WorldBeat: Designing a Baton-Based Interface for an Interactive Music Exhibit

Jan O. Borchers
Telecooperation Research Group
Department of Computer Science
Linz University, 4040 Linz, Austria
+43 732 2468 9888, +49 731 502 4235
jan@tk.uni-linz.ac.at
http://www.tk.uni-linz.ac.at/~jan/

ABSTRACT

This paper presents the interface design of the *WorldBeat* system, an interactive exhibit about using computers in musical education, and as musical instruments. The system allows even computer and music novices to create aesthetically pleasing music, using a new, consistent interaction technique: Visitors control the complete exhibit using two *infrared batons* as pointing device, conductor's baton, and musical instrument interface, making keyboard and mouse unnecessary.

The paper summarizes special requirements when designing computer-based exhibits, how we used batons as a new type of input device to meet those requirements, and how user feedback iteratively optimized the look and feel of the exhibit to convey its "message" in an understandable and visually appealing way. We show how our results contribute to "Looking to the Future" of HCI, and how they could be of general use to other researchers and practitioners designing user interfaces for interactive exhibits.

Keywords

interface design, interactive exhibit, baton, music, education

INTRODUCTION

In recent years, interactive, computer-based exhibits have been installed increasingly in museums and similar public places. Especially many "Technology Museums" [2] use such interactive systems to make today's and tomorrow's technology understandable to the broad public. Typically, however, the target user population of such installations has special knowledge neither in computing, nor in the specific subject area that the exhibit addresses. This puts special demands on HCI research and practice to create systems that convey their message to visitors quickly and easily.

The *WorldBeat* system described in this paper is a perfect example of those exhibits: It was designed for permanent display in the *Ars Electronica Center (AEC)* [6], a technology "museum of the future", and its goal was to demonstrate to visitors how computers can open up new ways to musical creativity, and musical education, regardless of the visitor's prior musical knowledge.

This scenario called for a new interface technology that would be easy to learn and use, and that was appropriate for a musical exhibit. We met those requirements by developing a software system that uses the input of two *infrared batons* to control the complete exhibit in a consistent way, from menu selection to playing instruments and conducting a piece of music. The system has been implemented completely, and has been used under real-world conditions by thousands of museum visitors. Many of them produced valuable feedback which we used to further improve the system in terms of attractiveness and usability.

Overview

The rest of this paper is organized as follows: **Background** summarizes the ideas and goals behind the *Ars Electronica Center (AEC)* and its *KnowledgeNet* floor where the *WorldBeat* exhibit is located, its required functionality, and a classification of the system. **User Interface Design Goals** lists user interface requirements for interactive exhibits in general, and for *WorldBeat* in particular. **Design Solution** presents our idea to solve this interaction design problem - using infrared batons, not only as musical controllers, but also to replace mouse and keyboard input. **Implementation** describes the system architecture, how the batons are used, and how we solved major software-engineering problems of this approach. **Evaluation** gives some examples of user feedback and improvements. Finally, **Conclusion** summarizes the "lessons learnt" that may be of general use to other designers of computer-based exhibits, and discusses how the design of the *WorldBeat* interface can contribute to "Looking to the Future" of HCI.

BACKGROUND

The *WorldBeat* exhibit is situated on the *KnowledgeNet* floor of the *Ars Electronica Center (AEC)*.

The Ars Electronica Center

The AEC is a "museum of the future" [6], demonstrating to the general public how information technology will change the way we live, work, learn, relax, and communicate in the next century. It has been opened in September 1996 in Linz,

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Austria. The AEC consists of five floors, each addressing a different aspect of life - from a 3D "Cave" in the basement that lets users experience virtual realities with a focus on entertainment and scientific visualization, to the "Sky Media Loft" café in the third floor with a focus on personal and Internet communication.

The KnowledgeNet Floor

The second floor is taken up by the *KnowledgeNet* environment, focusing on aspects of computer use in learning and working environments. It has been designed and equipped by our Telecooperation Research Group at Linz University. It consists of a *Class/Conference Room of the Future* [10] demonstrating the use of group support systems, teleconferencing technology, interactive whiteboards, etc., and an area with *WorldBeat* and other individual exhibits that deal with certain subject areas like new media, new user interfaces, or new learning approaches, in more depth.

The message we wanted to convey within this floor was that careful use of information technology can improve learning in three fundamental ways:

1. Learning can become a more *active* experience, because interactive systems can offer "learning by doing" for many problems.
2. It can become more *cooperative* as collaboration-aware systems begin to provide means to learn together, both locally and over distance.
3. It may become more *motivating* since adaptive hypermedia systems can present learning material in more interesting and individual ways.

Details of this approach can be found in [10]. It had a strong influence on the design of the *WorldBeat* user interface which would have to convey this message by demonstrating these improvements to the visitor.

The WorldBeat Exhibit

WorldBeat should be an exhibit that shows how computers can support learning about music by playing it. Our next step, then, was to decide on the functionality we wanted to offer to the visitor in order to reach this goal.

Functional Requirements

We agreed on the following set of *WorldBeat modules* that would each demonstrate a different aspect of computer use in music:

- The *Joy-Sticks* module allows the visitor to play different "virtual instruments" directly. It demonstrates how computers can be used to emulate traditional instruments, enhance them with new controls, or create new ones.
- The *Virtual Baton* module enables the visitor to conduct a piece of music. It shows that a computer system can play back a stored score while leaving (rhythmic and dynamic) control over the actual performance to the user.
- In the *Query By Humming* module, visitors hum the beginning of a song, and the computer locates the complete piece in its database. This demonstrates how computers can simulate human musical recognition processes.
- With the *Musical Memory* module, visitors can test how good they are at recognizing instruments through their sounds alone. It is an example of a game-like courseware to learn about music.
- In the *NetMusic* module, visitors can exchange compositions with partners over the network, or even play together with them online in special sessions. It demonstrates cooperative possibilities of computer-based learning environments.
- Finally, using the *Musical Design Patterns* module, users can change basic parameters of musical improvisation and performance, e.g., the "groove" (swing) in a Blues piece, and they can even improvise to the music without playing wrong notes. This module shows that computers can offer a completely new way of creating music that can be attractive and rewarding to all players, regardless of their prior musical knowledge and abilities.

A detailed description of all these modules would be beyond the scope of this paper; we will, however, describe later on how we made each module available to the visitor via an appropriate set of user interface metaphors.

Classification

For interactive systems in public spaces, or "kiosk systems", a classification has recently been proposed by the author [3] that distinguishes between four basic types, depending on their main *task.* Those types are *information, advertising, service,* and *entertainment* kiosks which each have different implications on user interface design guidelines, intended session duration, etc. In terms of this taxonomy, interactive exhibits like *WorldBeat* can be defined as entertainment kiosks, although with a certain information kiosk goal that is "wrapped" into the interactive, game-like experience. The implications of this classification are:

- The initial motivation to use the system is curiosity which the exhibit has to arouse through a visually appealing and interesting design, especially of the start page.
- The average time users spend at the exhibit should be *maximized* (within reasonable limits) so that they use the system long enough to pick up many of its "messages".
- The user interface has to be visually appealing *and* simple at the same time, a combination that often leads to design conflicts.

USER INTERFACE DESIGN GOALS

From the interaction designer's point of view, the problem now was to create a user interface for the *WorldBeat* exhibit with the following features and characteristics - we believe that our list applies to interactive exhibits in general, and that it can be of use when designing similar systems:

- *consistent:* Find a way so that the user can operate the complete exhibit with its diverse functions in a uniform way, ideally without having to change between different input devices;
- *innovative:* Exhibits have to attract passing visitors and "lure" them into explore the system. In a technology museum, an exhibit that features a standard computer, monitor, keyboard, and mouse will hardly appear exciting to the passing-by visitor. The *affordances* [11] of an

exhibit, the actions that its user interface suggests to the visitor, have to promise a new, unusual experience.

- *explorable:* As deduced from the classification as entertainment kiosk, once the user has started to examine the system more closely, the interface, especially the user guidance and navigation component, has to enable her or him to actively discover successive exhibit features, offering new, motivating experiences throughout the session.
- *intuitive:* Make the interaction principle easy to grasp and use. Of course, this is a requirement for any interactive system, but with exhibits it becomes crucial: If visitors who stop in passing by to explore the system do not get along with it right away, they will walk on and leave the exhibit alone. The statement that “Users Are Cruisers” [9] who will leave an information space quickly if unsatisfied with the presentation holds especially true for museum visitors. As mentioned in the kiosk classification, this goal often conflicts with the task to create an interesting, explorable environment.
- *comprehensible:* Even if the exhibit is explorable as stated above, a sense of *closedness* is important to provide the visitor with feedback when an exhibit feature has been successfully tried out, and a certain “message” of the exhibit has been delivered. If this closedness is missing, visitors will quickly lose track of the intended goal, and will not understand what the exhibit wanted to convey, leaving it behind to walk on to the next point of interest. In case of doubt this rule should dominate over the goal of an explorative interface: The best presentation of a message will be lost if the user got lost before reaching it.
- *non-technical:* In an already technology-oriented environment, like the AEC, technical-looking exhibits scare away visitors that are often computer novices. Especially an exhibit about music can provide a refreshing counterpoint in this environment if it manages to create a non-technical impression. This appearance can also stress our concern that computers should not dominate learning, but support it as creatively usable tools.
- *domain-appropriate:* An exhibit about music, for example, should ideally use devices and interface metaphors that closely resemble musical interaction of some sort, like playing or conducting.
- *ability-neutral:* The exhibit should be usable by visitors of all ages and abilities. This means that the devices have to be physically reachable and operatable also by small children and from wheelchairs, and that the required accuracy of operation has to be suitable for use with a range of motorical, aural and visual abilities as wide as possible.
- *exposable:* Exhibits in public spaces like museums put extreme demands on robustness, maintainability, and security. Whatever the devices used are, they have to be sufficiently rugged to survive sustained everyday use, including occasional accidents (like involuntarily banging them against each other, or against a desk), they have to minimize the learning effort and work load for the staff to keep the exhibit up and running, and they have to be secured against theft.

We extended these general design goals by items that reflect the specific messages we wanted to convey through the exhibit:

- *activity-oriented:* According to our message, computers should promote learning by doing. The interface can convey this if it lets the user become active from the start, not just conceptually, but also physically by requiring him or her to move and operate something, and by letting the user learn about music by playing it.
- *cooperative:* We also declared that information technology enables cooperative learning, both locally and over distance. Composing (offline cooperation) and playing (online cooperation) over the network is the subject of the *NetMusic* module in WorldBeat, but the local cooperative aspect, which is often underrepresented in exhibits, had to be stressed through interface design: Several functions of the exhibit are designed for use by two people simultaneously. This mode has to be made clear to visitors by creating specially marked groups of setups that can be used by two people. In fact, encouraging cooperative use should be a general design goal for exhibits.
- *fun:* The third part of our message was that learning could become a more enjoyable experience. This influenced not just our selection of generally “enjoyable” musical styles to play with, but also the interface design which includes metaphors to drum away on a set of percussion instruments, etc.

All design goals were taken into consideration when we developed the interaction principle for the WorldBeat exhibit that is presented in the next section.

DESIGN SOLUTION

After we had considered the various constraints put onto the WorldBeat user interface, we started to play around with different ideas on how it could be designed. We eliminated keyboard and mouse interaction as being too technical, conventional, inappropriate for music, and inconsistent with using musical devices. Furthermore, we found that textual input would not be necessary at all for the functionality we had in mind, so it would not be necessary to bother the visitor with a virtual on-screen keyboard at any time.

Looking into electronic instruments, we developed the idea to use some MIDI controller for user input and navigation. (MIDI, for Musical Instruments Digital Interface, is the standard format to describe musical information and exchange it between synthesizers, sequencers, and computers.) We first considered using an electronic *drum pad* (an array of touch sensitive fields to be played as electronic drums) whose shape would be reproduced on-screen. They have been used successfully by similar exhibits that only deal with drum-like input [14]. However, we abolished the idea because, even though such pads can in principle deliver continuous controller values, when operated by visitors with their hands, they can essentially only be used as an array of buttons. This meant that users would have had to control “sliders” for continuous values by pressing pads as “up” and “down” arrows - certainly not the most intuitive way to accomplish this type of input.

Finally, we came up with the central new idea of the WorldBeat user interface:

We decided to let the visitor *control the complete WorldBeat exhibit consistently using two infrared batons.* This integrates into one interface concept all major tasks occurring during interaction with the exhibit:

- *navigating* through the hierarchy of the WorldBeat system, choosing from selections, setting sliders, etc.;
- *playing* a number of virtual instruments;
- *conducting* pieces of music;
- *improvising* to some accompaniment.

In short, the batons work both as *musical* and *navigational* input device. The visitor can use them to carry out typical operations in the graphical user interface, e.g., selecting the *Virtual Baton* conducting module, and then use the same baton to actually conduct the piece. This distinguishes the interface of the WorldBeat exhibit from other baton-based systems like the *Digital Baton* developed at the MIT Media Lab (see [8] which also contains a comprehensive overview of other electronic baton systems) that often offer more control over musical parameters, but do not integrate musical and navigational interaction into a single interface.

IMPLEMENTATION

Hardware Environment

The *WorldBeat* exhibit runs on an Apple Power Macintosh 8500/120 computer. A MIDI Interface connects it to a *Buchla Lightning II* spatial MIDI controller [13] that consists of two wireless, infrared *batons* (see Fig. 1), a *tracker unit* that we attached to the computer monitor, and the *base unit* that contains the controller interface and MIDI sound module. The batons are battery-operated and each feature an additional action button.The exhibit further consists of a microphone connected to a Roland pitch-to-MIDI converter (for *Query By Humming*), and standard audio equipment (amplifier, tape deck, speakers, and headphones).

Software Environment

We developed the *WorldBeat* software using the *MAX* multimedia programming environment [4] by Opcode Inc., a development system especially for applications that process MIDI data in real-time. *MAX* supports visual programming for most standard tasks. Applications are created as a hierarchical network of *patches* that each process data (usually MIDI messages) in a certain way.

Figure 1: The Lightning II infrared batons.

User Interface Data Flow

The idea to use the infrared batons as navigational devices results in the following data flow in the WorldBeat system (see Fig. 2):

- The visitor stands in front of the exhibit (see Fig. 3), watching the computer monitor, and gestures with the two batons in her hands. Each baton contains infrared light emitting diodes that continuously emit signals in all directions. Special signals are sent when the action button on a baton is pressed or released.
- The infrared tracker, mounted directly below the monitor, measures the angles at which it receives the signals from the two batons, and converts these into horizontal and vertical position data with a resolution of 128 steps in each dimension. It also uses the button press/release events sent from the batons to determine the current button states. This results in a stream of $(x_1,y_1,b_1,x_2,y_2,b_2)$ tuples sent to the Lightning base unit, with coordinates $x_i,y_i \varepsilon \{0,...,127\}$ and button flags $b_i \varepsilon \{0,1\}$.
- The base unit converts those tuples into MIDI messages that imitate four continuous and two discrete MIDI con-

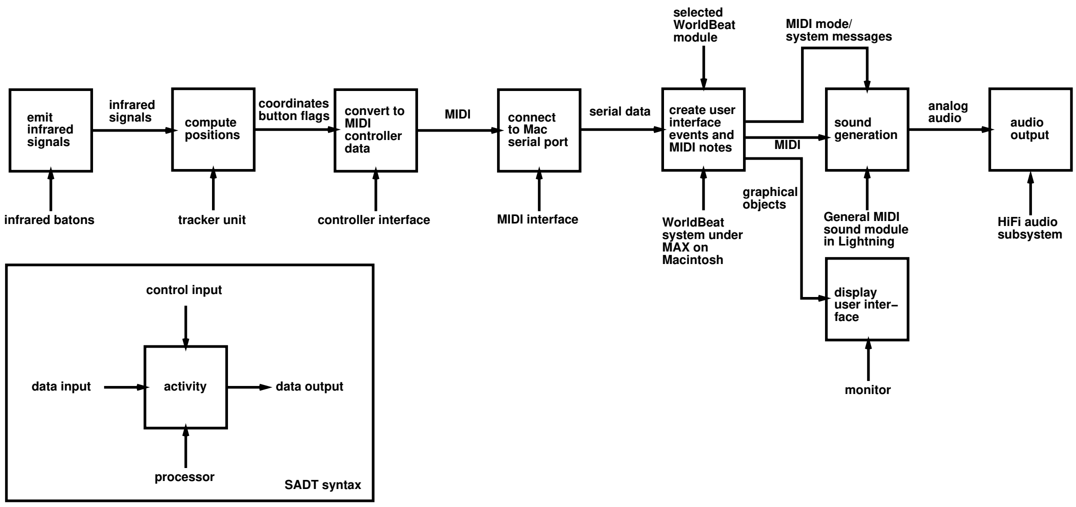

Figure 2: WorldBeat data flow diagram (SADT notation)

trollers, and sends those out to its MIDI port. The unit also contains basic gesture recognition which its presets use to directly create MIDI notes from downward "beat" gestures. This is used by WorldBeat modules that just require the user to play a virtual instrument with the batons in a drumstick-like fashion.

Figure 3: A visitor using the WorldBeat exhibit in the AEC.

- In the more advanced WorldBeat modules, the MIDI controller data is sent via the MIDI interface to the Macintosh serial port, where it is picked up by the WorldBeat system and interpreted in several ways: The interface manager computes the cursor position on the screen depending on the position of the right baton, and the currently selected WorldBeat component usually uses the data to perform other actions.
- All resulting events that describe MIDI playing messages are finally sent back from the Macintosh via the MIDI interface to the Lightning base unit. It contains a sound card with sampled instrument sounds that follow the *GM (General MIDI)* standard for MIDI instrument setups. The base unit creates the requested audio signals that are then sent to the amplifier and loudspeakers, tape deck, or headphones.

Baton-Based Interaction With Instruments and Music

To explain how the visitor actually interacts with the system, the following section describes the playing metaphors used in each module.

When walking up to the exhibit, the visitor first gets a short on-screen explanation how to *navigate* with the batons. Since the Lightning system features two batons, we established the convention that the right baton is always used for navigation, i.e., replacing the mouse. The visitor simply points at the screen where a yellow spot shows the current cursor position, and presses the action button to select something.

Playing virtual instruments in the *Joy-Sticks* module uses metaphors that are built into the Lightning hardware and depend on the instrument type. Instruments that are played with one or two *mallets* (including drum kits, xylophones and similar instruments) use a natural mapping: downward beat gestures play the instrument(s) in a velocity-sensitive way. *Chordal* instruments are either reduced to two-finger operation (as in one of the piano settings), or a number of fixed chords are placed into 2-D space and can be triggered by beat gestures at their position (as in a guitar setup). Finally, instruments that in reality require some different action to play a note (like wind-instruments) are simulated using the *action button* on the baton to play a note, and the 2-D baton position information to control pitch and velocity simultaneously.

Conducting a piece in the *Virtual Baton* module uses a more refined gesture recognition than the one built into Lightning to give exact control over the playback speed and dynamics of a classical piece. The software tracks the right baton, concentrating on vertical movement only, and plays the next beat each time it detects a change from downward to upward movement. Gesture size determines playback volume. The original algorithm was developed by a group of computer music professionals [7]; we adapted it to be usable by normal visitors and integrated it into WorldBeat.

Improvising in the *Musical Design Patterns* module finally uses a new musical interaction metaphor: The visitor again plays with downbeat gestures on an "invisible xylophone" in front of him. The actual notes that are mapped onto the "keys" of this xylophone, however, are constantly recomputed by the system to fit into the current harmonic context of the accompaniment. That way, the user has complete control over rhythm and melodic shape of his performance, while the system modifies his input with its own harmonic knowledge to create an aesthetically pleasing result. For musical experts, this support can be switched off, showing the adaptability of the system to different user experience levels.

In all modules, we supplied a visual interface that allows the user to navigate through the functions easily and get online descriptions of the current metaphor.

Interface Manager

Like all *WorldBeat* modules, the user interface component was implemented as a hierarchical network of *MAX* patches. Since *MAX* specializes in processing MIDI data, converting the MIDI controller data from the right baton into a cursor position on the screen was relatively easy. To create and manage graphical hypermedia documents that could serve as user interface, however, we had to extend *MAX* by implementing a new patch type *interface manager* in C. It defines an object-oriented concept of *nodes* (representing *WorldBeat* screen pages) that can contain other *text, image*, *movie* and *button* objects.

Buttons support three different states: normal, highlighted, and activated. The 'highlighted' state displays a short online help when the user just moves the cursor over the button. The 'activated' state gives visual feedback when the button is actually selected (pressed). An example can be seen in Fig. 4, the main *WorldBeat* selection screen, where the user has just moved the cursor over the *Musical Design Patterns* module icon. The three-state-button concept keeps screen pages from being cluttered with help texts, invites users to explore the exhibit, and still offers a reasonable amount of online help and guidance.

Links are first-class objects and connect a button to a target node that is displayed when the user activates the button. Nodes can be derived recursively from other nodes, allowing the interface designer to define *templates* with images and buttons that are required on a number of similar pages. This approach proved very useful for quick changes, e.g., to replace the “back” arrow image on all pages simultaneously.

To define a node hierarchy for use with the interface manager, the interaction designer specifes the desired objects in a textual description file using a simple language. All images are stored together with the description file (in its “resource fork”), and referenced in the description text through a unique ID. For example, the description file

```
template StandardPage 1001;
node StartPage StandardPage;
button NextButton 1002 1003 1004 100 80;
link NextButton NextPage;
```

defines a start page that uses a template containing the standard page appearance (in the image with ID 1001), adds a button with image IDs 1002-1004 for the three different states, positioned at coordinates (100,80), and links this button to a next page that would be defined later in the file.

Once the interface manager has read this description file, it displays the root of the specified node hierarchy, and processes incoming events, like MIDI controller data from the batons, or a message to display a certain object, and updates the display accordingly. At this point, the user can begin to control the WorldBeat system using the batons. If the user walks away, the interface manager jumps back to the start page after a configurable amount of idle time.

Visual Design

For the visual design of the WorldBeat pages, we worked together with a graphic design student. Using our ideas as input, she created logos to represent WorldBeat and its modules. A major issue was to create a non-technical look; we achieved this by scanning and rescaling her hand-painted logos, instead of having her draw them using graphics software. The designer created similar logos for the remaining KnowledgeNet exhibits and for common user interface elements (buttons, arrows, etc.) which helped to create a homogeneous appearance for the complete floor.

The actual WorldBeat pages were then created using photo-retouching software. The scanned material was combined with computer-rendered texts into page elements that were copied as resources into the description file. The WorldBeat interface manager assembles those image elements at runtime into the final presentation form. This modular approach proved much more memory-efficient than storing each page as a complete, full-size image.

EVALUATION

Three types of evaluation took place in developing the WorldBeat system and its user interface: During the design phase, we continuously had novice users have a look at our interface and had them use the exhibit modules that were already working. During the opening week of the AEC, the author spent five days at the exhibit, demonstrating its use to visitors and receiving direct feedback, but also observing users and recording interaction problems and common errors. Finally, a large survey among AEC visitors was carried out which also asked them about their general judgement of the WorldBeat exhibit. The three evaluation phases and their specific results are discussed below.

User Feedback in the Design Phase

As soon as the functionality of the WorldBeat system had been specified, we started implementing the various modules, and concurrently created graphical design sketches to find an appropriate visual representation. The design of the *main WorldBeat page* where visitors select which module they would like to try out is one of the best examples for the iterative nature of this process.

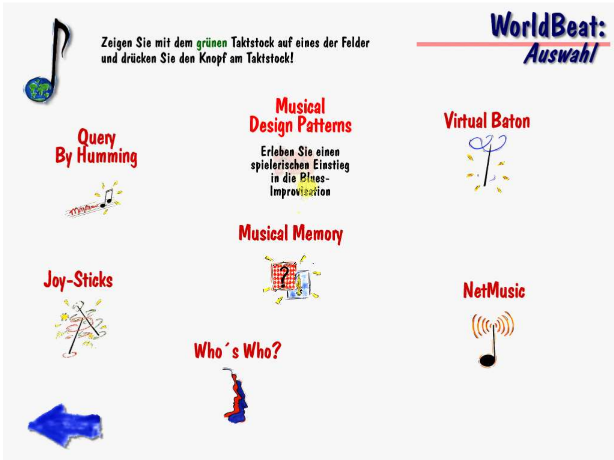

Figure 4: Main selection screen of the WorldBeat exhibit.

Fig. 4 shows a snapshot of the main selection screen in the final design. Our *first design* had used hand-painted dark-blue buttons, with a light reflection when highlighted, and that changed their color to yellow when pressed. User feedback showed, however, that the appearance was too dense and crowded, especially after another module button was introduced. It was also considered as having no connection to the subject field “music”. Users liked, however, the clear feedback the three-state buttons were conveying.

In a *second design,* we used musical objects like lines of a stave as background images, and note heads in the foreground. Even though the appearance became “lighter”, the round note heads still wasted too much screen space, leaving less space for the explaining text. We solved this problem by displaying the text only in the highlighted button state. This made the interface less crowded and intimidating. When users asked us to include the icons of the various WorldBeat components for better orientation, however, the overall appearance again became too packed.

Finally, we abolished our initial assumption of a uniform “button” area. Instead, we just used the icons themselves as irregularly shaped buttons, and put the module title above them. When highlighted, the icon fades into the background, and the explaining text is displayed in front. This effect makes use of color to create a spatial effect, and to direct attention to the newly appeared text, as demonstrated in [15], and presented in more detail in [1]. Pressing the button finally changes the text color from red to blue. When compared to the other alternatives, this design produced the best user feedback, especially in terms of visual attractiveness. This is the design shown in Fig. 4.

Many other details of the user interface were determined in a similarly iterative and experience-based process. For example, we replaced the initial Helvetica sans-serif font by a brush-like script font for a more non-technical impression, and the colors of interface objects were not only determined by theoretical models, but also influenced by consistency requirements imposed on all KnowledgeNet exhibits.

Detailed User Feedback in Observations

During the opening week of the AEC in September 1996, the WorldBeat exhibit was first exposed to use by the broad public. Apart from minor memory leaks in *MAX* that could be overcome through automatic restarts every night, the system proved to be stable enough for use as a permanent exhibit. The author demonstrated the system to over one thousand visitors, and watched several hundred people of virtually all ages end levels of experience - both in computers and in music - exploring the system on their own. These observations led to a number of further improvements.

Acceptance of Interaction Metaphors

Thanks to the direct visual feedback, users showed few problems with our *navigation* metaphor, although to use the full resolution of the tracker, the pointing direction is not always exactly the same as the location of the on-screen cursor. We also enlarged some interface objects (like the “back” arrow) and moved them towards the screen center to reduce problems that some visitors had with their selection.

Playing instruments was understood immediately when the mapping was natural, as with a drum kit, etc. Several visitors asked for better visual feedback; we are working on a better visualisation than just the current on-screen cursor. Playing chordal instruments was less obvious and required reading the short explanation on the screen. In a guitar setup, many users held the baton sideways as if strumming a real guitar. However, this posed no problems since the batons have infrared transmitters in all directions.

Conducting proved more suitable for musically inexperienced people since it just required moving one baton up and down. However, the system reacts to the “turn-around” at the bottom of the gesture, and not to the downward motion (professional conducters work that way too since it gives a more exact timing). People thought the system reacted with a delay, until we compared the triggering gesture to “pulling a fish on a rod out of the water” in the online help.

Improvising in the *Musical Design Patterns* module finally turned out to be the most attractive component. Users enjoyed “jamming” with a blues band without playing wrong notes. This module seems to have found the right balance between free user input and system guidance. With freedom in rhythm and melodic shape, nobody cared that the keyboard constantly changes to offer a matching scale.

Other User Interface Improvements

We introduced audio feedback for the action button to give users a hint that the system had processed their input.

When small children or people in wheelchairs used the batons, the tracker did not recognize their input because it was below its sensor field. We fixed this by reconfiguring it to reach from 50cm to 150cm above the floor, with a width of about 150cm. Also, people would sometimes stand too far away or too close to the tracker, impairing tracking data quality. We added a line on the ground, indicating a good position to stand on when using the exhibit (which is now also mentioned on-screen).

Watching visitors exploring the exhibit on their own confirmed what we all had feared: Users Don’t Read Instructions - until they have no idea anymore what to do next. We used this behaviour to redesign our online help. On the one hand, we added short introductory pages that the user would have to pass through to get to a specific module. This way, our “message” was likely to be at least skimmed. On the other hand, we added very short instructions on pages where visitors actually use the functions, to reduce the need to memorize prior instructions. We also made many phrases simpler and more action-oriented, e.g., “vertical movements of the right wand strum the strings of a virtual guitar” became “move the right wand up and down to play a guitar”.

The fact that the batons serve as navigational and musical input devices simultaneously posed no problems to most visitors, probably because they always concentrate on only one aspect - either navigation, or making music - of the interaction at any time. With good online help on how to use an instrument, the “mode change” seemed natural.

Overall User Feedback in Surveys

After the opening week, the AEC conducted a survey among visitors. Each of the 13 major exhibits was given a grade from 1 (“very easy to understand, very interesting”) to 5 (“very complicated to understand, very uninteresting”). The 104 participants gave *WorldBeat* an average grade of 2.08, i.e., the second best grade possible (std. dev. σ=1.12).

The participants were also asked to list their three favorite exhibits. Here, WorldBeat reached the third position, with 13.5% of the participants listing it in their “Top Three” list. Only the two million-dollar virtual reality installations in the AEC - the 3D Cave, and a VR flight simulator - were listed more often. We consider this remarkable success of an exhibit whose hardware can be purchased for around 15000US$ a result of our design that focused on conveying a learning experience as outlined in our initial message: activity-oriented, cooperative, and fun.

CONCLUSION AND FURTHER RESEARCH

We identified special user interface design goals for public computer-based exhibits: To be attractive to visitors, they should be innovative, explorable, activity-oriented, cooperative, and simply fun. To ensure usability, they should be consistent, intuitive, and comprehensible, but also non-technical, appropriate to the exhibit domain, ability-neutral, and exposable. The interface of the computer-based *WorldBeat* exhibit about computer use in music, which was described in this paper, shows that using a domain-specific device like infrared batons not only for domain-specific, musical, but also for general-purpose, navigational interactions can result in a new type of interface that helps to fulfil the above requirements to a much higher degree. We also showed how design iterations and intense, personal contact with users helped us meet those requirements.

The surprisingly positive feedback from AEC visitors, especially on our *Musical Design Patterns* module, confirmed our belief that a more abstract and structured representation of music (and other multimedia data), together with new metaphors to interact with this representation, is the key to a new generation of interactive multimedia systems. We are continuing our research in this direction.

When "Looking to the Future" of HCI, the WorldBeat interface design points out a number of important directions:

- It shows the design, implementation, and evaluation of a new input device that allows users to interact with musical systems in an integrated and intuitive way;
- it shows that the new type of interactive systems for public spaces may require re-evaluation of established design guidelines, and suggests a set of guidelines for discussion;
- it involved a diversity of disciplines, from software developers over graphic designers, to musical experts;
- it shows how to use computing power in a new way - to create systems that do not have to be "programmed" to create music, but that can be used as interactive, intelligent, and adaptive instruments that don't replace but augment the range of classical instruments;
- it demonstrates an interface suitable for a wide range of physical abilities, that can be of advantage to all people;
- it is a living example of how HCI technology may change people's learning and leisure activities (e.g., hobby conductors could now actually control an orchestra instead of just conducting alongside a fixed recording!);
- it shows that HCI can create systems supporting a more active, cooperative, and motivating learning experience;
- and the non-technical appearance of *WorldBeat* shows how HCI can help lowering the anxiety threshold that still keeps large parts of society away from exploring and using computer systems for their own needs.

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