Using Music Performance Software with Flexible Control Interfaces for Live Performance by Disabled Musicians

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Abstract

This paper first discusses the principles of music performance software which can map performer actions to musical output in a flexible manner.
The use of the MIDIGrid and E-Scape software is described, with particular regard to work done by the Drake Music Project in facilitating music making by severely disabled performers using E-Scape. This enables musical material to be performed by a wide variety of movements, using such devices as trackball, ultrasonic beam and switches as a musical performance interface.
The ideas of 'conducting' and 'scrolling' as modes of processing performer input to play prepared musical material are examined, and extended features provided by E-Scape are presented, together with musical examples.

Music technology utilises microprocessors in a variety of demanding real-time applications. The synthesis of sounds is most usually performed via custom VLSI hardware within a synthesiser or 'sampler' (the dividing line is becoming ever more blurred), but increasingly can be performed via software synthesis running on a computer with general purpose CPU, which can provide great flexibility and controllability. The former is still more robust on stage, however! Sounds can now be created with quite impressive subtlety and musical performance control of timbre.

There is also programmable microprocessor-controlled hardware which can be utilised for the control and performance of sounds - utilising the ubiquitous MIDI (Musical Instrument Digital Interface) standard for conveying musical information between devices. As well as the obvious keyboard controllers, there are many other devices which can be used, connected directly to synthesisers etc and used to perform music.

Good examples are the MIDICreator and Soundbeam [4] devices, which convert switches and other sensors (eg drum pads, pressure sensing floor tiles, capacitative sensors, and ultrasonic distance detectors) into MIDI data. Thus, a variety of physical movements (inputs) can be converted into musical control parameters understood by the synthesiser, and the performer can trigger notes, or chords, and alter many timbral parameters in real time.

However, if this MIDI data is instead sent into a computer, software provides a far greater capability for creating a flexible mapping between the movements of a performer, and the desired musical output. A generalised system is shown in figure 1.

A number of sensors, switches and pads are connected to the computer, via MIDI, plus switches and trackball - all can be used to perform. music.

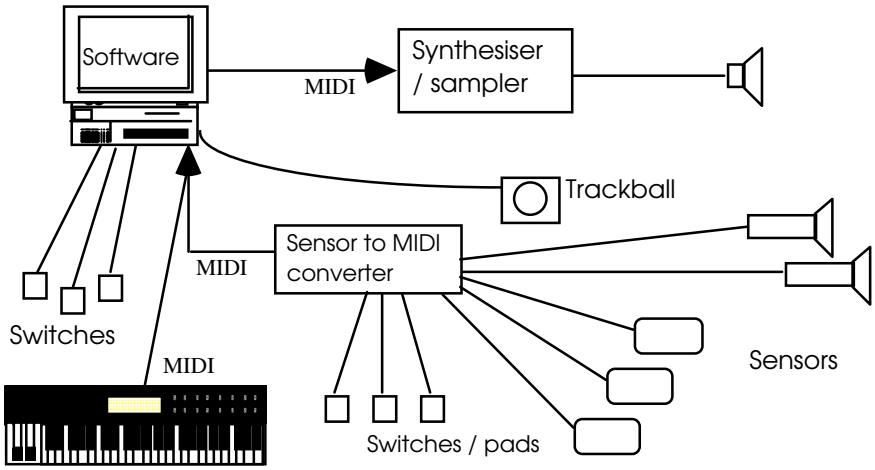

Fig 1 - Generalised system of sensors processed by software to produce musical output

This can be done to suit the physical capabilities of the performer in a flexible manner, and is one of the main techniques used by the Drake Music Project to facilitate *disabled* performers - movements which would normally be difficult to use musically, can be 're-mapped' to appropriate musical parameters, within a pre-planned framework. This planning phase is very

important musically to create the desired expressive performance.

Technology allows the boundary between planning, composition and performing to be flexible and movable.

For example, one performer may always hit a pad hard, and be able to hit reliably within three bands of strength ('hard' 'very hard' extremely hard'!). These inputs can then be mapped to musical material, eg a sequence of 5 chords which start quietly and get gradually louder. Each hit on the pad will play the next chord in the sequence, either at its pre-programmed loudness (which increases through the sequence), or with two variations: slightly louder than programmed, or slightly quieter. Another performer may be able to hit with *12* levels of hardness, and would want a more direct mapping, to produce 12 variations of volume in the musical output. They may want to have total control of the loudness of each note, or may still want only to vary it from its pre-programmed loudness. The former allows for more expressive playing, but with more scope for errors; the latter can free up the performer to concentrate on some other aspect of performance, with the loudness 'taken care of' - for example, it would still sound at a reasonable level, if one time the performer accidentally pulled back and unintentionally struck the pad very gently.

The point is that the system can be altered to suit each person, and each occasion. It may be that a person's capabilities alter with time, and again the flexibility to be able to alter the relationship between movement and musical output is highly useful.

It should not be forgotten that the system is still operating as a musical instrument - the performer still needs to practice with the system set up the way he/she is used to, to create a good performance. The fact that even a novice can produce some sort of reasonable performance (if the system has a lot of well-planned material in it, for example) should not negate the fact that a skilled and practised performer will make it sound musical and special.

Such a performance system thus consists of a variety of sensors which allow performer actions to be input into a computer. Software then processes these various inputs into a musical output.

Sensors and hardware

Various microprocessor-based music technology devices are available, which incorporate sensors plus some degree of flexible mapping to a musical output. Such devices monitor the position of a part of a performer's body (eg finger, leg, head, whole electric wheelchair), in one, two or three dimensions. Movement in space can be determined from video analysis, infrared or ultrasonic detectors (eg 'Soundbeam'), or more directly by physically moving something (eg a trackball) with part of the body. One example is to move the trackball in one dimension (with software set to ignore the other) using the chin. Again, the range of movement can be defined: for example, some people may want to use a large movement of the foot; others may want to use a tiny movement from a finger.

Many sensors have a one dimensional (longitudinal) sensing area, with a set of positions defined - typically up to 128, although 16 or 32 are often more usable; even as few as 2 or 4 positions may be appropriate for some circumstances. Other sensors have a hemispherical area of operation, sensing polar distance from a central point.

Moving in one dimension, each position can be mapped to a musical output, eg a particular note on a scale, or in a melody. This has the musical effect of running up and down a scale (imagine a saxophone or clarinet solo). Other input/output mappings may be programmed: Soundbeam for example, allows each position to be mapped to a chord of up to four notes, plus the option to control other musical parameters such as loudness, pitch bend, stereo pan position, or timbre. These can be from the absolute position within the sensor's range, or determined from the speed of movement.

Performers who are able (or want) to move in *two* dimensions can use two sensors to control two sets of musical events at the same time. Alternatively, they can use a single sensor but use the second dimension of movement to move sideways (in and out of the sensor's range), in order to start and stop notes at *any* time (rather than having to rely on pre-programmed note durations). Other sound control parameters (as above) may be derived from relative position (distance moved since entering the sensor's range).

Movement in a third dimension could use a third sensor, and control other parameters, but is difficult to use effectively.

Software processing - movement into music

The Drake Music Project is a charity, one of whose main objectives when it started (over ten years ago) was to develop software to enable a single-switch user to compose music. The 'E-Scape' system [2] has been the result, and has successfully enabled a number of severely disabled people to learn about, and compose their own music.

Drake has also from the outset been active users of the MIDIGrid system [3] to help disabled people to *perform* music - using the mouse (or trackball) to trigger musical events (notes, chords or phrases) from an on screen grid, or stepping through a prepared set of events in order. In more recent years, E-Scape has been developed into a performance system with a greatly extended variety of performing facilities.

Two particular factors stand out in this development: first, the fact that the entire system can be operated by a severely disabled user, not only to perform, but also to prepare the musical material and set up the system appropriately for each performer; secondly, that the system's features have evolved from intensive experience of active use by disabled musicians and Drake tutors, and has responded to their needs (and demands!) for new performance facilities.

Three main strands of performance have been developed from the seminal MIDIGrid system.

1. 'Conducting'

This performing mode has been termed 'conducting' in reference to the fact that a lot of the material can be prepared earlier: musical events can be stored in order, and then played in turn in response to signals from the performer, who is thus some ways acting as a conductor. Events can consist of a note, chord or phrase ('sequence') played via MIDI on a synthesised instrument, or a note can trigger longer portions of digitally 'sampled' sounds.

These could consist of such things as segments of music played skilfully or expressively, singing (eg the flamenco vocals demonstrated in the presentation), or even a performer's own vocalisations. These can be practised, selected, edited or processed 'off line' to give the desired musical result in the performance. Some of the parameters may have already been set up, eg pitch, volume, duration, or all be frozen in the sampled phrase. But, even at this extreme, the performer could still have control over overall volume, and most importantly the onset time - just controlling this single parameter in a musically skilled way is surprisingly expressive.

This again illustrates how the division between musical preparation and performance has been made a flexible one by technology - a performer can do more work before, to enable them to attend to fewer control parameters during the performance itself - the results can still be musically impressive with a skilled performer, and well-chosen material.

'Conducting' thus facilitates ways of performing and improvising using a restricted set of bodily movements, including at the limit one single movement, which may in some cases be tiny, eg a twitch of an eyelid or small muscle in the finger. The rather dry term 'single switch user' does not describe the pleasure which can be experienced, and the creativity released by being able to control and perform on a musical system with a very limited body movement.

MIDIGrid has a simple facility to select and store the on-screen boxes (each containing a music event) in a chosen order; these can then be triggered in turn by pressing the mouse button. As an interesting aside, this concept was implemented in the early micro-processor based 'home' keyboards of the early 1980's (often labelled 'one key play') to let you step through a monophonic melody or set of chords by pressing a switch. This feature has now largely disappeared.

Drake made the simple adaptation of connecting an external switch to the mouse button, enabling a disabled performer to play using a variety of switches or pads. Only the *timing* of musical events now needs to be attended to when performing, but musical skill and judgement is still much required, both to prepare appropriate material, and to then trigger it at the right time. To be able to perform with other musicians, practise is still required!

Extended 'conducting' using E-Scape

Some of the developments of these basic concepts which have been created within the E-Scape system are now described, in response to demands from disabled performers and Drake tutors for more ways of playing.

Sets of notes or chords are presented visually in E-Scape within a conventional sequencer edit window (where X = time and Y = pitch), and can be quickly edited for pitch, duration, or volume. They can be played conventionally as tracks, or treated as musical material for performing, as shown in figure 2.

The 'conducting' concept has been expanded in a number of ways, which are often simpler to demonstrate than to describe:

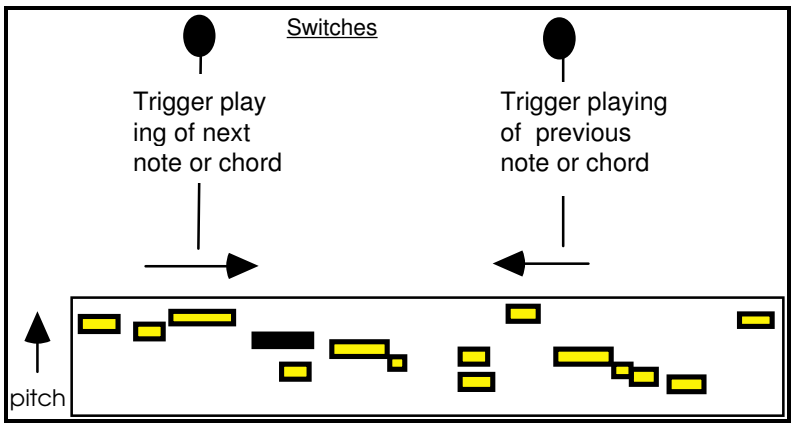

Fig. 2 'Conducting' using E-Scape

Notes can be set to continue forever (as MIDIGrid), or to only play for a pre-set duration. In addition, if the next event (eg a note) is triggered 'early' (ie before the present event has finished), the present note can be set either to *continue* playing to its natural end (as previously composed),

or to cut off immediately. The former can facilitate performing organ or piano music for example, where longer notes are held under others.

Events in a sequence can also be conducted backwards, ie pressing a further switch will play the previous event. Thus a piece of music can be played backwards and forwards a bit at a time. This is surprisingly effective - you can create a totally new piece out of an existing one, or improvise *up*, as well as down a scale.

A further switch can allow the performer to change to a *different* sequence of events, as shown in figure 3.

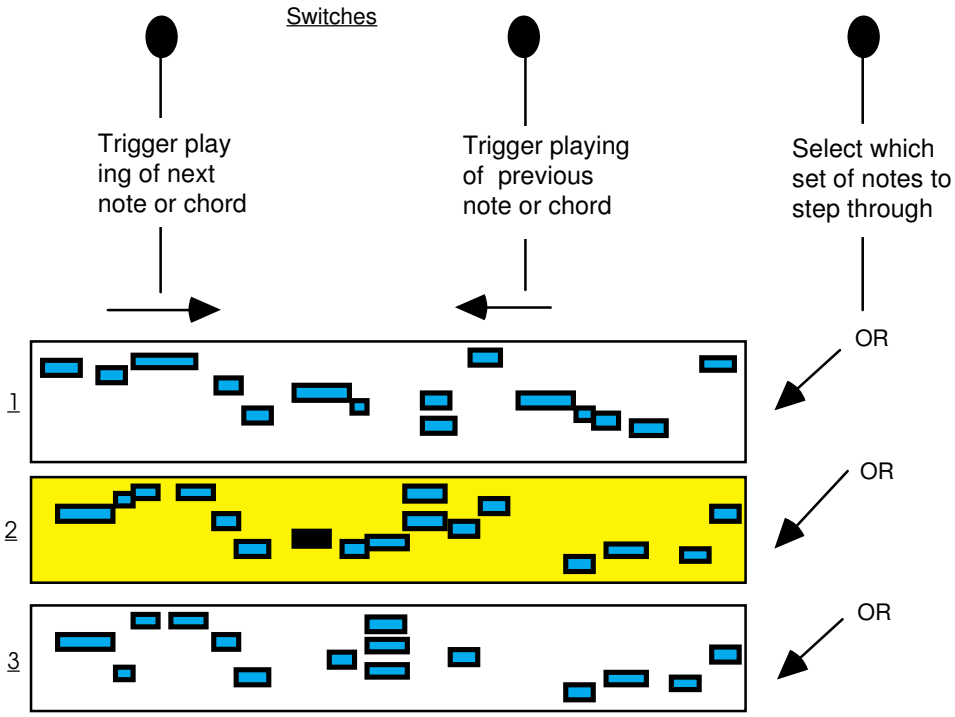

Fig. 3 Conducting a number of sequences of notes using E-Scape

This development is actually very *important musically* to enable a performer to play with other musicians. The new sequence can be a different key, different sounds, a different scale, different dynamics, or be totally different in every way, eg change from conducting through some backing string chords, to a saxophone solo.

Any number of event sequences can in fact be employed, and if the performer is able to, two switches (in addition to the one used to 'conduct') can facilitate moving backwards or forwards through the set of sequences. An example will clarify this idea: a piece might start by conducting through a sequence <A> of backing chords, then move on to a second set of chords <B> in a different key, then move on to a third sequence <C> with the same chords, just a bit louder (perhaps another band member is doing a solo at this point), then go back to the quieter chords <B>. Then go on to a sequence <D> of single shorter notes with a sax sound for a solo, changing back and forth between this and a second sequence of sax notes with a different key or melody. Then go back to the sequences <B> & <C> of chords while other players do solos. Finally go back to the original string chords <A> for the end of the piece.

Another example could have many sequences with the same set of notes, but with different dynamics (eg volume, crescendos etc). Thus a person could, with two or three switches, learn (with practice!) to play quite expressively. E-Scape allows the player to swap sequences at any point, and picks up each one where it was last left.

The idea of triggering notes in a set or sequence has been described, but a performer may want to trigger longer segments of music, as shown in figure 4.

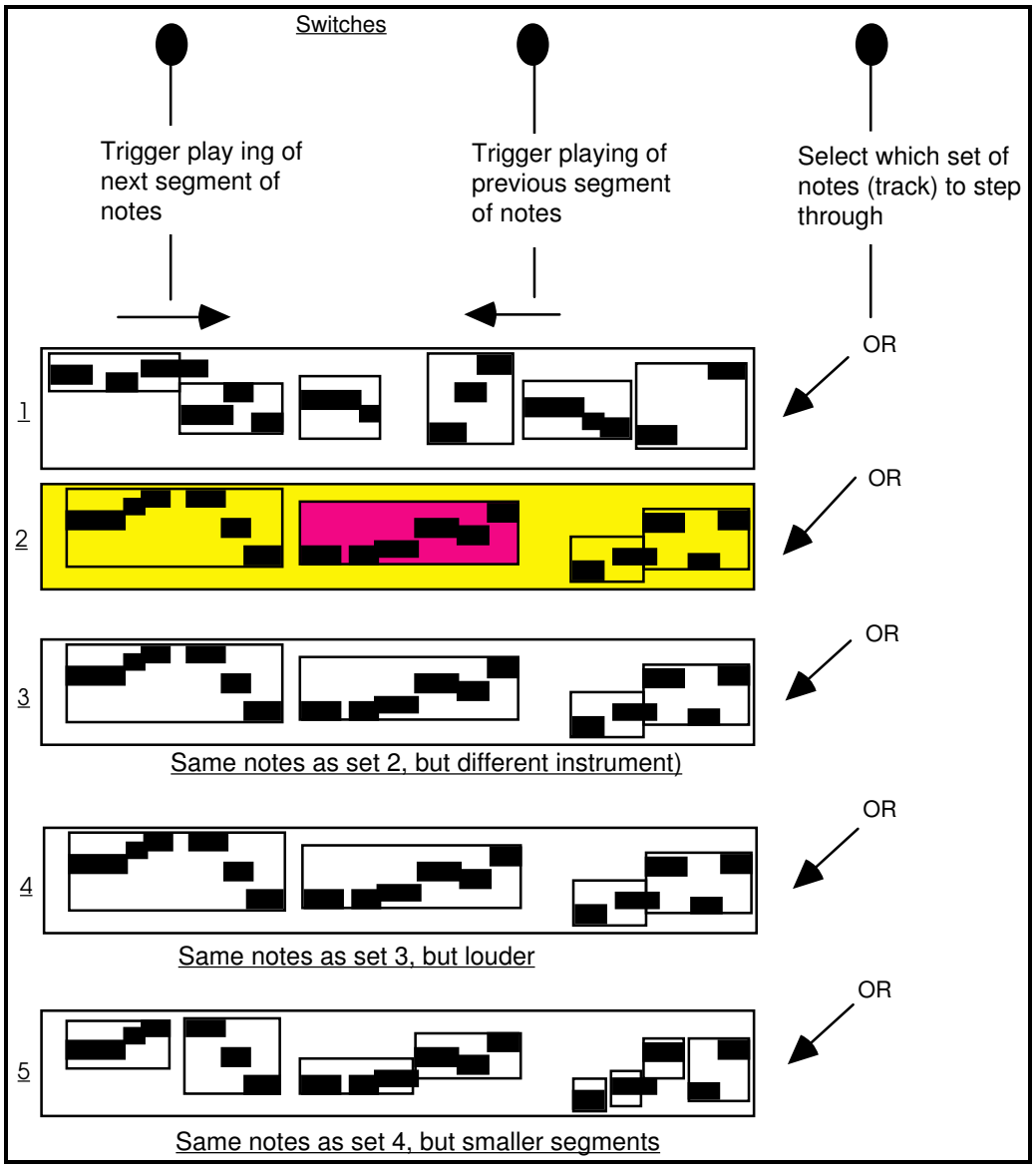

Fig. 4 Conducting several sequences of segments using E-Scape

This enables notes to be played faster than the performer is able to press a switch etc, or allows the performer to prepare (pre-compose) material which has critical timing, or subtle expression which could not be performed reliably live. E-Scape is able to easily split up a piece of music into segments of any length within each track (as in fig. 4), or for the piece as a whole. Segments can also incorporate time-varying control values for such things as pitch bend, volume or filter frequency. These can greatly increase the subtlety and musicality of the performance.

Well known classical or pop music can be loaded in the standard MIDI file format, widely available commercially or on the internet. The piece can then be deconstructed into parts of the desired length (even every note), then performed, in a variety of ways: for example, a number of performers could each conduct one or two tracks each, or some of the tracks can play themselves with the performer conducting one or more tracks themselves live (the 'music minus one' concept), or even the whole piece (see below). This is an excellent way to learn the structure and rhythm of a piece, but the idea is that performers can play it in their own way; eg faster, slower or even going backwards sometimes to create their own variations. Of course many people Drake work with also compose their *own* music for themselves or others to play.

If a piece has been recorded in 'real time' with tempo variation (rubarto) it will sound pleasantly natural and expressive, but will present problems of how to split it up, as there are no fixed time divisions to utilise (you can't say split every half bar). Selecting each group of notes manually and

specifying them as a segment would be very laborious, although this is possible in E-Scape. An easier method has been provided to 'tap along' (press a switch etc) with the piece (eg with the beat) when playing, and the system will remember these points and create segments accordingly. This enables some very pleasing live recordings to be used quickly for conducting.

Rather than conduct through a sequence, then change it, a performer can also use several switches to conduct through *multiple* sequences at the same time - each switch conducting through a *different* sequence, as shown in figure 5.

Alternatively, a number of performers can play together, each conducting one or more tracks. Again, judicious preparation of material is needed to create a satisfying musical result.

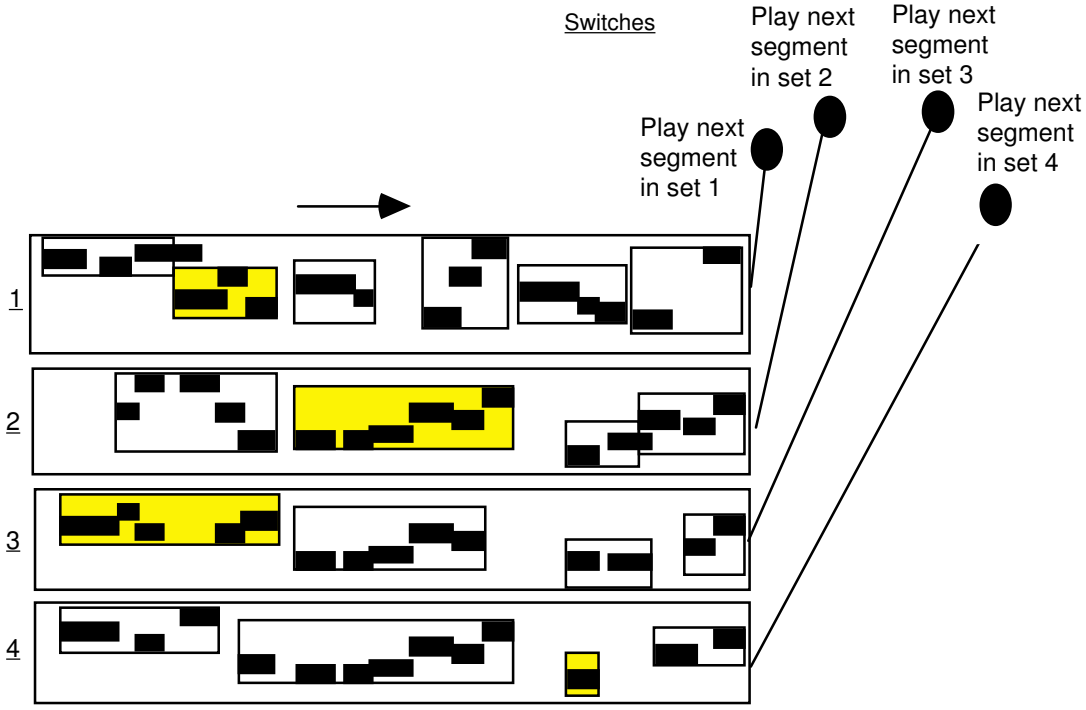

Fig. 5 Conducting multiple sequences independently

As well as conducting each set (track) individually, the entire piece can be conducted as one. Several modes are provided, eg:

(i) Performers first select one track which they will identify with (eg the 1st violin) and specify what segments they want in this track. The performer then conducts this track, and the other tracks (eg orchestral parts) then attempt to follow. The other tracks always play the first note of the *next* segment at the 'right' time (ie as composed), as if they are assuming the performer is going to carry on. If in fact the performer *waited* (ie did not play the next segment at the expected time), the other tracks will then pause until the performer continues. This is far easier to hear than to describe, but feels surprisingly realistic, and is also great fun.

(ii) Players can 'beat out time' by pressing a switch etc (having first selected how quickly they want to beat). Whatever musical events occur on each beat (ie a note starting or stopping) will be played. The finer the time interval specified, the more control the player has, but the faster they have to conduct. Any events which are composed to be *faster* than the chosen time interval for conducting will play themselves between switch presses. A development not yet implemented is for the system to interpret the current tempo from the speed of conducting, and scale the times of any such faster events to fit it.

2. 'Scrolling'

The Drake Music Project has over the years developed a number of ways of using the MIDIGrid software, which allows a disabled performer to trigger musical events by mouse movement or MIDI input. For example, using a grid which is one box high, events can be triggered by a sideways mouse movement, with up-down being ignored. without needing to press the mouse button. By using a trackball positioned under the chin, and having prepared an appropriate set (eg a scale) of notes (one in each box), a disabled performer can improvise on a scale with a sideways movement of the head. The video example shows how effective this can be, operating as a bona fide musical instrument when used by someone with a good musical sense.

This performance mode can be termed 'scrolling': each position of a variable input device corresponds

to a musical 'event' - which can be a silence (very important musically!) as well as notes or chords. With devices like the trackball, the performance input is contiguous, ie the performer has to pass through each value in order. The performer thus has only one degree of freedom, after playing each note they can only move to the adjoining events in the set.

Extending 'scrolling' using E-Scape

In E-Scape, these ideas have been expanded in several ways:

As well as movement of trackball, the location of the performer in space can be used as input, using MIDI notes. There are various sensors which convert distance to MIDI notes (the main one used by Drake is the 'SoundBeam'), and E-Scape can be set to use these incoming notes, mapping onto whatever the current set (sequence) of notes is selected.

Using such a set-up allows the performer's input to be non-contiguous: the performer is able to *jump* from one value to another within the range. This corresponds more to a conventional instrument, a performer can instantly jump to any note on the scale, by moving in and out of the beam, as shown in figure 6.

Thus, the performer can choose to stop triggering events then start again (moving position meanwhile). This is equivalent to stopping blowing (eg) a clarinet, then repositioning the fingers on the keys before starting to blow again. However, as this mode requires an additional dimension of movement, some disabled performers may not be able to employ it.

The duration of notes played can be controlled in two ways: either playing indefinitely until another note is played, or playing for its pre-set duration. Both modes are useful in different situations.

The mouse or beam position can be set either to trigger every note in the set (divided equally), or to trigger whatever is at the screen position pointed to. This allows a long note (say covering half the screen width) to sustain, while other shorter notes which overlap it are switched on and off as the performer moves. Silences of any length can be built in by having gaps between notes.

Another extension provided by E-Scape is to allow the set of notes in use to be altered via a switch press (or indeed another MIDI note), in the same way as for conducting, described above. Again, this is vital for playing in a real situation - imagine a clarinet player who could only play one scale, or in one key! The mouse button can also be utilised to change track, as well as a switch or MIDI note.

Gestural movement can also be used to trigger musical events. E-Scape can use the location information from Soundbeam (eg) to detect when the performer has changed direction, and use this as a switch, eg to trigger events.

The best illustration of these ideas is via real pieces, for example in a 1998 Drake Music Project concert at

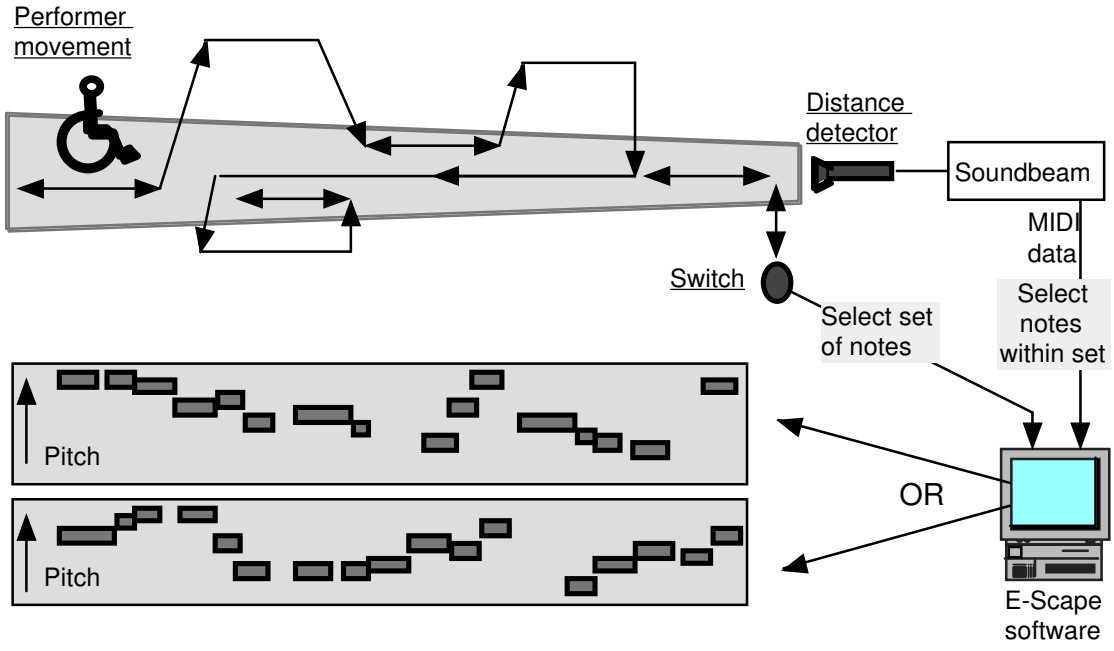

Fig. 6 'Scrolling' through different sets of notes, using Soundbeam

Queens Hall, Edinburgh, performers played E-Scape, accompanied by a backing band and a string quartet from the Scottish Chamber Orchestra.

Disabled performers first created sets of notes, using switch control of E-Scape software. One performer then played E-Scape via the Soundbeam with an electric wheelchair, producing notes depending on the position across the whole front of

the stage. In addition, the performer moved *out* of the beam to *stop* notes playing when desired, and

moved back into it to start at a *different* place in the set of notes. A floor-switch was then pressed to change *which* set of notes (track) was in use at any time. Another performer used a trackball in two dimensions to trigger events.

When composing, attention was paid to the volume and the duration of the notes, to make the performance expressive.

3. 'Mapping'

A switch action can just trigger a single event (rather than step through a set of them). For example, in MIDIGrid, notes on a music keyboard (connected via MIDI) can be set to trigger each box of the grid independently. Each input is thus 'mapped' to a musical event; this could well be a single note, but more often will be more complex, eg a chord, phrase or large segment of music.

The performer is thus controlling a set of inputs (any input which can be converted to a MIDI note can be used, eg switches, drum pads and various sensors) but is producing a more complex musical output.

Extended mapping using E-Scape

As described above, MIDI notes from an ultrasonic distance detector can be 'mapped' to trigger the notes in the active set (track). These incoming MIDI notes could also come from a music keyboard, which can provide a number of useful features to a (perhaps less severely) disabled performer who wants to play keyboard. This requires an additional 'sustain mode' for notes, in addition to 'as composed' and indefinite' - where notes sustain indefinitely *until* the key is lifted (ie an incoming 'note off' message received).

Incoming notes can be mapped to a screen position, and trigger whatever is there (one or more notes, or silence). Thus, some incoming notes can play nothing, some one note, some several notes. If a note on screen is quite long, then it will be mapped to several incoming notes, thus overlapping and sustained notes or chords can be played by pressing a single key, ie using a just one finger or toe.

Any incoming notes which are not mapped will remain silent, which is very useful for players using a foot for example, or who have difficulty not hitting an unintended key. For example, only the black keys could be used, but set to play a major scale. If any white note is accidentally played, nothing will be heard.

The volume and timbre of each note can either be derived directly from the incoming note played, or can be pre-set. This is useful if the performer can not press keys very hard, or consistently. A further option provides a mixture of the two - some real time control which affects (scales) the pre-set note velocities.

Again the mapping can be instantly changed by pressing a key (or switch etc), so one can actually play in any key or any scale just using, say, the black notes of the keyboard.

Conclusion

Recent development enable several performers to use E-Scape simultaneously to do separate things. For example, two players can be conducting segments on two tracks each independently, while another player can be scrolling, and switching between, three sets of notes

It can be seen that the E-Scape system thus provides great flexibility as to how a performing 'task' can be carried out, and is starting to facilitate the provision of complex 'Hyper Instruments' [1] which can be played in a flexible manner, using multiple configurable performer inputs. For example, two or more players could collaborate, each performing actions appropriate to their physical capabilities: one player could be responsible for the conducting itself, (which requires a good sense of timing), while a second player could make the equally important musical decisions as to which material should be selected to be conducted at any point, eg to change the key or dynamics of the first player.

The elements of planning, preparation and setting up are equally as important as the actual performing, and E-Scape allows the boundaries between these components to be flexible. The key to making good music with such systems is in creating or selecting appropriate musical material and 'performing mode' for each situation, ie the musical goals and the experience and physical capabilities of each performer.

These are skills in which Drake has developed great experience in recent years, and in the right hands, the results can be every bit as impressive as from conventional instruments and performance techniques.

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