ANALYSIS AND SYNTHESIS OF THE GUQIN -A CHINESE TRADITIONAL INSTRUMENT

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1. BACKGROUND

The GuQin, a seven-stringed zither, is China's oldest stringed instrument, with a history of some 3000 years. In Chinese, “Gu” means old and “Qin” means musical instrument. Historically, GuQin was referred to as " Qin " in most ancient Chinese writings. Owing to its long history, it has been widely called GuQin during the last 100 years. This summer in China, we conducted an interview with Fengyun Lee, a renowned master of the GuQin. She introduced the characteristic of GuQin and showed some of typical playing techniques to help us to understand the acoustics and techniques related to the GuQin.

Throughout the history, the GuQin has been viewed as a symbol of Chinese high culture. Qin music has been regarded as the essence of highly complicated aesthetics, philosophy, and musical temperament. It was the popular instrument of the Chinese literati, who played it for self-cultivation and personal enjoyment. In ancient China, a well-educated scholar was expected to be skilled in Four Treasures: Qin (the GuQin), Qi (Chinese chess), Shu (calligraphy) and Hua (painting).

In the long history of Chinese music, GuQin is most able to express the essence of Chinese music. More than 100 harmonics can be played on the GuQin, allowing the instrument to produce a large number of overtones. Undoubtedly, the GuQin is a part of world’s heritage, but today fewer than two thousand people can play it and only about 70 pieces have been transcribed into modern western music notation. In order to preserve world heritage, we propose using physical modeling techniques to simulate the acoustic GuQin. This paper will introduce these models and how they apply to the GuQin.

2. PHYSICAL MODELLING

Physical modeling of musical instrument is an exciting topic in digital sound synthesis, and it has been a very popular research domain since the 1980s. By using physical modeling techniques that simulate a real instrument, the sound of virtual instrument can be more realistic and controllable, because the sound created is based on real-world information and parameters. To model the process of plucking a GuQin string to create a synthesized “virtual GuQin”, the simplest algorithm to use is the Karplus-Strong algorithm.

A typical elementary GuQin tone consists of a short fast attack and long smooth decay. The Karplus-Strong algorithm can be used to model this plucked-string behaviour.

The original Karplus-Strong algorithm is based on wavetable synthesis. In wavetable synthesis, a buffer is filled with samples that are then read by a pointer that circulates from the beginning of the table to the end and then starts back at the beginning, thus creating a periodic sound. The initial conditions of the wavetable determine the resulting timbre and its length determines the periodicity of the sound, and hence the pitch. Kevin Karplus and Alex Strong [4], two researchers at Stanford University, used similar idea in the early 1980s. Karplus and Strong suggested using a delay line to represent the waves on the string. The waveguide is initially filled with random values or white noise to represent the pluck effect, and the wavetable is low-pass filtered to simulate the decay in the higher-frequency harmonics over time.

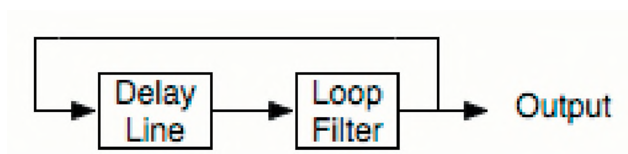

Figure 1. The Karplus-Strong Algorithm

Karplus and Strong have explored different variations and refinements of their algorithm. Jaffe and Smith [1] also proposed a number of ideas that improved the Karplus-Strong algorithm in its usefulness and accuracy. They not only solved some of the original Karplus-Strong algorithm problems, they also proposed a dynamic control system. Meanwhile, Sullivan suggested a number of methods based on Karplus-Strong. He suggests using two delay lines, one to represent waves travelling in one direction and another to represent the opposite direction. By this method an electric guitar’s pickup and its output were represented. Smith [5] extended the ideas of physical modelling and model-based synthesis further, resulting in the digital waveguide technique, an important principle for discrete-time modelling of acoustic system. Later, Karjalainen *et al* [3] presented a detailed derivation of reduced string models.

This has shown how the two-directional digital model can be reduced to a more efficient signal delay loop (SDL) model. They also mentioned the idea of dual polarization of the guitar string. The system is different from the Karplus-Strong algorithm in that the excitation is provided by an impulse instead of random noise.

3. SIMULATION OF THE ACOUSTIC GUQIN

From the description of playing techniques, we now move to analysis and synthesis of the GuQin. Basically, the GuQin is able to produce three types of sound: *san yin* (open notes); *fan yin* (harmonics), and *an yin* (stopped notes). Some of the most important and typical analysis and simulation are present in below.

It should be noted that since GuQin music is usually used to express the player's feeling and personality, sometimes a harder attack might be required than is available in current physical modelling techniques. This is also a special part of GuQin.

3.1 Tuning

Open notes simply require that the correct string is plucked. By using Karplus-Strong synthesis, the strong and clear sound for the important notes of GuQin can be produced. More tasteful sounds could possibly be produced by extended the original Karplus-Strong algorithm. Therefore, a further refinement is achieved by applying other types of filtering. When a GuQin string is plucked, the high pitch decays faster than the low pitch. The low frequencies will last longer in sometimes non-harmonic ways. To entirely control the decay-time, we should know how to shorten or stretch the decay. These are solved by introducing a loss factor and a strength factor for modifying note duration. When playing GuQin using the fleshy part of the finger, the loss factor is set close to 1 to simulate a string being damped by soft materials.

3.2 Simulation of pluck location

When playing GuQin, pluck location is an essential element to decide tone. An effective solution of simulating pick position is to introduce comb filter. This can fairly accurately mimic the effect of plucking a string at varying distances from the bridge of GuQin.

3.3 Simulation of Sliding Effect

One of the characteristics of GuQin music is the number of glides. Indeed some authorities prefer to call stopped notes. It is also called sliding sounds. To play stopped notes, a left hand finger presses the string firmly while the right plucks, then may slide to other notes or create many different vibratos or ornaments, to achieve delicate and expressive sounds. By changing the delay buffer length over time, a rapid alternation of ascending and descending pitch changes is possible, offering a sliding sound.

3.4 Simulation of Style of Attacks

Attack pattern is an important element in perception of timbre, and using a different degree of finger pressure or pluck strength will create a different timbre as well. The inwards and outwards movements of different fingers on the string can change the attack character. A realistic simulation of attack style has been created by using a one-pole, lowpass filter.

3.5 Sympathetic String Simulation

A sympathetic vibration will be produced by a string close to the string that is plucked, which has a resonant frequency close to the frequency of the note played on the plucked string. Here we can define that as in the basic algorithm the input of random value is indicated as the plucked string, and algorithm is excited by plucked string is indicated as the sympathetic string. In the original Karplus-Strong, each string and resonance has the same pitch. To present sympathetic string effect, it needs a copy of string by a small percentage of the output from the plucked string to create a different pitch.

The sympathetic string can be seen to act as a bandpass filter. Frequencies close to the resonances of the partials of the plucked string will be reinforced, and all other partials will die away. To prevent an overflow problem with harmonic reinforcement, a loss factor will be involved in this modification.

References

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