Digitally Augmented Everyday Objects in Music Composition

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***Abstract*—This paper discusses three instances of compositions, in which physical and cyber everyday objects interact. The physical objects such as plastic corrugated tubes, plastic superballs, glass marbles, cocktail shakers, electric blenders, and others provide unique musical data for the performance and input data for their physically modeled counterparts. Besides the compositional strategies, the article focuses on the software and hardware issues connected with tracking, parametrical mapping, interfacing, and physical modeling of everyday objects.**

Keywords: everyday objects, interactive music composition, physical models, gestural models, cyberinstruments, sensor technology

I. Introduction

Composing music with everyday sounds is no novelty in the contemporary music. In the early 20th century, the Italian Futurist Luigi Russolo designed, built, and composed with a set of musical instruments called *intonarumori* (noise intoners), which mechanically reproduced everyday sounds. Everyday sounds became subjects of exploration for a number of *music concrete* composers and researchers after World War II. Rather than reinforcing the link between the sound and its production mechanism, it was desired to disassociate the sounds from the sources, which produced them [1].

In the1950s, Fluxus performance artists embraced the concept of ready-mades, previously proposed by Marcel Duchamps. The Fluxus engaged everyday objects in their loosely structured performances, which focused primarily on the exploration of the objects' visual aspects. In the same time, the experimentalist composers such as John Cage, Harry Partch, La Monte Young, and Cornelius Cardew investigated the sonic properties and potential for artistic expression of the everyday objects [2].

In this paper, we contextualize everyday objects in the arena of contemporary interactive electroacoustic music composition, thus extending the legacy of research initialized by Russolo and others. By examining the compositions *Garden of the Dragon, Revelations,* and *Neither Stirred, Nor Shaken*, we will exemplify how the everyday objects can be (1) defined as musically meaningful entities and used in a structured composition, (2) digitally simulated by means of physical modeling synthesis, (3) tracked and parametrically mapped to the physical models, and (4) effective in interactive musical discourse, which combines physical and cyber everyday objects.

Further, we discuss the performative aspects of the compositions. All everyday objects used in these compositions are easy to manipulate. Therefore it is the intention of the compositions to be performed by people not necessarily trained in any specific music area. We hope that the interaction between the physical and cyberinstruments by physical modeling synthesis will enable a larger number of performers to develop a relationship with the technology and acquire understanding of computers musical expressivity and creative potential.

II. Garden of the Dragon

Garden of the Dragon (2003) is a composition written for cellophane, plastic corrugated tubes and electronics. The work constitutes an ecosystem in which everyday objects such as cellophane and plastic tubes cohabit with the cyberinstruments.

The singing tube was a largely popularized musical toy in the 1970s due to its pleasing sonorities and easy manipulation. The tube produces a series of tones based on the harmonic series. The whirling speed influences, which tone will sound. The faster whirling will result in higher pitch and the lower tones will be produced at the slower whirling rate. The acoustics of the singing tube, its physical model, and compositional application were detailed in [3].

Garden of the Dragon is structured to follow the trajectory of timbral evolution from percussive cellophane sounds to the almost pure sonorities of plastic tubes and their cyber counterparts and, finally, to the percussive sonorities produced by tapping and scratching the tubes. These sonic areas and performance modes frame the composition.

In *Garden of the Dragon*, the sound of physical tubes is tracked in real-time by the *fiddle~* object [4] in MAX/MSP environment [5]. It is worth to mention that, due to the purity of the tube tones, this pitch tracker works extremely efficiently. The synthetic tubes are programmed to follow one leading physical tube while being parametrically expanded and diminished throughout the piece. The leading player is able to control directly the relationship between the physical activity of tube whirling, the tones produced by the physical tube, and the particular extensions of timbres generated by the cyber tubes. Such relationship is compositionally fixed, as all the players are instructed to rigorously follow the score. Nevertheless, the aurally transparent feedback established by interlocking the physical and synthetic forces confirms a fluent continuum between the physical gestures and sounds produced by the physical and cyber objects.

The performative aim of this composition is to involve a larger number of performers not necessarily trained in music. Thanks to the common availability of the instruments, their uncomplicated manipulation, and capacity to generate attractive sonorities, we achieved to stage performances with as many as ten players.

An excerpt from the score of *Garden of the Dragon* can be seen in Fig. 1. The top system displays the overall motion of electronics, while three bottom parts indicate the gestures performed by the three players.

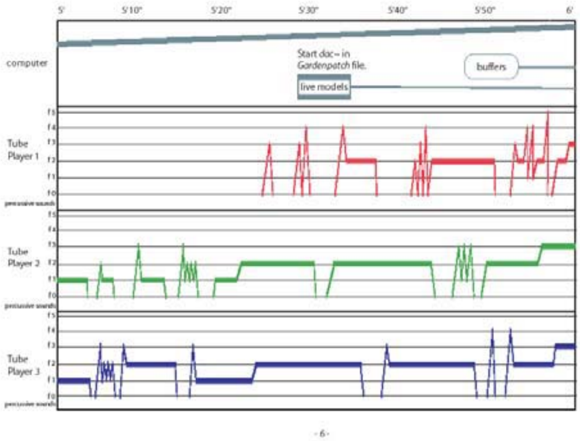

Fig. 1. An excerpt from the score of *Garden of the Dragon*.

III. REVELATIONS

Revelations is a composition for circular toys, resonant plates, and electronics composed in 2005. In this composition, everyday objects such as rubber, metal, and glass balls are digitally enhanced. Performance modes such as shaking a single or multiple balls in an enclosed container, free and forced ball bouncing and rolling, as well as scraping the balls on a variety of flat surfaces such as custom made plastic, aluminum, and brass resonant plates produce simple, yet appealing, sonorities. These sonorities are digitally complemented by physically modeled shakers, bowed percussion bars, physically modeled strings, and synthesized rolling and bouncing sounds. Such extensions enrich greatly the timbral properties of the physical circular toys.

A. Circular Toys

Circular toys are no innovation in games and music. For example, bouncing ball is a toy originating from China. The mothers were creating balls for the children to play. Traditionally, the ball was created of remnants from old kimonos. The fabric was tightly layered and stitched. Condensed fabric would allow the ball to eventually bounce. The ball, *temari*, was brought to Japan six hundred years ago [6]. The youngsters would play ball-bouncing games (*temari-uta*), a mixture of game and singing. In the game song, the rhythmic patterns of different complexity were combined with chanted syllables [7]. Traditional *temari* balls became an embroidery art after the rubber was brought to Japan, and the hyper-bouncing rubber ball was introduced to the toy market.

Circular toys such as rubber balls have been continuously explored in a variety of musical contexts around the world. Scraping a surface of a drum with a rubber ball placed on a mallet is common in the frame drum and steelpan performances. As a special effect, bounced and scrapped rubber balls were employed more recently by composers such as Sofia Gubaidulina, Annea Lockwood, John Williams, John Adams, and Eleanor Hovda to name a few.

The use of digitally extended circular toys in musical performance is, however, an uncommon phenomenon. The following sections detail the musical experience, which resulted from pairing the physical and synthesized sounds of circular toys in the composition *Revelations*.

B. Overview

Precisely, *Revelations* is scored for rubber superballs, Patang metal balls, glass marbles, flat circular resonant plates made of Plexiglas, glossy and matte plastic, aluminum, and brass, and computer. The three performers use circular toys to excite the plates in a variety of performance modes such as bouncing, rolling, and scraping. Additionally, the players gather glass marbles in an enclosed container, which is defined as a percussive shaker and perform with it. The actions of physical circular toys are amplified. Sonorities of physical circular toys are combined with their either physically or gesturally modeled counterparts in the Max/MSP environment. The performance's audio signal was tracked, and its amplitude was analyzed by means of *bonk~* [4] and *fiddle~* objects.

The composition is divided into three parts, according to the prevalence of a particular performance mode such as shaking, scraping, rolling, and bouncing. Acoustic performance modality does not necessary align with the computer sound. For example, acoustic bouncing is complemented by the sound of physically modeled shakers in the opening section.

Figure 2. *Revelations* performance set up.

Fig. 2 shows the setup for revelations, and Fig. 3 dispalys an example from the score. The graphic notation enables the musically untrained players to participate in the performance. A microphone is positioned under each plate to assist in transferring the audio signal into

MAX/MSP. The relationship between physical and cyberinstruments resulted from parametrical mapping of the amplitude contours provided by the physical instruments gestures to the various cyberinstrumental parameters. The amplitude shapes reflect the physical activities of bouncing (short discontinuous bursts of energy in amplitude spectrum), scrapping (decaying amplitude gestures of duration no longer than 2 seconds with an initial strong attack), rolling (continuously sustained amplitude with slight fluctuation bumps in energy spectrum), and shaking (continuously sustained amplitude in the upper range with larger peaks; these are primarily a result of assigned musical gestures).

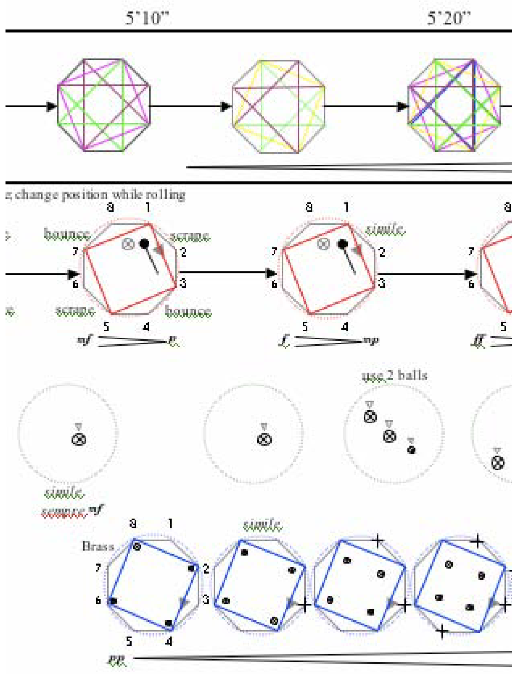

Figure 3. An excerpt from the score of *Revelations*. The top system signifies the computer performance, while the three bottom systems show instructions for three players.

C. Shakers

The sound of circular toys shaken in an enclosed container may be identified with the sound of percussion shakers. Thus, physically informed stochastic models (PhISM) developed by Perry Cook [8], and implemented in MAX/MSP as a library of external objects PeRColate [9] are used to digitally enhance the acoustic instruments. More precisely, the models of cabasa, guiro, and maraca are employed. All these cyberinstruments involve circular exciters (beads) and enclosed resonators in sound production.

In the opening part, the three performers use bouncing rubber balls to control the cyber shakers. Traceable parameters of the acoustic bouncing balls include peak amplitudes of individual bounces, number of attenuating bounces in one gesture, bouncing speed (derived from the time in between individual bounces), overall gain (based on the difference between the initial and final bounce amplitude), and previously examined resonant frequencies of the flat plates, which are less problematic to track when isolated. These parameters are alternatively mapped to the controllable parameters of cyber shakers.

D. Scraping Balls

MAX/MSP implementations of bowed percussion bar physical model developed by Georg Essl and Perry Cook [10] and string physical model [11] are used to complement the friction activity and sounds of the physical rubber ball scrapping against hard surfaces. The models parameters are controlled in real-time. Acoustic scraping gestures can be characterized by short duration (ca. 2 seconds), and amplitude envelope with initial strong attack (peak amplitude) and dominant sustain period. Amplitude ranges in which the initial and terminal amplitudes of the gesture are located suggest the scraping pressure levels.

Mapping between these parameters and those of the models are aligned, yet augmented. For example, frequencies of the model correspond with extreme transpositions of the frequencies identified with the flat plates.

E. Rolling and Bouncing: Gestural Approach

Simulation of rolling balls obtained by using a rolling filter is described in [12]. More precisely, a second order bandpass filter simulates the rolling mechanism. The filters spectral characteristics are derived from the rotational speed of the ball. As MAX/MSP implementation of this simulation was not available at the time, we synthesized the sound of rolling using a simple gestural model approach in MAX/MSP.

Gestural rolling model is based on an empirical observation of sonic and physical rolling behavior. Rather than departing from complex spectral results of interaction between the exciter (ball) and resonator (surface), this approach emphasizes the overall evolution of gesture in time. Thus, the frequency components are added after modeling the correct gesture shapes is defined.

When a ball rolls on a surface, as the rolling decelerates, the amplitude decreases, and duration of individual rolls increases. Amplitude between transient rolls actually never reaches 0, as continuity is the key attribute of rolling. Although rolling parameters such as amplitude, duration, speed, and number of rolls differ according to the particular characteristics of involved elements such material and texture, the overall gesture contour maintains valid in a variety of situations.

This behavior simulated by a simple accumulative function (1)

$$f(x) = x * a \qquad (1)$$

in which each following x is replaced by the result of the previous calculation, and a can be either a constant or variable. The argument a signifies the rate at which rolling decelerates. Whether constant or variable, a must remain larger than 1 to ensure continuous increment of the interval between the results and, thus, speed deceleration of the rolling gesture.

The time between the subsequent calculations is measured and reported to an envelope function, which designates the shape and duration of individual rolls. This function is finally applied to the frequency spectrum, which is the result of desired ball/surface interaction. Frequency spectra, derived as suggested in [13] from the spectra of 5 resonant circular flat plates, are simulated with additive and FM syntheses.

Parameters of the rolling gesture model in MAX/MSP that can be controlled in real-time are velocity of rolling, number of rolls, deceleration time (simulation of damping), overall gain, amplitude envelope (shape) of individual rolls, and frequency spectra (as a result of ball/ interaction surface consideration).

Bouncing and rolling phenomena share similar properties such as countable number of events (rolls or bounces) and overall decaying gain shape. Yet, while rolling decelerates, bouncing accelerates over time.

For purpose of this composition, bouncing was also simulated using a simple gestural model, rather than following the physics based approach suggested in [14]. In the physics based approach, the timing between different bounces is derived from the size and material of the balls. This timing contributes largely to the definition of bouncing gesture. Similarly to rolling, a simple accumulative function was used to simulate the accelerated motion of a bouncing ball. As opposed to rolling, however, the argument *a* in the function must be smaller than 1 to ensure this acceleration. Individual bounces are modeled as short amplitude envelopes with sharp attacks. Frequency components are derived in a similar fashion as those of rolling.

In general, certain parameters of physical and gestural models remain fixed or controlled by MAX/MSP internal mechanisms. This ensures connection between the compositional design of the piece and its real-time components. For example, increasing the number of bounces and beads continuously corresponds to the increasing number of beats within rhythmic patterns performed by the live performers.

Gestural modeling approach is particularly effective (and inexpensive) in simulation of sounds in which temporal behavior is essential to the sound's existence. For example, rolling and bouncing will be only identified when a number of events unfold in time. Unless placed in the temporal sequence, a single bounce or roll are difficult to characterize as such.

As suggested earlier, *Revelations* was composed and notated with the intention of complete control over the musical material and human-computer interaction. Accordingly, the performers' physical activities unidirectionally control the cyberinstruments. Complexity of relationships, that arise from the number of involved instruments is balanced by a transparent mapping level. That is, the performers are able to hear clearly and without delay how their actions affect behavior of the cyberinstruments. As opposed to the singing tubes in *Garden of the Dragon*, the more sophisticated circular toys enable a larger number of timbral possibilities, stronger control and closer contact between the performer, physical action and sound production mechanisms. Better control and tactile contact between the toys and surfaces results in a creation of focused and delicate physical and also cyber sonorities. The physical and cyber circular toys weave a delicate network of actions and sounds in *Revelations*.

IV. Neither Stirred, Nor Shaken

Neither Stirred, Nor Shaken (2007) was composed for cocktail glasses, shakers, blenders, and electronics. Three performers produce sounds while they stir liquid and ice with a metal spoons in a highball cocktail glasses, shake their concoctions in metallic shakers, and mix them in electric blenders.

The physical objects are coupled with the physical models of shakers, engine rattles, and singing glasses in order to create rich timbral and textural tableaux.

The composition was inspired by research, which discusses influence and potential health benefits of stirring over shaking in preparation of the martini cocktail [15]. *Neither Stirred, Nor Shaken* examines the musical potential of the physical activities such as stirring, shaking, and mixing, while engaging everyday objects, sensors, and physical models. The composition engages three performers in the act of cocktail making with the products being not only a tasty beverage but also an electroacoustic composition.

The composition is structured into three parts. Stirring, shaking, or blending and their sonic terrain dominate each section. A cocktail drink is produced during each part. After seven minutes, the players have the opportunity to taste the drinks prepared during the performance and evaluate them. Then, the players arrange the drinks according to their quality. The first player inputs the order data for each player into a MAX/MSP assessment patch. Depending on the entered data, a simple algorithm decides which of the three potential solo-electronic sections concludes the composition.

The set up for each player is displayed in Fig. 4. It consists of a highball cocktail glass, a tall metal spoon, metal shaker, electric blender, ice, clear liquid, sensors, and Make Controller board [16].

Figure 4. Complete set up for *Neither Stirred Nor Shaken*.

As opposed to *Garden of the Dragon* and *Revelations*, this composition utilizes sensor technologies connected to the Make Controller board in the process of acquiring the data from the everyday objects. The Make Controller board is connected to a computer running the MAX/MSP application via a USB cable, although other connections (e.g. Ethernet) are also possible.

A. Sensors, tracking and mapping

A temperature sensor, accelerometer and piezo sensor track some of the physical parameters of the cocktail-making process in real-time. The temperature sensor is embedded in a used CD case for protection from moisture emitted from the cocktail glass as can be seen in Fig 5. The case conveniently serves as a glass stands. The accelerometer is woven into the textile band, which is worn on the palm of the hand operating the shaker as displayed in Fig. 6. The piezo sensor is attached to the engine exit of the electric blender as shown in Fig.7.

In the opening section, a cocktail glass filled with ice and liquid is placed on the glass stand over the temperature sensor to be stirred. The sensor measures the temperature decrease of the initially stirred drink over the period of the composition (ca. 9 minutes). The number of cubes varies for each player (5, 10, and 15). Therefore the resulting temperature decrease and their rates are slightly different for each player. Stirring, as a performance mode, is a delicate process, and the subtle changes in the data flow reflect this feature.

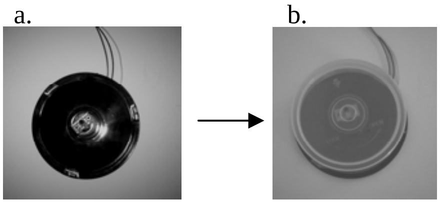

Figure 5. The temperature sensor (a) placed and (b) embedded in the plastic case for protection.

On the other hand, shaking can be rather dramatic. In the section two, an ADXL 330 triple axis accelerometer [17] is attached to a textile band, which can be worn on a hand, which holds the shaker. The sensor tracks the acceleration of the containers in motion. After the concoction is well shaken and poured into a cocktail glass, the sensor band is removed from the hand.

Figure 6. Accelerometer woven into a textile band.

The piezo sensor (LDT0 solid state switch/vibration sensor) is used in the final portion of the composition. At this time, the players begin performing on three electric blenders. The sensors are attached to the rare air exits of the engines and track the changes of the air pressure resulting from various mixing modes.

Depending on the resistance to the material the number of ice cubes in the containers significantly varies from player to player the engine will radiate more or less air. Therefore these sensors track the energy that was generated in the production of the cocktail. A two-speed five-mode blender with the pulse function was used for the experiments and initial performance.

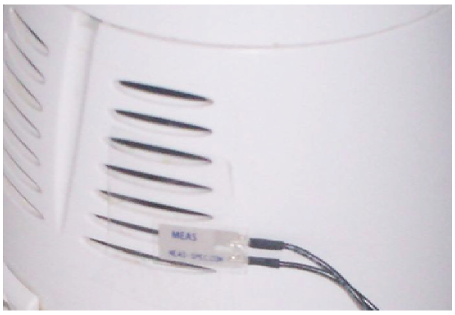

Figure 7. A piezo sensor attached to the rare engine grid of an electric blender.

The complete sensor set up is displayed in Fig. 8. Data obtained from the sensors control the cyber shakers, engine rattles, and singing glasses physical models.

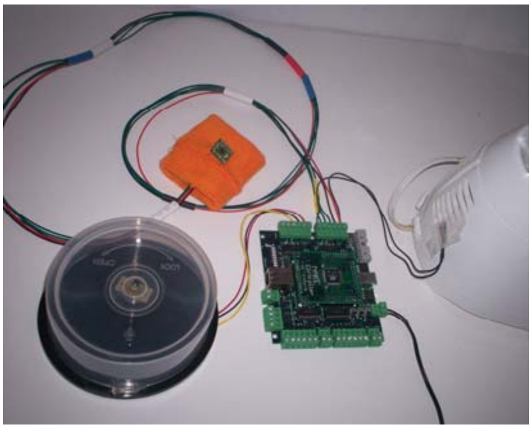

Figure 8. Complete sensors set up for *Neither Stirred Nor Shaken*.

B. Physical models

The pitch materials of *Neither Stirred, Nor Shaken* are largely provided by the physical model of a cocktail glass, an adaptation of wine glass model previously described in [18].

By examining the spectrum of the hit target cocktail glass, two main resonances were identified, as shown in Fig. 9. Such resonances were used as the target for the resonator’s model. The modeled singing glasses were simulated by means of banded waveguide synthesis. The models can be excited by either hitting or rubbing. They are capable of reproducing the sonorities of physical crystal cocktail glasses on which they are based and timbrally extend them.

Shakers and rattles were simulated as physical models of liquid sounds as proposed in the previous research [19]. All models were implemented in the MAX/MSP environment for real-time performance. The sounds of the cyberinstruments extended the percussive timbres of the physical stirring, shaking, and blending.

Thanks to the more precise sensor technologies, the activities of the performers can be fairly well tracked in *Neither Stirred Nor Shaken*. Further, the sensors facilitate a closer contact between physical gestures and cyberinstruments, while eliminating the data transmission via air as in the case of *Garden of the Dragon* and *Revelations*.

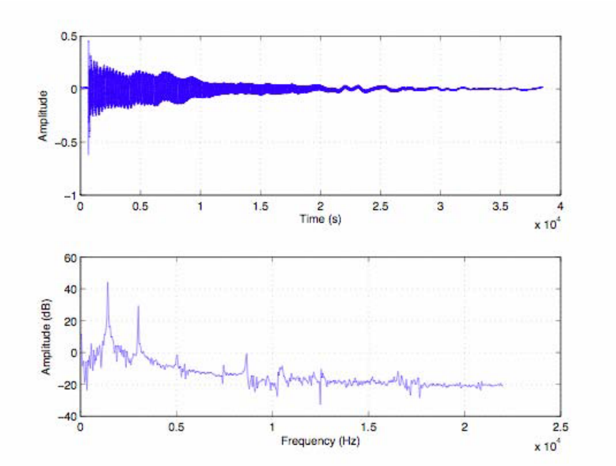

Figure 9. Top: time domain, bottom: spectrum of the cocktail glass used in the simulations.

In the opening section of *Neither Stirred Nor Shaken*, the performers initiate energy by stirring, but they leave the melting process to be decided by such factors as room and liquid temperatures. Shaking instigates precise three-dimensional control of hand gestures and imminent sensation of coldness. Mixing involves the initial trigger of the performer, but it is the machine, which generates the necessary energy.

This composition focuses on initiation, transformation, and transportation of energy. Activities such as stirring, shaking, and blending prompt the act of transformation of solid ice to liquid. Such initiation can be further either completed (e.g. during blending) or less forcefully applied (e.g. during stirring), thus leaving space and time for the material itself to develop gradually in the environment. The temperature sensor traces the temperature decrease, which induces steady but slow alteration of the material. The accelerometer measures rapid gestural changes, but this is only possible while the performer and shaker remain in contact. The piezo sensor reflects often the most miniscule modifications of the blender's sustained energy supply. This is only possible when the machine is turned on.

The mapping strategies reflect the physical process of imposed ice melting. The physical and cyberinstruments are not always paired, yet they do not compete. Rather they contribute to a creation of a fluid augmented sonic reality. Depending on the conditions such as ice cube size, shaker material and blender model, each reiteration of *Neither Stirred Nor Shaken* will be slightly different. Further musical flexibility is reflected in the concluding part, which, featuring solo live electronics, may sound uniquely at each performance. It encapsulates the accumulated knowledge acquired throughout the given performance.

V. CONCLUSION

The music compositions described in this paper utilize forms of interactions detailed in the taxonomy of everyday sounds suggested by W. Gaver in [20]. Gaver proposed a hierarchical grouping of everyday sounds, which can be classified as vibrating, aerodynamic and liquid sonorities. While the taxonomy is not exhaustive, it nonetheless presents an efficient way to describe and classify a large variety of everyday sounds.

Fig. 10 summarizes the variety of simulated interactions and the compositions in which they were used. As can be seen from the figure, we adopted and explored all the interactions described in [20] in our simulations and compositions.

A singing tube was used in *Garden of the Dragon* and the corresponding spinning sound obtained by rotating the instrument in a circular motion was simulated. In addition to the rolling and bouncing balls, the vibrating objects such as plates were excited by rubbing, scraping, bouncing in *Revelations*. Lastly, stirred, shaken, and blended liquids were simulated and used in *Neither Stirred, Not Shaken*.

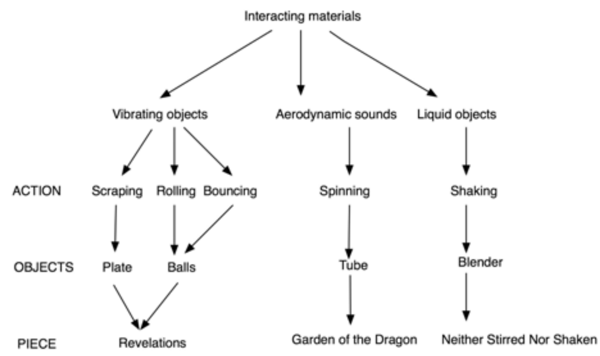

Figure 10. The different sound models used in the compositions are classified according to the taxonomy proposed in [20].

The data for the control over the physical and gestural models were acquired either via tracking the audio signal (*Garden of the Dragon*, *Revelations*) or physical activity (*Neither Stirred, Nor Shaken).* While it is efficient and accurate to track the frequency of the almost pure signal of the tube and the percussive gestures of the bouncing balls, the processes of stirring, shaking, and blending proved to be more manageably tracked with the sensor technologies.

All these works were composed in a three-part form. Each part investigates the musical potential of a particular physical activity. The resulting novel timbral trajectories frame the continuum of interaction between the physical and cyber sonic zones. The compositions further share the following features: (1) the instruments can be easily obtained and controlled, (2) they can be played by performers not traditionally trained in music, and (3) they suggest a constitution of novel augmented analog-digital reality, in which physical and physically modeled instruments are intertwined. From the educational point of view, we engaged musically inexperienced performers to participate in these interactive music compositions primarily due to their playfulness and involved physical activity.

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