Multiple Media Interfaces for Music Therapy

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This article describes interfaces (and the supporting technological infrastructure) to create audiovisual instruments for use in music therapy. In considering how the multidimensional nature of sound requires multidimensional input control, we propose a model to help designers manage the complex mapping between input devices and multiple media software. We also itemize a research agenda.

Music has a profound effect on human beings. It's more than entertainment; it can uplift our mood, bring back memories, bring comfort during times of depression or sorrow, and is often used to inspire religious worship. The act of making music brings people together in an intimate dialogue resulting in a shared immersive experience.

Music therapy (http://www.musictherapy.org/; http://www.bsmt.org/) is a clinical practice that engages both client and therapist in this sort of dynamic musical interaction. Found in all cultures around the world, music has the power to touch the human spirit at a deep level, often without the use of words. It can therefore be used by a trained therapist to reach people isolated by a mental, physical, or emotional block. As well as providing emotional release, music therapy can facilitate mobility, use of the voice, and general coordination.

Clients who have physical or mental difficulties can challenge music therapists, due to the clients' lack of the requisite physical and cognitive skills typically required to play conventional instruments. Music technology can give people access to music (and thus to music therapy) by providing a means of transducing limited physical gestures into musical expression. The sidebar, "Context and Background," describes recent work in music technology applied to therapy.

Technology in music therapy

Much work on interactive artistic and technological systems has taken place at the University of York, which we review here, followed by a look at issues that are paramount when researchers consider the use of these systems for therapy.

For many years, we've brought together researchers, music therapists, and special-needs teachers with the aim of targeting research toward the needs of therapists. Out of these discussions, a number of instruments, devices, and new ways of thinking have emerged. Our basic premise is that technology can offer benefits to music therapy by providing:

- access to real-time sound control for those with limited movement,
- new sound worlds, and
- attractive, up-to-date technology.

We elaborate on each of these points in this article.

Access to real-time sound control for those with limited movement

Many branches of music therapy make use of improvisation sessions for client and therapist. It's therefore important that the client has access to a device which enables real-time musical interaction. Traditional acoustic musical instruments are customarily used, but have limitations when clients' movement is restricted. In this situation, the use of electronic music technology devices becomes important. It's possible to use the electronic systems we describe later to control (for instance) large, expansive sounds with small physical movements. By extension, we can configure musical instruments to match an individual's physical and cognitive requirements. It thus becomes possible, for example, to perform a flute improvisation using sensors placed on the headrest of a wheelchair, triggered by the player's head and neck movements.

New sound worlds

We can produce new timbres and sound worlds using electronic instruments. This opens up exciting and stimulating possibilities for musical improvisation away from the constraints of acoustic musical instruments and traditional musical rules about harmony.

Attractive, up-to-date technology

Some traditionally trained musicians can be left uninspired by the use of computers in music. What's less often reported is the fact that some

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Context and Background

The disciplines of music therapy and music technology are both relatively recent, having emerged late in the 20th century, so combining the therapy with the technology is still considered novel. Recently, as patients are able to gain access to a range of complementary therapies, and as computers have reached a stage where real-time audiovisual interaction is possible, projects that address therapeutic issues with multiple media technology have started to emerge.

The European Union's Creating Aesthetically Resonant Environments for the Handicapped, Elderly, and Rehabilitation ("Care Here"; http://www.bris.ac.uk/carehere/) Project uses interactive multiple-media technology to improve people's motor and mental skills. The project developers have coined the phrase *aesthetic resonance* to describe a state where individuals are so engrossed in the intimate feedback loop (with an audiovisual control system) that the physical difficulties encountered in creating the movement are forgotten.

The Multisensory Environment Design for an Interface between Autistic and Typical Expressiveness (Mediate Project; http://web.port.ac.uk/mediate/) concerns the production of an audiovisual-tactile environment specifically for autistic children. The target user group is involved in developing systems for immersive interaction, and a strong goal is for people to have fun in such an environment.

The Control of Gestural Audio Systems (COST-287 ConGAS; http://www.cost287.org/) Project is looking into how human gesture works in the context of controlling musical instruments and multiple-media technology. One aspect being studied is the special case of gestural control where the user's available gestures are limited, for example, because of a physical disability.

With many recent projects, the main aim is to develop technological systems that help people to "lose themselves" in artistic or emotional expression—in other words, for the quality of interaction to be so high that users aren't aware that they're "using technology."

groups of people are put off by traditional musical instruments. Mary Abbotson, a music therapist from Yorkshire, England, has worked with special-needs teenagers where the attraction of a "music computer" was the only thing that initially kept them in the music therapy room, which was otherwise filled with drums and other acoustic instruments.[1] It seems that traditional instruments are often associated with certain styles of music and with long-term, strictly disciplined methods of learning that can be offputting to young people.

Electronic instruments

Designers of new musical instruments must work hard to produce devices that give the user a good sense of control. Piano-type keyboards have tended to dominate the market for real-time control devices, but the keyboard is clearly not the only form of interface for live electronic music. We've been involved in the creation of new electronic instruments, particularly those with alternative user interfaces, for a number of years now.

Since the mid-1980s, electronic musical instruments have been equipped with a musical instrument digital interface (MIDI[2]), which lets keyboards (and other instruments) connect to computers. It works by coding and sending information about each note played from one machine to another. MIDI is well acknowledged[3] to have certain limitations concerning its bit rate (approximating 1,000 events per second) and its quantization of all major parameters to 128 values. These subtly affect the level of control that we can achieve, and many other faster communication systems are now under development. However, we've found that unless the mapping of human input to system controls is configured to optimize human performance, then the subtle limitations caused by system quantization are negligible. It's rather like a painter using a large paintbrush; an artist with good interaction can paint a picture even with limited tools, but if the interaction is severely hampered, the paintbrush resolution doesn't matter. So, many of our experiments use MIDI, a widely available protocol for prototyping interactive control, but which is gradually being replaced by faster technologies with higher resolution. However, the principles of interaction remain the same, whatever the technology.

We developed a MIDI-based computer program called MidiGrid[4] (http://www.midigrid.com) that lets users trigger musical material freely using the computer's mouse. The screen consists of a grid of boxes, each of which contains a nugget of music that's triggered as the mouse cursor moves over it. Hand gestures are thus converted, via the mouse, into notes, chords, and musical sequences (tunes). In music therapy, therapists have used MidiGrid to let people with limited movement engage in free improvisation on a palette of sounds chosen by the therapist or the client.[5] It additionally allows them to build up layered recordings of their improvisations, and lets the client play as a member of a musical ensemble.

Figure 1. The shell instrument, which is responsive to touch. The instrument is a fiberglass mold set in transparent resin, in which piezoelectric sensors are embedded.

MidiCreator

We also developed MidiCreator[6] (http://www.midicreator.com), a device which converts the various signals from electronic sensors into MIDI. Assorted sensors are available that sense pressure, distance, proximity, and direction. These are plugged into the front of the unit, which you can program to send out MIDI messages corresponding to notes or chords. Thus movement is converted to music. Other devices exist that have similar functionality to MidiCreator. [7]

Dynamically responsive instruments

As the trials with MidiGrid and various sensors in therapy sessions have expanded, so has the need for new devices that are more identifiable as musical instruments but that the most severely impaired clients can still control. After consultations between the therapists, researchers, and the staff of a Yorkshire special school, we've devised and tested various prototype models of instruments, and controlled them in a variety of ways.

The specific association between gesture and sound is determined at the instrument designer's discretion, unlike with conventional synthesizers in which control is often restricted to switching notes on and off. Figure 1 shows as an example a shell instrument, which responds when tapped, scraped, hit, or wobbled. It consists of a specially designed fiberglass mold, set in transparent resin, into which a series of piezoelectric sensors are embedded. An umbilical cord connects the instrument to its electronics, housed in a separate box, which converts the vibrations on the instrument's surface into dynamically responsive MIDI signals that can control a sound module, piano, or computer.

Several shells, such as the one in Figure 1, have been specially designed by Jonathan Phillips of Ensemble Research. Sensors are housed within the brightly colored and individually cast shells, which can also contain the electronics. This configuration simplifies the wiring and provides an identifiable visual and tactile "character" to which the performer might relate.

Improving the sound of electronic instruments

Ensemble's music therapists and performers have identified many benefits from the use of electronic instruments, although they also cite a lack of control subtlety, and timbres that "wore thin" after much use. They found some of the standard MIDI sounds, whose timbre evolves as the note is held on, to be of particular interest and value in their work. However, the sounds evolve the same way every time, and clients and therapists wanted to have more dynamic control over the timbre of such sounds. A specific sound falling in this category, available on many synthesizers, is called ice rain.

The challenge for us, as Ensemble's instrument designers, was to address some of these limitations, beginning with ice rain. We identified the individual sonic elements within the sound and built them as individual components in Reaktor, a software synthesizer environment (http://www.native-instruments.com). Reaktor lets the instrument designer build sound from basic synthesis elements such as oscillators, filters, and envelope generators—and control these from external devices. In our case, this meant that we could continuously control specific elements of ice rain from sensors attached to MidiCreator. We could focus on and explore new dimensions of the sound, resulting in timbres that, although related to the original ice rain, were sufficiently different to be new sounds in their own right. We couldn't have achieved this use of sensors to modify ice rain's timbre with the standard synthesizer architecture.

The novel instrument we created allows one performer (for example, a therapist) to play music on a keyboard using a sound that's being continuously controlled by another performer (for example, a client). It rapidly became apparent that this new mode of musical interaction could be particularly useful in therapeutic situations.

The timbres produced in these ice rain experiments ranged from the conventional sound produced by commercial synthesizers to organ and harpsichord timbres and abstract electronic sounds, all under the client's control. The timbre seemed to have a radical effect on the person playing the keyboard. For example, the harpsi-

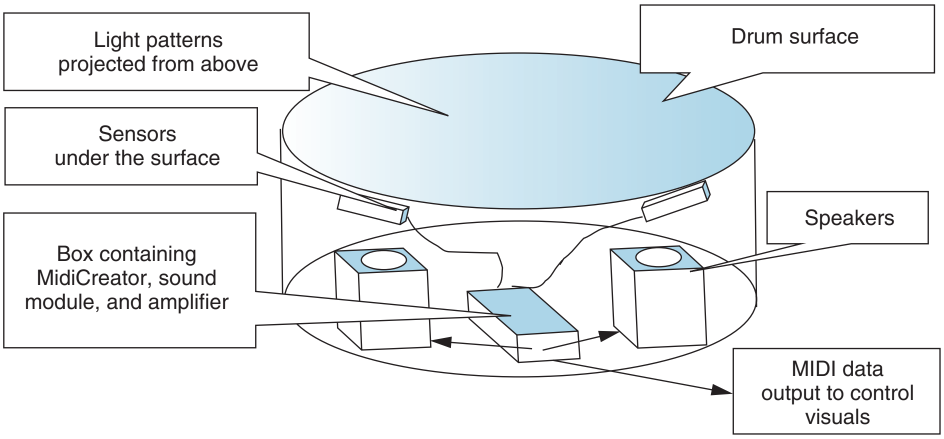


Figure 2. The audiovisual drum concept, shown in cross-section.

chord sound naturally suggested a baroque style of improvisation; the organ sound, a fugue-like style, and the electronic sound encouraged an avant-garde electroacoustic performance. The style of the music played on the keyboard in turn influenced the nature of the sound produced by the client. To observers, it was clear that the performers established a close interaction through the sound.

Audiovisual instruments

The connection between music and visual arts is deep running. Musical performance has always had a visual component, with the players' motions an inherent part of performances (at least until the 20th-century inventions of broadcasting and recording offered a way to isolate the listening experience). Opera exemplifies the combination of drama and music in a live multimedia spectacle. For several centuries, various inventors sought to create "color organs"—machines for live performance of both sound and visuals.[8] The development of cinema brought a requirement for music to accompany on-screen events and gave birth to new art forms as artists experimented with the medium to compose for sound and vision. Similarly, the modern rock or pop concert is often intensely visual, with bright lights, smoke, video screens, and pyrotechnics.

The concept

We now have the possibility of performing image as well as sound, given that today's computer systems are adept at handling real-time image generation and processing. We can produce images in exactly the same environments used for synthesizing sound and gesture processing. Thus an image could react to a user's movement (for example, by changing shape or color), driven by the same electronic sensors we've described. This possibility opens up new dimensions for exploration in therapy.

Felicity North, music therapist, was one of the founding members of Ensemble Research. Early discussions (personal conversation, spring 1998) helped us form the concept of an audiovisual drum that also acts as a projection surface for a multicolored dynamic image. As the drum is touched and played, the visual pattern reacts simultaneously with the generated sound.

Figure 2 shows the audiovisual instrument's general concept. It consists of a real bass drum, placed on its side with one of the drum surfaces uppermost. We chose a drum because it represents perhaps the most simple and rewarding acoustic instruments that music therapists regularly use in practice. The surface can be played in the traditional way using hands or sticks. However, beneath the surface are mounted a series of proximity sensors linked into MidiCreator, which allows the drum to sense when hands are close to a particular part of the drum's surface. Movement near these sensors is converted into sound via MidiCreator and a MIDI sound module. The sound emerges from within the drum, because the amplifier and speakers are contained inside. This was a crucial design feature because the therapists felt it important that the sound comes directly from the instrument, not from remote loudspeakers. Finally, the sensors' MIDI data is also processed to feed into a visual system that projects an image onto the drum's surface (either from above or from underneath using a series of mirrors to obtain the correct focal length from a data projector). Thus the sound and the visuals respond to the drum's surface being touched. Therapists also like this idea as they could imagine them-

Figure 3. York's Kings Arms pub showing water textures during flood.

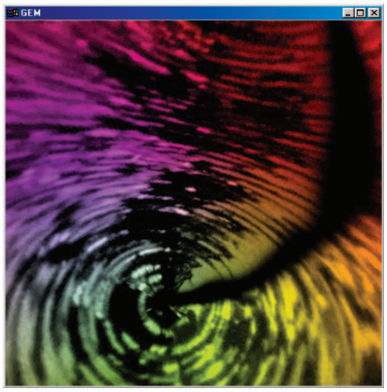


Figure 4. View from within a sphere, with the water image applied as a texture.

selves seated opposite their client, yet meeting in the middle to interact on a common surface. This design specification motivated us to initiate a number of projects that explored different facets of the audiovisual interaction.

Early experiences with instruments and therapists

The previous ideas were first explored in an Ensemble Research meeting at a special school in May 2002. This school had an interactive multimedia room with a custom-built lighting installation that could project colors and patterns onto a defined floor area, under MIDI control. We set up the system so that several therapists were seated around a small circular wooden patch on the floor, on which the lights were focused. We placed sensors around the edge of the circular area, such that bringing a hand close to a sensor caused a particular color to flood toward the center of the circle, while a simple sustained tone was played.

What happened next was fascinating. The therapists began improvising with movements near the sensors, with everyone watching the same resultant visual pattern. They took turns, they had color "battles," they cooperated to form complex patterns. Afterward, all agreed they had taken part in a unique musical experience and had gained a heightened awareness. At lunch time, the Ensemble technician turned off the light projector, opened the curtains, and walked across the wooden projection area on the floor. Half the therapists instinctively gasped in shock, and then laughed as they tried to explain how distressed they felt that someone had just "walked across their instrument." In mere minutes, this section of wooden floor had become a sacred space, a point of interaction and expression for several people. Such is the power of the human imagination, especially when coupled with interaction and multiple media. The therapists knew, at that point, that they could use such technology in their work, providing that it was easy to operate and control.

Real-time image control

To explore image control in a more flexible manner, we established a research project[9] to develop an interactive computer graphics system that could be controlled intuitively. The software platform we used was Pure Data (http://www.crca.ucsd.edu/~msp/software.html) with its associated Graphical Environment for Multimedia (GEM). Together, these provide a programming environment in which we can connect sonic and graphical components together. We mocked up images on the computer screen, so that ultimately we could project them onto the surface of an audiovisual instrument, such as the drum.

We decided to work with a single graphical object on the screen—a sphere whose size, color, and surface pattern could be interactively changed by a human user. We used a series of virtual lighting objects, whose colors and positions were independently controllable, to illuminate the sphere (providing a feeling of depth). Dramatic, abstract visuals were created when the sphere was enlarged so much that it extended beyond the edges of the screen, and was therefore no longer recognizable as a discrete object. Instead, the user sees (and controls) a dynamic wash of swirling colors and shapes.

We used *texture mapping* to wrap images around the sphere, giving shape and texture to the onscreen visuals. Two particularly effective visual textures originated from a photograph of a York pub taken during the flood of November 2000. The photograph in Figure 3 shows where the textures were taken from. The view in Figure 4 shows the inside of the sphere with one of these textures applied.

Next, we produced user controls for this visual creation. We drew up a list of possible controls, based on the most engaging interactions that occurred when experimenting with the control parameters (such as colorfulness, brightness, and perspective). We achieved perspective control by adjusting the z-axis scaling independently of other axes. As Figure 5a shows, this resulted in stretching the sphere toward infinity.

Simultaneous control of the perspective and width parameters gave some impressive effects reminiscent of sea and sky, separated by a horizon, as Figure 5b shows.

A set of physical sliders (configured to send out MIDI information) controlled the system parameters. We first demonstrated the audiovisual instrument at the Ensemble Research meeting.

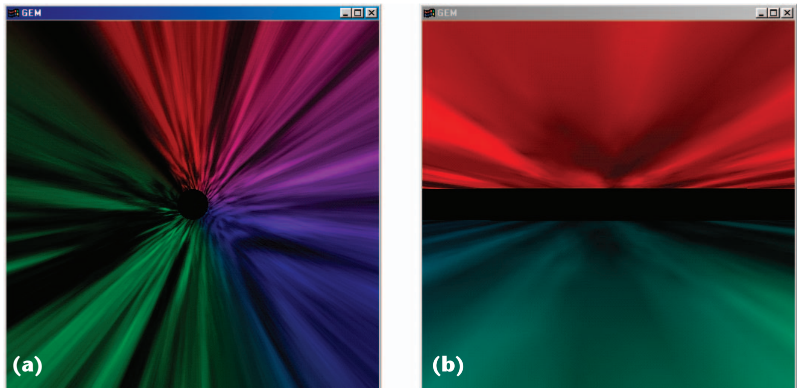


Figure 5. (a) The sphere stretched to infinity; and (b) producing a horizon effect with perspective and width.

Reaction

Some music therapists present at the meeting made positive, encouraging comments about the audiovisual system on questionnaires we asked them to fill out. Their responses indicated that the audiovisual instrument would be useful in music therapy and community music, and that the instrument could be useful for work with children, teenagers, adults, and clients with physical or mental difficulties. Music therapist Bianca La Rosa Dallimer commented that research would be needed on the suitability of an audiovisual instrument to particular client groups. For example, she wrote, in some cases the visuals may "distract the client from the music" whereas in other situations "… the visuals may be a 'way in' to a client who was previously struggling to become engaged in the music."

The therapists hypothesized that an audiovisual instrument could effectively be used with autistic children—often difficult to engage with music—who need to follow extremely logical, ordered sequences. The visual component could attract an autistic child's attention, leading the child to participate in music therapy by manipulating a sequence of interactive visuals prior to producing sound.

Integrating sound and image with intuitive control

A major component of our work involves integrating sound with visuals and controlling these intuitively through a user interface. Researchers in the computer music community have recently done much work on how to effectively map real-time user input onto lower-level system parameters (such as visual and audio synthesis controls).[10] We've taken an active part in this process and helped to develop the concepts of multilayer mapping.[11,12] Electronic-instrument designers typically don't dream up the complex types of interaction that occur in acoustic musical instruments. Because acoustic instruments are often considered superior to electronic instruments, in both sound quality and control subtlety, it's been necessary for us to develop ways to aid the design of such complex user-interface mappings for new electronic instruments.

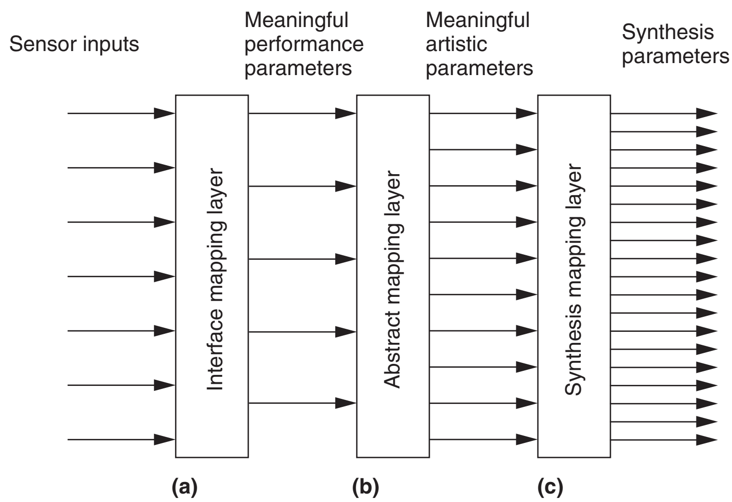
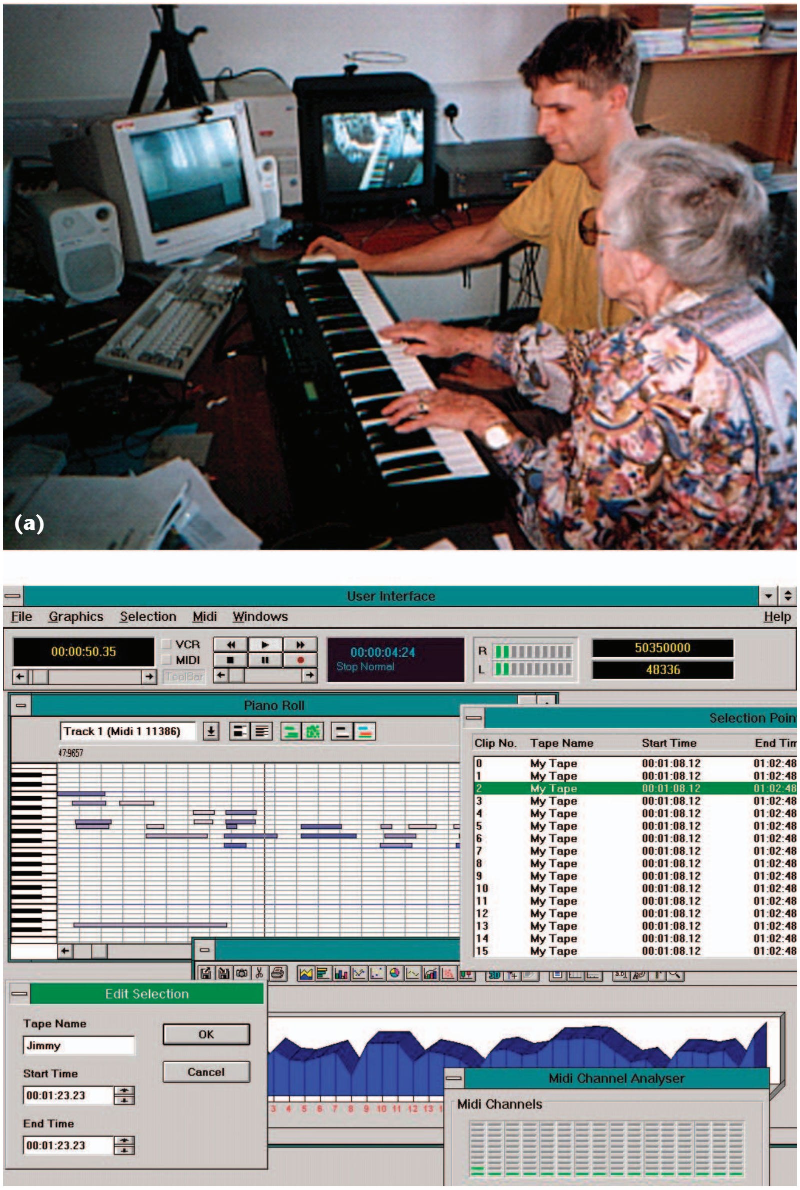


Figure 6. The three-layer mapping strategy for designing intuitive audiovisual interaction: (a) interface, (b) abstract, and (c) synthesis mapping layers.

Multilayer mapping helps designers come up with complex interfaces that allow artistic control. It also lets us integrate sound and visual control from the same real-time user interface. Figure 6 portrays a three-layer mapping approach in diagrammatic form.

The left side of the diagram represents data coming from the user via input sensors (for example, via MidiCreator). This low-level sensor information is taken directly from sensors, yielding parameters such as the position of slider 1, or the state of button A. The *interface mapping layer* in Figure 6 processes the sensor information into a series of meaningful performance parameters such as energy, velocity, and acceleration. The system can derive a measure of the user's energy, for example, by adding together the speeds of



(b)

Figure 7. (a) The CAMTAS system in operation, and (b) screenshot showing recorded notes and statistical analysis.

movement on several slider inputs, giving a sense of how rapidly the user moves the inputs.

The right side of the diagram represents the controls needed for synthesis—that is, to operate the audiovisual engine (the code that generates sound and image). The *synthesis mapping layer* allows these complex synthesis controls to be driven from a much smaller number of meaningful artistic parameters, such as brightness or harshness.

The *abstract mapping layer* lets therapists configure the interactive audiovisual system without needing to understand the workings of either the input or output layers. For example, at this level a therapist could map the performer's energy to sound harshness and visual perspective. The music therapist making such a mapping doesn't need to know how the performer's energy is derived, or how the synthesis engine creates sounds of increasing harshness, or how the visual system controls perspective.

Interestingly, this one-to-one mapping (for example, "energy mapped to harshness") works successfully with the above approach. In previous work, we've shown that one-to-one mappings are often not successful for expressive, playable electronic instrument design.[13] However, the multiple layers mean that, in reality, the mapping from sensor inputs to audiovisual engine parameters will be many-to-many (because of the complex data processing taking place within layers 1 and 3). The mapping is only one-to-one at the abstract level, and this aids comprehension of its artistic implications.

Quantitative analysis in music therapy

Music therapists are experiencing an increasing need for quantitative analysis of their work, to demonstrate the effectiveness of a course of treatment. We're working on a system to help therapists manage the data they collect and to produce numerical analysis where appropriate. The Computer-Aided Music Therapy Analysis System (CAMTAS), produced by Ensemble's Adrian Verity, was designed to do this.

CAMTAS

Because electronic instruments can intercommunicate using the MIDI musical code, MIDI messages can be recorded into a computer system, thus providing a record of all the musical activity that took place during a therapy session. Depending on how MIDI is used, this record could include gestural information from, say, MidiCreator, as well as musical note data (pitch, dynamic, and timbre) from a musical keyboard or MidiGrid.

CAMTAS captures all MIDI data supplied to it and displays it as a piano-roll–like display, as Figure 7b shows. The musical data produced by the therapist appears in horizontal bars of one color, while that produced by the client appears in another color. Color intensity indicates how loud or soft the therapist and client were playing at any point, giving a visual indication of the energy of performance. The therapist can then use the stored data to analyze musical interaction using the CAMTAS display after the session is finished.

Controls to fast-forward and rewind the data let the therapist scan for significant musical events. The system also includes controls for a video camcorder, which CAMTAS keeps synchronized with the MIDI data. Thus if the therapist fast-forwards through the data to a certain point, CAMTAS will fast-forward the video to the corresponding point. The video display (and its sound track) provides a useful record of events not otherwise captured in the MIDI data. Users can watch the video display in one corner of the computer screen. This system greatly reduces the time needed for session analysis and has already been found useful by music therapists engaged in research.

Research agenda

We've outlined a range of technological solutions to problems encountered by music therapists. However, three areas still need improvement: audiovisual instrument design, technical infrastructure refinement, and clinical practice integration.

Improve audiovisual instrument design

Researchers need to create instruments to give the same variety of shape, sound, and playing technique as acoustic instruments, but for clients with small amounts of movement. The timbral control (input devices, mapping, and sound quality) should compete with acoustic instruments, and there should be adequate tactile feedback. The link between image, sound, and human interaction demands further exploration, to allow exploration of the possibilities and to make these accessible to therapists without recourse to rewiring and programming.

Refine technical infrastructure for analysis and control

We're currently working on ways to put the entire sound and gesture processing systems within the molded shells, thus removing the need for an external computer, and producing completely self-contained instruments. We've developed a software system[14] (based on our MIDAS[15] multiprocessor architecture) which takes the form of a configurable set of units that the system can use to process the user's gestures. This runs on a microcontroller and lets gestures be amplified, altered, and used to trigger sounds or prerecorded musical sequences. However, you can download the same software onto a second chip—a digital signal processor—to run the actual sound synthesis algorithms.

This approach is significant for its use in therapy, because the gestural processing components are constructed in exactly the same environment as the sound synthesis. Consequently, it's possible to connect the gestural outputs to any sound synthesis generator input, giving a complete interleaving of gesture and sound, and continuous control over all aspects of the sound.

Although the instruments must be largely self-contained, we acknowledge the need for external amplification so that the sound can be felt and localized around the player. This involves placing several speakers around the individual, or perhaps under the wheelchair. Thus there can be a single umbilical cord from the instrument to the amplifier (based on the model of an electric guitar), but this cord can also be used to provide power to the instrument's electronics.

We're striving to ensure that these environments offer the scope needed to construct new instruments useful in therapy: the ability to make new sound worlds with an acoustical "depth" comparable to conventional instruments, in which the means of interaction can be customized to the individual's needs.

Integrate into clinical practice

The art of music therapy demands significant concentration on behalf of the therapist, and fluency with a set of reliable tools. Although some therapists are excited about the ideas outlined here, much work still remains to persuade others of electronic and computer technology's benefits to therapy. This situation results partly because conventional therapy is typically taught using purely acoustic instruments, and partly because the technology can still be complex to set up and configure. How is it possible to produce a toolkit which is open-ended enough to provide creative flexibility for the users (therapists) without frightening them away with the resulting complexity and new ways of thinking? This is both an engineering conundrum and a fundamental human–computer interaction problem that needs to be addressed in the coming years.

Conclusions

We stand at a defining moment in the history of the design of new electronic instruments. Although the conventional MIDI-based offerings from commercial suppliers have serious limitations that limit their use in therapy, other newly available tools such as Reaktor and Pure Data allow a less-restricted approach to the design of musical interaction. We can also add the synthesis of image and quantitative evidence-based monitoring to the repertoire of therapy practices.

This approach will open new interactive sound and image worlds and developments in the practice of therapy, which aren't so much limited by the client's capability but by the creativity shown in designing the new instruments and supporting toolkits, and our willingness to use them in practice. **MM**

Acknowledgments

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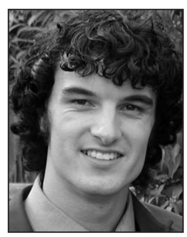

Matt Neighbour is currently working with Andy Hunt on the improvement of land mine detection using interactive sonification. He worked with Hunt and Kirk for his master's project on interactive multimedia systems, "An Audiovisual Instrument for Special Needs Applications." Neighbour has a master's in electronic engineering with music technology systems from the University of York, UK.

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