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A COMPUTER BASED SYSTEM TO ENABLE PEOPLE WHO CANNOT USE THEIR HANDS WELL, OR AT ALL, TO PRODUCE MUSIC WITH THEIR OWN INDIVIDUAL EXPRESSION

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INTRODUCTION

Physical disability, preventing normal use of the hands, makes no difference to a person's inherent musicality, but unaided, such a person can neither arrange, compose, nor perform music. A number of computer packages exist which can be used to arrange or compose music. To make a suitable package available to a person with such a disability, two approaches are possible, to adapt an existing commercial package or to develop a purpose designed system. There is an obvious limitation to the adoption of the first method in that the program source code will almost certainly not be made available. But various keyboard or mouse emulators can be used with some programs, which then "think" they are being driven in the normal way. Such an emulator may work with just one or two switches, possibly operated by head movements. Such operation is invariably clumsy and slow, and a purpose designed approach can give advantages: much greater speed, many less physical movements required, and more natural operation.

The people for whom this package was primarily designed are those with jerky, or poorly controlled, hand movements, or who have no use of their hands but who can use a foot or a head or mouth wand. Goals include simplicity of use, without sacrificing functionality, and to make the system appear to the user as much like a musical instrument as possible, rather than a computer.

Just as no one software package for music, or anything else, suits all able bodied people, the package to be described will not suit all physical disabilities. People whose hands which are physically very weak but capable of precise movements using a mouse may be better suited by the **MIDIGRID** program [1].

It is suggested that the system so developed may be equally attractive to non-disabled people: why should anyone want to make more physical movements than necessary to achieve a given end, or to do anything by a more complex method than necessary?

DESIGN REQUIREMENTS

The overall requirement is for a physically disabled person not to be handicapped, in composing, arranging, and producing a "stored performance" of a piece for later reproduction. The approach taken is to fully achieve this goal for certain types of music, rather than partly achieve it for a very wide range. The range of music to be further extended as the system is enhanced in continuing development.

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To achieve the goal, the system must produce high quality sound, and be able to provide good imitation of several real musical instruments playing together, as well as synthesised new sounds.

The following special considerations apply for the system to be used by those for whom it was primarily designed.

1. It should appear to the user to be like a musical instrument, not a computer, and for that reason, a piano type keyboard, together with some extra control keys, will form the user interface.

2. A user will be able to press keys on a piano type keyboard, one key at a time, but will not be able to press the key at a specific instant, nor hold it down for an exact length of time.

   To facilitate the pressing of keys, using a head or mouth wand, a special guide plate will be provided to guide the end of the wand on the the piano keys and control keys. The guide plate will also be useful for people who can use their hands but whose hands are very shaky: they can rest their hand on the plate while pressing the required keys.

3. Since a wheelchair cannot move sideways, the piano style keyboard needs to be short enough for all the keys to be reached from one position. Hence it will be of about 3 octaves if full size keys are used, or 4 or at most 5 octaves with the small keys used on some commercial keyboards. Means of moving the octave given by a key is therefore required.

4. The control keys must not be out of reach when sitting in a wheelchair in one position. This precludes the use of a computer keyboard placed at the side of the piano keyboard. For some users it may be possible to mount a computer keyboard above or below the piano keyboard, and where this can be done it avoids extra cost, but in general dedicated control keys are required, suitably positioned.

5. Excellent facilities are required for dealing with, and correcting mistakes. Mistakes especially include pressing the wrong key in error, eg due to jerky movements of the hand, and holding a key down for too long or not long enough.

SOUND GENERATION

There are two main choices (a) generation of sound directly by the computer, and (b) using MIDI (Musical Instrument Digital Interface) to produce sounds

on external MIDI equipped keyboards and synthesisers. MIDI was developed with keyboard instruments in mind, and is at its best with plucked and struck sounds. While it can produce wind and string sounds, there are several drawbacks and limitations. Hence if one wanted to produce a realistic 'cello sound, with all its vibrato, tremolo, slight pitch deviations, dynamic changes in volume and timbre according to the bowing, one simply could not do this fully using MIDI. But the problems of doing it any other way should not be underestimated - a major project in itself.

However for piano sounds, much the most realistic sound can be produced using MIDI. This is simply because manufacturers such as Roland and Yamaha have put a huge investment into producing MIDI based electronic pianos. The sound of these is generally much superior to general purpose MIDI based synthesisers offering a choice of a hundred or more sounds. If still more realism is demanded, a MIDI driven acoustic piano is available commercially.

Since the goal is, in short, to do some music very well, a MIDI based approach has been taken. Using a MIDI electronic piano several different piano sounds are usually available together with some others such as harpsichord and vibraphone. The choice of sound may be further extended by using MIDI "expander" modules: synthesisers without a piano style keyboard and so correspondingly less expensive. No one manufactures seems to produce an "expander" with attractive sounds for all the instruments one might wish to use. The author uses 2: the Yamaha TX81Z and the Roland D110, using selected sounds only, along with a Roland RD300 electronic piano. The outputs for all of these are fed to a mixer and reverberation and equalisation may be applied as desired. Two or more variants of a sound, possibly slightly detuned from each other, can give even better results.

Using this set up, a reasonable wide choice of attractive struck and plucked sounds is available. If the user wishes to use wind or string sounds, he of course may, but the goals will not be reached. One might remember that a good upright (acoustic) piano would cost about the same, and one would not demand that this also produce harpsichord sounds, far less those of a violin.

ENTERING NOTES

There are two main methods of entering the musical notes into commercial music packages.

"Real time entry" allows the notes to be entered very quickly, by simply playing the piece, possibly at reduced tempo, and having the keystrokes recorded by a computer, but this method cannot be used here.

"One note at a time" is a method which can be used by anyone, disabled or not, who cannot play the musical instrument in question (or play it well enough to play all the notes at once, in correct time, even at reduced tempo).

There are some intermediate systems, eg playing all the notes first without concern for timing then subsequently adjusting the time values.

The method we must adopt is the "one note at a time" method, but the details of how this is to be done is critically important for the success of the system, and before describing this it will be useful to look at some methods used in commercial packages.

Several systems allow notes to be entered by using either a mouse to place them on ledger lines, or from a piano keyboard. But the length (time value) of the note has to be preselected. Hence if notes are a dotted crochet, a quaver, and a crochet, one has to select the note length between each note being entered. In some systems it is necessary to "pull down" a menu of note values each time using a mouse: this is slow and wearisome and it involves lots of physical movements.

The method adopted is as follows. First a unit of length is selected, corresponding to 1,2 or 3 steps. Pressing a "duration" key cycles between these. When a music key is pressed it enters a note of that length. If the note is held down, then after a set time a bleep sounds warning that if the key is not released the note will be extended by the selected unit of length. If a key is held for too long, a press of the delete key removes a unit of length. If it is released prematurely, pressing a "continue the note" key extends it in length by a like amount. Rests are entered using a "rest" key. The "delete", "continue note" and "rest" keys are treated as ancillary music keys: they affect a like unit of length and they repeat in the same way as the ordinary music keys do. The repeat time can be set to suit, and is separate from the ordinary key repeat delay, for entering numbers etc., which can also be set.

Thus to enter a dotted crochet, a quaver and a crochet, we have a choice of three methods:

(a) Set the "duration" to 3, press the required note, press the "duration" key (which will result in a setting of 1 unit), press a note, and press the "duration" key again and press a note.

(b) Set the "duration" to 1. Hold down the "piano" key for the first note until it extends the note twice. Press the key for the second note. Press the key for the third note and hold it down until it extends once.

(c) Set the duration to 1. It is assumed that the music key repeat delay has been set to infinite. Press the required music key, then press "continue the note" twice. Press the next note then press "continue the note" once.

These choices suit different people and different situations. For example if there were a sequence of dotted crochets followed by a sequence of quavers, most people would choose method (a).

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EDITING METHOD

Staff notation is designed for real time performance by musicians. It is suggested that a more appropriate notation for the present purpose is a graphical representation, where each note is represented by a horizontal bar whose length is proportional to the time value. The height of the bar on the screen is determined in a similar way to staff notation, and each note in the scale is given a colour, which is the same in each octave, so that octave equivalence is much clearer than is the case with staff notation. The colour system used is the same as that developed by the author as a visual representation of music for deaf people [2]. Although not essential for the present purpose, it has the advantage over arbitrary colours that the logical connections between them are closely related to the acoustic relationships. At some special schools children are harmonising tunes on the basis of colours "which go together".

For those who wish to have a conventional staff notation version of their music, the piece could be read into a commercial musical notation package and printed out.

EDITING NOTES

Repeated sections are found in most music, hence the ability to place marks, ie to mark sections to be operated on, and copy them is important. The repeated section is often in a different octave, may occur in a different part, or may be transposed eg by a fifth.

The copy function allows all the parts to be copied to any position. Alternatively, a selected part may be copied to another part. An option for transposition is given within the copy as this saves several physical movements compared with two operations separately. For similar reasons an option is given to transfer marks to the copied section.

Various other editing functions are provided such as exchanging parts in a marked section, "two steps for one" and "one step for two". To explain these, suppose one puts in a piece of music with the the duration unit corresponding to a quaver, and one then comes across a semi-quaver, particularly for a person with disabilities should one say to them "It says in the instructions, 'make the duration unit the shortest note', you will have to abandon it all and start again". "Two steps for one" puts the situation right. But this facility is more useful than merely for correcting errors. It can be used to make note entry easier if there are only a few very short notes, exactly as in the "mistake" above. If desired it can also be used at a higher level in work on contrapuntal pieces where, for example, augmentation (a part playing with doubled time values) can be easily achieved.

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Facilities are provided through, a keyboard "pause" option, to try out notes without entering them. These notes can be heard on their own or against notes in other parts which have already been entered.

Default answers to all yes/no questions and requests for numbers are provided on the most likely basis (eg transposition by 12 semi-tones) and the default may be selected by pressing the control key "Return".

EXPRESSION IN THE MUSIC

Computer based music is frequently accused of being mechanical, often rightly, but there is no need for this to be the case given appropriate software and suitable sound generation.

Variation in timing is perhaps the most important expressive element - for example on the harpsichord and organ (excluding the swell) no variation in volume is possible within a single registration, yet playing can be expressive. In this package, each step is given a separate time interval which is stored with the piece, hence three successive crochets could be played evenly, or unevenly in time, just as they could by a performer.

Each step also has a separate "velocity" stored for each part, and this can be used to simulate the changes in volume and timbre which would be produced on a piano according to how fast the key is depressed, or it can be used to control other parameters of the sound. Each step has a detachment stored, ranging from 0, full legato, to 9, very staccato.

EDITING EXPRESSION

There are three ways in which the user can affect the expression of a piece to suit his own interpretation.

1. The time value, velocity and detachment of individual "duration" units can be set directly by pressing keys for each of these. Thus if the "duration" were set to 3 it would affect the current step and the two following steps.

2. A section can be marked in the same way as for editing notes. Begin and end values are requested for the marked section. The software then calculates the intermediate values on a square law basis. In this way a *rallentando*, or a *crescendo* etc can be formed. Or equal begin and end values could be given for the detachment of a section which is to be played staccato throughout.

3. An "expression pattern" may be set; eg, for a Viennese Waltz one might set a time values pattern of 7:9:8 which would result in some time being "stolen" from the first beat in the bar and given to the second. One might set a relative velocities pattern of 8:5:4 and 0:0:3 for the detachment. If this were applied to the whole piece it might be almost as mechanical as having everything even, so it would be usual to apply it to a marked section, with a slightly different pattern for another section. Exceptional values in certain individual bars could then be entered if desired. This process is carried out relative to existing values, hence a *crescendo* or a *rallentando* would not be removed by the pattern.

4. A control lever may be selected to affect either tempo or the velocity of all parts, or a chosen part, while the piece is playing, optionally at reduced tempo. In this way, a user can either have some real time control over "a performance" or opt to record the changes introduced by the lever which then becomes part of the stored performance.

   Even with hydraulic damping of the lever and software smoothing, this method is not successful with many people with very jerky hand movements. Yet it has obvious attractions for some people over the above methods which may be judged "too analytical". Part of the ongoing research will be to try a lever which controls the rate of change of a variable. Thus pushing the lever forward a little would give a slow, continuous increase, moving it further forward a larger rate of increase. Thus to achieve an even rallentando, the user would merely have to pull the lever back and leave it there, rather than having to move it continuously. But one problem which will have to be solved is how to return to "a *tempo*" etc.

Other functions for editing the expression include copying, scaling sections, and expansion and compression of dynamic patterns, both in respect of tempo and velocity.

DETAILS OF THE CONTROL KEYS

Extensive testing of the system with various users, at different schools and centres has shown that 16 control keys is about the optimum. This enables numbers from 0 to 12 to be entered directly, and all numeric input is obtained by pressing single keys. When entering numbers, choosing from menus etc, the user is in "normal" mode, the border round the screen is blue and the legends on the control keys are in blue.

To have keys available for most required operations directly, rather than having to press two or more keys in sequence, two other modes are provided: "compose notes" where the border and key legends are in red, and "compose expression" where they are in green. Separating these operations has the further advantages of simplifying use - one is either working on the notes or

on the expression, and it avoids the danger of accidentally changing the notes, by pressing a wrong key, when one is not working on the notes.

The function and legends on the 16 keys are as follows:

NORMAL MODE (blue)	COMPOSE NOTES (red)	COMPOSE EXPRESSION (green)
RETURN (default)	QUIT compose notes	QUIT compose expression
DELETE	DELETE NOTE	TEMPO OF NOTE
ABORT	ENTER A REST	VELOCITY OF NOTE
0	CONTINUE NOTE	DETACHMENT OF NOTE
1	<--- (cursor left)	<--- (cursor left)
2	---> (cursor right)	---> (cursor right)
3	<<=>> (cur. to L/R edge)	<<=>> (cur. to L/R edge)
4	KEYBOARD OCTAVE UP/DOWN	
5	PAUSE MODE ON/OFF	TEMPO FOR MARKED SECTION
6	ACTION HERE	VELOCITY FOR MKD. SECTION
7	MARK / MARK OPTIONS	DETACHMENT FOR MKD. SECTION
8	CHANGE PART	CHANGE PART
9	CHANGE DURATION	CHANGE DURATION
10	SOUND PREVIOUS CHORD	PLAY FROM BEGINNING
11 / NO	PLAY IN CONTEXT	PLAY IN CONTEXT
12 / YES	PLAY CURRENT PAGE	PLAY CURRENT PAGE

IMPLEMENTATION

The system is implemeted on the Acorn Archemides or A3000 with MIDI interface and a medium resolution RGB monitor.

The software package is called ***Vistamusic*** and is available form the author.

REFERENCES

[1] Hunt, A D and Kirk, R P, "MIDIGRID - a new musical performance and composition system", Proc. I.O.A. Vol 10 Part 7 (1988)

[2] The system was described, using colour overlays, at the Second National Conference on Music and the Hearing Impaired at Galaudet University, Washington DC, 1989.

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