JUGGLING SOUNDS

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ABSTRACT

In this paper we describe JUGGLING SOUNDS, a system for realtime auditory monitoring of juggling patterns. We explain different approaches to gain insight into the movements, and possible applications in both training and juggling performance of single-juggler patterns. Furthermore, we report first impressions and experiences gained in a performance and its preparation, which took place in the CUBE at the Institute of Electronic Music (IEM), Graz.

1. MOTIVATION

Juggling is a complex artistic task. Obviously, this is due to the difficulty of throwing and catching several (possibly different) objects in an aesthetical manner. In order to master this complexity the juggler needs to develop automatisms. These allow her to spend less attention on the particular single throws, and instead focussing on more complex structures, i.e. patterns, and the process of switching between them. Training situations in particular require that the artists monitor their juggling movements in order to achieve a reasonable level in both, technical and aesthetical terms. This is the case, especially when precision and hand to hand symmetry has to be trained.

The JUGGLING SOUNDS setup aims at supporting such training situations as well as the actual performances by reflecting the motions of juggling clubs in realtime using spatialized sounds surrounding the artist and –in a performance– the audience, too. In order to ensure that the sonification covers as much of the available information of the juggling performance as is needed, the system uses both direct mappings of low-level feature-streams and detected events for the sound synthesis.

In Section 2 we describe general approaches to design auditory displays for realtime analysis, and focus on the application of juggling. Section 3 gives an overview of the used hardware and software setup, whereas Section 4 describes the currently used features and their sonification in relation to the juggling movements. Section 5 covers the sound design, followed by the conclusion, giving a first insight into results and observations made and describing future directions of research.

Figure 1: During the JUGGLING SOUNDS Performance

2. BACKGROUND AND DESIGN GUIDELINES

Many approaches for realtime monitoring by sonification of data streams have been developed: While some of them use semantically driven approaches where specific knowledge about the data is used to compute rather complex features [1], others tend to use simple, more arbitrarily chosen mappings to popular soundscapes, often as an amusement for the audience at public places, e.g. [2]. Rather simple and direct mappings in a scientific context where introduced in the sonification of human arm swinging [3] which uses using vocal sounds or the EMG sonifications as presented in [4]. Also, [5] have done a realtime monitoring of a virtual ball to be caught interactively.

In this section we want to give a background for the decision that we designed JUGGLING SOUNDS as a monitoring environment trying to exhaust the possibilities of quantitative audio displays combined with low-level event-based features. Therefore we first give an introduction to *juggling* and the related *swinging*, especially focussing on aspects that are interesting to monitor.

Juggling in general is the art of throwing and catching objects. Against the common sense it is not only a circus and performance art, but borrows aspects of dance, game, sports and even meditation. The way the juggler is throwing completely determines the object's motion in air-time, i.e. their trajectories and rotations simply follow the laws of gravity and inertia in free falling. If we look on the ratio of the time the objects held in the hand versus the time they are in the air we encounter something like 2.3 : 1.

In swinging only two objects (usually clubs or pois) are used. They more or less stay connected to the hand of the juggler. Juggling and swinging can't be separated that strictly, since swinging moves are used in juggling with the clubs in the hand as well as throws are used in swinging routines. However, swinging movements are normally closer to dance movements; the requisites can be influenced at any time since they have always contact to the juggler. Nevertheless monitoring of ambidextrous symmetry is of high interest in swinging patterns as their aesthetic impression drastically depend upon exact symmetry in movements.

To improve ambidextrous symmetry and precision in throw time and throw height, respectively swinging patterns, video analysis is a common practice. This method however only provides its additional information after the performance, since it is impossible for the artist to anticipate additional optical information while juggling. Fortunately, juggling and swinging does not make any sound apart from the noises made by catching the clubs, so this modality is not used by the artist. We propose an auditive display as a system for direct feedback in realtime on the precision and symmetry of artistic patterns allowing a direct feedback loop for the juggler respectively the audience.

2.1. Categorization of the System

The presented system called JUGGLING SOUNDS can be used in the following fields:

Exploration

Possibly a better understanding of the dynamics in juggling can be achieved. JUGGLING SOUNDS may be used as a monitoring-tool for the artist: *what am I right now doing right/wrong in terms of timing?* This results in a closed-loop control system.

Monitoring

The artist is able to monitor moves for learning purposes, whereas the audience gets a deeper insight into the performance. JUGGLING SOUNDS may also be used as a juggling display for blind people, whether they are involved as part of the audience or as juggling artists.

Art

JUGGLING SOUNDS may heighten the awareness for details of movements and motions. It displays additional information of what is happening for jugglers as well as for non-jugglers. And, last but not least, juggling to juggling-controlled sound can be enriching and enjoyable for both audience and performer.

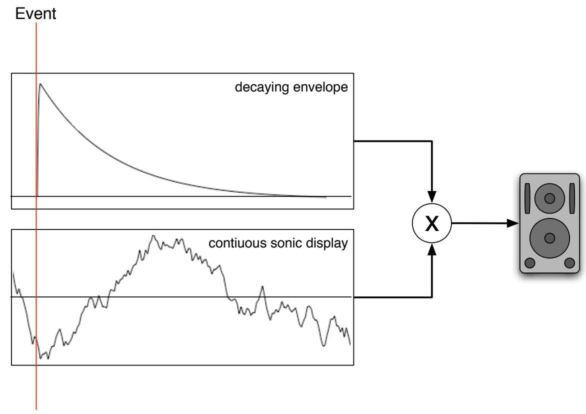

Figure 2: The sonification strategy mostly used in JUGGLING SOUNDS.

2.2. Systematics of realtime display types

Approaches to realtime monitoring of motions may be found between the extremes of (a) strict *full analysis, then displaying the results* (cf. to as qualitative display) and (b) displaying raw data in simple forms (cf. to as quantitative display). While detailed analysis provides an appropriate view on already known features, by definition it does not allow to find unexpected or even unknown patterns or structures. Data analysis always requires one to know what to search for. Additionally, analysis heavily relies on the quality of its models used to determine the known patterns. Resulting exploration systems often use relatively simple displays with predefined sets of qualities; in sonification this often leads to auditory icons, mapping arbitrary sounds (in the sense that their sounds are not directly data-driven) to events triggered by the analysis system.

In contrast, a direct mapping of given features –concerning juggling this would be the position, orientation or velocity of the clubs– provides a direct feedback. Here, analysis of the displayed data is shifted from machine-powered analysis to the pattern-recognition abilities of the human listener, who may or may not find structural information like the ones described in the full analysis approach, but also is able to unveil new, otherwise not found relationships and structures. Key factors in designing this type of exploration system is the decision for (a) the mapping between data-dimensions and sonification parameters and (b) the used sounds.

During development of JUGGLING SOUNDS we found that a direct mapping is necessary to get reasonable infor-

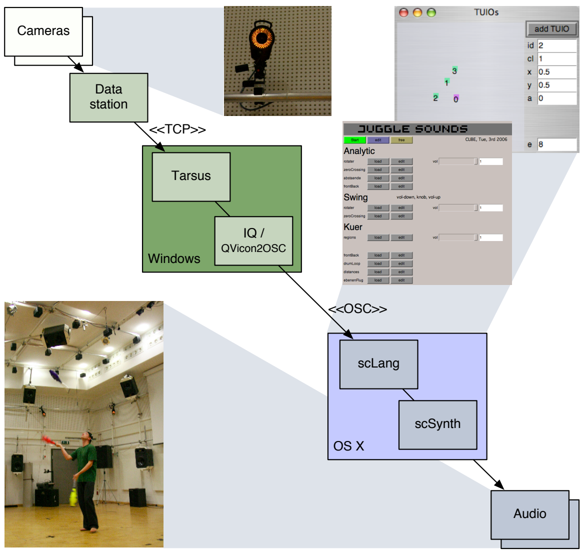

Figure 3: The JUGGLING SOUNDS setup. Sata is captured by a commercial motion tracking software, whereas the sonification is done via a customized TUIO server based on SuperCollider.

mation on the juggling process. Especially the realtime constraints of JUGGLING SOUNDS limit the possiblities, since a proper analysis would be too expensive by means of computational power. Nevertheless we noticed that a simple mapping of the incoming low-level streams results in uninteresting to boring sounds and an overloaded soundscape. We think that this is due to the fact that most of the time the motions of the clubs are deterministic and regular. By combining the data streams with relatively low-level events, calculated out of the data, we managed this difficulty in a reasonable way. Fig. 2 shows a schematic diagram of this approach.

3. SETUP

The JUGGLING SOUNDS environment consists of two parts, data acquisition via motion tracking and sonification via customized TUIO server as shown in Fig. 3.

For tracking the motion of the clubs in real-time, a state-of-the-art optical motion capture system produced by the Vicon company [6] and installed at the IEM CUBE was used. Such systems are tailored towards applications in animation, biomechanics, and engineering. They use infrared high-speed high-resolution cameras to record the positions of lightweight reflective markers via triangulation. Such a system can compute the position and orientation of objects defined by a set of markers in realtime using inverse kinematics. Although designed for full-body 3D motion capture, the systems can also track objects defining rigid bodies in six degrees of freedom (6-DOF). For the system, rigid bodies are configurations of markers whose relative positions do not change. Therefore we attached nine lightweight markers in irregular and different patterns to each club. Also, five markers were placed on the juggler's head via a headband. Once the rigid bodies defining the clubs and the head were presented to the system in a calibration step, their position and orientation could be obtained. In order to reduce the jitter of the position data, a predictive filter (Kalman filter) built into the Tarsus server has been used when tracking the clubs.

The tracking system itself consists of 6 cameras, a data station and a PC running the Vicon iQ 2.0 software as well as the server application called *Tarsus* connecting to the data station via Ethernet. The Tarsus server is controlled by the iQ software, which allows for server configuration, data management and realtime visualization of all tracking operations. The tracking data was read from the Tarsus server and translated into OSC messages [7] by QVicon2OSC (developed at IEM [8]), and then sent at 120Hz to the actual application written in SuperCollider3 and inSETO, the SuperCollider Environment for Tangible Objects [9, 10] running on a separate computer. Here the object management and sonification rendering takes place.

4. SONIFICATIONS

For motion display we decided to use several different display styles which all follow the same guideline of direct mapping, but emphasize different parts of the juggling procedure. The juggling features used however remain the same.

We use the following rather simple motion features for the juggling sounds system:

Streamed (realtime, 120Hz)

- rotation velocity around a flipping axis
- distance of club to head
- club's position wrt. room
- club's position wrt. jugglers head
- club's position wrt. jugglers position and orientation (parallel to ground)

Events/States

- club crosses a horizontal plane
- club crosses coronal plane (behind/in front of head)
- club crosses lateral plane (left/right of head)

To respect the different motions respectively meanings of juggling and swinging we also designed sonifications for them in different ways. The next subsections explain and distinguish them from each other by giving a short description and substantiation.

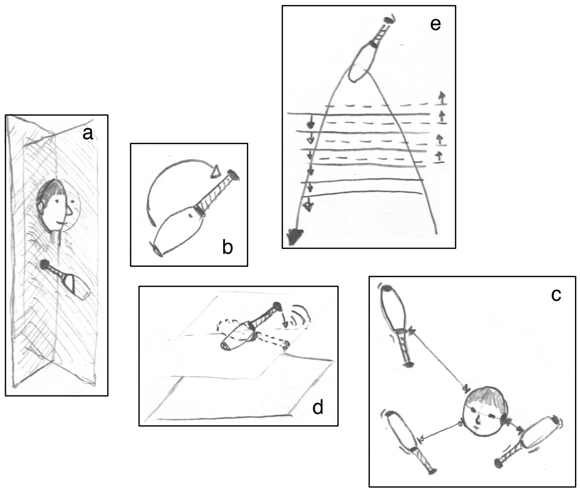

Figure 4: Used Sonifications: (a) Left-Right Triggers, (b) Rotation, (c) Distance to Head, (d) Rotation Trigger, (e) Horizontal Planes.

4.1. The Sonification Designs for Juggling

Rotation While the rotation speed of the clubs controls the frequency of a grain train, each grain's pitch is directly coupled to the height of the clubs. This emphasizes possible symmetries in the juggler's motion: Similar rotation speeds will create similar grain rates, and similar heights will produce similar pitch maxima in the respective streams.

Rotation Trigger Every full rotation cycle of a club triggers a sound, whose resonant pitch is determined by its distance to the ground. Note that adjusting the decay of the grain implicitly shows/ hides more or less information on the club's height change (read velocity). Since the sound is triggered when the club's rotational axis is at a specific angle (e.g. parallel to the floor), the timing pattern of identical angles for the different clubs is audible, and the juggler can get a clear impression of her throwing accuracy.

Distances to the Head This sonification captures and mediates much of the inherent dynamics in juggling. Each juggling pattern creates its own characteristic sound pattern.

Left-Right Trigger Each crossing of a club through the lateral plane triggers a sound whose pitch is directly coupled to the club's height above the ground, and differs depending on its position in front of or behind the head.

Trigger at Horizontal Layers We designed a discrete level indicator by placing several virtual horizontal planes in the air at equidistant heights, and linking each one to a differently pitched sound. Each crossing of a club results in a small sound grain which is different on the way up and down.

4.2. The Sonification Designs for Swinging

Rotation Here, essentially the same mapping as in the corresponding juggle sonification enables the artist to experience the amount of synchronicity in motion as well as the differences in height of the triggering points.

Rotation Trigger Especially tricks like the counterrotating clubs in front of the body or the 1-5-Circle may be monitored concerning their accuracy in execution for training purposes.

To get an insight into the above described sonification approaches consult the example videos provided at [11].

5. SOUND DESIGN

We aimed for clarity of individual components in order to allow for layering; both to allow richer monitoring and more interesting soundscapes for artistic purposes.

Apart from the maxims described in Section 2 we tried to use sparse sound representations. E.g. mapping the rotation angle onto the frequency of a continuous tone covers much of the time, and is hard to locate spatially, whereas the mapping of the rotation onto a sound's grain rate as in the Rotation Sonification creates an effect similar to bicycle spokes; there is still space for other sounds; e.g. of the other clubs. In addition this implicitly results in the welcomed behavior that faster rotations map to faster grain rates and no rotation does not lead to any grain triggering. This preserves a natural zero.

We used the 24-speaker setup of the IEM CUBE for spatialization of all sounds according to the relative position of the clubs to the head of the juggling artist. By doing so, the different sound sources declutter; the display gets much clearer.

6. INTERACTION EXAMPLES

At [11] we provide seven different videos of interaction examples using the different sonifications introduced in Section 4. All videos feature the second author as juggling artist.

Example 1 shows the artist juggling three clubs feeding the Rotation Sonification. Different patterns are juggled; especially different club-turnings are interesting to experience.

In Example 2 the same moves as shown in the first example are performed. Here the Rotation-Trigger Sonification gives a nice insight into timing accuracy as well as height differences. This impression will even be deepened while watching Example 4 and 5, showing the artist swinging different patterns.

Most of the juggling dynamics is covered in the third Example where the distance to the head is sonified. Like all other described sonifications, this one profits particularly from the spatialization of the sounds specific to the clubs. Only this way it is possible to distinguish between them in the performance.

Example 7 shows an extract of the performance where four different sonifications are distributed into four regions. These contain Trigger at Vertical Layers (rear-right) and Left-Right Trigger (front-right). Here it is easy even for a spectator to deiscern the throwing height as well as the position.

7. CONCLUSION

We introduced a new approach for auditory monitoring of realtime data acquired by motion tracking of juggling clubs. After a qualitative analysis of the juggling environment we proposed to use a mixed sonification approach with low-level data streams as well as trigger events in order to take only the interesting parts of the data streams into the sonifications. We reported the design decisions made regarding the sounds used and described first results shown in interaction examples recorded at a JUGGLING SOUNDS performance in October 2006 at the CUBE, IEM.

Apart from the results covered in detail in this paper we got various other insights during the design and development of JUGGLING SOUNDS. These are among others:

- The sampling rate of the tracking system has to be high; more then 100Hz are necessary for smooth latency-free experience.
- Spatialization is easy to understand and helps to de-clutter sound sources.
- Juggling is a deterministic motion most of the time; the artist is only able to change the pattern and its resulting sound at the rather short contact-time.
- Swinging may be more interesting regarding the obtainable sound complexity.
- Different sounds for different clubs are irritating (but perhaps interesting when one learns them).
- Offline development of sounds without someone juggling live is nearly impossible. There is almost at any time the need to discuss the results with the juggler and his comment on how this particular sound *feels*.

In the near future we plan to extend the system by additional features, e.g. the moment of catching and the moment of throwing in order to get more interesting triggers for sound events, and to differentiate better between the specific juggling rythms. We also want to extend the system for using it with other juggling objects like devil-stick, diabolo or juggling-balls. The practice of juggling shows that club-swinging is an attractive field to work on realtime sonifications because the air-time is limited, and therefore the club's dynamics is greater than it is in normal juggling.

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9. REFERENCES

[1] Thomas Hermann, Gerold Baier, Ulrich Stephani, and Helge Ritter, "Vocal sonification of pathologic eeg features," in *Proceedings of the International Conference on Auditory Display (ICAD 2006)*, Tony Stockman et al., Ed., London, UK, 6 2006, International Community for Auditory Display (ICAD), pp. 158–163, Department of Computer Science, Queen Mary, University of London.

[2] B. N. Walker, M. T. Godfrey, J. E. Orlosky, C. Bruce, and J. Sanford, "Aquarium sonification: Soundscapes for accessible dynamic informal learning environments," in *Proceedings of the 12th International Conference on Auditory Display*, June 2006, pp. 238–241.

[3] Jonathan Berger Max Kleimann-Weiner, "The sound of one arm swinging: A model for multidimensional auditory display of physical motion," in *Proceedings of the 12th International Conference on Auditory Display*. ICAD, June 2006, pp. 278–280.

[4] Andy Hunt and Sandra Pauletto, "The sonification of emg data," in *Proceedings of the International Conference on Auditory Display (ICAD)*, London, UK, 2006.

[5] Thomas Hermann, Oliver Höner, and Helge Ritter, "Acoumotion - an interactive sonification system for acoustic motion control," in *Proc Int. Gesture Workshop GW 2005*. GW 2005, May 2005, Springer, submitted.

[6] "Vicon company," URL, 2006, `http://www.vicon.com`.

[7] M. Wright, A. Freed, and A. Momeni, "Opensound control: State of the art 2003," in *Proceedings of the 2003 Conference on New Interfaces for Musical Expression (NIME-03), Montreal, Canada*. NIME, 2003, pp. 153–159.

[8] Christopher Frauenberger and Johannes Zmoelnig, "QVicon2OSC," URL, `http://sonenvir.at/downloads/qvicon2osc/`.

[9] "Supercollider hub," URL, July 2004, `http://supercollider.sourceforge.net/`.

[10] Till Bovermann, "Tuio homepage," URL, 2006, `http://tuio.lfsaw.de/`.

[11] T. Bovermann, A. de Campo, J. Groten, and Gerhard Eckel, "Interaction examples for juggling sounds," URL, Janurary 2007, `http://sonenvir.at/downloads/juggling/`.