Prolegomena to sonic toys

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***Abstract*—A variety of electronic sonic toys is available in the market. However, such toys are usually played by pushing buttons which trigger different sampled sounds. In this paper we advocate the possibility of using continuous natural gestures connected with synthesized sounds for the creation of enactive sonic toys.**

***Keywords*— sonic toys, Human-Computer Interaction, Multimodal Interaction**

I. Introduction

The toy industry proposes a variety of sonic toys, from simplified reproductions of musical instruments to musical blocks or elaborated robotic kits.

Most electronic toys present poor interactivity and annoying sonic feedback. In the different toys available in the market, infact, it is merely possible to push different buttons while triggering different sampled sounds. Such sounds are usually unnatural and annoying.

In this paper we advocate the use of continuous interactions in the design on sonic toys in an enactive perspective. We believe that electronic toys can be improved by designing objects with which children can interact in the same way as they interact with everyday objects, where their actions are continuously coupled with the feedback they produce enahncing the learning process.

We focus our attention on electronic handeld toys, without analyzing the products which are for example developed in the computer game industry such as dancing and singing games [1].

We start by presenting an overview of sonic toys developed in academic projects and available in the market, which present continuous interaction between the player and the object. We then describe a possibile enactive approach to the desing of sonic toys and we present three sonic toys implemented by the authors using this perspective.

II. An overview

An example of sonic toys in which the resulting sounds vary according to the gestures of the user are the Beatbugs [13]. The Beatbugs are hand-held percussive instruments used to stimulate collaborations among children by creating different rhythmic patterns. Each Beatbug is designed as a bug-shaped controller, with a speaker on the mouth, two bend sensors as antennae and a piezo drum trigger in the back. Visual feedback when the bug is hit is provided by using white and colored LEDs. The piezo sensors measure how hard the bug is hit, while the bend sensors allow subtle control of different aspects of the sound. The behavior of the Beatbugs is controlled by using the Max/MSP software.[1] The Beatbugs are part of the Toy Symphony, a music performance and education project directed by Professor Tod Machover from the MIT Media Lab [7].

Part of the same project are the Squeezables, six squeezable balls whose goals is to provide a malleable responsive interface offering a novel tactile experience to the users [14]. Inside the balls, five force-sensitive resistors indicate the amount of squeezing. As before, the data provided by the sensors are digitised and used in Max.

Similar to the Squeezables is the Sonic Banana [12]. The Sonic Banana is a flexible rubber tube embedded with bend sensors. As in the previous toys, by squeezing the banana the sensors data are triggered and sent to the Max/MSP synthesizer.

Perry Cook has also designed a variety of sonic toys, to be used as controllers of his PHISEM (Physically Inspired Stochastic Event Modeling) algorithms [3]. This research consists on the development of algorithms to synthesize particle-type percussion sounds, and the control of such sounds with familiar everyday objects such as a maraca or different shakers. Another interesting example of a continuous interaction which is connected to synthesized sounds is the Pebblebox [5]. The Pebblebox is an interface in which users manipulate physical grains. It consists of a foam-padded container, which holds a number of non-brittle objects. The sound produced by such grains is detected by a microphone, and used to manipulate granular synthesis algorithms.

The projects described until now present all the following characteristics:

- Natural interaction
- Continuous interaction
- Expressive sonic feedback

We believe that the characteristics listed above are essential for the design of successful sonic toys. Moreover, from the implementation point of view all the instruments described above are designed as objects embedded with sensors, which control different sound synthesis algorithms.

The New Interfaces for Musical Expression community[2] has seen a proliferation of such objects embedded with sensors, which are presented at the annual conference.

In the following, we present two commercial projects which are interesting from the interaction point of view.

[1] http://www.cycling74.com
[2] www.nime.org

An example of a commercial electronic sonic toy with which players can interact with more natural gestures is the Bop-it by Hasbro.[3] The Bop-it is a game in which a single player responds to auditory commands by performing different mechanical actions. Such actions vary from twist, pull, roll and push.

Fig. 1. The Bopit by Hasbro.

Another novel commercial product are the Picocrickets[4]. The Picocrickets are tiny blocks embedded with sensors which can be used to create interactive installations and musical sculptures.

III. CLOSING THE LOOP

The Enactive Network of excellence[5] has studied and developed Enactive Interfaces, proposing a common fundational knowledge about enactivity in Human Computer Interaction. The enactive knowledge is stored in the form of motor responses and acquired by the act of 'doing' and is based on the active use of the body for learning tasks. An example of enactive knowledge is represented by the competence required by tasks such as typing, playing a musical instrument, sculpting objects, whistling and tying shoelaces. This type of knowledge transmission can be considered natural and intuitive, since it is based on the experience and on the perceptual responses to motor acts and it can be particularly important designing toys and interfaces for children. Playing is in fact one of the most important activity for all children's development: by playing they start to explore the world and to acquire and master new skills which can be vital for them, learning in a closed loop environment what are the consequences of their actions.

The target of our toys are children of the preschool years, that typically proceed form specific exploration of the object to more playful behaviour, as illustrated also in an experiment by Hutt [6]. This experiment is particular important because it shows how a novel object can elicit exploratory behaviour in young children and how this behaviour can change according to the particular sensorial stimulus that is given. In particular the object, which was a red metal box with a lever with a buzzer sounding and a bell ringing and counters to register movements, could be explored with no sound or vision, vision only, sound only or both sound and vision available. The results showed that the sessions with sound only and sound and vision, where the ones in which the children explored the object longer, manipulating it with interest. These sessions showed also that after a quite long exploration more playful or game-like behaviors increased, using the object pretending for instance it was something else.

The toys that we want to develop, are thought to elicit this behaviour: exploration is forced by tactile and auditory feedbacks that changes in real time according to the child's gestures and movements. Children learn then by doing how to use the toy-object, exploring what are the consequences of their gestures. They can discover rough and very sophisticated causality relations [8] interacting with the object in a perceptive closed loop. The inspiration for such objective comes from the Bruner theory of child's cognitive development [2], in which the first way of representing the world is the *enactive* mode of representation. The world is represented by the child through action. All the events are represented through appropriate motor responses (e.g., building with bricks, riding a bicycle, whistling etc.). The knowledge of the child at this stage is an 'enactive knowledge': information is gained through perception-action interaction in the environment. In many aspects the enactive knowledge is more natural than the other forms both in terms of the learning process and in the way it is applied in the world. Such knowledge is inherently multimodal because it requires the coordination of the various senses and it gives more attention on the motor action aspect of interaction.

We believe that the characteristics described above, especially continuous interaction and expressive sonic feedback lack in most sonic toys available in the market. In the following sections, we describe three projects which use sonic toys and maintain a familiar sensorimotor experience, while augmenting the original object by using sensors and sounds synthesised using physical models.

IV. THE SINGING TUBE

A corrugated plastic tube produces pleasant sonorities while rotating in a circular motion.

Singing corrugated tubes became popular in early 70s when a toy called *hummer* was introduced to the market. The hummer is a corrugated plastic tube about one meter long, similar to the one shown in Figure 2. When whirled in the air, the tube produces a series of discreet frequencies, starting from the first harmonic to its overtones.

Mark Silvermann, after a visit to Japan where he heard the Japanese children's performance, studied the acoustics of such tubes [11]. He mounted the corrugated tube to a thin slab attached to a wheel free to rotate in a vertical plane, with a counterweight fixed at the opposite end of the slab so that the center of mass of the system laid on the axis of the wheel. A motor whose velocity was varied using a rheostat was moving the wheel. Using a microphone, a stroboscope and a counter, the tones

[3] http://www.hasbro.com/bopit/
[4] http://www.picocricket.com/
[5] http://www.enactivenetwork.org

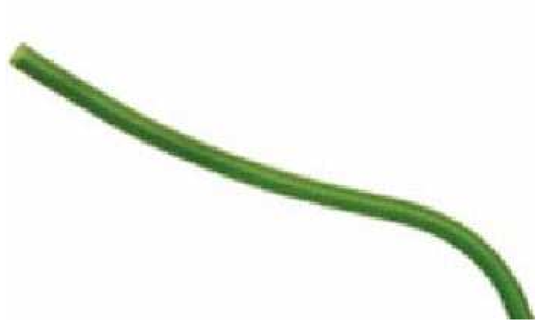

Fig. 2. *A singing plastic tube.*

produced were recorded and the spin rates measured. The data were analyzed by Fourier analysis.

Crawford also studied the acoustics of corrugated tube using a different device [4]. He attached the tube to his car and took it for a ride. Different tones were produced according to the car's velocity.

Both researchers made the following observations: whirling the tube slowly initiates the first overtone; with increased velocity, the higher partials resonate. Obviously, the length of the tube determines the pitches that will sing. Blowing into a smooth tube or whirl it in the air, no sound is produced. However, whirling a corrugated tube results in a noticeable tone. In a corrugated tube open at both ends, a tone is produced when the "bump" frequency of the air flowing through the tube equals one of the resonant frequencies of the tube. Air velocity, tube length, corrugation and diameter sizes therefore influence the pitch and volume of the sound produced.

The interest of toy makers as well as composers on singing tubes is due to the fact that the tubes' pure tones create an unusual ear-pleasing sonority. Singing tubes have also been used as pedagogical tools, to teach children fundamental notions of acoustics and connections between rotational velocity and sound produced. Although singing tubes are merely acoustical objects, we augmented them by tracking their fundamental frequency in real-time in the Max/MSP program [9] and connecting them with a physical model of a rotating corrugated tube [10].

In this way a sonic toy was designed, in which a continuous and natural gesture (rotation of the tube) produced pleasant sonorities for the player. The augmented tubes have been used in different occasions, from interactive performances to demonstrations. We noticed how all users learnt very easily how to interact with the instruments, and were attracted by their pleasant sonorities.

V. The Interactive Book

Current commercial interactive books for children are very often similar to conventional colored stories with the addition of some pre-recorded sounds which can be triggered by the reader. The limitations of these books are evident: the sounds available are limited in number and diversity and they are played using a discrete control (typically a button). This means that very often sounds are irritating rather than being a stimulus to interact with

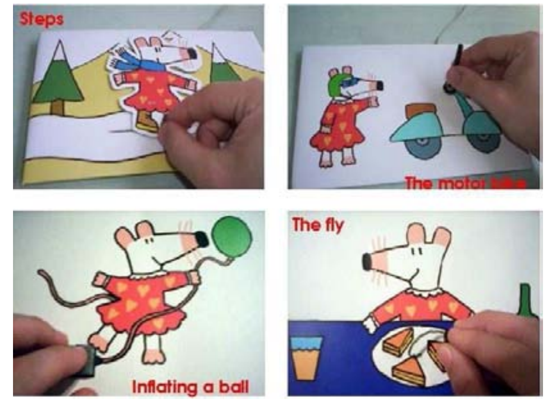

Fig. 3. Four different scenarios of an Interactive Book prototype

the toy-book and to learn by interaction. The purpose of this prototype is to develop new digitally augmented books, using sensors to allow continuous user interaction and to generate (not just play back) sounds in real time. This, in turn, will allow the user to intuitively modify and control the sound generation process, and engagement will certainly be boosted.

One of the first scenarios that has been implemented is the steps scenario that shows a rural landscape with a road full of snow. An embedded slider allows the user to move the main character along the road, and all movement data is sent to the computer, where the velocity of the character is calculated and a sound of footsteps is synthesized in real-time.

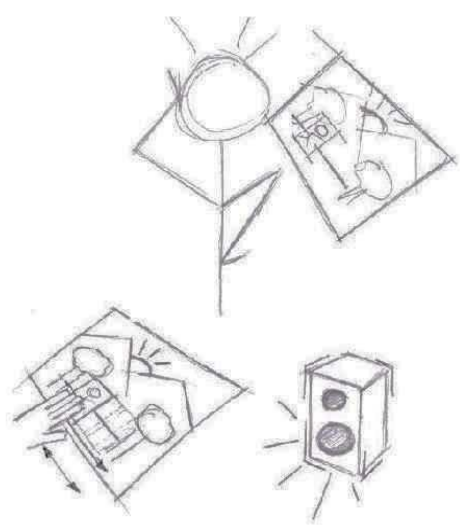

Fig. 4. The user is looking at the scene, identifies the moving part and tries to move the character generating sound

When opening this page of the book, the user has to discover a number of things:

- What should I move to make something happen?(*mh, what should I do? mh, there is this little think coming out from the page, maybe I should move it!*)
- What is the character doing in this part of the story? how should I move this 'interaction' point? (*yes, Lucy seems to walk, so maybe I should move this*

little thing: also Lucy is moving whit it! it makes her walking through the road!)

- Now that it is sounding, what kind of sound is it produced? what kind of information do I get from the sound? (*yes, and now that I moved her, I can also hear her steps! oh, hear the sound steps, oh yes there is the snow on the road!*)
- How many different sounds can I produce? (*look, the sound is always different!*)
- How is the sound changing according to my gesture? *hey, if I move faster Lucy, also her steps sounds faster!*)

It is quite clear that just by adding a new feedback (the audio one) and many different points of interaction, we solicit the imagination of the user and we engage him in a complex learning process which, by the way, can also be perceived as a funny game.

In this particular scenario the timing, distance, and force of the sound of each step is modified as a function of the control velocity of the impact model. Figure 4 shows a preliminary sketch, while Figure 5 shows the final prototype with the embodied sensor.

Fig. 5. Interaction through slider: the footsteps scenario prototype

VI. Everyday sounds machines

It is very common to find in the market sonic toys designed as interfaces with different buttons, in which each button triggers a samples everyday sound, usually animal sounds. We were interested in designing a sonic toys in which everyday sounds can be continuously controlled. To achieve this goal, we designed a reproduction of the Intonarumori machines. The Intonarumori were instruments designed as the beginning of the 20th century by Luigi Russolo. Each Intonarumori was designed as a box, provided with a level on top and a crank on the side. The level allowed to control the tension of a vibrating string placed inside the box, while the crank allowed to excite such string. Russolo designed about 27 Intonarumori, each varying in material and size. Each Intonarumori simulated different everyday sounds. In the attempt to create a modern reconstruction of Russolo's Intonarumori, which could be used both as a musical instrument on its own and as an interface for real-time sound synthesis, we designed the Croaker, shown in Figure 6.

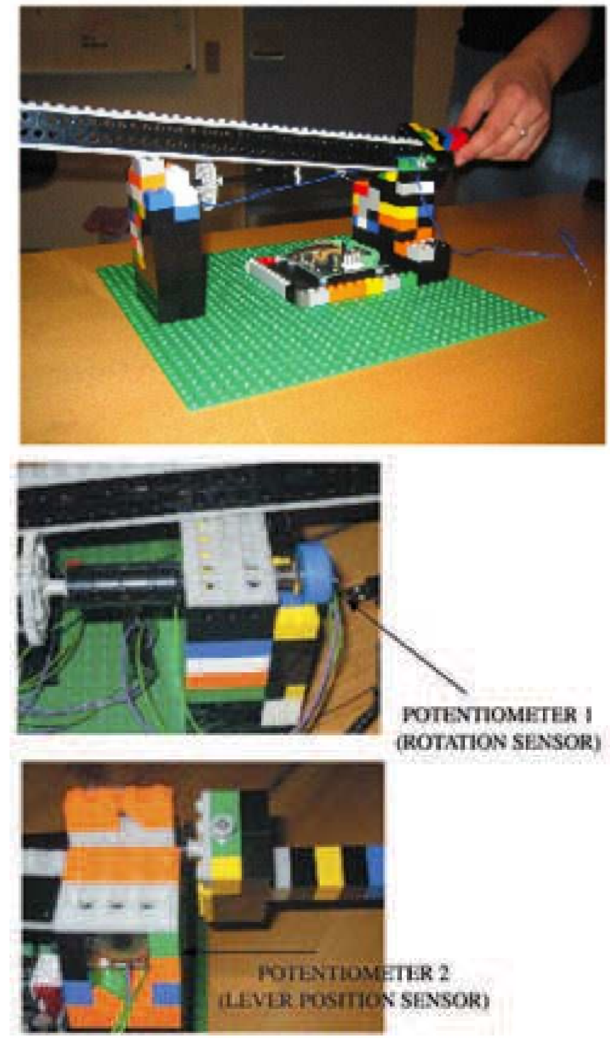

Fig. 6. The first prototype of the Croaker (left). Placement of the two potentiometers in the Croaker. The first potentiometer detects the position of the lever, while the second detects the position of the crank (right).

The first prototype of the Croaker, shown in Figure 6, is an interface built with Lego blocks. The name of the instrument derives from one of the original Russolo's instruments.

As in the original Intonarumori, the Croaker is provided with a one degree of freedom lever moving vertically, and a rotating crank. The position of the lever is detected by a potentiometer, attached as shown in Figure 6. The rotation of the crank is also sensed by a second potentiometer, attached to the wheel as shown in Figure 6.

The second prototype of the Croaker is shown in Figure 7. Compared to the one shown in Figure 6, the instrument has a more compact shape, and a linear slider is provided. Such slider allows to vary the frequency range of the instrument.

The current prototype of the Croaker is shown in Figure 8. As the original instruments, the Croaker is now made of wood. The more robust design allows the instrument to be used in performances.

In all prototypes, the sensors are attached to a Teleo

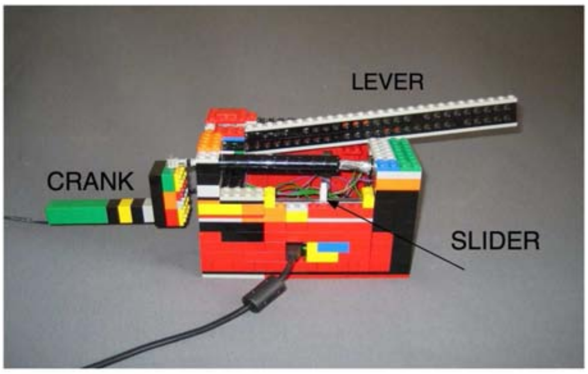

Fig. 7. The second prototype of the Croaker.

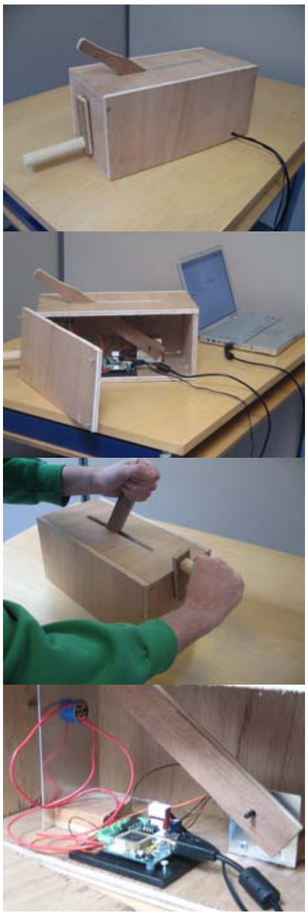

Fig. 8. The current prototype of the Croaker. From top to bottom: a view of the instrument, a view of the microcontroller and the sensors inside the instrument, use of the instrument and a close view of how the sensors are connected to the lever and crank.

microprocessor manifactured by Making Things.[6] The microprocessor is connected to a computer through the USB port. In the current prototype, the microprocessor is placed inside the Lego box.

By using the Max/MSP and Jitter software, some ad-hoc external objects have been developed by MakingThings, which convert the sensors data into numerical input which can be read by Max. Such data are used as controllers to different sound synthesis engines, as described in the following section.

[6]www.makingthings.com

VII. Conclusion

In this paper we described three case studies regarding the use of physical interfaces controlling physical models in the context of the development of sonic toys. By using physical models and novel interfaces embedded with sensors, the sonic feedback produced by the toys is tightly coupled to the gestures of the child, facilitating and encouraging the exploration of the toy and eliciting a natural enactive interaction. We believe that such interfaces represent only a limited range of the possibilities offered by the development of interactive sonic toys. In particular the addition of the haptic feedback would really enhance the effectiveness of the interaction that would lead to a new generation of interfaces for children: the enactive toys.

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References

[1] T. Blaine. The convergence of alternate controllers and musical interfaces in interactive entertainment. *Proceedings of the 2005 conference on New interfaces for musical expression*, pages 27–33, 2005.

[2] J. Bruner. *Processes of cognitive growth: Infancy*. Clark University Press, Worcester, MA, 1968.

[3] P.R. Cook. Physically Informed Sonic Modeling (PhISM): Synthesis of Percussive Sounds. *Computer Music Journal*, 21(3):38–49, 1997.

[4] F.S. Crawford. Singing Corrugated Pipes. *American Journal of Physics*, 42:278–288, april 1974.

[5] G. ESSL and S. O'MODHRAIN. An enactive approach to the design of new tangible musical instruments. *Organised Sound*, 11(03):285–296, 2006.

[6] C. Hutt. Exploration and play in children. In *Symposia of the Zoological Society of London*, London, 1966.

[7] T. Machover. Shaping Minds Musically. *BT Technology Journal*, 22(4):171–179, 2004.

[8] J. Piaget. *The Child's conception of the world*. Rowman & Littlefield Publichers, Totowa N. Y., 1979.

[9] M. Puckette, T. Apel, and D. Zicarelli. Real-time audio analysis tools for Pd and MSP. *Proceedings of the International Computer Music Conference*, pages 109–112, 1998.

[10] S. Serafin, N. Böttcher, and S. Gelineck. Synthesis and control of everyday sounds reconstructing Russolo's Intonarumori. *Proceedings of the 2006 conference on New interfaces for musical expression*, pages 240–245, 2006.

[11] M. P. Silverman. Voice of the Dragon: the rotating corrugated resonator. *Eur. J. Physics*, 10:298–304, 1989.

[12] E. Singer. Sonic banana: a novel bend-sensor-based MIDI controller. *Proceedings of the 2003 conference on New interfaces for musical expression*, pages 220–221, 2003.

[13] G. Weinberg, R. Aimi, and K. Jennings. The Beatbug network: a rhythmic system for interdependent group collaboration. *Proceedings of the 2002 conference on New interfaces for musical expression*, pages 1–6, 2002.

[14] G. Weinberg and S.L. Gan. The Squeezables: Toward an Expressive and Interdependent Multi-player Musical Instrument. *Computer Music Journal*, 25(2):37–45, 2001.