moments were employed. The addition of VOT, intensity rise time and relative intensity to the spectral moments did not improve the classification accuracy of each sound and the overall results of both languages. However, the Oromo /k'/ could benefit from the addition of the acoustic parameters while the Amharic sounds did not benefit at all.

4. Discussion

This study aims at comparing the acoustic features of Amharic and Oromo ejective stops. One of the findings of the study is that there are significant variations within ejective stops in all acoustic features considered except F0 of the following vowel. VOT of ejective stops increases from anterior to posterior of the oral cavity in the current study. A similar finding was reported in previous studies for French and English stops, and Georgian ejective stops [5, 9]. The sounds in the current study do not have the same place of articulation; /p'/ is bilabial, /t'/ is alveolar and /k'/ is velar [1, 2]. The acoustic features which show significant variations with an ejective category can serve as reliable acoustic correlates of place of articulation of the sounds. However, the features are not robust to disambiguate all ejective stops as such. The subsequent pairwise comparisons indicate that only spectral mean separates all possible pairs of the three ejective stops. Other measures cannot separate /t'/ from /k'/ though they significantly separate /p'/ from other ejective stops.

The other finding of the study is that the acoustic features do not show significant variations with language type. One possible reason for their similarity might be that the speakers of Oromo had studied Amharic as a subject starting from grade five. In addition, the speakers had a chance to use Amharic with non-Oromo speakers at the university since Amharic is a language of a wider communication. A lack of a significant difference between the languages may be because of the impact of the phonetic knowledge of Amharic on part of the Oromo speakers [34]. The other reason could be that Amharic has been in close contact with Oromo and other Cushitic languages for many years though it is remotely related genetically to these languages. The impact of this language contact has been already attested in the morphosyntax where Amharic has a nominalisation pattern which is similar to that of the Cushitic languages [35]. A language contact might have caused ejective stops of the languages to have similar acoustic properties. Clearly, a further study is needed to identify the possible reasons for phonetic similarities of ejective stops of the languages.

The study also shows that spectral moments of noise bursts classify ejective stops of Amharic (65%) and Oromo (75%) by far better than VOT, intensity rise time, relative intensity and h1-h2 do. Spectral moments may be considered as primary acoustic cues for places of articulation of ejective stops of both languages and they are particularly more robust in separating /p'/ from the other sounds. Again, they are more robust in separating Oromo ejective stops, which suggests that the strength of acoustic cues of the sounds differ between languages. When they were employed together with VOT, intensity rise time and relative intensity, the classification accuracy of ejective stops of both languages did not improve because the two sets may have an overlapping or complementary role in disambiguating the sounds based on their places of articulation. Clearly, additional studies may be needed to investigate the relative roles of the two sets of acoustic parameters in classifying ejective stops of these languages and those of other languages. Overall, the discriminant analysis indicates that Oromo ejective stops with different places of articulation (bilabial, alveolar and velar) were better classified but in both languages, the alveolar sound, /t'/ was poorly classified, being confused with the other sounds. This sound was better separated when the spectral moments were used, which suggests that spectral shapes of their bursts present reliable acoustic cues for their places of articulation.

One of the objectives of the current study was to investigate how the ejective stops of the two languages would behave typologically. The traditional classification (either weak or strong) is particularly problematic as ejective stops hardly satisfy all the criteria set in some previous studies [4]. In one of such studies, VOT and creaky phonation are viewed as reliable parameters for classifying ejective stops [36]. In another study, 60 ms of VOT is used as a threshold to classify ejective stops into strong and weak; if the duration is greater than 60 ms, the sound is classified as strong, otherwise as weak [37]. Both studies provided no explanations why 60 ms is set as a threshold and why VOT is a reliable measure. This binary division of ejective stops into strong or weak has been challenged. Evidence from the comparison of some languages shows that the variation of acoustic features with language makes this binary division impossible or difficult to work for many or even for two languages [16, 24]. In other words, the other acoustic features do not pattern together with VOT to classify the sounds into weak or strong ejectives.

The current study used VOT together with other acoustic measures to determine how the languages typologically behave [4, 17, 18]. Like languages in the previous studies, Amharic and Oromo have both weak and strong ejective stops in their sound systems [11, 16]. Collectively, Oromo ejective stops have faster intensity rise time (0.11 ms) and greater relative intensity (8.2 dB). Based on these measures, the Oromo sounds can be collectively classified as strong ejective stops. As a group, Amharic ejective stops have longer VOT (70 ms), and higher F0 (180.62 Hz) for the onset of the following vowel. As a result, Amharic ejective stops generally tend to be realised more as strong. Both languages have high positive h-h2, which suggests that their ejective stops are strong causing modal phonation in the following vowel. This is consistent with the generalisations made above. Nonetheless, the individual sounds show a different pattern; for instance, the sound /k'/ likely belongs to the class of strong ejective stops because in both languages, it has longer VOT, fast rise time, intense burst, high F0 and modal phonation in the following vowel. The position /t'/ could occupy on the continuum of weak and strong ejective stops is variable based on the acoustic feature considered. Taken together, the current study provides good evidence in favour of the proposal that considers the typological classification of ejective stops as a continuum of weak and strong sounds.

In the past studies, the overall spectral shape of bursts as indicated by standard deviation and kurtosis were used to classify plain stops into diffuse and compact based on place of articulation [13, 14]. Particularly, kurtosis is used for the classification since it is strongly correlated with standard deviation, [r (430) = -0.84, p<0.001]. The presence of strong correlation between the two measures is taken as evidence for representing the same articulatory feature [13]. In the current study, the two spectral moments were employed to classify burst spectra of ejective stops /p', t', k'/ into compact and diffuse. Standard deviation is inversely related to compactness but directly to diffuseness. These sounds, /p'/ and /k'/, have the lowest (417.16) and the highest mean standard deviations (1564.61) respectively, representing the two ends of a diffuse-compact continuum. Burst spectra of ejective stops will become more and more compact (but less and less diffuse) when their place of articulation moves to the posterior of the vocal cavity. Thus, /k'/ is the most compact ejective stop while /p'/ is the most diffuse ejective stop for Amharic and Oromo. The burst of /t'/ has more compact than diffuse spectrum as its standard deviation (1303.65) is closer to that of /k'/.

As explained above, the sounds significantly differ on all spectral moments, but language effect is not significant in any one of the spectral measures. Oromo ejective stops have collectively higher mean standard deviation (1316.56) and lower mean kurtosis (1.43) for their burst spectra than do Amharic ejective stops, suggesting that bursts of Oromo ejective stops tend to be realised more as compact than diffuse spectrum. Amharic has higher mean kurtosis (1.66) and lower mean standard deviation (1287.89) for burst spectra of its ejective stops than does Oromo, which implies that burst spectra of Amharic ejective stops tend to be realised more as diffuse than compact. Like the binary division of weak and strong, the diffuse-compact dichotomy (as in [14] is problematic as there is no cut-off-point to assign sounds to one of the categories based on mean standard deviation or mean kurtosis of their burst spectra or both. This problem could be somewhat solved if the categories are construed as a continuum of diffuse and compact.

5. Conclusion

This study is most probably one of the few studies that investigated acoustic variations within ejective stops and across languages. The study found significant acoustic differences within ejective stops with respect to all acoustic properties considered with the exception F0. A significant variation between the two languages was not found in all acoustic features. Spectral moments could correctly classify more tokens of ejective stops of both languages than do VOT, intensity rise time and relative intensity as a group. Typologically, ejective stops of the two languages could not be classified as strong or weak and diffuse or compact but they could be placed on the continua of the categories on the basis of their acoustic features. Overall, the ejective stops show significant differences among themselves but not between languages. In the current study, acoustic measures were extracted from the onsets of monosyllables to compare acoustic properties of ejective stops of two languages. Future studies will provide us with more reliable and valid data if they compare acoustic features of ejective stops, which are extracted from initial and medial positions of real words.

References

[1] T. Wako, The Phonology of Mecha Oromo, Addis Ababa: Addis Ababa University: Unpublished MA, 1981.

[2] L. M. Bender, "Amharic," in *In International Encyclopaedia of Linguistics*, vol. 6, New York, OUP, 1992, pp. 51 -5

[3] M. Gordon and P. Ladefoged, "Phonation Types: A cross-linguistic overview," *Journal of Phonetics,* vol. 2 , p. 383–406, 2001.

[4] R. Wright, S. Hargus and K. Davis, "On the Categorisation of Ejective stops: Datafrom Witsuwit'en," *Journal of the International Phonetic Association,* vol. 32, pp. 43-47, 2002.

[5] T. Nearey and B. L. Rochet, "Effects of Place of Articulation and Vowel Context on VOT Production and Perception in French and English Stops," *Journal of the International Phonetic Association,* vol. 24, p. 1–19, 1994.

[6] I. Maddieson, S. L. Caroline and B. Nicola, "Aspects of the Phonetics of Tlingit," *Anthropological Linguistics,* vol. 43, no. 2, pp. 135-176., 2001.

[7] D. Demolin, "Acoustic and Aerodynamic Characteristics of Ejective stops in Amharic," *Journal of the Acoustical Society of America,* vol. 115, no. 5, p. 2610, 2004.

[8] D. Demolin, "Acoustic and Aerodynamic Characteristics of Ejective stops in Amharic," *Journal of the Acoustical Society of America,* vol. 115, no. 5, p. 2610, 2004.

[9] C. Vicenik, "An Acoustic Study of Georgian Stop Consonants," *Journal of the International Phonetic Association,* vol. 40, no. 1, p. 59–92, 2010.

[10] K. R. Shosted and S. Rose, "Affricating Ejective Fricatives: The Case of Tigrinya," *Journal of the International Phonetic Association,* vol. 41, no. 1, pp. 42-63., 2001.

[11] J. Hajek and M. S. Stevens, " On the Acoustic Characterisation of Ejective Stops in Waima'a," in *Proc. Interspeech*, 2005.

[12] A. Jongman and J. D. Miller, "Method for the Location Bust-onset Spectra in the Auditory-perceptual Space: A Study of Place of Articulation in Voiceless Stop Consonants," *Journal of the Acoustical Society of America,* vol. 89 , no. 2, pp. 867- 873., 1999.

[13] M. Sundara, "Acoustic-phonetics of Coronal Stops: A Cross-language Study of Canadian English and Canadian French," *Journal of the Acoustical Society of America,* vol. 118 , no. 2, p. 1026–1037, 2005

[14] M. Tabain, G. Breen, A. Butcher, A. Jukes and R. Bear, "Stress Effects on Stop Bursts in Five Languages," *Journal of the Association for Laboratory Phonology,* vol. 7 , no. 1, p. 1–23, 2016.

[15] S. E. Blumstein and K. N. .. Stevens, "Acoustic invariance in speech production: Evidence from measurements of the spectral characteristics of initial stop consonants," *Journal of the Acoustical Society of America,* vol. 66, 1979.

[16] N. Warner, "Acoustic Characteristics of Ejective stops in Ingush," in *In ICSLP 96*, 1996.

[17] M. Lindua, " "Phonetic Differences in Glottal Consonants." Journal of Phonetics 147-155 (12)," 1984.

[18] J. Kingston, The Phonetics and Phonology of the Timing of Oral and Glottal Events. Berkeley: PhD Dissertation, University of California., 1985.

[19] J. Hillenbrand, L. A. Getty, M. J. Clark and K. Wheeler, "Acoustic analysis of American English vowels," *Journal of the Acoustical Society of America,* vol. 97, p. 93099– 3111, 1995.

[20] D. Williams, P. Escudero and A. Gafos, "Spectral change and duration as cues in Australian English listeners 'front vowel categorisation," *Journal of the Acoustical Society of America,* vol. 144 , no. 3, p. 576–581, 2018.

[21] A. Jongman, R. Wayland and S. Wong, "Acoustic characteristics of English fricatives," *Journal of Acoustical Society of America,* vol. 108 , no. 3, pp. 1253-1263, 2000.

[22] CSA, "Statistical Report and Housing Census," Addis Ababa, Ethiopia, 2007.

[23] A. Derib, An Acoustic Analysis of Amharic Vowels, Plosives and Ejective Stops, Addis Ababa: Addis Ababa University: Unpublished PhD Dissertation, 2011.

[24] M. Percival, Variation in Ejective Stops: An Acoustic Study of Stop Contrasts in Eastern Oromo and éłį̨nę̨ Slavey, Toronto : Unpublished master's thesis: University of Toronto, 2014.

[25] H. Seid, S. Rajendran and B. Yegnanarayana, " "Acoustic characteristics of ejectives in Amharic." 10th Annual Conference of the International Speech Communication Association. Brighton, United Kingdom: INTERSPEECH 2009. 2287-2290.," 2009.

[26] M. Habtemariam, ""Regional Variations in Amharic.," *Journal of Ethiopian Studies,* vol. 11 , no. 2, pp. 113-129, 1973.

[27] M. Noguchi, "An Acoustic Study of Pulmonic and Ejective Stops in Final Coda Position in Yucatec," in *In the Proceedings of 169th Meeting of the Acoustical Society of America*, Pittsburgh, Pennsylvania, 2015.

[28] P. Boersma and D. Weenink, "Praat: Doing Phonetics by Computer," 2019.

[29] D. Bates, M. Martin, B. M. Bolker and S. C. Walker, "emmeans (version 1.7)," 2015.

[30] R. V. Lenth, P. Buerkner, M. Herve, J. Love, H. Riebl and H. Singmann, "Package 'emmeans'," 2021.

[31] H. Singmann, "afex package," 2021.

[32] J. Kuang, " " Covariation Between Voice Quality and Pitch: Revisiting the case of Mandarin," 2017.

[33] B. Hauk and J. Hakin, "Acoustic Properties of Singleton and Geminate Ejective Stops in Tsova-Tush," in *ICPhS2019*, Melbourne, Australia, 2019.

[34] M. Fricke, J. F. Kroll and P. E. Dussias, "Phonetic Variation in Bilingual Speech: A Lesson from Studying the Production–comprehension Link," *Journal of Memory and Language,* vol. 89, p. 110–137, 2016.

[35] M. Shimelis, Nominalisation via Verbal Derivation: Amharic, Tigrigna and Oromo, Wiesbaden: Harrassowitz Verlag, 2015.

[36] M. Stevens and J. Hajek, "Positional Effects on the Characterisation of Ejective stops in Waima'a," in *Proc. Interspeech*, 2008.

[37] S. Bird, "Dalkek Ejective Stops: Evidence for New Ways of Classifying," in *Paper prsented at the 76th Meeting of Linguistic Society of America*, San Francisco, CA., 2002.


ACOustics begins with ACO™
SLARMSuccesses™
Red Rocks & ATTPAC, Dallas
ODM Family
41.0 dBZ
NetSLARM™
NORMAL
ALERT
ALARM
CONNECT
PS9200KIT
1/2 Inch
1 Inch
1/4 Inch
Systems
<2Hz >120kHz
<0dBA >170 dBSPL
7052PH
PHANTOM POWER
A-TECH
INSTRUMENTS LTD.
MEASUREMENT & CONTROL FOR RESEARCH & INDUSTRY
TEL: (416) 754.7008 | FAX: (416) 754.2351
EMAIL: SALES@A-TECH.CA | WWW.A-TECH.CA
P.O. BOX 252 | SCARBOROUGH | ONTARIO M1E 4R5
Exclusive Canadian Agent
ACO Pacific, Inc.
www.acopacific.com sales@acopacific.com

Acoustics of Infrasound and Audible Noise Inside Homes Near Wind Turbines Using Multichannel Spectral Processing

Andy Metelka *1,
1Sound and Vibration Solutions Canada Inc, Halton Hills, Ontario, Canada

1 Introduction

Previous measurements inside homes show presence of BPF's (Blade Pass Frequencies) below 10Hz as far away as 120km from the nearest Wind Turbine, Figure 2. This holds true for measurements inside homes, yet outside measurements become more challenging at all frequencies due to Wind Turbulence. Random wind turbulence occurs at the microphone screening devices as well as adjacent structures predominantly at lower frequencies. The homes, both near and far, act as windscreens in these low frequency settings, un-masking the BPFs that appear inside. This paper discusses both near and far field measurements in different locations inside homes while making simultaneous spectral measurements outside.

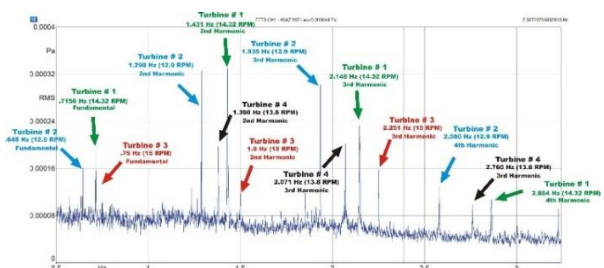


Figure 1 Spectra measured in a home over 100km away from the nearest WT show four different WTs each with three harmonics.

2 Measurements and data analysis

Two Sinus Soundbooks and two SINUS Apollo 4-analysers were deployed at times in four separate homes synchronized to the nearest second. An advanced 8-channel set up is outlined in Figure 2 Synchronous Audio and Video were also recorded for ease of analysis during playback. In one case four homes were measuring continuously in Real-time for three months. The long data sets were required since conditions for ideal weather played an important role. The homes were also occupied so contamination from human artifacts such as door slams had to be verified and eliminated. The 24-hour SONOGRAM plot validated good project days vs. contaminated days, or days without wind. All four systems were also monitored and controlled via the Internet. This validated our process and setup. It gave us the confidence that good measurements were being made and recorded continuously. Refining set-ups based on the previous weeks results allowed us to continuously optimize the set-ups therefore no further post processing was required.

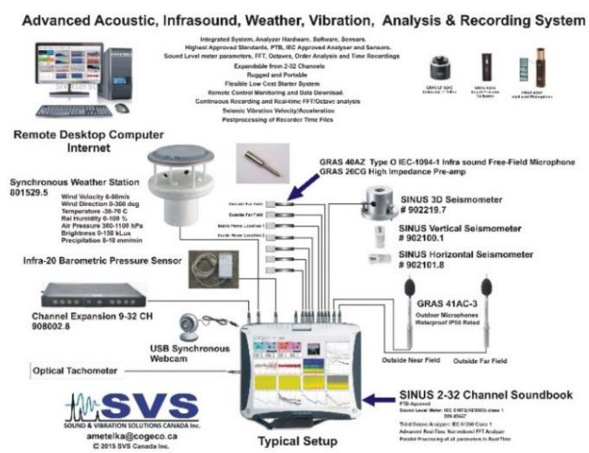


Figure 2: Advanced set-up, SINUS Soundbook with SAMURAI software GRAS 40AZ, This sensor weather station, USB Webcam.

Both outside and inside, GRAS 40AZ-Type I Precision Measurement microphones were used. The analyzer also had a LF cutoff of less than 0.5Hz. The analyzer sampling rate was 200Hz/channel, however SLM parameters up to 20kHz were also measured in these same channels using Class I IEC61672-1 filters. Special dual stage wind screens were designed, adding waterproofing to the GRAS 40AZ laboratory grade microphones for continuous use even during the winter. GRAS 42AG, 42AE and 42AE Low Frequency calibrators were used. BPFs measurements outside were not as distinct during high wind conditions compared to low wind conditions. Ideal times where during high wind shear or low ground wind speed even below 2 M/s for these outside locations.

In most cases the inside BPFs were identical and sometimes even slightly higher at the fundamental and 2nd, 3rd, and 4th Harmonic of BP. The basement room furthest from the dominant WT aimed at the home had the least amount of infrasound. The outside far-field microphone, closest to the WT in Figure 3 shows the effects of wind turbulence masking the BPFs.

In the extreme far field various WTs can sometimes be measured,[1, 2] however only inside homes not disturbed by airflow turbulence. These spectral peaks were correlated with wind direction from the SW and only occurred with steady winds. The peaks disappeared when Southern Ontario experienced no wind or wind power production.

*andymetelka@gmail.com

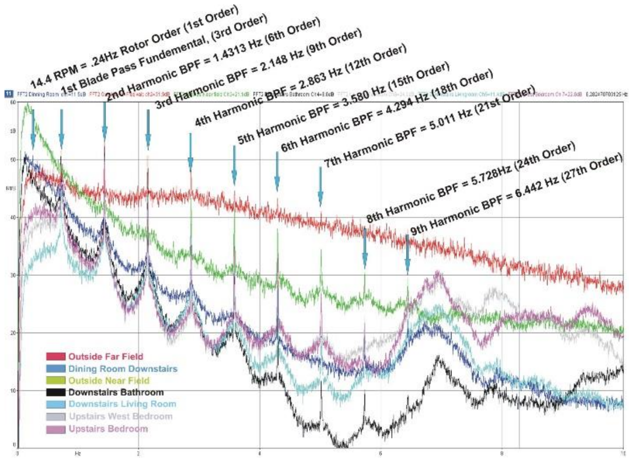


Figure 3: Spectra of 2 outdoor and 4 indoor compared. Close to 10 WTs with-in 1 km.

3 Post-processing

Further post-processing using statistically averaged cross properties such as the COH, TF and COP were deployed for various reasons [3]. The elimination of uncorrelated noise (outside) and the linear relationship between the outdoor BPFs and indoor BPFs were validated. The example in Fig 3 shows a perfect Coherence of 1 at the first 4 BPFs. This is not always the case since other artifacts can occur contaminating the statistical average.

Coherence using this FFT Analyzer can be defined as:

$$C_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)G_{yy}(f)}$$

where, $G_{xy}(f)$ is the Cross-spectral density between x and y $G_{xx}(f)$ and $G_{yy}(f)$ the autospectral density of x and y respectively. Although Figure 4 was post processed it could also have been setup for real-time analysis allowing faster review of many results. It also serves as a good real-time quality indicator such that the system is operating correctly without sensor error.

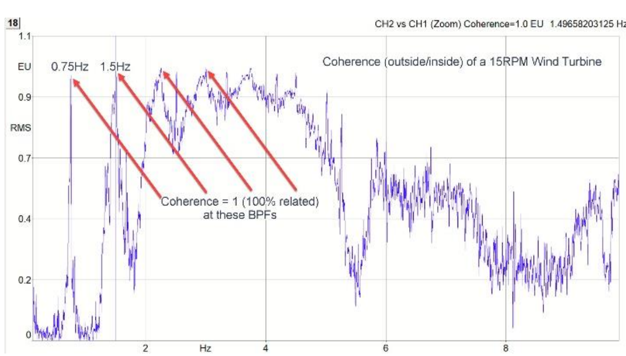


Figure 4: Coherence after 1000 statistical averages indicate 100% relationship between the indoor and outdoor WT BPFs.

Sensitive receptors have had symptoms as far a 10km away from WTs under certain conditions. Figure 5. had a single WT less than 500 meters from a home, turn into the direction where the home was downwind. The occupant felt change immediately in the case without visualizing the WT and faster than the FFT processing could validate.

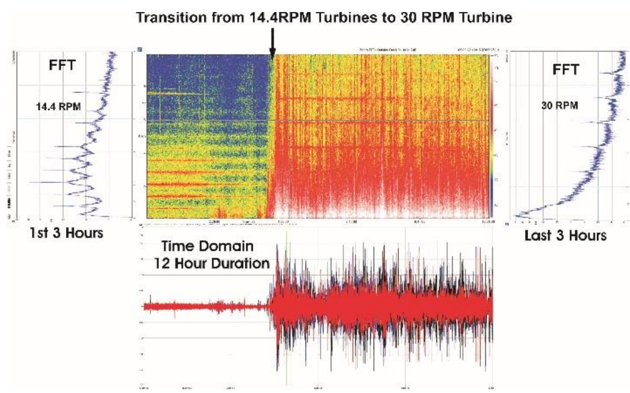


Figure 5: A single WT turns on and faces a home masking the far field 14.4 RPM turbines.

4 Summary

Measurements inside, being free from wind turbulence, indicate BPF's are clear and distinct at all times of day and year. The BPFs only appear with wind and power production. The home can act as an ideal random infrasonic turbulent resistant windscreen. This allows for further calculations such as transmissibility in each location inside a home with a laboratory grade infrasound measurement microphone. The measurements indicate it is not what you hear; it is what you may feel inside quiet rural homes that are free from Random Dynamic Pressure fluctuations between 0.5-3 Hz where the fundamental and 3 harmonics of WT BPFs become periodic.

Acknowledgment

There are too many international associates to thank and recognize over the years however, Dr. John Vanderkooy and Dr. Werner Richarz are the Canadian professors involved with the physics, science, acoustics and instrumentation.

References

[1] Acoustic Interaction a primary cause of infrasonic spinning mode generation and propagation from wind turbines 166th Meeting ASA San Francisco Dec 2013 Kevin A. Dooley Andy Metelka

[2] Measurement Techniques for determining Wind Turbine Infrasound Penetration into Homes 7th International Meeting on Wind Turbine Noise, Rotterdam, the Netherlands, 2nd – 5th May 2017 Andy Metelka, SVS Canada Inc, Canada

[3] J. Vanderkooy and R. Mann, "Measuring Wind Turbine Coherent Infrasound", 6th International Conference on Wind Turbine Noise (WTN2015), Glasgow 20-23 April 2015.


Acoustic
Production Test
Redefined
The APx517B Acoustic Analyzer
An integrated system for the production test of
speakers, microphones, headphones & headsets
• Power Amplifier
• Analog Inputs & Microphone Power Supply
• Stereo Headphone Amplifier
• Optional Digital I/O
• Comprehensive Rub & Buzz
Defect Detection
Audio precision
www.ap.com
Distributed in Canada by GerrAudio Distribution
sales@gerr.com | (613) 342-6999

Yearly Reviewer List / Liste annuelle des évaluateurs

The high scientific standards maintained by Canadian Acoustics in its papers owe much to the continuing dedication of the journal's reviewers, who give freely of their time and expertise. JCAA is pleased to pay tribute to this contribution by recognizing those who have participated in the review process. Thus, the Editorial Team of Canadian Acoustics acknowledge with particular gratitude the following reviewers who have reviewed papers during the last 12 months.

Les normes scientifiques élevées maintenues par la revue Acoustique canadienne doivent beaucoup au dévouement constant des réviseurs de la revue, qui donnent généreusement de leur temps et de leur expertise. JCAA est heureux de rendre hommage à cette contribution en reconnaissant ceux qui ont participé au processus d'examen. Ainsi, l'équipe de rédaction de l'Acoustique Canadienne reconnaît avec une gratitude particulière les réviseurs suivants qui ont examiné des articles au cours de la période des 12 derniers mois.

Daniel Aalto
University of Alberta
CANADA

AJISH ABRAHAM
All India Institute of Speech and Hearing
INDIA

Maedot S. Andargie
University of Toronto
CANADA

Wintta Ghebreiyesus
Ryerson University
CANADA

Dr. Sebastian Ghinet
National Research Council Canada, Aerospace Portfolio
CANADA

Gino Iannace
Università della Campania Luigi Vanvitelli
ITALY

Josée Lagacé
University of Ottawa
CANADA

Prof. Ulhas A Malawade
Mechanical Engineering Department, Jayawantrao Sawant College of Engineering, Pune, INdia
INDIA

Stéphane Moreau
CANADA

Mr. John O'Keefe
O'Keefe Acoustics
CANADA

Rich
Engineers for Change, Inc. & RION Co., Ltd.
UNITED STATES

Md. Sanaul Rabbi
Associate Professor, Department of ME, CUET
BANGLADESH

Prof. Frank A. Russo
Ryerson University
CANADA

Lamberto Tronchin
University of Bologna, Emilia-Romagna IT
ITALY

Benjamin V. Tucker
University of Alberta
CANADA

Arife Uzundurukan
Université de Sherbrooke
CANADA

Kiran Vadavalli
École de technologie supérieure Montreal
CANADA

Prof. Jérémie Voix
ÉTS, Université du Québec
CANADA

Jianhui Zhou
University of Northern British Columbia
CANADA

ACOUSTICS WEEK IN CANADA 2021
SEMAINE CANADIENNE D'ACOUSTIQUE 2021

FINAL REPORT

Acoustics Week in Canada 2021
Oct 5–7, Online

---

1 Overview

Acoustics Week in Canada (AWC) was originally planned for October 2020 in Sherbrooke (QC). It has been postponed to October 2021 due to the COVID pandemic. We hoped for a physical event, but the situation was so uncertain that we preferred an online format for this conference. Acoustics Week in Canada 2021 was thus held online Tuesday–Friday, October 5–7.
Total attendance was approximately 110 people over the three days of the conference (40 people online on October 5 - 40 people online on October 06 - 30 people online on October 7). Net proceeds were $1554.95 after the deduction of fees related to online tools.

Contacts/Organizing Committee

Conference Chair:	Olivier Robin, Université de Sherbrooke
Technical Chairs:	Patrice Masson, Université de Sherbrooke
	Sebastian Ghinet, NRC

Exhibit/Sponsor

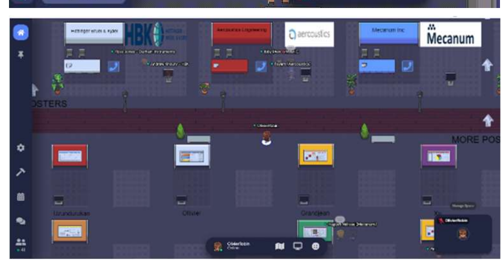
Coordinators:	Julien Biboud, Mecanum Inc.
Student Prizes and Subsidies:	Victoria Duda, Université de Montréal

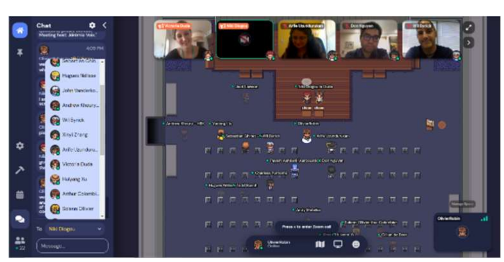
2 Online platform

The gather platform has been used to offer:

- A main room in which the plenary lectures and lightning sessions have been streamed using a zoom support,
- A virtual room dedicated to researchers, students and exhibitors to discuss/exchange after video presentations, including poster presentations, videos and face-to-face interactions.
- Open spaces to discuss/exchange.

Print screens of the gather platform are presented beside : upper – open space; middle – presenting room that includes both exhibitors and researchers; lower – the plenary room.





3 Technical Program

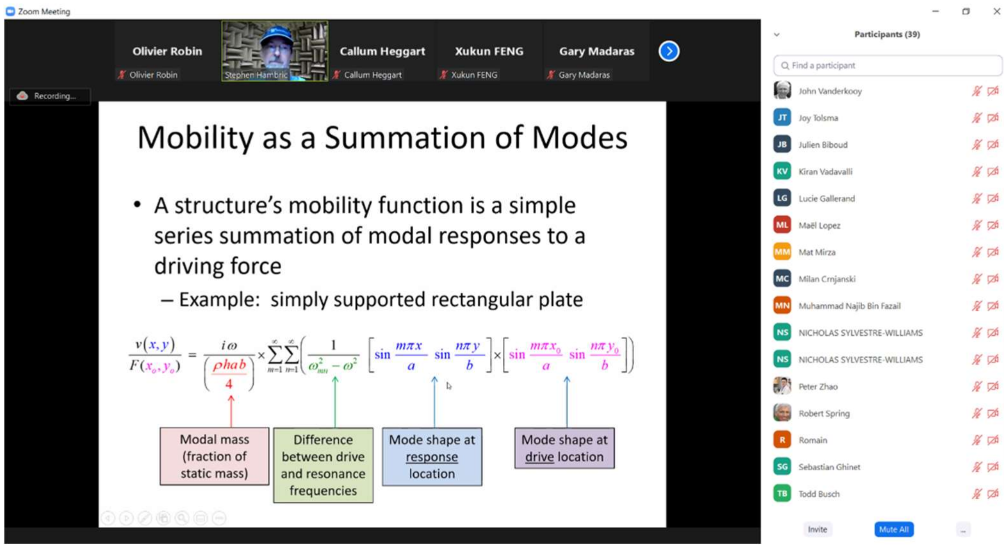
The technical program consisted of 48 contributions, and three 'half-days' were structured around three general themes

- October 5 - ACO1 'Acoustics and structures': works mostly involving room acoustics, building acoustics, vibroacoustics, ultrasound, shock and vibration,
- October 6 – ACO2 - 'Acoustics and living beings': works mostly involving psychoacoustics, hearing, bioacoustics, musical acoustics, education in acoustics,
- October 7 – ACO3 - 'Acoustics and computers': works mostly involving computations, simulations, signal processing applied to any acoustics domain.

In order to accommodate people for different time zones, each of the three days began with a plenary talk at 12:00 PM, and was followed by the technical program until 4:00 PM.

Plenary speakers were chosen to cover a wide range of topics of interest to acousticians and included:

- Steve Hambric (Vibroacoustics tutorial)
- Catherine Guastavino (50+ years of soundscape research – A tribute to R. Murray Schafer / 1933-2021)
- Steve Larouche and Sebastian Ghinet (Satellite Components Acoustic Analysis and Test Correlation)



Steve Hambric during his presentation with 39 attendees.

In addition, 25 two-page papers were published in the CAA Journal, *Canadian Acoustics*, in the October 2021 issue.

4 Registration/Attendance

Registration rates were simplified and largely reduced for this online meeting, and were as follows (registration to CAA was mandatory):

Registration Type	Regular
Three-Day Registration (Members of CAA)	25
Three-Day Registration (Student Members of CAA)	10

5 Exhibition

The Exhibition was held on gather platform, during the whole conference. Exhibitor fees were set at $350. For this fee, exhibitors received a virtual booth table and complimentary three-day conference registrations. A complete list of exhibitors with logos is given in Appendix A.

Appendix A: Exhibitors

Mecanum

SVS
SOUND & VIBRATION SOLUTIONS CANADA Inc.

HBK HOTTINGER BRÜEL & KJÆR

aercoustics

Rockfon®

PLITEQ®

Canadian Acoustical Association
Association canadienne d'acoustique

2021 PRIZE WINNERS / RÉCIPIENDAIRES DES PRIX 2021

EDGAR AND MILLICENT SHAW POSTDOCTORAL PRIZE IN ACOUSTICS /
PRIX POST-DOCTORAL EDGAR ET MILLICENT SHAW EN ACOUSTIQUE

Nikoletta Diogou (University of Victoria)

BELL GRADUATE STUDENT PRIZE IN SPEECH COMMUNICATION AND HEARING /
PRIX ETUDIANT BELL EN COMMUNICATION VERBALE ET AUDITION

Don Nguyen (McGill University)

FESSENDEN GRADUATE STUDENT PRIZE IN UNDERWATER ACOUSTICS /
PRIX ETUDIANT FESSENDEN EN ACOUSTIQUE SOUS-MARINE

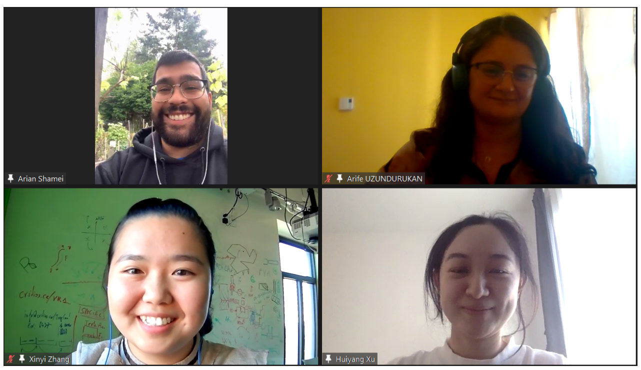
Jack Lawson (University of Victoria)

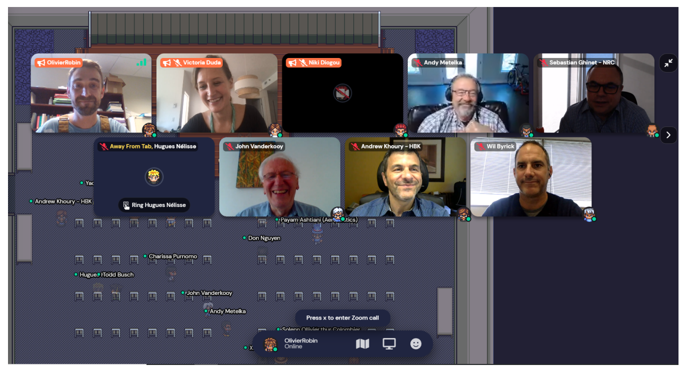
CAA BEST STUDENT PRESENTATION AWARD /
PRIX DE LA MEILLEURE PRESENTATION ÉTUDIANT DE L'ACA

Huiyang Xu (École de Technologie Supérieur)
Arife Uzunduruken (Université de Sherbrooke)
Arian Shamei (University of British Columbia)

CAA AUDIENCE AWARD FOR BEST PRESENTATION /
PRIX DU PUBLIQUE ACA POUR LA MEILLEURE PRÉSENTATION

Xinyi Zhang (École de Technologie Supérieur)





Award winners **Jack Lawson** (top Left), **Don Nguyen** (top right), **Arian Shamei, Arife Uzunduruken, Xinyi Zhang** and **Huiyang Xu** (bottom left), and **Nikoletta Diogou** (bottom right), with Awards Coordinator Prof. Victoria Duda, conference chair Prof. Olivier Robin and other participants at the Awards Ceremony during the Acoustics Week in Canada 2021 carried out online.

Récipiendaires des prix de l'association, **Jack Lawson** (en haut à gauche), **Don Nguyen** (en haut à droite), **Arian Shamei, Arife Uzunduruken, Xinyi Zhang** et **Huiyang Xu** (en bas à gauche), and **Nikoletta Diogou** (en bas à droite), avec le coordinateur des prix Prof. Victoria Duda, le président de la conférence Prof. Olivier Robin, et d'autres participants à la cérémonie de remise des prix lors de la Semaine Canadienne d'Acoustique 2021 en ligne.

CONGRATULATIONS / FÉLICITATIONS

Canadian Acoustical Association
Association Canadienne d'Acoustique

PRIZE ANNOUNCEMENT • ANNONCE DE PRIX

CANADIAN ACOUSTICAL ASSOCIATION
ASSOCIATION CANADIENNE D'ACOUSTIQUE

Prize

Edgar and Millicent Shaw Postdoctoral Prize in Acoustics
Alexander G. Bell Graduate Student Prize in Speech Communication and Hearing
Eckel Graduate Student Prize in Noise Control
Fessenden Graduate Student Prize in Underwater Acoustics
Raymond Hetu Undergraduate Student Prize in Acoustics
Thomas D. Northwood Graduate Student Prize in Architectural and Room Acoustics
Albert S. Bregman Graduate Student Prize in Psychological Acoustics

Prix

Prix Post-doctoral Edgar et Millicent Shaw en Acoustique
Prix etudiant Alexander G. Bell en Communication orale et audition (2^{e} ou 3^{e} cycle)
Prix etudiant Eckel en Controle du bruit (2^{e} ou 3^{e} cycle)
Prix etudiant Fessenden en Acoustique sous-marine (2^{e} ou 3^{e} cycle)
Prix etudiant Raymond Hetu en Acoustique (1er cycle)
Prix etudiant Thomas D. Northwood en Acoustique Architecturale et Acoustique des Salles (2^{e} ou 3^{e} cycle)
Prix etudiant Albert S. Bregman en Psychoacoustique (2^{e} ou 3^{e} cycle)

Deadline for Applications:
April 30^{th} 2022

Date limite de soumission des demandes:
30 Avril 2022

Consult CAA website for more information
Consultez le site Internet de l'ACA pour de plus amples renseignements
(http://www.caa-aca.ca)

ANNOUNCEMENT

ACOUSTICS WEEK IN CANADA

MEMORIAL UNIVERSITY, ST. JOHN'S,
NEWFOUNDLAND AND LABRADOR
SEPT 27-30, 202

Acoustics Week in Canada 2022 will be held on September 27-30 2022, in St. John's, Newfoundland and Labrador.

Vue du centreville de St John's

You are invited to be part of this three-day conference featuring the latest developments in Canadian acoustics and vibration. This is the first time Acoustics Week will be held in the province of Newfoundland and Labrador, and reflects Memorial University's growing profile in acoustics research.

The keynote talks and technical sessions will be framed by a welcome reception, conference banquet, Acoustical Standards Committee meeting, technical tour and an exhibition of products and services related to the field of acoustics and vibration.

Take few days before or after the conference to enjoy the area and the cultural activities! While in Downtown St. John's be sure to try some of the world-class restaurants on Duckworth and Water Street. Become an honourary Newfoundlander by kissing a cod and getting screeched-in on George Street, while enjoying endless live music. Right next to downtown is Signal Hill National Historic Site, where Marconi received the first transatlantic radio signal. Signal Hill has great views of the city, and amazing hiking trails. For a longer hike, the East Coast Trail comprises 25 segments along the Atlantic coast of varying difficulty, most within an hour's drive of St. John's.

Venue and Accommodation

The conference will be held at the Sheraton Hotel Newfoundland in St. John's. A block of rooms in the hotel will be available at a special rate of $179/night. Please refer to the conference website for further details and registration: https://awc.caa-aca.ca/index.php/AWC/AWC22

Water Street, St John's

Plenary, technical sessions.

are planned throughout the conference. Each day will begin with a keynote talk of broader interest and relevance to the acoustics community. Technical sessions are planned to cover all areas of acoustics including:

AEROACOUSTICS / ARCHITECTURAL AND BUILDING ACOUSTICS / BIO-ACOUSTICS AND BIOMEDICAL ACOUSTICS / MUSICAL ACOUSTICS / NOISE AND NOISE CONTROL / PHYSICAL ACOUSTICS / PSYCHO- AND PHYSIO-ACOUSTICS / SHOCK AND VIBRATION / SIGNAL PROCESSING / SPEECH SCIENCES AND HEARING SCIENCES / STANDARDS AND GUIDELINES IN ACOUSTICS / ULTRASONICS / UNDERWATER ACOUSTICS

Exhibition and sponsorship.

The conference offers opportunities for suppliers of products and services to engage the acoustic community through exhibition and sponsorship.

The tabletop exhibition facilitates in-person and hands-on interaction between suppliers and interested individuals. Companies and organizations that are interested in participating in the exhibition should contact the Exhibition and Sponsorship coordinator for an information package. Exhibitors are encouraged to book early for best selection.

The conference will be offering sponsorship opportunities of various conference features. In addition to the platinum, gold and silver levels, selected technical sessions, social events and coffee breaks will be available for sponsorship. Additional features and benefits of sponsorship can be obtained from the Exhibition and Sponsorship coordinator and on the conference website.

Students.

Students are strongly encouraged to participate. Students presenting papers will be eligible for one of three $500 Best Presentation Student prizes to be awarded. Conference travel bursaries will also be available to those students whose papers are accepted for presentation.

Registration details.

Please refer to the conference web site: https://awc.caa-aca.ca/index.php/AWC/AWC2022 1

Contacts.

Conference Chair:

Len Zedel
(zedel@mun.ca)

Ben Zendel
(bzendel@mun.ca)

Flatrock, along the East Coast Trail

ANNONCE

SEMAINE CANADIENNE D'ACOUSTIQUE

UNIVERSITÉ MEMORIAL, ST. JOHN'S, TERRE-NEUVE ET LABRADOR

SEPT 27-30, 2022

La Semaine canadienne d'acoustique 2022 aura lieu du 27 au 30 septembre 2022 à St. John's, Terre-Neuve et Labrador. You Nous vous invitons à prendre part à cette conférence de trois jours concernant les derniers développements en acoustique et vibrations au Canada. C'est la première fois que la Semaine Canadienne d'acoustique aura lieu dans la province de Terre-Neuve et Labrador, ce qui reflète le profil croissant de recherche en acoustique de l'Université Memorial.

View of downtown St John's

Les exposés principaux et les séances techniques seront encadrés par une réception de bienvenue, un banquet, une réunion du comité des normes acoustiques, une visite technique et une exposition de produits et services liés au domaine de l'acoustique et des vibrations.

Prenez quelques jours avant ou après la conférence pour profiter de la région et des activités culturelles! Au centre-ville de St. John's, assurez-vous d'essayer les restaurants de classe mondiale sur la rue Duckworth et la rue Water. Devenez un(e) Terre-Neuvien(ne) honoraire en embrassant une morue et en vous faisant 'Screeched-in' sur la rue George, tout en profitant de la musique live sans fin. Juste à côté du centre-ville se trouve le Lieu historique national de Signal Hill, où Marconi a reçu le premier signal radio transatlantique. Signal Hill a une vue imprenable sur la ville, et des sentiers de randonnée incroyables. Pour une randonnée plus longue, le sentier de la côte Est comprend 25 segments le long de la côte atlantique de difficulté variable, la plupart à moins d'une heure de route de St. John's.

Lieu et hébergement.

La conférence aura lieu au Sheraton Hotel Newfoundland à St. John's. Un bloc de chambres dans l'hôtel sera disponible à un tarif spécial de 179$ par nuit. Veuillez consulter le site Web de la conférence pour plus de détails et pour l'inscription: http://awc.caa-aca.ca/AWC/AWC2022

Rue Water, St John's

Des séances plénières, techniques et des ateliers.

Des séances plénières, techniques et des ateliers sont prévus tout au long de la conférence. Chaque journée débutera avec une plénière intéressante et pertinente pour la communauté de l'acoustique. Des sessions techniques sont prévues pour couvrir tous les domaines de l'acoustique, y compris :

AÉROACOUSTIQUE / ACOUSTIQUE DU BÂTIMENT ET ARCHITECTURALE / BIOACOUSTIQUE / ACOUSTIQUE BIOMÉDICALE / ACOUSTIQUE MUSICALE / BRUIT ET CONTRÔLE DU BRUIT / ACOUSTIQUE PHYSIQUE / PSYCHOACOUSTIQUE / CHOCS ET VIBRATIONS / LINGUISTIQUE / AUDIOLOGIE / ULTRASONS / ACOUSTIQUE SOUS-MARINE / NORMES EN ACOUSTIQUE

Exposition et parrainages.

La conférence offre aux fournisseurs de produits et de services la possibilité de faire participer la communauté acoustique par l'exposition et le parrainage.

L'exposition sur le plateau facilite l'interaction en personne des fournisseurs et des personnes intéressées. Les entreprises et organisations désirant participer à l'exposition doivent contacter le coordonnateur de l'exposition et du parrainage pour obtenir un dossier d'information. Les exposants sont encouragés à réserver tôt pour obtenir de meilleures opportunités.

Les étudiants.

Les étudiants sont fortement encouragés à participer. Les étudiants qui présenteront seront admissibles à l'un des trois prix de 500$ pour les meilleures présentations. Des subventions de voyage seront également offertes aux étudiants dont les communications sont acceptées pour présentation.

Pour plus d'informations sur l'inscrition.

Veuillez consulter le site Web de la conférence : http://awc.caa-aca.ca/AWC/AWC2022.

Contacts.

Prsident de la conférence:

Len Zedel
(zedel@mun.ca)

Ben Zendel
(bzendel@mun.ca)

Flatrock, sur le sentier de la côte Est

CANADIAN ACOUSTICAL ASSOCIATION

Minutes of the Board of Directors Meeting

Monday, October 4th, 2021 2:30 PM – 5:30 PM (EDT)

by Zoom videoconference

1. Call to Order

Meeting called to order at 14:35 (EDT)

Board members present online: Jérémie Voix (chair), Alberto Behar, Umberto Berardi, Bill Gastmeier, Bryan Gick, Dalila Giusti, Michael Kiefte, Andy Metelka, Hugues Nélisse, Roberto Racca, Joana Rocha, Frank Russo, Mehrzad Salkhordeh.

Jérémie introduced the proposed agenda which was approved after minor discussion of the items.

2. President's report (Jérémie Voix)

Jérémie presented to the Board for discussion various action and initiatives undertaken or proposed, including:

- Promotion and support of the TC43 ISO standardization meeting in Montreal 2023, through advertising of the event in the Association's media and hosting of a dedicated mini site. The event will be hosted at ETS, and various members of the CAA are involved in its organizing.
- Creation of a new membership category for retired professionals who are no longer supported by an organization, with annual fees reduced by half, and introduction of a free one-year membership or extension of existing membership for all winners of CAA awards. Jérémie noted that these changes would be presented to the Association's membership and opened for any comments during the AGM.
- Management of advertising in Canadian Acoustics as part of the Open Journal System online portal, essentially creating new types of "membership" (with a given duration and a price matching the number and typeset size of ads they represent) that would be dedicated to advertisers. Among other benefits this will simplify the invoicing process as payment will be made online as part of placing the advertisement; it will also enable advertisers to access the current issues of the journal (including the ones featuring their content) for the duration of their ad run.

Jérémie noted that he and Cécile Le Cocq had begun implementing the framework for advertising support in the OJS but had been diverted from the task by other issues to be urgently addressed with that platform (see below); they were now again set to complete the task. Dalila remarked that unless a human coordinator was involved there would not be retention of advertisers because of lack of follow-up. She pointed out that a system which simply dropped ad runs automatically if not pre-paid or renewed would likely result in loss of interest on the part of advertisers, and a human coordinator likely would remain necessary to maintain business relations. Further discussion followed, and it was agreed to go ahead with the new system as the underlying framework but likely maintain a person involved in the volunteer role of liaison with advertisers.

Moving on to new business, Jérémie mentioned that difficulties had occurred with the Open Journal System portal following its migration to a professionally hosted environment and subsequent version upgrades; this caused numerous problems including failure to send automated membership renewal reminders, outages in some web site functions due to scripts having broken, and other complications. He indicated that these issues were being actively tackled and addressed but a few still lingered, including the side effect of Google Scholar having de-indexed the journal content due to the change in hosting – something that Jérémie was actively engaged in restoring.

Jérémie went on to present a list of major projects for which volunteer were required and, in some cases, had already been identified. The projects, each of which Jérémie described in some detail, were as follows:

- Revamping and migration of web site to latest WordPress (no volunteers yet)
- Inventory of acoustical training programs across Canada (Umberto)
- Operation manual and procedures update (Michael)
- Solicitations for Practitioners Corner (Alberto; Bill willing to assist)

- Canadian Acoustics web portal language pack revamping (Roberto)
- Local chapters' starter kit (no volunteers yet)
- Adaptation of "What's an acoustician?" video to a Canadian audience (Andy will look at technical feasibility)
- Implementation of CAA manuals and procedures as an online wiki (no volunteers yet)

To conclude his presentation, Jérémie queried the Board about the continuation or renewal of their roles, to coordinate for the AGM the next day. He asked whether Board members whose 4-year terms were up for renewal would be willing to stay in their roles and received confirmation that all would. Jérémie welcomed the commitment of current Board members but he noted that in the longer term each director should keep in mind the need for both continuity and renewal, so potentially consider successors to nominate and especially for members of the executive, candidates who could replace them well in their role. He also noted the importance of diversity and inclusion in the composition of the Board and suggested that a more balanced gender ratio could be sought in considering successors.

3. Treasurer's report (Dalila)

Dalila opened with an apology for not having been able to participate in the previous year's fall BoD meeting due to an overwhelming professional commitment at the time and noted that her report, though brief, would be somewhat of a hybrid of what she would have presented then and the current one. She noted that the Association was doing well financially and fulfilling its role of supporting the acoustics community for example by giving out $8,000 in awards this year at the virtual conference.

Dalila reported that all tax filing obligations of the Association had been met and as per usual, HST rebates had been received for both 2019 and 2020. She explained that her budget review this year would not include a comparison against actuals for FY 2021 since a budget forecast had not been filed, so the proposed budget for FY 2022 would be based on the 2021 actuals. No changes in membership fees would be recommended (the last increase had been in 2019) as the current income position was satisfactory. In reply to a question from Roberto, Dalila remarked that the introduction of a discounted membership rate only for retired members would not substantially affect the budget; Jérémie noted that it would likely in fact lead to retaining or regaining memberships that we'd lose otherwise as older members left the active profession.

Highlighting some key entries in the 2021 actuals, Dalila noted that advertising revenue was an issue since it was down to barely over $1,000 in large part due to non-collection (which she and the advertising coordinator would try to rectify) but even with that shortfall, and the lack of any conference proceeds, the revenue had covered expenses with a small margin which was essentially the desired financial position for the Association. Moving to the FY 2022 proposed budget, Dalila noted she had forecast a shortfall of ~$15K but that was based on very conservative assumptions such as zero advertising revenue, so it was fully expected that the outcome would be substantially better.

Roberto moved to accept the Treasurer's report, seconded by Jérémie; carried unanimously.

4. Secretary's report (Roberto)

Roberto presented a categorized table of the various membership and subscription figures and their trend over the past 18 months. He noted that a year and a half had passed since the introduction of the "stimulus package" in the summer of 2020 whereby recently lapsed members and sustaining subscribers had been reinstated and the term of current memberships had been extended, with the aim of re-engaging people as well as reintroducing them in the cycle of renewal reminders and other contacts. This had shown a positive and seemingly lasting effect in revitalizing the numbers that had dwindled due to missed renewals and other attrition. Indeed, the surge in numbers induced by the package had predictably settled at its tapering off at the end of December 2020, but a satisfactory wave of renewals by members and sustaining subscribers had taken place at that time that kept the levels buoyed. The total number of individual memberships as of the date of the BoD meeting stood at 195, including regular (168) and student (27) members, with the number of sustaining subscribers at a very respectable 20. Roberto commented that the numbers had picked up somewhat even after the critical renewal period of end December, partly because of the requirement to be a member to participate in this year's online version of Acoustics Week in Canada. He noted that a key to this continued re-engagement remains an effective communication between executive and membership that will strengthen participation and motivate the renewal of adhesion.

Moving to other matters Roberto noted that past problems with completing renewals and purchases on the OJS had largely faded away, and the main cause of queries he received from prospective members or subscribers had to do with the understanding of rights and benefits associated with individual categories (for example, a sustaining subscriber wondering about "membership" status for their organization). Roberto welcomed the opportunity outlined by Jérémie to revamp the language packs behind the OJS pages to make the terms and definitions clearer and unambiguous, which he expected would enhance the experience of people using the portal and lead to greater engagement.

In a brief question period that followed, Joana asked about the accuracy of the statistics presented; Roberto explained that they were obtained from direct queries of the database for active status and current expiry date, and Dalila noted that she could cross-verify the numbers against individual payments received online. Joana raised the further point that with an online payment system accessible from the OJS there could be concerns about security of our web portal; Roberto commented on the level of watchfulness against security breaches maintained by Jérémie and others involved in system administration, and Jérémie noted the recent transition in OJS hosting for security reasons and the responsiveness of the OJS open-source community to discovery of any new hacks or vulnerabilities, with patches issued very promptly.

5. Awards Coordinator's report (Joana Rocha)

Before formally presenting her report Joana made some remarks about the inconsistent updating of the awards information on the CAA-ACA web site and indicated that she had been working with the webmaster to ensure that the lists of recipients and other details are current. Highlighting some points of her formal report, she acknowledged Sean Pecknold having replaced temporarily Stan Dosso as coordinator for Shaw Postdoctoral award to avoid a conflict of interest given the related affiliation of a candidate. She also indicated that the three winners of major awards this year had confirmed that they would be attending the virtual Acoustics Week in Canada meeting and thus on hand to receive their prizes at the Award Ceremony on 7 October. She noted that with the help of the CAA media editor, Romain Dumoulin, this year the application and deadlines information for the various awards had been publicized on CAA social media platforms, such as Twitter and LinkedIn. Still, despite that enhanced exposure and the individual coordinators' efforts to solicit candidates, some of the prizes had seen no applicants. Joana also brought up the point that for several years the granting of the Directors' Awards for best papers in Canadian Acoustics had not taken place; there was a general sense among the Board that they should be reactivated, whilst recognizing that the selection process was an onerous one.

Joana presented a list of winners for the awards granted this year along with the subject of the winning papers, and she thanked the coordinators of individual prizes for their work. She also noted that the student presentation prizes would be awarded over the three-day AWC virtual conference that would start the next day. Lastly, she mentioned that owing to a new responsibility she had assumed at her institute she would no longer be able to fulfill the position of Awards Coordinator and she had already informed Jérémie of her intention to hand over the role to a colleague at the University of Montreal, Victoria Duda, of whom she gave a brief professional overview. Joana stated willingness to maintain her role on the Board whereas Victoria would only take up the Award Coordinator's position. This announcement prompted considerable discussion among other directors about whether the position should be linked to being on the Board, and how the process would unfold in the framework of Board renewal and continuity. In final analysis it was determined that under the Continuation provisions an additional position on the Board could be created on an annual basis, and on that basis the Board agreed to bring in Victoria as an interim additional member in her new position.

6. Present and Upcoming Meetings

<u>AWC 2021 – Virtual:</u> (Chair: Olivier Robin)

- Jérémie presented a brief overview of event to be hosted virtually by the University of Sherbrooke for the following three days, noting that Olivier Robin could not join in to report to the Board personally as he was quite busy setting up and testing the system.
- All registrants would have received a private link unique to their e-mail address to join the event on a platform called Gather (www.gather.town); this was not a free meeting with open participation but required enrollment much like a regular congress.
- Registration and online payment had been set up through the CAA-ACA conference management portal and worked similarly to the OJS membership & subscription management platform.

- Each of the three days of the event was scheduled to run from 12:00 pm to 4:00 pm EDT save the last day that would extend to 4:30 pm to include the award ceremony; each day would begin with an hour-long plenary invited lecture.

<u>AWC 2022 – St-John's:</u> (guest Len Zedel, AWC 2022 co-chair)

- Len informed that he and his co-chair Ben Zendel did not have much to report save that they had finalized the booking of the conference hotel. They were somewhat on standby, but they would begin planning in earnest very soon.
- Jérémie commented that as soon as the present virtual conference was over it would be the logical time to switch over all planning to AWC 2022 and to begin, start adding content and details to the year-specific web site and prepare to send out a formal announcement and call for papers to appear in the December issue of Canadian Acoustics.

<u>ISO TC43 Plenary – Montréal 2023:</u> (Jérémie Voix)

- Everything on course; already discussed briefly earlier in the meeting.

<u>AWC 2023 – Proposal of Ryerson</u>

- Jérémie remarked that the plan to host the 2023 event in Ottawa was no longer valid (see later) and suggested that possibly Ryerson could have considered advancing to that year their hosting of the event that had been originally offered for 2025. Umberto commented that likely he would have been too busy to be the chair of such an event in 2023 and noted as well that in terms of geographic representation it would have been preferable to hold the 2023 AWC at a location in western or central Canada.
- After some discussion the Board left open the option to seek interest from potential organizers in the western or prairie Provinces, but not rule out other geographic options altogether.

7. Editor's report (Umberto)

Umberto gave a quick overview of the issues published so far in the year: the first (March) was a regular issue, the second (June) mostly so as well but it included a special tribute to Ramani Ramakrishnan on his retirement, with his photo on the cover and some nice words in the editorial and in a special contributed feature by various people. The September issue had been posted online a couple of days before, and printed copies were making their way to people. Umberto commented that five accepted regular papers had been awaiting publication, but they had not been added to the conference issue (although a little thinner than normal) so as not to alter its identity as a collection of proceedings. That meant that with three further papers accepted over the summer, there would be no difficulty filling up a solid December issue.

For 2022 Umberto mentioned that there could be the opportunity to consider either a topic issue or a regional issue; he noted that a couple of specialized issues had been produced in recent years and there had been a successful run of regional issues for Montreal, Toronto, and British Columbia. On the matter of special issues, he remarked that they could be a vehicle to give the journal greater international exposure, as a call for papers on a relevant specialized subject might be answered by a geographically wider circle of researchers – and the resulting issue would likely garner greater interest in the journal. On the matter of visibility Umberto commented on the fact that because of technical issues mentioned earlier by Jérémie the journal had temporarily lost indexing by Google, but the situation was getting back on track. Lack of indexing would not necessarily affect the core readership of the journal but would impact the wider international exposure of its content.

Umberto moved on to discussing the matter of the journal's three-person editorial board, which had heavily relied on Ramani who was now retiring and making corresponding life plans. Decisions would have to be made on future roles and responsibilities also depending on how much Ramani wished to remain involved in the longer term. Regarding roles associated with the journal, Umberto also mentioned that there was an ongoing dearth of reviewers in the subjects of underwater acoustics and bioacoustics (which also receive a lower volume of contributions than by rights they should).

Lastly Umberto advised the Board on a couple of practical points, one related to the physical (print) version of the journal and the other to its virtual existence. On the physical side he mentioned that he had been consistently archiving a few extra copies of each issue of the journal, and that Ramani upon retiring had added a considerable cache of earlier editions going back may years; those back issues could be used to satisfy subscribers' requests for missing copies or possibly for archival uses. On the virtual side, he remarked that currently the Association only advertises on its social media channels the publishing of a new issue of the journal, so a media shout-out every three months. He advised that it would be far more effective to post on a monthly (or even more frequent) basis links to individual articles with excerpts and illustrations as other journals do, adding value to any content published in Canadian Acoustics. He noted that in the post-COVID environment many journals more commercially driven than Canadian Acoustics may struggle, and that gives us a unique opportunity to stake out recognition as a relevant and sought-after academic publishing target.

8. Social Media Editor report (Romain Dumoulin)

Jérémie gave a presentation on behalf of Romain Dumoulin who could not attend the meeting. Referring to statistics provided by Romain, Jérémie noted that the CAA-ACA group on LinkedIn had reached a membership of 929, adding 86 new members and 14 moderated posts since April 2021. The Association's Twitter account counted 503 followers, 226 tweets and 208 "likes" in total, with 37 followers, 25 tweets and 28 "likes" added over the same six-month period. Content has included relaying of "job alert" posts from the web site, announcements of new issues of Canadian Acoustics or conference related news, and publications, posts and events from CAA members or the broader acoustics community. Romain is beginning to take a more creative role in the production of posts, rather than mostly re-posting information from other sources; some of the planned actions are to add items like "gems from the past" excerpts from the Canadian Acoustics archives and to provide enhanced alerting of job opportunities for Association members.

9. Varia

Bryan inquired whether there had been any action on a suggestion made at a previous Board meeting that the Hétu prize book award be complemented or replaced by a monetary sum. Dalila raised the point that the monetary value of various awards should likely be reassessed and increased; some discussion ensued which further broadened the issue, and the Board agreed that a comprehensive review of existing and potentially new awards would have to be undertaken at the next meeting.

10. Next meeting

April 2022, date to be decided, by virtual conference.

11. Motion to adjourn

By Jérémie, at 17:40 (EDT)

Canadian Acoustical Association

Minutes of the Annual General Meeting

Tuesday, October 5th, 2021 5:00 PM – 6:00 PM (EDT)
by Zoom videoconference

1. Call to Order

Meeting called to order 17:10 (EDT) by Jérémie Voix (President).

Jeremy Voix said a few words of welcome to the about 25 people in attendance online and introduced the meeting agenda.

2. President's Report (Jérémie Voix) and Election of the Board

Jérémie gave an overview of various actions and initiatives undertaken by the Association with the Board's approval, including:

- Promotion and support of the TC-43 ISO standardization meeting in Montreal 2023, through advertising of the event in the Association's media and hosting of a dedicated mini-site.
- Creation of a new membership category for retired professionals who are no longer supported by an organization, with annual fees reduced by half.
- Introduction of a free one-year membership or extension of existing membership for all winners of CAA awards.
- Management of advertising in Canadian Acoustics as part of the Open Journal System online portal, essentially creating new types of "membership" (with a given duration and a price matching the number and typeset size of ads they represent) that would be dedicated to advertisers. Among other benefits this will simplify the invoicing process as payment will be made online as part of placing the advertisement.

Jérémie went on to acknowledge that difficulties had occurred with the Open Journal System portal following its migration to a professionally hosted environment and subsequent version upgrades; this caused numerous problems including failure to send automated membership renewal reminders, outages in some web site functions, and complications in the production and distribution of the Journal. He indicated that these issues were being actively tackled and addressed, but a few still lingered.

Jérémie mentioned that they had proposed to the Board new project initiatives, for some of which he appealed for assistance from volunteers among the membership; he highlighted in particular:

- The migration of the main CAA-ACA web site to the latest WordPress environment, with corresponding need to update the underlying theme style.
- The coordination and support of local chapters promoting acoustics knowledge and the activities of the Association, through visibility on the CAA web site, management of distribution lists, and the creation of a "starter kit."
- The creation of a wiki to capture the accrued knowledge and experience of the Association, including manuals and procedures specific to certain roles like Webmaster or Media Editor.

Lastly, Jérémie addressed the subject of composition and renewal of the Board of Directors. He pointed out that the Association has 12 Directors, 7 of whom are members at large and 5 have designated (executive) roles; the mandate is four years (renewable) and currently 5 members were due for election. He noted that at the previous day's Board meeting all current directors had indicated willingness to be reconfirmed in their roles and asked for any nominations for potential new members. None being made, he moved that all present Board members be reconfirmed; the motion was seconded by Daniel Aalto and passed unanimously by (video and/or digital) show of hands. Jérémie then announced that at the request of incumbent Joana Rocha a temporary position on the Board would be formed for a one-year duration (as allowed in the by-laws) for a new Awards' Coordinator. Joana nominated Victoria Duda to replace her in the executive role, and Jérémie solicited the attendees for any alternative nominations. There being none, he proposed the appointment of Victoria, which was seconded by Daniel and unanimously accepted.

3. Treasurer's Report (Dalila Giusti)

Dalila presented a comparative summary of assets over the past few years, explaining the division between capital funding (from which awards are distributed), operating funds (for general expenses) and investments, and pointed out the healthy financial position with $520,000 in assets. She noted that the Association's principal revenue streams are membership dues, sustaining subscriptions, advertising, and interest; occasionally a donation is received that will support a new award. She then presented a list of award disbursements over the past few years (payout for the current year being $8,000) along with the earned interest out of which they are funded. Capital is invested in market funds whose interest fluctuates but can be as high as 25-30% over the long term and have been performing quite well and easily supporting the awards. She noted that last year not all awards were distributed because of disruptions from the pandemic.

Dalila then presented the current year and proposed next year's budget, which predicted a deficit of about $15,000 albeit based on very conservative assumptions – including no forecast revenue from advertising or the annual conference. Daniel Aalto asked whether the $10,000 level of support budgeted for students travel to the annual conference would be sufficient based on pre-COVID numbers; Dalila replied that the allocation had been put in place a couple of years back as a means of funding students travel adequately regardless of the fortunes of any given conference. She noted that because of travel restrictions there had not yet been a chance to test the funding for adequacy, but hopefully next year the conference would be held in Newfoundland which would give a real-world scenario to assess the subsidy.

4. Secretary's Report (Roberto Racca)

At the opening of his presentation Roberto noted that the aim of his activity had continued to be to maintain a positive interaction between the Association's general membership and the executive and Board, a role shared with the President as the persons on the executive most involved with regular communications with members and sustainers. He remarked that some challenges with the online platform for management of memberships persisted, as already pointed out by Jérémie, leading to ongoing need for user assistance that he had tried to provide in a timely manner. The pandemic-triggered transition to online events ,to replace in-person meetings, primarily the annual conference, also increased the challenge of maintaining a constructive and collaborative level of exchange and networking. Through all this, however, the level of engagement and support from many individuals and organizations has remained encouragingly steadfast.

Turning to the membership figures and their trend over the past 18 months, Roberto noted that the "stimulus package" launched in the summer of 2020 by reinstating recently lapsed members and sustaining subscribers and extending the term of current ones had a positive and seemingly lasting effect in revitalizing the numbers that had dwindled due to missed renewals and other attrition under the combined impact of pandemic concerns and technical issues with the journal management portal. He expressed gratitude at the surge of renewals by members and sustaining subscribers that had taken place in December 2020 as the stimulus period tapered off. The total number of individual memberships as of the date of the AGM stood at 195, including regular (168) and student (27) members, with the number of sustaining subscribers at a very respectable 20. A sustained good showing in the numbers past December 2021, he noted, would be a welcome indication of the re-engagement of our base after the past slump; key to this re-engagement remains an effective communication between executive and membership that will strengthen participation and motivate the renewal of adhesion.

To that end, Roberto concluded, the Board and executive would keep improving the online experience of the main CAA-ACA web site and the Journal and membership / subscription portal, to provide engaging content and timely updates. He noted that activities of the Association and announcements of interest to the acoustics community are regularly posted on the web site and social media, and heartily invited all involved following them. In closing he reiterated that in his role as executive secretary he remained always at people's disposal to be approached with questions, concerns and suggestions that would be promptly addressed and/or passed along to other members of the Board and the executive.

5. Awards Coordinator's Report (Joana Rocha)

Joana opened her address with the remark that the most current information about award winners had been communicated to webmaster Philip Tsui and updated on the CAA-ACA web site for people to look up. Highlighting some points of her formal report given to the Board the previous day, she acknowledged Sean Pecknold having replaced temporarily Stan Dosso as coordinator for Shaw postdoctoral award to avoid a conflict of interest given the related affiliation of a candidate. She noted that with the help of the CAA media editor, Romain Dumoulin, this year the application and deadlines information for the various awards had been publicized on CAA social media platforms, such as Twitter and LinkedIn. And she indicated that the three winners of major awards this year had confirmed that they would be attending the virtual Acoustics Week in Canada meeting and thus on hand to receive their prizes at the Award Ceremony on 7 October.

Joana mentioned the imminent transition of her duties as Award Coordinator to Victoria Duda, newly appointed to a temporary position on the Board for the next year. She indicated that she had been working with Victoria to facilitate the transition by making available and clarifying the documentation associated with the role. She then presented a list of winners for the awards granted this year along with the subject of the winning papers, and she thanked the coordinators of individual prizes for their work. She remarked that despite the coordinators' best efforts to solicit candidates some of the prizes had seen no applicants, and while the pandemic might have been a factor the lack of entries had also occurred in past years. Joana encouraged members of the Association to publicize the CAA awards and attract candidates to them.

During the questions and comments period Jérémie noted that there would be three subject-specific student presentation prizes granted this year, one for each day of the ongoing virtual conference, as well as an overall student video presentation quality award selected by an audience vote. Olivier Robin, chair of the conference, gave a quick overview of the adjudication process for the daily awards, selected by the committee, and the public voting process done online via the conference portal. Bryan Gick raised the question of whether presentation awards should continue to be open only to graduate students or should be extended to undergraduates as well, given that the latter are fully entitled to present at the conference and publish in the proceedings issue. Jérémie thanked Bryan for bringing up a valid point and noted that this fell in the scope of a broader reassessment of eligibility criteria that Joana and Victoria would be undertaking and presenting to the Board for deliberation ahead of the next conference.

6. Editor’s Report (Umberto Berardi)

Umberto reported that Volume 49, the current year’s, was on a good track with the first three issues having been published and the fourth well underway. The June issue had included a special tribute to Ramani Ramakrishnan, a long-time former editor-in-chief of Canadian Acoustics, on his retirement; the September issue had been slimmer than usual for a conference edition due to fewer contributions of proceeding papers, but still regular sized. He remarked that the publication had a fruitful year despite the slowing down of research activities due to the pandemic: submissions had been steady, and the journal was attracting national and international attention. He encouraged members of the acoustics community at large to contribute to the journal, including shorter features and practitioners-oriented content.

Umberto commented on the fact that 2022 would see the publication of Volume 50 of the journal, and it was a considerable achievement for a publication to reach 50 years of uninterrupted run. He again exhorted members to contribute features to this special volume and stated his commitment to dedicate the time and effort necessary to move forward all submitted articles promptly through the editorial process. Daniel Aalto asked what the timeline would be for submissions to be considered for the “jubilee” issue. Umberto noted that there were four issues in Volume 50 and so it would be a rolling timeline for an article to appear in one of them, also depending on the peer review process. He mentioned two to three months as an indicative time between submission of a typical paper and when it would be ready for publishing, keeping then in mind the quarterly editorial schedule for the actual publication. In response to a question by Gillian de Boer about whether there would be a particular theme for the volume, Umberto indicated that there were no plans for themed content at least for the first two issues, which would feature the regular range of contributed articles. He further noted that a topical issue has the drawback of pushing any pending articles not related to that subject further down the line for publication. He suggested that a special content could be envisaged for the fourth issue of Volume 50, to appear in December 2022; rather than a special topic issue, however, it would more likely be a regional issue featuring papers about diverse research topics in acoustics but all originating from the same Canadian geographic region.

Jérémie thanked Umberto for his dedication to the difficult task of running the journal and his willingness to be open to new ideas and suggestions that contribute to the calibre of the publication. In closing Jérémie noted that as a regrettable side effect of the hosting server migration mentioned earlier, Google Scholar had blocked indexing of the journal contents. He was now in the process of filling and submitting the necessary paperwork to have the block lifted and indexing restored.

7. Social Media Editor Report (Romain Dumoulin)

Jérémie gave a presentation on behalf of Romain Dumoulin who could not attend the meeting, with the preamble that visibility on the internet in now an essential requirement for any organization and Romain had been hired two years earlier with the specific goal to establish an online presence for the Association. The aim had been achieved solidly on two social media platforms that could be defined as “traditional”: LinkedIn and Twitter. Referring to statistics provided by Romain, Jérémie noted that the CAA-ACA group on LinkedIn had reached a membership of 929, adding 86 new members and 14 moderated posts since April 2021. The Association’s Twitter account counted 503 followers, 226 tweets and 208 “likes” in total, with 37 followers, 25 tweets and 28 “likes” added over the same six-month period. Content has included relaying of “job alert” posts from the web site, announcements of new issues of Canadian Acoustics or conference related news, and publications, posts and events from CAA members or the broader acoustics community. Planned actions are to add items like “gems from the past” excerpts from the Canadian Acoustics archives and to provide enhanced alerting of job opportunities for Association members.

8. Conferences Present and Future

Jérémie opened the topic with a comment about the importance of Acoustics Week in Canada to the cohesion of the acoustical community across the country and the expansion of intellectual horizons for students in this field – something that would not be possible in a larger organization where specific branches of acoustics tend to be siloed in interest groups. He went on to compliment Olivier Robin for his successful organizing of the current virtual conference and the previous year's online event and gave him the floor.

AWC 2021: Virtual meeting (Olivier Robin, Chair)

Sharing a short slide presentation, Olivier gave an overview of the status of AWC 2021 so far. He noted that the event had originally been planned to be held in October 2020 in Sherbrooke, Québec, then postponed in the early months of the COVID pandemic to a year later, still hoping for a physical meeting. The ongoing uncertainty surrounding travel and gatherings later forced the plans to be changed to the virtual event currently unfolding. The technology adopted for the virtual meeting was a combination of the classical platform Zoom for the plenaries and a more immersive virtual environment, Gather, for other presentations. The organizers leveraged the use of recorded video presentations as a means of making the online sessions less stressful; they also simplified the structure of the conference to three main topics, one for each day: "Sound and objects" on Day 1, "Sound and human beings" on Day 2, and "Sound and computers" on Day 3. The call for papers attracted 6 two-page papers and 13 abstracts for Day 1, 15 papers and 7 abstracts for Day 2, and 4 papers and 3 abstracts for Day 3 which also featured the award ceremony. 6 exhibitors enrolled to participate virtually, and Olivier publicly acknowledged them for their support. The organizers chose to place exhibitors and presenters in a single room in the Gather meeting environment, to facilitate an exchange between the groups of exhibitors, professionals, and students which in a physical setting would tend to remain more isolated. For Day 1 just concluded, the online attendance was about 40 people; Olivier noted the difficulty of attracting a large audience to a virtual meeting given the overload of such events in today's professional life. He noted that the next day had the largest program and might gather a more sizeable group.

Jérémie congratulated Olivier for the well-conceived organizing and moved on to the plans for future events. He confirmed that AWC 2022 was planned as an in-person event in St John's, Newfoundland, under the guidance of Ben Zendel and Len Zedel. On behalf of the Chairs, Jérémie gave a few updates on the progress of the organizing: the venue (Sheraton Hotel) had been booked for the 27th to 30th of September, somewhat earlier than the traditional week for the conference in the past. Jérémie expressed hope that people would gather in good numbers for a successful return to in-person events despite the relative remoteness of the location. Beyond 2022, he pointed out, there were no clear plans yet for AWC. He noted again the ISO TC 43 event in Montréal in 2023 and remarked that INTERNOISE 2025 might be in Ottawa and hosted by Joana Rocha and colleagues, which could offer an opportunity for a major joint event with AWC. Joana added an update on the prospects of INTERNOISE 2025 being in Ottawa, saying that they had submitted an informal proposal to I-INCE and we are waiting to hear back before the year's end about assembling a full bid package.

9. Varia

Olivier Robin noted that some action is needed to make the Association more visible and interesting to the public and media; he suggested as a worthwhile initiative to consider the creation of a noise map of Canada through the contribution from ordinary persons equipped with a smartphone noise capture application. Olivier had already been in touch with the Noise Planet team in France who had conceived the original concept and the app, and he suggested that properly promoted this could be a prominent initiative with strong public and news interest potential. There was positive response to the idea of meeting participants.

10. Motion to Adjourn

Moved by Jérémie, seconded by Daniel.

The meeting adjourned at 18:20 (EDT)

CANADIAN ACOUSTICS ANNOUNCEMENTS - ANNONCES TÉLÉGRAPHIQUES DE L’ACOUSTIQUE CANADIENNE

Looking for a job in Acoustics?

There are many job offers listed on the website of the Canadian Acoustical Association!

You can see them online, under http://www.caa-aca.ca/jobs/

August 5th 2015

COVID-19 Situation

Because of the COVID-19 situation, the Acoustics Week in Canada (AWC) originally planned for October 2020 in Sherbrooke (QC) will be postpone to October 2021. Nevertheless, and as a ”warm up”, Sherbrooke”s organising committee is currently looking into setting up a little 1-day online celebration for October 2020. You can find more information on the AWC20 and AWC21 websites. Please note that St-John’s (NL) will host the AWC2022 conference.

May 13th 2020

Extended: International Year of Sound (2020 – 2021)

Highlighting the importance of sound and related sciences and technologies for all in society

The International Year of Sound is a project that the International Commission for Acoustics (ICA), an Affiliated Member of the ISC, has been preparing for many years. The theme of the international year is the Importance of Sound for Society and the World and is underscored by the UNESCO Charter of Sound and resolution 39C/49 on the ‘’Importance of sound in today’s world – Promoting best practices’’. Other partners for the international year include “La Semaine du Son” (LSdS), the International Science Council and ISC members the International Union of Pure and Applied Physics (IUPAP) and the International Union of Theoretical and Applied Mechanics (IUTAM). The main goal of any international year is to to promote international collaboration and to raise awareness on how science contributes to innovation for the benefit for all society. However, for the International Year of Sound, soon after the opening in Paris at the Grand Amphitheatre of the Sorbonne on 31 January 2020, it became clear that the impact of the COVID-19 pandemic would curtail the outreach events that had been planned throughout the year and around the globe. As expected, very few of the activities planned for 2020 were held with physical presence of the participants. Some, including major international conferences, were held online with considerable success, with the international year encouraged by new online technologies. The activities, organized by member societies and affiliates of the ISC, included scientific conferences and workshops, exhibitions, presentations explaining the importance of sound to a general public in collaboration with museums, universities, schools, research centers and cultural organizations, as well as postings in social media, podcasts and concerts. Many events, competitions and conferences have been rescheduled, and ISC members and their communities can find out more by visiting www.sound2020.org.

April 29th 2021

Acoustic Training in Canada Database: Help us to help the younger generation and seasoned professionals

CAA is building a comprehensive list of all training programs offered in acoustics in Canada and we need your help! Below is a survey to help us populate that database that will eventually be available on CAA website. Please return all valuable input at your earliest convenience to Mr. DeGagne (wdegagne@caa-aca.ca)!

Dear CAA members, past members and friends, The purpose of this survey is to develop an online database of all the professional, undergraduate, and graduate acoustical courses and training programs offered through universities, colleges, associations, etc. This database would benefit the entire Canadian acoustic community in the following manner: 1. Track the different acoustical courses and training programs offered nationally 2. Allow CAA members to plan their acoustical training and easily select their perfect training program to meet their career aspirations 3. Allow CAA members to compare and contrast courses and training programs from different institutions 4. Allow institutions and the CAA to determine where the training gaps are and to plan for future programs demands To help us populate this database, simply return the following information at your earliest convenience to Mr. William

DeGagne (wdegagne@caa-aca.ca), volunteer for CAA: 1. Place of the Course or Training program (university, colleges, etc.): 2. Name of Course or Training program: 3. Approx. date the Course or Training was followed: 4. Level (graduate, undergraduate, college course or professional training program, etc.): 5. Brief description of the Course or Training program: 6. Webpage of Course or Training program: 7. Location of Course or Training program (City, Province): 8. Course or Training program language: Thanks for you help towards the younger generation and seasoned professionals! :-)

May 31st 2021

À la recherche d'un emploi en acoustique ?

De nombreuses offre d'emploi sont affichées sur le site de l'Association canadienne d'acoustique !

Vous pouvez les consulter en ligne à l'adresse http://www.caa-aca.ca/jobs/

August 5th 2015

Situation COVID-19

En raison de la situation COVID-19, la Semaine canadienne de l'acoustique (AWC) initialement prévue en octobre 2020 à Sherbrooke (QC) sera reportée à octobre 2021. Néanmoins, et comme "échauffement", le comité organisateur de Sherbrooke étudie actuellement la possibilité de mettre en place une petite célébration d'une journée en ligne pour octobre 2020. Vous pouvez trouver plus d'informations sur le site des conférences AWC20 et AWC21. Veuillez noter que St-John's (NL) sera l'hôte de la conférence AWC2022.

May 13th 2020

Extension : Année internationale du son (2020 - 2021)

Mettre en évidence l'importance du son et des sciences et technologies connexes pour tous dans la société

L'Année internationale du son est un projet que la Commission internationale d'acoustique (ICA), membre affilié de la ISC, prépare depuis de nombreuses années. Le thème de l'année internationale est l'importance du son pour la société et le monde et est souligné par la Charte du son de l'UNESCO et la résolution 39C/49 sur l'"importance du son dans le monde d'aujourd'hui - promouvoir les meilleures pratiques". Parmi les autres partenaires de l'année internationale figurent la Semaine du Son (LSdS), le Conseil international de la science et les membres de l'ISC, l'Union internationale de physique pure et appliquée (UIPPA) et l'Union internationale de mécanique théorique et appliquée (IUTAM). L'objectif principal de toute année internationale est de promouvoir la collaboration internationale et de faire prendre conscience de la manière dont la science contribue à l'innovation au profit de toute la société. Cependant, pour l'Année internationale du son, peu après l'ouverture à Paris au Grand Amphithéâtre de la Sorbonne le 31 janvier 2020, il est apparu clairement que l'impact de la pandémie de COVID-19 réduirait les événements de sensibilisation qui avaient été prévus tout au long de l'année et dans le monde entier. Comme prévu, très peu des activités prévues pour 2020 se sont déroulées avec la présence physique des participants. Certaines, notamment les grandes conférences internationales, se sont tenues en ligne avec un succès considérable, l'année internationale étant encouragée par les nouvelles technologies en ligne. Les activités, organisées par les sociétés membres et les affiliés de l'ISC, comprenaient des conférences et des ateliers scientifiques, des expositions, des présentations expliquant l'importance du son au grand public en collaboration avec des musées, des universités, des écoles, des centres de recherche et des organisations culturelles, ainsi que des publications sur les médias sociaux, des podcasts et des concerts. De nombreux événements, concours et conférences ont été reprogrammés, et les membres de l'ISC et leurs communautés peuvent en savoir plus en consultant le site www.sound2020.org.

April 29th 2021

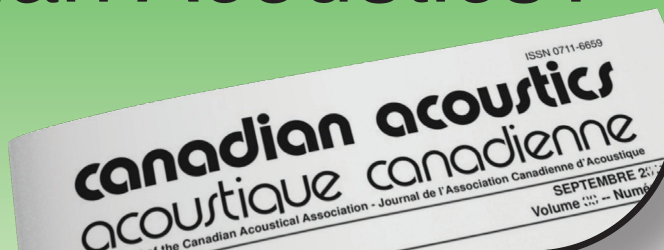
Répertoire des formations en acoustique au Canada : aidez-nous à aider la jeune génération et nos professionels d'expérience

L'ACA est en train de dresser une liste complète de tous les programmes de formation offerts en acoustique au Canada et nous avons besoin de votre aide ! Vous trouverez ci-dessous un sondage qui nous aidera à alimenter cette base de données qui sera éventuellement disponible sur le site Web de la CAA. Veuillez retourner vos précieux commentaires à M. DeGagne (wdegagne@caa-aca.ca) dans les plus brefs délais !

Chers membres, anciens membres et amis de l'ACA, Le but de cette enquête est de développer une base de données en ligne de tous les cours et programmes de formation en acoustique professionnels, de premier et de deuxième cycle, offerts par les universités, les collèges, les associations, etc. Cette base de données profiterait à l'ensemble de la communauté acoustique canadienne de la manière suivante : 1. Suivre les différents cours et programmes de formation en acoustique offerts à l'échelle nationale. 2. Permettre aux membres de l'ACA de planifier leur formation en acoustique et de choisir facilement le programme de formation idéal pour répondre à leurs aspirations professionnelles. 3. Permettre aux membres de l'ACA de comparer et d'opposer les cours et les programmes de formation de différentes institutions. 4. Permettre aux institutions et à l'ACA de déterminer où se trouvent les lacunes en matière de formation et de planifier les demandes de programmes futurs. Pour nous aider à alimenter cette base de données, il vous suffit de retourner les informations suivantes dans les meilleurs délais à M. William DeGagne (wdegagne@caa-aca.ca), bénévole pour l'ACA : 1. Lieu du cours ou du programme de formation (université, collèges, etc.) : 2. Nom du cours ou du programme de formation : 3. Date approximative à laquelle le cours ou la formation a été suivi. 4 : 4. Niveau (études supérieures, premier cycle, cours collégial ou programme de formation professionnelle, etc :) 5. Brève description du cours ou du programme de formation : 6. Page web du cours ou du programme de formation : 7. Lieu du cours ou du programme de formation (ville, province) : 8. Langue du cours ou du programme de formation : Merci pour votre aide à l'intention de la jeune génération et de nos professionels d'expérience ! :-)

May 31st 2021

Why publish in Canadian Acoustics?



Because, it is...

- A respected scientific journal with a 40-year history uniquely dedicated to acoustics in Canada
- A quarterly publication in both electronic and hard-copy format, reaching a large community of experts worldwide
- An Open Access journal, with content freely available to all, 12 months from time of publication
- A better solution for fast and professional review providing authors with an efficient, fair, and constructive peer review process.

Pourquoi publier dans Acoustique canadienne ?

Parce que, c'est...

- Une revue respectée, forte de 40 années de publications uniquement dédiée à l'acoustique au Canada
- Une publication trimestrielle en format papier et électronique, rejoignant une large communauté d'experts à travers le monde
- Une publication "accès libre" dont le contenu est disponible à tous, 12 mois après publication
- Une alternative intéressante pour une évaluation par les pairs, fournissant aux auteurs des commentaires pertinents, objectifs et constructifs

Application for Membership

CAA membership is open to all individuals who have an interest in acoustics. Annual dues total $120.00 for individual members and $50.00 for student members. This includes a subscription to ***Canadian Acoustics***, the journal of the Association, which is published 4 times/year, and voting privileges at the Annual General Meeting.

Subscriptions to *Canadian Acoustics* *or* Sustaining Subscriptions

Subscriptions to ***Canadian Acoustics*** are available to companies and institutions at a cost of $120.00 per year. Many organizations choose to become benefactors of the CAA by contributing as Sustaining Subscribers, paying $475.00 per year (no voting privileges at AGM). The list of Sustaining Subscribers is published in each issue of ***Canadian Acoustics*** and on the CAA website.

Please note that online payments will be accepted at http://jcaa.caa-aca.ca

Address for subscription / membership correspondence:

Name / Organization ____

Address ____

City/Province ____________________ Postal Code __________ Country ____________________

Phone ____________________ Fax ____________________ E-mail ____________________

Address for mailing Canadian Acoustics, if different from above:

Name / Organization ____

Address ____

City/Province ____________________ Postal Code __________ Country ____________________

Areas of Interest: (Please mark 3 maximum)

1. Architectural Acoustics
2. Engineering Acoustics / Noise Control
3. Physical Acoustics / Ultrasound
4. Musical Acoustics / Electro-acoustics
5. Psychological / Physiological Acoustic
6. Shock and Vibration
7. Hearing Sciences
8. Speech Sciences
9. Underwater Acoustics
10. Signal Processing / Numerical Methods
11. Other

For student membership, please also provide:

__________ __________ ____________________

(University) *(Faculty Member)* *(Signature of Faculty Member)* *(Date)*

I have enclosed the indicated payment for:
[ ] CAA Membership $ 120.00
[ ] CAA Student Membership $ 50.00

Corporate Subscriptions (4 issues/yr)
[ ] $120 including mailing in Canada
[ ] $128 including mailing to USA,
[ ] $135 including International mailing

[ ] Sustaining Subscription $475.00
(4 issues/yr)

Please note that the preferred method of payment is by credit card, online at http://jcaa.caa-aca.ca

For individuals or organizations wishing to pay by check, please register online at *http://jcaa.caa-aca.ca* and then mail your check to:

Executive Secretary, Canadian Acoustical:
Dr. Roberto Racca
c/o JASCO Applied Sciences
2305–4464 Markham Street
Victoria, BC V8Z 7X8 Canada

Formulaire d'adhésion

L'adhésion à l'ACA est ouverte à tous ceux qui s'intéressent à l'acoustique. La cotisation annuelle est de 120.00$ pour les membres individuels, et de 50.00$ pour les étudiants. Tous les membres reçoivent ***l'Acoustique Canadienne***, la revue de l'association.

Abonnement pour la revue *Acoustique Canadienne* et abonnement de soutien

Les abonnements pour la revue ***Acoustique Canadienne*** sont disponibles pour les compagnies et autres établissements au coût annuel de 120.00$. Des compagnies et établissements préfèrent souvent la cotisation de membre bienfaiteur, de 475.00$ par année, pour assister financièrement l'ACA. La liste des membres bienfaiteurs est publiée dans chaque issue de la revue ***Acoustique Canadienne***..

Notez que tous les paiements électroniques sont acceptés en ligne http://jcaa.caa-aca.ca

Pour correspondance administrative et financière:

Nom / Organisation ___________________________________

Adresse ___________________________________

Ville/Province ________________ Code postal__________ Pays ________________

Téléphone ____________ Téléc. ____________ Courriel ____________________

Adresse postale pour la revue Acoustique Canadienne

Nom / Organisation ___________________________________

Adresse ___________________________________

Ville/Province ________________ Code postal__________ Pays ________________

Cocher vos champs d'intérêt: (maximum 3)

1. Acoustique architecturale
2. Génie acoustique / Contrôle du bruit
3. Acoustique physique / Ultrasons
4. Acoustique musicale / Électro-acoustique
5. Physio / Psycho-acoustique
6. Chocs et vibrations
7. Audition
8. Parole
9. Acoustique sous-marine
10. Traitement des signaux /Méthodes numériques
11. Autre

Prière de remplir pour les étudiants et étudiantes:

__________ __________________ ______________________ __________

(Université) (Nom d'un membre du corps professoral) (Signature du membre du corps professoral) (Date)

Cocher la case appropriée:
[ ] Membre individuel 120.00 $
[ ] Membre étudiant(e) 50.00 $

Abonnement institutionnel
[ ] 120 $ à l'intérieur du Canada
[ ] 128 $ vers les États-Unis
[ ] 135 $ tout autre envoi international

[ ] Abonnement de soutien 475.00 $ (comprend l'abonnement à *L'acoustique Canadienne*)

Merci de noter que le moyen de paiement privilégie est le paiement par carte crédit en ligne à *http://jcaa.caa-aca.ca*

Pour les individus ou les organisations qui préféreraient payer par chèque, l'inscription se fait en ligne à *http://jcaa.caa-aca.ca* puis le chèque peut être envoyé à :

Secrétaire exécutif, Association canadienne d'acoustique :
Dr. Roberto Racca
c/o JASCO Applied Sciences
2305–4464 Markham Street
Victoria, BC V8Z 7X8 Canada

Canadian Acoustical Association
Association canadienne d'acoustique

Board of Directors - Conseil d'administration

SUSTAINING SUBSCRIBERS - ABONNÉS DE SOUTIEN

The Canadian Acoustical Association gratefully acknowledges the financial assistance of the Sustaining Subscribers listed below. Their annual donations (of $475 or more) enable the journal to be distributed to all at a reasonable cost.
L'Association Canadienne d'Acoustique tient à témoigner sa reconnaissance à l'égard de ses Abonnés de Soutien en publiant ci-dessous leur nom et leur adresse. En amortissants les coûts de publication et de distribution, les dons annuels (de 475$ et plus) rendent le journal accessible à tous les membres.

Acoustec Inc.
Jean-Philippe Migneron - 418-496-6600
info@acoustec.qc.ca
acoustec.qc.ca

Acoustex Specialty Products
Mr. Brian Obratoski - 2893895564
Brian@acoustex.ca
www.acoustex.net

AcoustiGuard-Wilrep Ltd.
Mr. William T. Wilkinson - 888-625-8944
wtw@wilrep.com
acoustiguard.com

AECOM
Alan Oldfield - 9057127058
alan.oldfield@aecom.com
aecom.com

Aercoustics Engineering Ltd.
Nicholas Sylvestre-Williams - (416) 249-3361
NicholasS@aercoustics.com
aercoustics.com

Audio Precision (c/o GerrAudio Distribution in Canada)
Peter Snelgrove -
peter@gerr.com
www.gerr.com

Dalimar Instruments Inc
Monsieur Daniel Larose - 450-424-0033
daniel@dalimar.ca
www.dalimar.ca

dB Noise Reduction
Mehrzad Salkhordeh - 519-651-3330 x 220
mehrzad@dbnoisereduction.com
dbnoisereduction.com

FFA Consultants in Acoustics and Noise Control
Clifford Faszer - 403.508.4996
info@ffaacoustics.com
ffaacoustics.com

GRAS Sound & Vibration (c/o GerrAudio Distribution in Canada)
Peter Snelgrove -
peter@gerr.com
www.gerr.com

HGC Engineering Ltd.
Bill Gastmeier -
bill@gastmeier.ca
hgcengineering.com

Hottinger Bruel & Kjaer inc.
Andrew Khoury - 514-695-8225
andrew.khoury@hbkworld.com
bksv.com

Integral DX Engineering Ltd.
Gregory Clunis - 613-761-1565
greg@integraldxengineering.ca
integraldxengineering.ca

JAD Contracting Ltd
Jake Ezerzer - 1-855-523-2668 toll free
info@jadcontracting.ca
jadcontracting.ca

Jade Acoustics Inc.
Ms. Dalila Giusti - 905-660-2444
dalila@jadeacoustics.com
jadeacoustics.com

JASCO Applied Sciences (Canada) Ltd.
Roberto Racca - +1.250.483.3300 ext.2001
roberto.racca@jasco.com
www.jasco.com

Pliteq Inc.
Wil Byrick - 416-449-0049
wbyrick@pliteq.com
pliteq.com

Pyrok Inc.
Howard Podolsky - 914-777-7770
mrpyrok@aol.com
pyrok.com

RWDI
Mr. Peter VanDelden - 519-823-1311
peter.vandelden@rwdi.com
rwdi.com

Scantek Inc.
President, Scantek, Inc. - 1-410-290-7726
steve.scantek@gmail.com
scantekinc.com

Soft dB Inc.
Dr. Roderick Mackenzie - 5148056734
r.mackenzie@softdb.com
softdb.com

Xprt Integration
Mr. Rob W Sunderland - 604-985-9778
rob@xprt.ca