Modeling and Design of String Musical Synthesizer

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ABSTRACT
Physical modeling is a technique of creating audio using the numerical computation. It generates sound that is different to actual physical response of the system. The physical modeling approach can be applied, in principle, to any musical instrument; the most success has been obtained in modeling the physical processes involved in stringed instruments and in woodwinds. The different synthesizer technology used analog synthesis, frequency modulation, additive synthesis, sampling and physical modeling. Different techniques are chosen based on the criteria as per the application. This paper aims to generate physical modeling of string musical instruments piano using finite difference method. The approach used in the proposed paper will be by using DSP processor

Keywords
Physical Modeling synthesis, Waveguide Synthesis Model, Finite Difference Method,

1. INTRODUCTION
Sound synthesis is a method to create and transform sound using mathematical techniques. The reason for the relative success of physical modeling in synthesizing strings and woodwinds is that the sound generation process in these instruments can be described as an excitation of a transmission line or waveguide. In a waveguide or transmission line model, the vibrating portions of an acoustic instrument are broken up into short segments. In each of these segments the incoming wave is partially transmitted to the next segment, and partially reflected back to the previous segment. A portion of the input is also lost (neither reflected nor transmitted) as heat. In more complex models, a portion of the input can also be stored, typically in the elastic material making up the instrument. These complex models can be very nonlinear and difficult to control. They are also very challenging to implement computationally in a stable manner. The mathematical equations describing such structures are rather simple (wave equations) and straightforward to implement computationally. Each technique is based on a certain model capable of representing and generating a class of sounds. We can distinguish two types of models: On the one hand, there are models that describe the sound phenomenon or commonly referred as the sound signal. On the other hand, models are in use that describes the production mechanism of sound, which is usually a physical process and therefore these models are generally referred to as physical models. For the composer the main difference between the two types lies in the way the models are parameterized.

2. PHYSICAL MODELING TECHNIQUES
The physical modeling techniques can be divided into four group waveguide synthesis, finite element methods, modal synthesis methods, and banded waveguides. Physical Modeling Can be done using one of the above methods or combination of two or more methods. This proposed work will be implemented using Finite Difference Method. While sometimes the instruments modeled are electronic gizmos like analog synthesizers, the challenge is to model the tonal characteristics produced by acoustic instruments, including all of their performance gestures. Although physical modeling was not a new concept in acoustics and synthesis, having been implemented using finite difference approximations of the wave equation, it was not until the development of the Karplus-Strong algorithm, the subsequent refinement and generalization of the algorithm into the extremely efficient digital waveguide synthesis.

2.1 Waveguide Synthesis Method
The Waveguide Synthesis Method is the basic method and still serves as the foundation for most of the physical modeling. Digital waveguide synthesis models are *computational physical models* for certain classes of musical instruments (string, winds, brasses, etc.) which are made up of *delay lines, digital filters*, and often *nonlinear elements*. A lossless digital waveguide is a *bidirectional delay line* at some wave impedance. Waveguide synthesis methods frequently are based on a traveling wave, usually modeled by using delay lines .Some examples of waveguide synthesis techniques include Karplus-Strong Synthesis, McIntyre, Schumacher, and Woodhouse Synthesis, and Digital Waveguide Synthesis.

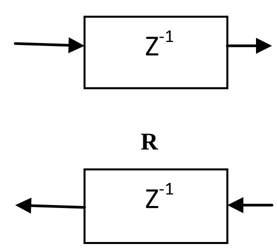

Fig 1: Sampled travelling wave simulation for an ideal string or acoustic tube

2.2 Finite Element Method
One of the early approaches to digital simulation of physical systems was the finite- difference method. Finite difference models have been used i n a couple of different settings with regards to physical modeling. Finite difference models are done by replacing derivatives in physical systems with finite differences. There are a couple ways this has been accomplished.

$$y(t,x) \approx [y(t,x)-y(t-T,x)]/T \approx [y(t+T,x)-y(t-T,x)]/2T.$$

In this equation, represents time in seconds, is the position along the string, and T is the sampling period. A variation is called centered finite difference. It requires an extra factor of two over sampling in its magnitude response for a given accuracy; however it holds the advantage of not introducing a time delay.

3. ARCHITECTURE

The proposed architecture of the system is as follows.

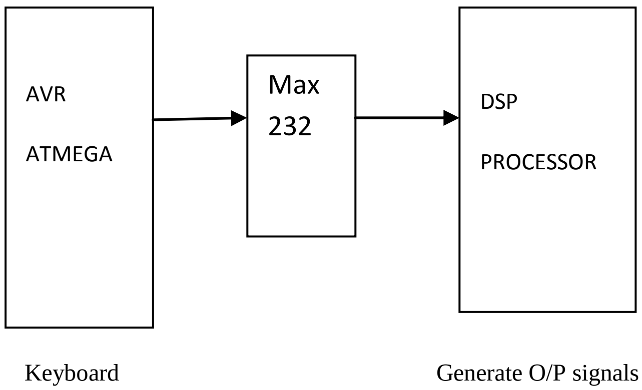

Fig 2: Architecture of the proposed System

The keyboard will be generated using AVR Atmega 32.Different sound signals will be generated due to the variable delay. Due to this facility even users can have the choice of variable sound just by varying the delay. The sound signals will be passed on by the Max 232. The MAX232 is a dual driver /receiver that include a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5 V, and can accept ±30-V inputs. These signals will then be processed on to the DSP Processor using Finite Difference Method.

3.1 DSP Processor

The transition from analog to digital video storage and transmission has created a large demand for products conforming to open standards. Audio and video compression standards such as MPEG, broadcast transmission standards such as DVB, and demodulation standards such as QAM, QPSK, and VSB, demand high-performance DSP technology. Texas Instruments developed the TMS320AVxxx product family for this exciting new market.

3.2 Max 232

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5 V, and can accept ±30-Vinputs. Each driver converts TTL/CMOS input levels into EIA-232 levels. The MAX232 has a successor, the MAX232A. The ICs are almost identical, however, the MAX232A is much more often used (and easier to get) than the original MAX232, and the MAX232A only needs external capacitors 1/10th the capacity of what the original MAX232 needs. It should be noted that the MAX232(A) is just a driver/receiver. It does not generate the necessary RS-232 sequence of marks and spaces with the right timing, it does not decode the RS-232 signal, it does not provide a serial/parallel conversion. All it does is to convert signal voltage levels. Generating serial data with the right timing and decoding serial data has to be done by additional circuitry, e.g. by a 16550 UART or one of these small micro controllers (e.g. Atmel AVR, Microchip PIC) getting more and more popular.

4. IMPLEMENTATION

Physical modeling which deals with a special type of method for simulating musical systems—finite difference methods. These are not the same as digital waveguides, and are not like modal synthesis methods either. Instead, the total behavior of a musical object, such as a string, bar, plate. Some components of musical instruments are conveniently described in “1D,” meaning that one dimension of the object is significantly longer than the others. Among the best known are strings, used in keyboard Instruments such as the piano, and in members of the string instrument family, and in guitars, and bars, used typically in percussion instruments such as xylophones, marimbas, chimes, etc. The most basic difference between a string-like object and a bar is in how it responds to a “push,” or deformation. A string possesses no restoring force of its own; it must be under tension in order to resist such a force, and thus vibrate.

4.1 An Ideal String

An ideal string is one of infinitesimal thickness, no loss, and vibrating at low amplitudes; furthermore, every point on the string is assumed to move up and down only; there is no longitudinal motion.

4.2.1 Pitch

In fact, though, it is only a combination of these parameters which has perceptual significance. For instance, if the string is fixed at both ends, the number f0.

4.2 Adding Losses

Loss is crucial, in that it leads to decay in string tones. There are many sources of such loss; all are related to various mechanisms, such as sound radiation, and internal damping.

4.3 Adding Stiffness

Real strings are stiff; they are not like rubber or shoe laces, which require tension to be applied in order to support vibration. Addition of stiffness allows a whole range of objects to be simulated

5. CONCLUSION

This paper presents proposed work for the design and implementation of string musical synthesizer using finite difference method. This implementation will be done by using finite model method. Finite difference models have been used in a couple of different settings with regards to physical modeling. Finite difference models are done by replacing derivatives in physical systems with finite differences. Thus, this Approach is a hardware implementation of finite difference method using DSP Processor.

6. REFERENCES

[1] M. Karjalainen, V. V¨alim¨aki, and T. Tolonen, "Plucked String Models: from Karplus-Strong Algorithm to Digital Waveguides and Beyond," Computer Music J., vol. 22, no. 3, pp. 17-32, 1998.

[2] A. Fettweis, "Wave Digital Filters: Theory and Practice," Proc. of the IEEE, vol. 74, no. 2, pp. 270-327, 1986.

[3] J. Bensa, S. Bilbao, R. Kronland-Martinet, and J. O. Smith III, "The simulation of piano string vibration: From physical models to finite difference schemes and digital waveguides," J. Acoust. Soc. Am., vol. 114, no. 2, pp. 1095–1107, 2003.

[4] K. Karplus and A. Strong, "Digital synthesis of lucked string and drum timbres," Computer Music Journal, vol.7, no. 2, pp. 43–55, Jun. 1983.

[5] J. O. Smith, "Physical modeling using digital waveguides,"Computer Music Journal, vol. 16, no. 4, pp. 74–91, 1992.