PENDULA: An Interactive Installation and Performance Instrument

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ABSTRACT
This paper describes the processes involved in developing Pendula, an immersive installation and novel performance instrument, using three swings, gesture tracking, and an interactive audio/visual environment. A short overview of related work will be followed by the development and implementation process of Pendula as both an installation and performance instrument in a professional artistic context. This includes descriptions of the physical and technical attributes, composition and choreography development using a lexicon of gestures developed for the novel instrument. Lastly, observations, design challenges and future goals are discussed followed by project conclusions.

Author Keywords
multimodal expressive interfaces, sound art installation, novel controllers, motion gesture and music.

1. INTRODUCTION
Swings are a universal playground apparatus that provide a familiar experience for individuals across all ages. They are a transcultural familiar artefact that are intuitive to use and can provide instinctive enjoyment for the users. For such a simple structure, swing sets can provide multiple levels of interactivity. A single user can engage with the framework through different ranges of their motions, as well as with other users interfacing with the apparatus. The action of multiple users can create swinging motions that may result in conjunct and/or disjunct movements in relation to one another. The result of this kinesthetic interaction provides a rich range of movement information, since it is based on the nuanced movements of each individual user. The rhythmic motions produced by swings are analogous to the properties of sound: they have a cycle, phase, period and amplitude. These properties provided a foundation for creating an intuitive tracking system that seeks to unify the diverse range of swinging movements with control over electronically generated audio/visual content.

The creation of Pendula comprised of an enclosed immersive environment equipped with three swing sets, four ambient projections, quadraphonic sound, and installation textiles. A gesture-tracking system was developed for the users' control of electronic audio/visual processes by analyzing the nuanced movements that occur during the interaction between the individual and the swing set. Multiple tracking systems were implemented in order to gain maximum amounts of data. From there, a model was created to act as a framework for calibration, which could then be scaled and applied to any user. The audio and visual parameter controls were distributed across the three swings, which allowed different levels of interactivity and experience, depending on the number of users and their collective movements.

Furthermore, Pendula augmented the familiar usability of the swing set mechanism and transferred it into new contexts. This was achieved by developing the swings to be used as a performance instrument: where one player would control audio and video processes through technique and choreography developed specifically for the framework. Pendula was exhibited during the 2015 TD Vancouver International Jazz Festival in a high traffic area adjacent to the main stage. Multiple performances were featured in the Pendula environment to encourage public participation and provide context of the swings' interactivity for the installation of Pendula.

This paper will provide a short overview of related work and present the development and implementation process of Pendula as both an installation and performance instrument. This includes descriptions of the physical and technical attributes, composition and choreography developed using a lexicon of gestures implemented for the novel instrument. Lastly, observations, design challenges and future goals are discussed followed by project conclusions.

2. RELATED WORK
Prior research on developing interactive swing set installations for public spaces have implemented similar design techniques and user processes. However, rather than creating an immersive electronic audio / visual environment, previous installations have solely focused on either audio or visual processes to be controlled by the user's swinging motions. These gesture tracking frameworks have incorporated singular user processes through the conventional forward and backward swinging motion. Pendula's design surpasses this through analyzing a diverse range of motion types between individuals. The result is the creation of a system which integrates multiple motion types to a larger range of generated audio and visual processing. This expands on previous swing set tracking systems by creating multiple levels of interactivity based on tracking a variety of movement types.

The focus on aural interactivity is exhibited in 21 Balancoires by Daily Tous Les Jours. This outdoor 21 swing instrument is programmed with pre-recorded sounds to be played as melodies through swinging motions. When in motion, each swing triggers different notes, and when used all together, the swings create a musical composition in which certain melodies emerge only through cooperation [1]. Similarly, SwingScape by Gronbaek et al. also utilizes cooperation to create aural components. The intention of the installation is to make a remix of a song through participation [2]. This is realized through each individual's role of triggering single audio tracks based on their movement. In addition to triggering discrete aural (note on/off) events through the user's movements, Pendula added audio processes that outputted continuous sonic manipulations through multiple motion types: forward and backwards, side to side and circular. These effects included sample filtering, playback-speed, and spatialization. Moreover, Pendula's interactivity of multiple participants extended to the user's' ability to control visual parameters and was also intended to be used as a performance apparatus.

Pendula additionally aimed at transforming a familiar framework into a novel performance instrument. Unlike the usual emphasis of a novel instrument within the NIME community, the focus was to perform the instrument in a number of high profile artistic performances. This is analogous to the Prosthetic Instruments developed by Hattwick et al [3]. The Prosthetic Instruments were also developed specifically to use in prominent artistic performances, which required high technological and physical durability to withstand this application. This was also reflected in the Pendula swing instrument, which underwent numerous tests to meet these requirements. Both Pendula and Hattwick et al. underwent development by consulting with a professional choreographer. However, instead of designing the instrument for professional dancers, Pendula aimed at creating a novel instrument that could be accessible and intuitive to untrained users. This has been discussed by Knichel et al. who describes design methods for novice users, who will spend only a short time within the installation, and the need for different strategies rather than creating an interface for expert musicians. The mode of operation has to be primarily self-explaining and natural [4]. As will be discussed later, Pendula's instrumental design was based on an intuitive mapping system that is accessible to both trained and untrained users'.

3. DEVELOPMENT AND IMPLEMENTATION

This section describes the installation, hardware and software design for Pendula, followed by more details of the prototype techniques and interactive observation.

3.1 Physical Structure and Installation Environment

Pendula was devised as an immersive environment, consisting of three swing sets enclosed by a 20 x 20 feet tent. A wooden swing set structure, 9 x 9 x 9 feet in size, was constructed inside the tent to support the swings. The enclosed textiles included three large white-sheer fabric panels hanging on three sides of the tent, and four smaller white-sheer fabric panels staggered on the side of the entrance (Figure 1).

Each swing set was made of vinyl-upholstered wooden seats and doubled-up nylon ½" rope. Four projectors were mounted to the ceiling by a custom-built rack. The projectors created a visual ambience by displaying visuals on opposite fabric panels. Four speakers were placed on the corners of the space, producing quadraphonic sound.

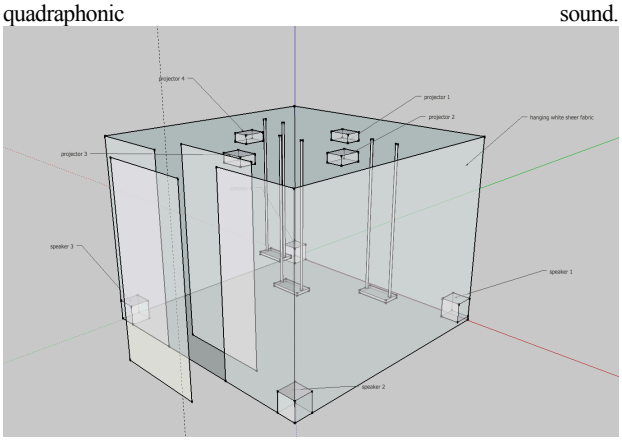

Figure 1. Proposed Pendula installation for the 2015 TD Vancouver International Jazz Festival.

3.2 Software and Hardware

The following data acquisition system was used to capture and maximize the data generated by participants: An Arduino Uno microcontroller with circuits built consisting of a triple-axis gyroscope and accelerometer in order to measure the swings' six degrees of freedom and the rate of change of the swinging motions. The microcontroller and sensors were attached to the bottom of the swing seat by a custom built case and fastened with hardware.

The initial step of this project was to analyze the broad range of movements that were exhibited while users are swinging. This included video recording and analyzing the nuanced movements that occur during these interactions. This lead to building a lexicon of gestures that was similar across users. Once this was achieved, a model was created that could be scaled and applied to any participant using the system. This acted as a framework for calibration with the initial users providing the calibration dataset.

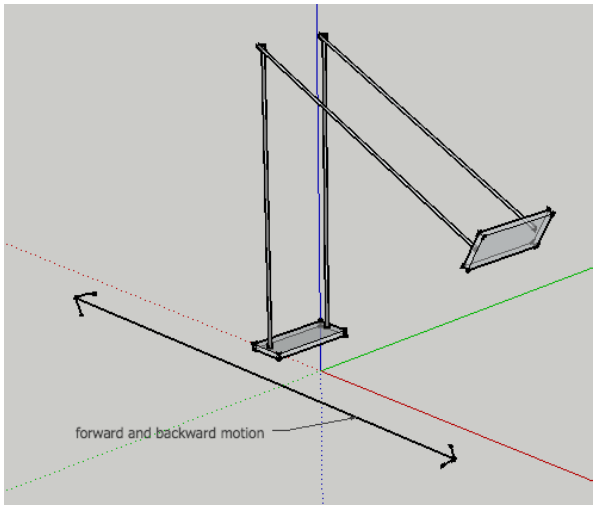

Figure 2. Swing motion range along the x-axis (forward and backward motion).

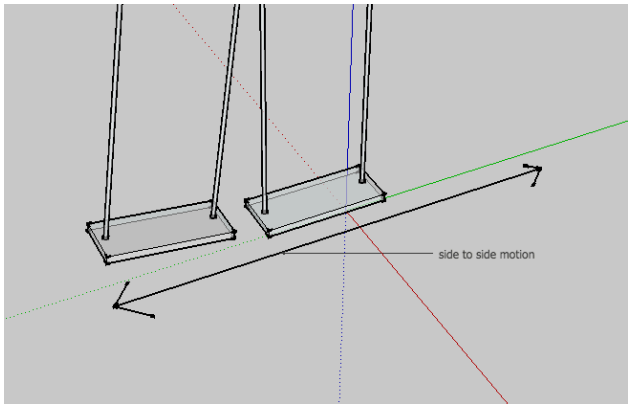

Figure 3. Swing motion range along the y-axis (side to side motion).

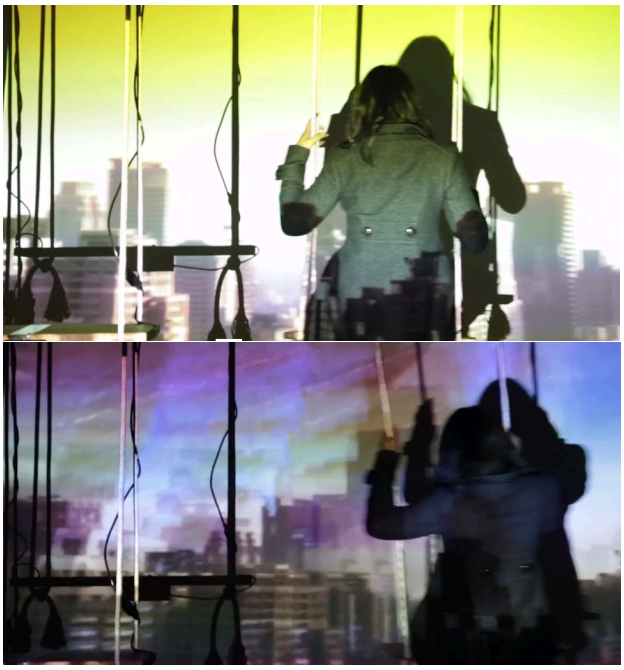

Figure 4. Participant triggering both xy-axes visual effects parameters by moving in a circular motion.

The two data types were extracted through a written Arduino sketch via USB. From there, the data was parsed into a Max/MSP patch and were further programmed to send corresponding controls to execute audio and visual effects. The sonic controls were distributed between two of the swings. Examples included triggering aural events note on/off, pitch, filtering, and spatialization. The visual controls were distributed between two of the swings that were programmed using Resolume Arena software. The gyroscopic data was sent from Max/MSP to Resolume Arena via OSC to manipulate the resulting visual output.

Conclusions on mapping audio / visual content to the three swings were decided upon observing movements and interactions of users. The visual processes were distributed between two of the swings because it was evident that the users perceived and reacted to these controls faster than those of the audio processes. These findings are synonymous with studies which conclude that auditory reaction time is slower than visual reaction time [5], where reactivity is composed of: 1) the time for perceiving, identifying and analyzing of stimulus, 2) deciding on the proper motor response [6].

The installation consisted of four different modes (four distinctive audio / visual environments). These modes included varying audio and video components. The software developed allowed seamless mode switching operations through switch controls to route audio and video signals, recalibration of the swings, and overall audio and video mixing of the installation environment.

4. SWING AS A PERFORMANCE INSTRUMENT

This section describes the processes of developing the swings as a performance instrument. This includes gesture analysis, musical composition and choreography approaches created for the Pendula exhibit.

4.1 Development of Gesture Lexicon

Five gesture types were discovered by experimenting with different motions which produced the best range of data-output and visually correlated with the aural components. These movements were additionally intuitive for the performer.

A lexicon of gestures was established to be used by the performer: (1) Default - conventional forward and backward swing motion (Figure 5) (2) Flip (Figure 6) (3) Side lift (Figure 7) (4) Spin (Figure 8).

These gestures were incorporated in Pendula because they were able to produce the largest threshold range to optimize data generation to channel the whole kinesthetic modality into a sound and video domain. These gestures allowed for the broadest range of perceivable changes for the swing performer and provided the most sense of physical agency on the instrument.

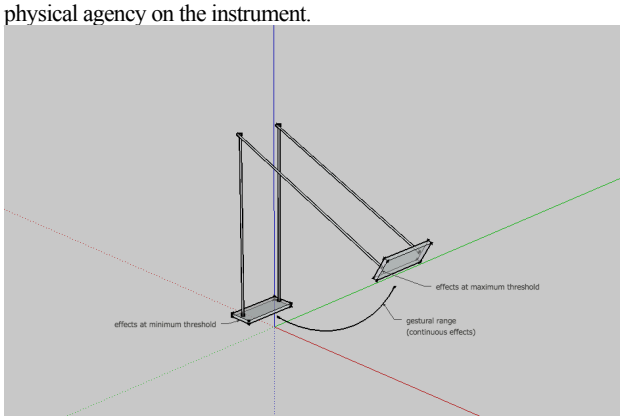

Figure 5. Gesture type: Default - conventional forward and backward swing motion.

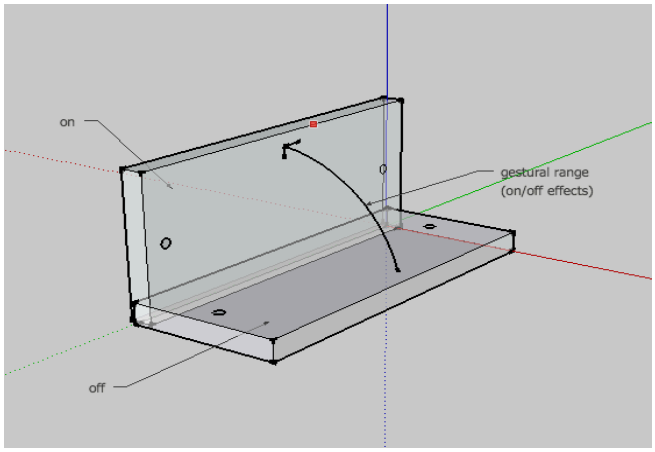

Figure 6. Gesture type: Flip.

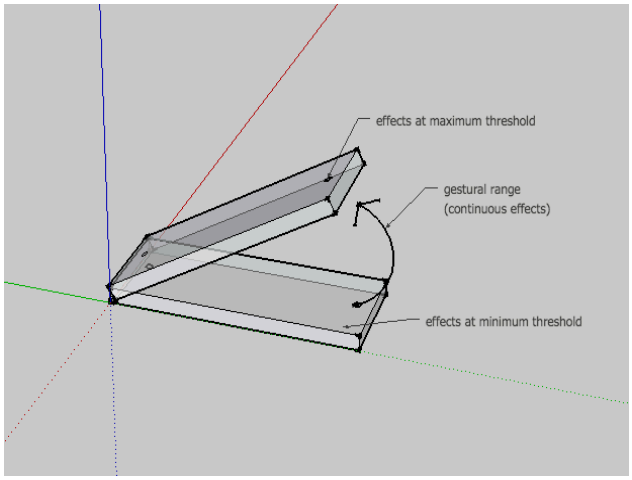

Figure 7. Gesture type: Side lift.

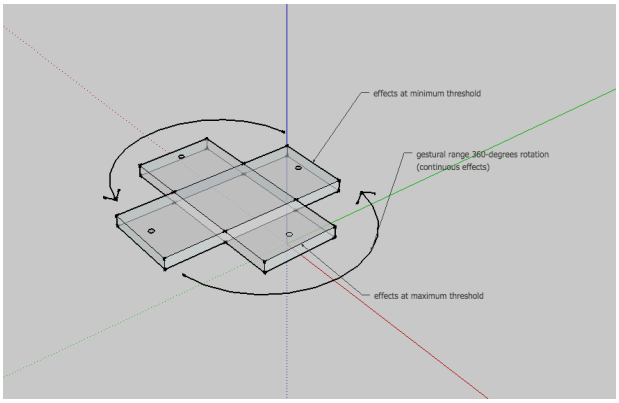

Figure 8. Gesture type: Spin.

4.2 Musical Composition

The concert presentation of this environment involved real-time processing of the in-performance sounds of cello, clarinet, tabla, and bansuri, with the control of the audio and visual media by the choreography developed using the varying gestures within the lexicon.

Mapping of gesture types with audio/visual processes (Table 1) were chosen to create intuitive usability analogous to other instruments' performance designs. For instance, the increase in pitch of a bell sequence (outputted by the swing - refer to Figure 5 for default gesture type) is similar to performing a string instrument - as a hand plays up the neck of the instrument, the pitch increases. This logic was also applied to the mapping of pitch shift and increase in the dry/wet mix of delay. Similarly, the spatialization effect was mapped to the spin gesture because the spinning motion of the swing seat reflected the way sound traveled around the four speakers.

Table 1. Gesture types and their corresponding audio/visual processes.

Gesture Type	A/V Processes
(1) Default	Increasing pitch and rate of a bell sequence; Increasing visual effects threshold; Increasing dry/wet of delay for cello.
(2) Flip	Single bells - triggering bell on/off sequence; Clarinet - increasing/decreasing granulation length.
(3) Side lift	Increasing (right side) and decreasing (left side) ring modulator frequency.
(4) Spin	Spatialization of tabla sound through four speakers.

One element that aided the coordination of the performance was that the musical composition was written in free sections. Each section would consist of a figure, texture or role assignment (e.g. clarinet solo) for each player. This allowed the performers to have more freedom to improvise within the given materials, resulting in successful coordination because the timing of each section could be made very flexible. This meant that the swing performer was able to fully explore the gestural lexicon and space of each section without the concern for strict timing. This also meant that in the event of a technical difficulty (e.g. recalibration mishap, loss of connection to a sensor) that the section could be bypassed and driven forward without any noticeable technological hindrances. Since the piece contained freely improvised structures, the musicians were not fixated on the musical score, allowing them to maintain eye contact with the rest of the ensemble. This facilitated in effectively communicating cues, technical problems and other vital information during the performance.

4.3 Choreography Development

The objective was to develop new innovative ways to interact with the swing beyond conventional forward and backward seated swinging motions. Dance phrases were developed using different body parts including the back of hands, arms, thighs, and abdomen as contact points to trigger different gestures for the swing seat. Audio/visual processes were generated through intuitive dance phrases that produced the best range of data while performing compelling gestures.

A choreographer was consulted to develop performance choreography based on the lexicon of performance gestures. Choreographer Ralph Escamillian explained his process working with the swing, "I was interested in the surface of the swing seat and what bodily contact points could be used, and analyzing the swing's physical features such as how long the ropes were and how much distance the swing is from the ground. How would I partner with the swing if it were a body? How does weight work when partnering? Partnering is using all parts of the body...If the swing seat were a torso, I could lift it with my knee" [5]. (Figure 9)

Figure 9. Swing performer executing the side lift gesture.

Figure 10. Swing performer executing the default gesture.

Figure 11. Swing performer executing the spin gesture.

5. OBSERVATIONS AND IMPLEMENTATION CHALLENGES

5.1 Observations from Pendula as an Installation

Pendula was installed adjacent to the Downtown Jazz Weekend's main stage during the TD Vancouver International Jazz Festival. It took place in a high traffic area, which garnered a considerable amount of interest and participation from festival attendees. The Pendula performance composition took place at the top of each hour, which assisted with inviting the audience to participate in the public installation. A line-up started forming 15-minutes prior to each performance outside the tent, and attendance exceeded the capacity of the tent (full capacity is approx. 30 people) for each performance., with a total of approximately 200 attendees in total. Prior to each performance, a brief introduction about the function of the swings was presented. During each performance, there were numerous body and facial reactions witnessed from the audience that suggested and inferred their awareness of the swing's interactive functions within the composition.

Many different interaction approaches and reactions were witnessed during the public installation. Some participants were aware of the audio and video interactivity of the installation and would test out each swing to determine their functions; some participants were more interested in enjoying the swing in its conventional context - to swing high as possible or simply to sit on; some participants were interested in the interactivity but did not feel comfortable sitting on the swing in front of other people; some participants expressed their lack of understanding of the interactivity of the swinging motions.

Although many audience members understood the cause and effect relationships of the swing instrument, they did not imitate the choreographed movements exhibited by the swing performer; they still interacted with the swing in its conventional way, by sitting and rocking back and forth, during the public installation.

5.2 Implementation Challenges

5.2.1 Environmental Interference

There were numerous production limitations and environmental interferences that clouded the coherency of the installation. Due to its location in a busy, high traffic area, Pendula was competing with urban ambient sounds in addition to musical performances from a large-scale performance stage. As a result, participants could not always comprehend the aural component of the installation and performance. Since the festival took place during the summer, daylight interfered with the visual projections, notably the projection closest to the tent opening. The windy weather conditions also caused disturbances during the installation resulting in the tent shifting from its position. The tent was built on ground covered in mulch that added to the playground aesthetics but interfered with the air quality within the tent.

5.2.2 Structural Safety

Since the swing set structure was not secured into the ground, safety reminders were communicated to participants who exhibited dangerous behaviors on the swings (e.g. standing on the seat or swinging with enough force to shift the structure).

6. FUTURE DESIGN GOALS

Future design goals for Pendula seek to incorporate new software, hardware, research and structural designs for new environmental contexts. Software goals include creating a self-contained system that can operate both the audio/video softwares without noticeable latency. Hardware goals include developing a wireless system reducing wiring obstructions and distance limitations that would allow for more installation freedom in a physical environment. Research goals would include creating a new experimental design method which would incorporate a user survey to analyze the synchronization between the three swings and the user's' subsequent experiences. The survey would also ask participants questions about their awareness and interpretation of the audio and video content. Structural goals include designing a physical environment that can accommodate more than three swings and to explore different swing designs such as tire swings. This would aid in further developing new gesture types to add to the pre-existing lexicon, and provide new opportunities to explore different composition styles and performance techniques for the swing instrument. To improve overall aesthetics and audio/visual coherency for participants and performers, Pendula could be installed in more environmentally appropriate spaces with less light, sound and weather interferences.

7. CONCLUSION

The objective of Pendula was to create a novel performance and public interactive installation employing swings, interactive video and audio in an immersive environment. A tracking system was developed to account for varying movement types. This consisted of analyzing gyroscopic and accelerometer data of each swing seat and programming corresponding electronic audio and video processes. A lexicon of performance gestures was created through discovering new ways to interact with the swings. A multimedia composition emerged through this research comprising of an improvisatory piece that explored the relationships between traditional instruments and the newly invented swing instrument. Through their rhythmic motions, Pendula created a social environment for participants to sway in a digital breeze of projection and sound.

Despite various challenges encountered during Pendula's installation, Pendula did succeed in capturing festival attendee's attention and curiosity. By utilizing a familiar artefact, participants were able to play within the installation environment without the need for instructions. This was achieved by connecting everyday people with everyday objects in new contexts through an inhabitable synthesis of technology, movement, and social space generating an installation that participants both occupy and co-create.

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