Music alphabet for low-resolution touch displays

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ABSTRACT
In this paper we present a novel approach to writing music on handheld pen-based devices which has been developed during the implementation of *MusicMan*, our pen-based music score editor. A new alphabet of music symbols has been designed especially for use on devices with small screens by musicians skilled in writing the music by hand. Our alphabet is based on simplification of the common Western music notation symbols, making them easier to write on PDA while retaining their overall feel. A user study described in this paper revealed that the alphabet is significantly faster, easier-to-use and more accepted by the first-time users of PDA than the state-of-art method for pen-based writing of music.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Ergonomics, Input devices and strategies – *touchscreen, mobile device.* H.5.5 [**Sound and Music Computing**]: Methodologies and techniques

General Terms
Design, Languages

Keywords
Music Score Editor; Pen-Based Interfaces; Handwritting; Comparative Study

1. INTRODUCTION
Composing music is a process of transforming music invention into a musical piece. As with any other creative process, the music invention arrives very often while the composer is focusing on some other activity but it is vital that the composer records this invention as it may be easily forgotten. Different composers adopt different strategies to prevent this. For example, a Czech composer Leos Janacek (1854 – 1928) was often seen to write pieces of music on the wristbands of his shirt. Other composers would keep a music notebook or a voice recorder with them at all times.

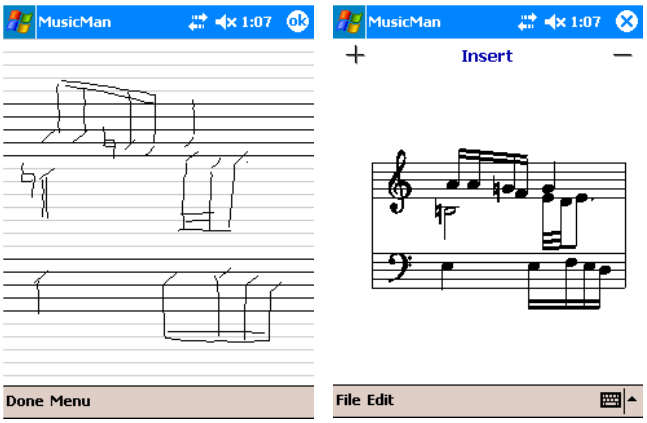

Figure 1. The MusicMan application. a) MusicMan Alphabet b) Recognized and typeset notes

Nowadays many music composers use personal computers for writing, arranging and storing their music scores. While the current music authoring and arrangement tools, such as *Finale* or *Sibelius*[1], offer ample range of music editing functions, there is usually a significant effort needed to access these tools, such as turning on the PC etc.

This paper presents our pen-based music editor *MusicMan*, input music alphabet and a user study we have performed. Our aim was to develop a solution that would provide the main features of the computer music software (interactive playback, music score data transfers) while keeping the preparedness of the music notebook. The result of this effort is a PDA-based application *MusicMan* where the composer uses an alphabet of music symbols (MusicMan Alphabet) which is based on the contemporary Western music notation and has been designed with respect to the limited screen resolution and computing resources of PDA.

The goal of *MusicMan* (see Figure 1) is to provide a portable solution for writing down music ideas and parts of future compositions, including polyphonic motives and harmonic structures. The application is intended for recording an instant idea which can be subsequently expanded in composer's favorite music editing tool.

2. RELATED WORK
There are numerous methods to write and process the sheet music on the PC: WIMP[2] based editors (such as already mentioned

[1] http://www.sibelius.com, http://www.finalemusic.com

[2] Windows, Icons, Menus, Pointer

Finale or *Sibelius*) in which the user enters the score by traditional combination of mouse and keyboard, MIDI keyboard-based editors in which the music played by the user is converted to score, or optical music recognition (OMR) [2] that aims at conversion of arbitrary printed or hand-written music to a machine-legible form.

Pen-based interfaces of music editors are generally designed for users who prefer handwriting. These systems usually offer methods of entering music that are closer to traditional writing of music on paper. Nevertheless a specialized hardware which makes the pen-based input possible is always needed (e.g. tablet or a tablet PC). Each system makes use of an on-line recognition of user's strokes into music symbols.

The pen-based systems can be divided into two groups according to the method of entering music symbols – simple gestures or handwritten music. The gesture-based applications convert gestures (single strokes, see Figure 2) to commands for modifying the score, such as "create a new note" or "halve note duration". Gestures are usually far from common music notation symbols and the user needs to memorize a set of them in order to be able to use the applications efficiently. On the other hand it is computationally inexpensive to recognize the gestures and therefore high performance and accuracy can be achieved.

Figure 2. Example of Presto gestures. Dot represents beginning of the gesture.

One of the first gesture-based system [3] defined a limited set of gestures for entering simple notes and rests. *Presto* [1, 9] combined gestures of 13 commands for the most frequent music objects and menus for less common ones. Another gesture-based application *Music Notepad* [4] came with complete set of gestures, avoiding the use of the pull-down menus. It is controlled by a four-button stylus for controlling different operations (a button for sheet manipulation, a button for moving the objects, etc.).

The handwritten music systems recognize conventional or slightly modified music notation symbols, where each symbol can be composed of several strokes. The key advantage of this approach is obvious: the composer can use a familiar set of notation symbols. George [5] used artificial neural networks to classify 20 fundamental symbols with 80% accuracy. However, this method only supported the recognition of stand-alone symbols and did not allow their aggregation to chords or beams, etc. Mitobe [7] has used Hidden Markov Models to recognize 26 simplified basic strokes such as note head, stem or flag. Shapes of the strokes were similar to the conventional notation except for filled note heads and rests. Miyao [8] describes recognition of the same set of strokes by means of the support vector machine to achieve better accuracy (98%). Unlike [5], this system supported chords. However, none of the handwritten music systems mentioned above was capable of recording multiple voices, musical staves and even beams, which is crucial for music notation (see [1]).

The methods and applications mentioned above are inappropriate for our use case because of the following reasons:

1. We do not want users to remember a large set of hardly memorizable gestures.
2. Current handwritten music systems do not enable connecting notes together (beams, etc.)
3. The state-of-art solutions are not well suited for mobile application.

3. MUSIC MAN ALPHABET DESIGN

Our music notation derives benefits from both approaches described in the previous section. Handwriting is the most natural method for recording music, therefore we followed principles of handwritten music. We consider individual strokes as music symbols or parts of music symbols unlike gesture approach, in which strokes represent commands. When the user wants to add a sharp in front of a note, the best way is to draw it instead of using gesture such as shown in Figure 2. On the other hand gestures are easy to draw and easy to recognize, because there are no complicated strokes. This approach also influenced our notation.

Figure 3. Noteheads.

Our aim was to design the alphabet in the way that the music notation is easily produced on PDA screen as well as it is easily memorized by the user. Our intention was to develop a portable solution for recording music inventions, which does not need to handle all properties of music notation. We carefully selected symbols to be included in the input MusicMan alphabet (MMA). The most frequent symbols were chosen according to [1] as well as our observation – note heads, stems, flags, rest, beams and accidentals. We omitted elements such as slurs, tuplets, or lyrics.

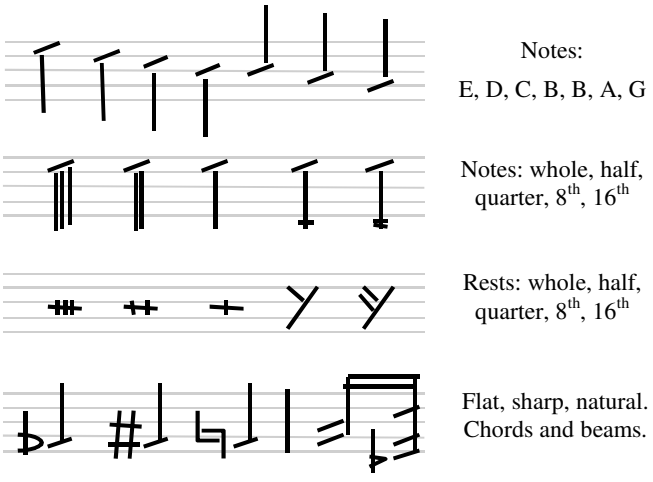

Figure 4. MusicMan Alphabet (MMA)

However we focused on the complex structure of interconnected musical symbols. MMA supports beams, chords, multiple staves and multiple voices within a staff. The MusicMan Alphabet (MMA) is a result of an iterative design with a usability study performed in each iteration. Several variants of the alphabet were proposed and the final version of the MMA is shown in Figure 4. During the design we identified the crucial problem of entering

notes by music notation on PDA screen: users felt uncomfortable when drawing filled objects such as note heads or whole and half rests. Mitobe [7] proposed a special stroke for the filled note head (see Figure 3). The stroke did not prove usable on PDA as it was difficult for the users to draw it. We have therefore decided to reduce the note head to a line.

Music notation in our alphabet consists of three *microsymbols* – dot, line and three-point polyline. Combination of the microsymbols produce a basic symbol (e.g. note, accidental, rest etc.). Further combination of basic symbols produces symbols of higher level (e.g. chord, a group of beamed notes). Since the microsymbols are basic geometric shapes, they can be easily classified. Meaning of a microsymbol is determined by surrounding context. Note that microsymbols can vary in length which is characteristic for music notation – consider for example bars or stems.

4. IMPLEMENTATION

The MusicMan application can be launched on any device equipped with Windows Mobile operating system. The application is capable of entering notes using MMA, editing a score and playback of the music. The music can be loaded and saved in the MusicXML [6] interchange format and also exported to MIDI format. The input is recognized only on user demand, usually after several strokes have been made. The user's input is then converted to the typeset music.

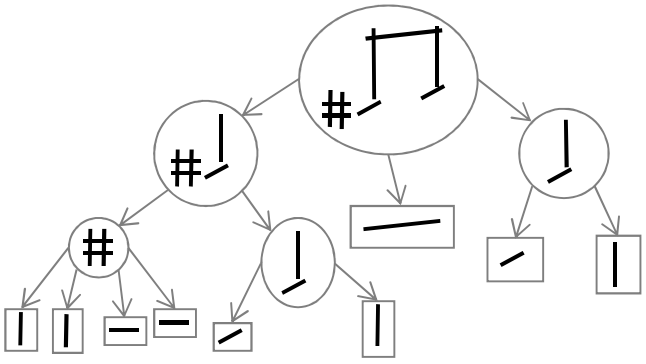

Figure 5. Data structure for score representation. Decomposition of notes with beams. Note that leaves (shown in rectangles) are always microsymbols.

In order to deploy our application on PDA, we have developed a computationally inexpensive algorithm for recognition of MMA. During the recognition process the symbols and microsymbols are combined together to produce hierarchical description of a musical score stored in a tree data structure (see Figure 5). The process is driven by grammar rules as only valid combinations of microsymbols are allowed. This approach provides very high speed of recognition. An average measure (approximately 50 microsymbols) is converted in 15 ms on Intel PXA270 CPU running at 624 MHz (HP iPAQ hx2410).

5. USER STUDY

The aim of the study was to compare common music notation (CMN), MusicMan Alphabet (MMA) and alphabet proposed by Mitobe [7] (MITOBE, several symbols are depicted in Figure 6) in terms of speed of writing and user satisfaction. The study focused on verification of design of MMA. Measurement of recognition accuracy was not part of the experiment and will be undertaken in a future study.

Figure 6. Mitobe approach. Noteheads, rests: whole, half, 8th

19 participants (10 males, 9 females, mean age=23, SD=3.1) took part in the study. 10 of them were amateur musicians (at least 8 years of basic music education) and the other 9 were conservatoire students (2-4 year). Their average music experience was 14.9 years (SD=5.1). All of them prefer handwriting for writing music, but sometimes they use a WIMP music editor. They were all experienced computer users (using computers at least 10 hours a week) but they were generally not familiar with PDA. At the beginning of the session, each participant was given necessary time to get to know both MMA and MITOBE alphabets.

The participants were instructed to write two different simple melodies (#1 and #2), each using MMA, CMN and MITOBE methods on PDA screen. The melodies of two well-known folk songs were used (5+7 measures, 27+36 music symbols, 6 different music symbols). The participants knew the melodies by heart. They were, however, instructed which key and beat to use before they carried out the task. The order of methods used by each participant was randomized to further minimize any learning effect. After performing all tasks, the participants were given a post-test questionnaire to subjectively rate the methods. A single session lasted approximately 50 minutes.

Table 1. Results of the user study. Mean times and SD are displayed for each melody.

Melody #	CMN		MITOBE		MMA	
	T_{mean} [s]	SD	T_{mean} [s]	SD	T_{mean} [s]	SD
1.	77	20	85	20	59	10
2.	83	21	95	19	74	14

The quantitative data obtained from the experiment were both objective and subjective – duration of each subtask was measured and post-test questionnaire was evaluated. Table 1 shows mean times and standard deviation for each method and task. The ANOVA test showed that the mean values of the duration t_{mean} for each method were not equal in both melodies. (Melody #1: $F(2,54)=10.3$, $p<.05$; melody #2: $F(2,54)=5.8$, $p<.05$). To find significantly different pairs the Scheffé method was used. Even though the participants were skilled in reading and writing CMN, MMA was significantly faster than CMN and MITOBE in the first task (melody #1). In the second task (melody #2) there was a significant difference between MITOBE and MMA. We believe that these are very good results with regard to the limited time the participants had to get acquainted with our alphabet. The learning curve of MMA as well as its long-term acceptance will be the subject of a further research.

The subjective data were gathered using a questionnaire filled out by each participant at the end of their session. The questions aimed at comparing MMA, MITOBE, and CMN. They are

Table 2. Questionnaire results. Scale 1 (= certainly yes) … 3 (= neither yes nor no)... 5 (= certainly no). Mean values and SD are displayed for each method and question.

Have you found MMA / MITOBE / CMN...		CMN		MITOBE		MMA	
		mean	SD	mean	SD	mean	SD
Q1	... easy to use?	2.2	0.92	3.6	0.90	1.9	0.91
Q2	...intuitive?			2.9	1.05	2.2	1.03
Q3	... acceptable for use?	2.6	1.37	3.9	1.17	2.1	0.96
Q4	... easy to learn?			2.1	1.02	1.7	0.99

summarized in Table 2 together with the aggregate results. Our method was subjectively considered to be the best of all three methods. According to ANOVA test, the users rated simplicity (Q1) and acceptance (Q3) of MMA significantly better than MITOBE (Q1: $F(2, 54)=17.6$, $p<.05$; Q3: $F(2, 54)=14.9$).

During the test we collected also qualitative data in an informal discussion with the participants: MMA was considered to be a fast, easy and comfortable approach to writing music on PDA. The users complained mostly about filling note heads when using CMN. They also confirmed our suspicion that MITOBE note head was unsuitable for low-resolution touch displays.

6. CONCLUSION

This paper presents a novel method of writing music on hand-held pen-based devices. The method was developed during the implementation of MusicMan, our pen-based music score editor. Our aim was to provide an easy-to-use method for writing down music ideas in mobile environment.

The MusicMan Alphabet (MMA) has been designed especially for devices with small screens, to be used by composers already proficient in writing music by hand. Our alphabet simplifies common music notation symbols, making them easier to write on PDA.

This paper has shown the MMA in a relation to other alphabets for music handwriting. A user study described in this paper revealed that the alphabet is significantly faster, easier-to-use, and better accepted by the first-time users than other alphabets for pen-based music writing. MusicMan is capable of entering polyphonic motives and harmonic structures such as notes with beams, multiple voices and multiple staves.

According to the user study we have performed the MMA is significantly faster than Mitobe [7] approach. The users found the MMA to be a fast, easy and comfortable approach to writing music on PDA. This has been established in a subjective part of the study which revealed that MMA was found significantly easier and better accepted by the users. Usage of MMA is comparable to common music notation in terms of speed and user satisfaction. Furthermore, the recognition of the MMA symbols is very computationally inexpensive and therefore suitable for input of the music on PDA.

In future work we will focus on conducting studies which will determine recognition accuracy and long-term acceptance of the MMA.

7. ACKNOWLEDGEMENT

This research has been partially supported by the MSMT under the research program MSM 6840770014. Adam Sporka's research is currently being supported by EC Marie Currie Excellence Grant for the ADAMACH project (contract. No. 022593).

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