MICON A Music Stand for Interactive Conducting

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ABSTRACT

The MICON is an electronic music stand extending *Maestro!,* the latest in a series of interactive conducting exhibits that use real orchestral audio and video recordings. The MICON uses OpenGL-based rendering to display and animate score pages with a high degree of realism. It offers three different score display formats to match the user's level of expertise. A real-time animated visual cueing system helps users with their conducting. The MICON has been evaluated with music students.

Keywords
Music stand, score display, exhibit, conducting.

1. INTRODUCTION

Conducting is a well-established and rich metaphor when interacting with a musical body such as an orchestra. Some people even enjoy conducting alongside a classical recording at home. *Personal Orchestra* [3], an interactive exhibit for public spaces, was the first system to let museum visitors actually control tempo and volume of an audiovisual recording via conducting gestures.

Visitors can also emphasize an instrument section by conducting towards it. This gives visitors, albeit limited, opportunity to change the musical expression and play a more active part. *Personal Orchestra* has been an exhibit at the HOUSE OF MUSIC VIENNA since 2000 [3]. Two follow-up systems with new gesture recognition and audio time-stretching algorithms have been developed since: *You're The Conductor* opened at the Children's Museum Boston in 2003 [6], and the latest, *Maestro!,* at the Betty Brinn Children's Museum in Milwaukee in 2006 [7,8].

These exhibits provide a previously unavailable interaction to people who are not professional conductors: the experience of conducting an orchestra. To make this experience more realistic, we wanted to provide the visitor with a music stand as an extension to *Maestro!*. To this end, the MICON (**M**usic Stand for **I**nteractive **Con**ducting Systems) was created.

Figure 1. A visitor conducting the Vienna Philharmonic in the *Personal Orchestra* exhibit at the HOUSE OF MUSIC VIENNA (http://www.hdm.at). The music stands were still merely decorative here.

2. DESIGN CONSIDERATIONS
The functional goals of the MICON were:

- To display the musical score to *Maestro!* visitors while they are conducting, and

- To indicate the current position in the score and automatically advance the pages following the music, to help visitors with their conducting.

The key constraints in creating the MICON were:

- **Production quality.** Since the *Maestro!* system featured professional orchestras, its look and feel had to fulfill high standards to be accepted by the museum and orchestra in question. The MICON had to look and behave as professional as the rest of the exhibit, which required excellent visual quality of the score display and fluid, non-distracting interaction with it.

- **Visitor profile.** Typical visitors using the system would be one-time users with a short dwelling time. The system had to provide for this through a particularly simple, self-explanatory, and obvious interface that required little or no interaction apart from the conducting itself.

- **Musical knowledge.** Some visitors might be amateur or even professional conductors, but most would have no prior experience in conducting. The MICON had to provide these beginners with alternatives to the complexity of a full orchestral score document. Hopefully, by interacting with the system, visitors would learn a little

more about conducting and experience some of its challenges and rewards.

- **Listener architecture.** The MICON had to extend the *Maestro!* system; to minimize dependencies between these two co-evolving projects, their communication interface had to be kept as narrow as possible, with the MICON essentially listening to the timing information that was already being generated by the *Maestro!* gesture recognition engine.

Additional guidelines for interactive music exhibits that we followed in this design can be found in [2].

3. RELATED WORK

There has been a wealth of research aimed at recognizing conducting gestures, which we will not cover here as it is not the focus of this paper. Similarly, a variety of systems have been developed previously that offer a more or less "complete" conducting experience—often limited to audio or video only, and frequently using synthetic (MIDI or VRML, for example) data as opposed to real audio and video material for playback. We refer the interested reader to [5] and [7] for a more detailed overview.

MOODS (Music Object Oriented Distributed System) is a synchronous real-time cooperative editor for music scores [1]: Every change is immediately made visible to all users. It is intended for orchestra musicians during rehearsal. MOODS consists of different types of lecterns for the instrumentalists, the conductor, and the orchestra's archivist. Editing in MOODS is based on different permissions for these groups. MOODS supports semiautomatic page-turning. The score on the instrumentalists' lecterns is separated horizontally; the page that is currently being played is shown below a separator, the following page appears above it. As the music advances, the separator moves downwards. The score on the conductor's and archivist's lectern is separated vertically between the current and next page. MOODS assumes a constant tempo for a piece; tempo variations have to be adjusted manually by a human operator during the performance, making it unsuitable for our purposes.

muse is a digital music stand for symphony orchestras [4]. It consists mainly of a portable display and a matching stand with integrated metronome and a pitch-generating tuner. It allows on-screen annotation and intrasymphonic wireless communication. Pages are turned automatically or manually. In automatic mode, an attached microphone captures the incoming sound, and the *muse* compares it against the score to turn pages at the appropriate moment. Instrumentalists load pieces from an archive over an encrypted connection to prevent copyright violation. *muse* was presented to the Pittsburgh Symphony Orchestra. However, it does not highlight the current score position, and its page-turning requires per-instrument microphones.

The commercial *eStand* (www.estandmusic.com) consists of a tablet PC and footswitch for manual page-turning. The system is optimized for low noise. The software displays the score, which has to be downloaded from the Internet or created with note-setting software. The musician can annotate the score with the provided pen. The eStand has a built-in metronome, tuning, music library management, and networked annotation sharing for ensembles. eStand does not highlight the current position in the score and does not advance the score automatically.
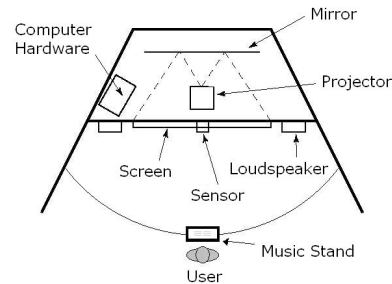

Figure 2. Typical conducting exhibit setup.

4. DESIGNING THE MICON

We will start with our envisioned usage scenario. Fig. 2 shows the layout of a typical conducting exhibit installation. The user stands in front of a large screen. Two loudspeakers are directed towards her. The computer hardware is hidden. In front of the user stands the music stand. A sensor tracks the baton and sends its position to the computer.

First, the user sees a list of music pieces on the large screen, points the baton towards the desired item and pushes the button on the baton. In the same way she selects the representation of the musical material on the music stand. She has three choices: full score, piano part score, or piano roll. In either case, the MICON shows the pulse notation at the top of the selected representation. After the selection, the orchestra appears, the user begins to conduct, and the orchestra starts playing, with the score display advancing automatically on the MICON.

A full score is an assembly of all the instruments' voices and the standard format that conductors use. There is a lot of information present in a full score: the notes for every instrument, dynamic markings, etc., and it requires very good music-reading skills. An extract of the full score for the piano is easier to read, as there are only two note systems, left hand and right hand. The piano-roll and the pulse notation do not require any score-reading abilities.

4.1 Score Animation and Highlighting

Fig. 3 shows the first page of the "Blue Danube" by Johann Strauss as it is presented on the MICON. The score is enhanced with additional information: An orange bar cursor marks the position of the music. While music plays, the cursor moves to the right. Above the cursor is a ball jumping up and down. This ball marks the beats in the music. The beats occur when the ball hits the "ground" (Fig. 4). The user can emphasize an instrument section by conducting towards it. This section is then highlighted on the music stand by coloring the corresponding lines red. The pages on the MICON do not have a flat appearance but are rendered more like naturally flexible paper. When the cursor reaches the last beat of the right page, the page lifts up (Fig. 5), turns (Fig. 6), and the next two pages become visible (Fig. 7).

When the cursor moves to another note system, it fades out smoothly. After it vanishes from the previous note system, it smoothly fades in at the new note system. The same happens to the jumping ball and the instrument group highlight during transition. When the jumping ball fades out completely at the end of the note system's last bar, it is located at the highest point of its trajectory. In the next note system the ball reappears at the highest point and moves downward while fading in (Fig. 8).
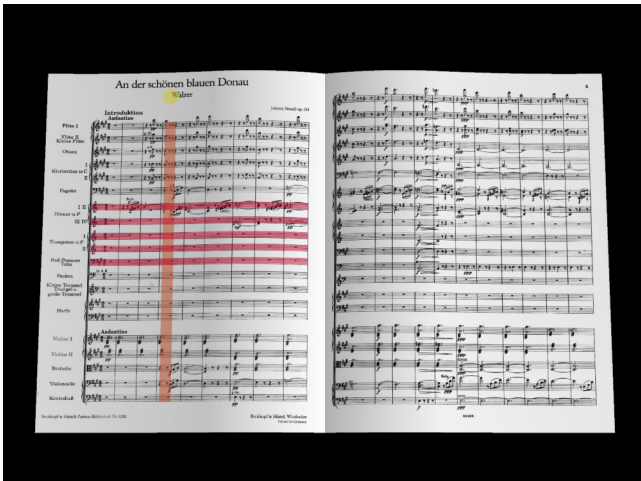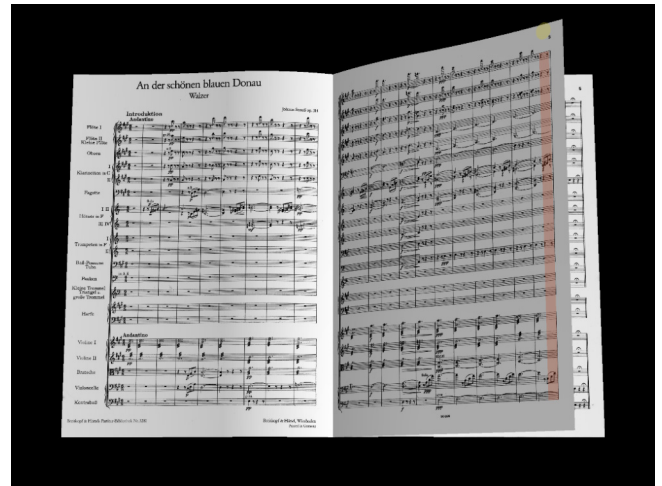
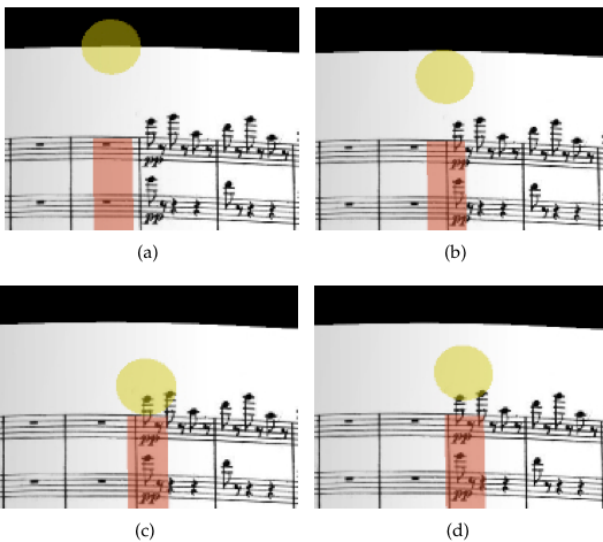**Figure 3. The "Blue Danube" on the music stand.**

Figure 5. Page turning begins.

**Figure 4. The jumping ball: (a) and (b) before the beat,
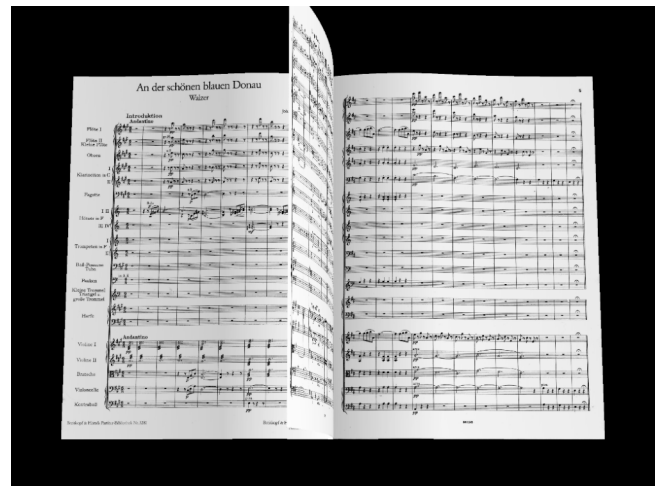(c) at the beat, (d) after the beat.**
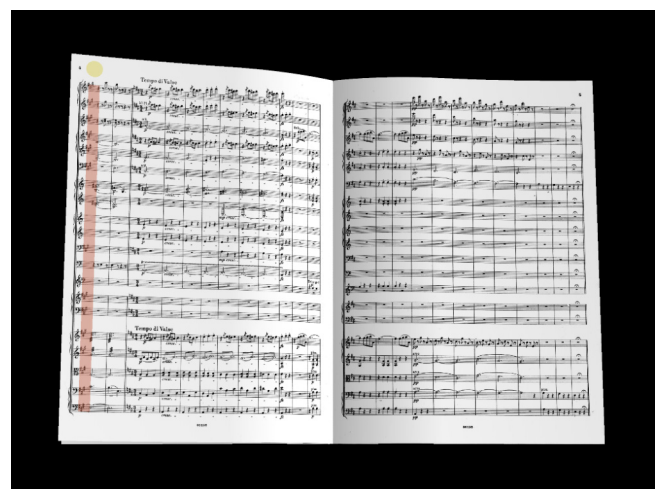

Figure 6. Page is halfway turned.

**Figure 7 Page turning ends. The bending behavior of the
page in the above panels aims to closely resemble physical
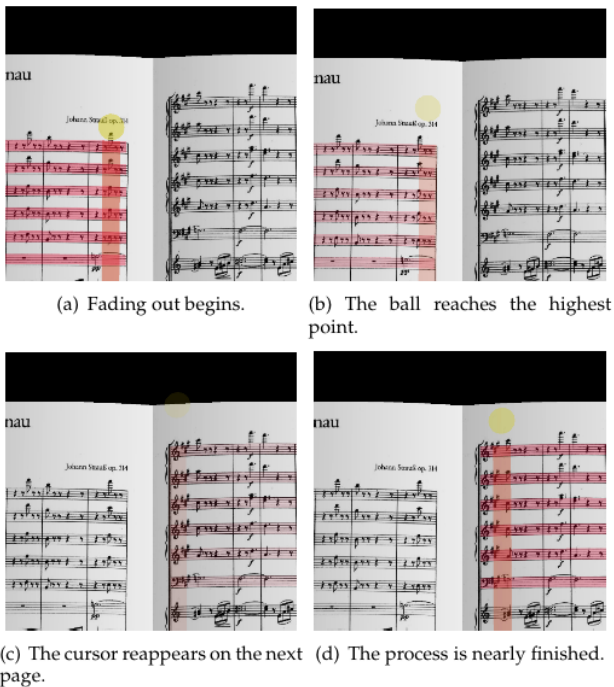paper.**

(a) Fading out begins.

(b) The ball reaches the highest point.

(c) The cursor reappears on the next page.

(d) The process is nearly finished.

Figure 8. The cursor moves to another note system.

4.2 Piano Roll Notation

The piano roll notation represents notes as boxes of uniform height. Box width represents the length of a note, the vertical position represents its pitch, and the horizontal position its onset time. Music software such as MIDI sequencers frequently uses piano roll notation to represent musical material, so that some users of the MICON may already be familiar with this notation. Fig. 9 shows the piano roll representation of bars 45–49 of the "Blue Danube" as it is presented on the MICON.

The notes that are currently played by the orchestra are in the center of the screen. In addition, they are highlighted in a brighter color. As time proceeds, the boxes move to the left, and the highlight moves to the following notes. The highlight moves rhythmically, mimicking the rhythm of the music. A user without prior experience with the piano roll notation can thus figure out the connection between this notation and the music.

4.3 Pulse

The pulse notation consists of circles representing the beats of the music. They are horizontally aligned. The more time there is between two beats, the longer is the distance between the two corresponding circles. Tempo changes lead to differing distances between the circles: the pulse notation outlines the tempo changes of the piece: It shows the metrical landscape of the music around the current beat, giving the user an indication of the recently passed and the upcoming tempo. Fig. 10 shows a metric landscape for a steady tempo, Fig. 11 shows a tempo decrease (ritardando).
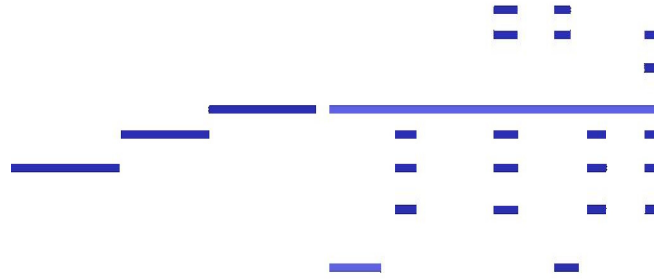

Figure 9. Bars 45–49 of the "Blue Danube" in piano roll notation. The beginning of the theme is still recognizable.

Figure 10. Steady tempo.

Figure 11. Tempo change (in a ritardando).

The circles move to the left as time proceeds. Coming from the right and approaching the center of the screen, they grow in size. Far from the center they grow only slowly, but as they approach the center, they grow at a higher rate. They reach their maximum size in the center of the screen, which marks the beat. Afterwards, they shrink again, first rapidly, then slowly, to their original size (Fig. 12, 13, and 14). Mathematically speaking, circle size is computed as the absolute value of a modified $1/x$ function, with $x=0$ at the center, and clipping the size to a maximum size at that point.
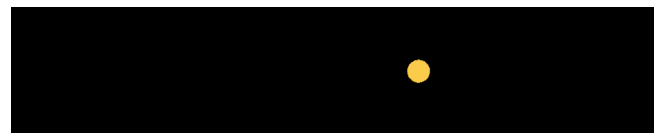

Figure 12. The circle approaches from the left (still original size).

Figure 13. The circle is in the center (maximal size). The beat occurs.

Figure 18. Circle in the middle barely visible. The other circles begins to move.

These animations are hard to describe on paper; therefore, we have created a screen capture that shows the system in use. See: http://media.informatik.rwth-aachen.de/micon.html.

5. IMPLEMENTATION

5.1 Preparing Music For The MICON

To add a music piece to the MICON requires to create four types of files:

- A MIDI file,
- A beats file,
- Page scans of the full score and the piano part, and
- ScoreInfo files for the full score and the piano part.

The piano roll and the recorded (digital audio) music have to be synchronized. Therefore, MIDI files were produced that closely resemble the tempo changes of the original recording. We created these files by playing alongside the orchestral recording on a MIDI keyboard and recording this performance to a MIDI file. Manual post-processing was done to correct minor errors and to achieve a better synchronization. In a second manual post-processing step, this synchronized MIDI file was refined under aesthetic considerations: The notes were quantized to a fixed raster and aligned so that notes belonging to a logical compound begin and end in the correct position. When, for example, a chord is played, the notes constituting the chord should all start and end at the same horizontal position. For *legato* passages, neighbouring notes should end respectively start at exactly the same horizontal position.

A beats file contains a list of time stamps indicating when each beat occurs in the orchestral recording. This allows the MICON to compute a mapping between the elapsed time (in seconds) and the position in the music (in beats). This mapping is required for the score and pulse representations. The beats file for a new piece can be created with *Midi2Beats*, a program we developed. *Midi2Beats* extracts the rhythm of a MIDI-file: Every *Note-On* in the MIDI file is stored as a beat event in the beats file. Therefore, a MIDI file has to be created that has exactly one *Note-On* on every beat. By deleting notes from and, sometimes, adding notes to the previously created MIDI file, it can be transformed into such a file. Using this file, the beats file is created using *MIDI2Beats*.

The ScoreInfo file provides graphical information about the score layout on the page. This is mainly:

- The *x/y* position of every beat,
- The position and extent of each note system and
- The position and extent of each instrument group on the score page (full score only).

We developed the *ScoreMarker* application (Fig. 19) to easily specify this information. First, the developer loads the graphical page scans into ScoreMarker. Using the mouse, he defines the note systems, beats and instrument groups in the score. *ScoreMarker* then creates the corresponding ScoreInfo file.
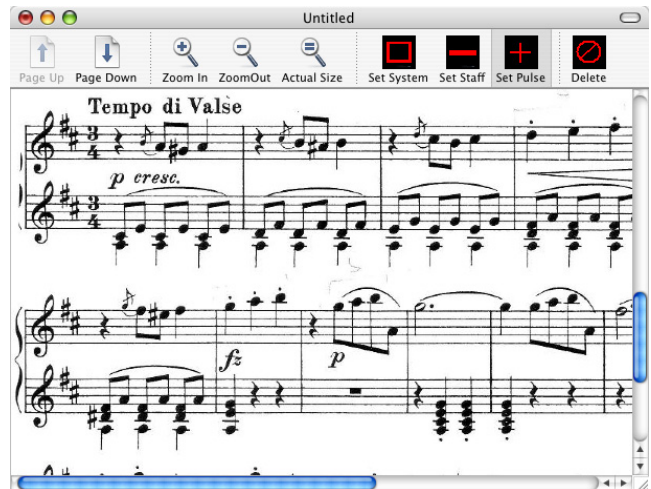
Figure 19. The *ScoreMarker* application.

5.2 Communication

Maestro! and the MICON communicate via a UDP-based protocol. Communication is one-way: *Maestro!* sends messages to the MICON which then updates its internal state. During the initial user selections, *Maestro!* informs the MICON about what piece and score representation the user chooses. During the piece, *Maestro!* continuously sends the current position in the piece to the MICON: every few seconds *Maestro!* sends the current instrument emphasis.

5.3 Rendering

MICON uses OpenGL for its graphical output and creates realistic-looking, curved score pages resembling physical paper more closely than a normal "flat" 2-D rendering would. Fig. 19 shows a curved score page. To create these pages, each page is sliced vertically into 100 equidistant pieces, which are then reconnected with their two neighbors to form the curved page. The angles between these neighboring slices were defined beforehand for several key frames of the page-turning animation. We experimentally chose values for these 99 inter-slice angles at each key frame. Rendering the slices for a given key frame is then straightforward: Starting at the origin, a slice is drawn along the *x* axis (the coordinate system is shown in Fig. 20). The origin is then translated along the *x* axis so that the origin now points to the right end of the drawn slice. Now, the origin is rotated around the *y* axis with the predefined angle, and the rendering of the next slice begins.
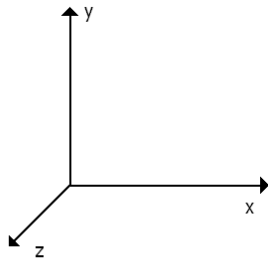
Figure 19. Score from the side.

Figure 20. Reference coordinate system for rendering the above page.

As the page turns, it changes its form: At the beginning (0°) and end (180°) of the page turn, the page has the "normal" shape shown in Fig. 19. In addition to these two key-frames, a configuration of the 99 angles was specified for a page turned 90 degrees. These angles were again chosen experimentally. For all other frames, the 99 inter-slice angles smoothly transition between these key frame configurations using linear interpolation.

6. EVALUATION

We tested advanced prototypes of the MICON and *Maestro!* with music students at the University for Music and Performing Arts ("Hochschule für Musik und Darstellende Kunst") in Frankfurt, Germany. The goal was to get feedback about the *Maestro!* system in general, and the MICON in particular. Ten students participated in the test: four pianists, four other instrumentalists (violinist, cellist, flautist, guitarist), and one composer.

Page turning speed originally only depended on the tempo of the music. It would start when the last beat of the right page was reached, and end with the first beat on the new page. When users conducted very slowly, this made page turning unnaturally slow, as two students criticized. MICON now completes page turning in two seconds maximum—or less if the tempo is above 30 bpm.

Many students were uncertain how to start conducting, for example, whether to conduct quarter or half notes. To help with this, the pulsating circle described in section 4.3 was added.

The students liked the appearance of MICON. Especially the curved pages and the animated page turning were appreciated.

7. SUMMARY

We presented the MICON, a music stand for *Maestro!,* an interactive conducting exhibit. The MICON displays musical material in various formats: full score, piano extract score, piano roll, and pulse notations. This enables a broad public to use the MICON, while still allowing expert music score readers

to benefit from their abilities. Several carefully designed animation techniques help users with their conducting. The MICON renders its output via OpenGL to create natural-looking curved pages and a realistic-looking page-turning mechanism. The MICON was tested successfully with music students, and their feedback incorporated into the final design.

8. FUTURE WORK

We intend to conduct more formal user studies to evaluate the MICON, and to make content creation less tedious. In particular, a (semi-) automatic way to create the piano roll MIDI files would greatly simplify this very time-consuming manual process.

9. ACKNOWLEDGEMENTS

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