The Kinetic Xylophone: An Interactive Musical Instrument Embedding Motorized Mallets

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***Abstract*— The *Kinetic Xylophone* is an interactive instrument, which plays music with motorized mallets by gestures from spectators. This instrument consists of fourteen metallic tubes, and reacts through embedded infra-red sensors with spectators. Those distance signals trigger the rotation of mallet attached to motors. Spectators can easily perform music with this installation by hand-waving gestures instead of grabbing mallets. Thus, this kinetic art work can also be performed by children, and persons with disabilities.**

I. INTRODUCTION

The *Kinetic Xylophone* was developed as an interactive installation which can be performed by spectators(Fig. 1). While a xylophone is played by the hands of a musician, the *Kinetic Xylophone* is designed as a touch-free instrument that performers can play by hand-waving gestures. When the performer's hand approaches the tube, the embedded infra-red sensor indicates its distance. Those measured signals transfer to the analog-digital converter, which translates the distance into the torque of the motor. The proportional algorithm triggers the rotational velocity of the motor. At that moment, the attached mallet strikes a tube, ringing a clear tone. This interactive xylophone consists of fourteen metallic tubes which are reconstructed and arrayed on the curved plate. For the ease of use, it was adjusted to scale of the structure so that children and persons with disabilities can efficiently perform this instrument in the range of two octaves. While robot musicians perform music by pre-sequenced programs, the *Kinetic Xylophone* can offer a natural usability through the random accessible characteristics in the form of digital kinetic art.

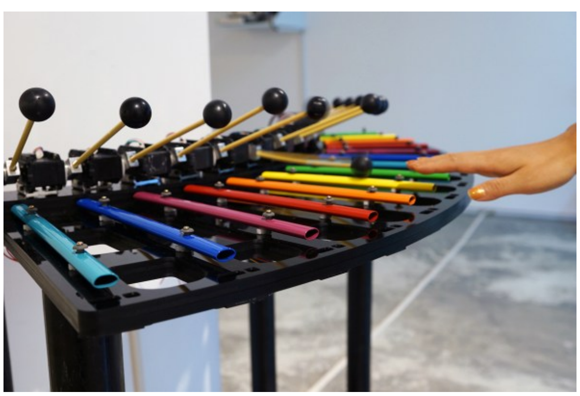

Figure 1. The Kinetic Xylophone, 2012 © Chang Geun Oh

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II. BACKGROUNDS AND CONCEPTS

A. Backgrounds and History of Kinetic Instruments

The xylophone is a musical instrument originated in the Malayo-Polynesian, as known as Javanese and Balinese, circa 500 AD. It belongs to the percussion family that consists of wooden bars struck by special hammers i.e. mallets. While the xylophone's bars are made of wood, the glockenspiel, which is similar to xylophone, those bars are made of metal plates or tubes, However, there is a variety of instruments and resembling forms derived from the old xylophone[1]. From the 17th century, mechanical instruments were developed, for instance, the flute-playing clock and the water organs under the term "Automatophonic"[2]. Beyond the invention of the jukebox in 1887, the first touch-free electronic instrument was invented by Leon Theremin in 1920. His musical instrument *Theremin* could be performed without the contact of a player by just waving hands between two antennas adjusting the oscillation[3]. During the development of electronic music, enthusiastic musicians tried to synthesize new sounds in the mid 20th century. A few kinetic artists e.g. Jean Tinguely and Nam June Paik also developed sound installations through mechanical movements[4]. Subsequently, robotic art was founded and developed under the influence of kinetic and cybernetic art in the 1960s[5]. Thus, the so called "robot musicians," as well as the term of "robotic instruments"[7] were derived from the context of that period.

B. Concepts of the Kinetic Xylophone

After the development of the *Automatic Banjo* in 1907, which contains an automatic xylophone, accordion, harp, and violin[2], there appeared many examples of automatic instruments from music boxes to robot musicians. Among them, percussion robots are generally activated by a motor or solenoid system that strikes the membrane with a stick[6]. Those musician robots are developed to interact with humans performing improvisations by their installed programs[7]. Conventionally, a xylophone and marimba must be played with a pair of mallets. Despite the simple technique with mallets, the training in music requires a long term exercise of executions. Thus, the *Kinetic Xylophone* was developed as a sound installation, which reacts to the performer without traditional executions, but with the intuitive accessibility, automatic generation of interval tones, and velocity controls. If we can perform a xylophone without the skill of mallets, far more people can play it with the use of gestures, and then even non-musicians may enjoy playing the xylophone. When spectators are interacting with a kinetic instrument, the perception of performing converts spectators to performers[8]. The *Kinetic Xylophone* can be played by children, also by persons who have a hand injury or learning disability without physical contact. A. Parkes et al.[2008] argued that we need to explore the language of motion in order to design kinetic user interfaces in an aspect of organic medium with reactive movements[9].

III. DESIGN AND TECHNOLOGIES

A. Design

The *Kinetic Xylophone* was reconstructed with metal tubes from a product originally made by AKAI for use of children. Children can immediately indicate the music scale of the tubes thanks to the colored surfaces. In consideration of the universal design method, the installation was scaled down to adjust to the size of children, while still being accessible by common spectators. Instead of squared plate under the tubes, it was reformed in the shape of curved plate playing duet by two performers at the same time. Each tube has a Fujitsu's infra-red sensor on the end closest to the performer. When the performer stretches his/her hands to the tube, the sensor measures the distance and movements in real-time(Fig. 2).

Figure 2. A child performs the *Kinetic Xylophone* with both hands.

B. Technologies

Most musical instruments allowed the velocity control to play music dynamically. In the *Kinetic Xylophone*, the sense of dynamics was expressed in rotational speeds of the motor. The velocity control results from the calculation of the value with connecting signals from a sensor into desired angles of the motor. In developing the *Kinetic Xylophone*, fourteen RX-28 servo motors made by Robotis[10] were implemented as actuators rotating mallets to strike the tubes with seven different velocities. The computational function is stored and operated in the Atmel's ATmega8 that communicates through the MAX485 transceiver simultaneously. The circuit is combined with a motor. If a hand or finger approaches a sensor within approximately ten centimeters, the motor begins its rotation to hit a tube. The mallet hits the tube with maximum velocity, when hands approach the closest position on the sensor(Fig. 3). Due to separated construction of each module i.e. a combination of sensor, circuit board, motor, and mallet, performers can play the *Kinetic Xylophone* in the range of two octaves polyphonically.

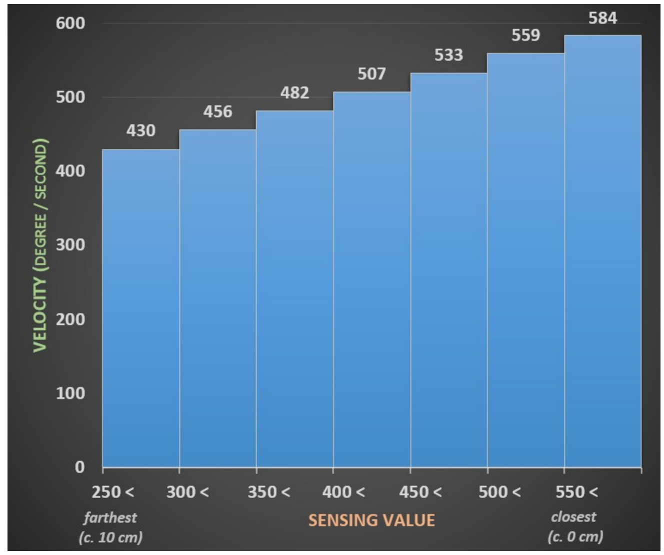

Figure 3. The graph shows a change in velocities as results of sensing values. If an infra-red sensor indicates hand approaches, then the combined mallet begins to rotate from the initial position to the tube, in the velocity range from 430 to 584 degrees per second. The higher value of a sensor triggers faster rotation of a motor. These seven different velocities can be adjusted by performer's hand-waving gestures.

IV. CONCLUSION

Beyond the acceptance of digital technologies in forms of art, digital art was introduced with the characteristics of random access and interactivity[11]. The *Kinetic Xylophone* presents those characteristics through the touch-free interaction with spectators as a form of digital kinetic art. We need to explore more the possibility of kinetic interfaces in the relationship between human and machine. Those possibilities might be increased in the field of robotic art, educational robots, kinetic designs, and even further in the field of human-computer interaction.

REFERENCES

[1] http://en.wikipedia.org/wiki/Xylophone
[2] C. B. Fowler, "The Museum of Music: A History of Mechanical Instruments," *Music Educators Journal*, Vol. 54, No. 2, Oct. 1967, pp.45-49.
[3] N. Nesturkh, "The Theremin and Its Inventor in Twentieth-Century Russia", *Leonardo Music Journal*, Vol. 6, 1996, pp. 57-60.
[4] A. Licht, *Sound Art: Beyond Music, Between Categories,* New York: Rizzoli International Publications, inc., 2007
[5] E. Kac, "Foundation and Development of Robotic Art," *Art Journal*, College Art Association, vol. 57, no. 3, autumn 1997, pp.60-67.
[6] A. Kapur, "A History of Robotic Musical Instruments," *Proceedings of the International Computer Music Conference,* 2005, pp. 21-28.
[7] R. Nikolaidis, G. Weinberg, "Playing with the Master: A Model for Improvisatory Musical Interaction between Robots and Humans," *IEEE International Symposium on Robot and Human Interactive Communication*, Viareggio, Italy, Sept. 2010
[8] P. Dalsgaard, L. K. Hansen, "Performing perception -Staging Aesthetics of Interaction, " *ACM Transactions on Computer-Human Interaction*, Vol. 15, No. 3, Nov. 2008
[9] A. Parkes, I. Poupyrev, H. Ishii, "Designing Kinetic Interactions for Organic User Interfaces," *Communications of the ACM,* vol. 51, No. 6, June 2008, pp. 58-65.
[10] http://www.robotis.com/xe/
[11] C. Paul, *Digital Art*, London, New York: Thames & Hudson, 2003.