MOGCLASS: A Collaborative System of Mobile Devices for Classroom Music Education

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ABSTRACT

We introduce MOGCLASS: a system of networked mobile devices to amplify and extend children's capabilities to perceive, perform and produce music collaboratively in classroom context. MOGCLASS includes various features for students to enhance their motivation, interest, and collaboration in music class. It provides a wide-ranging palette of easy-to-use musical instruments for students to choose from, and supports both collaborative silent practice with headphones, and collaborative performance with loudspeakers. To facilitate classroom management, the teacher's interface is used to control students' activities. Our evaluation results indicate that MOGCLASS is effective in increasing students' motivation in learning music and in supporting teachers' classroom management.

Categories and Subject Descriptors

H.5.5 [**Information Interfaces and Presentation: (e.g., HCI): Multimedia Information Systems**]: Sound and Music Computing; K.3.1 [**Computing Milieux**]: Computers and Education; J.5 [**Computer Applications**]: Arts and Humanities—*Music*

General Terms

Design, Experimentation, Human Factors.

Keywords

Mobile devices, music, education, musical instruments, children, user-centered design.

1. INTRODUCTION

Listening, performing and creating are crucial components in any music education program [7]. However, classroom music teachers face a number of difficulties [15] in aiding students' development of those skills:

(i) a limited range of instruments with which students may explore, experiment, create, and perform;

(ii) the time and physical skills required to gain basic competency with said instruments;

(iii) ineffective practicing in small groups (3-10 students) due to sound pollution in a shared classroom;

(iv) managing young children in music classes.

To address these issues, we created MOGCLASS (Musical mObile Group for Classroom Learning And Study in Schools), a multimodal musical environment with mobile devices (the Apple iPod touch), catered specifically for students and teachers as a result of careful attention to the needs of classroom music education practices.

The limited number of available instruments (problem i) is addressed by using mobile devices to simulate a wide range of easy-to-use instruments. These instruments uncouple physical instrumental skills (problem ii) from the teaching of more abstract music concepts such as musical creativity and improvisation. MOGCLASS addresses the challenging task of creating a system which "allows the player to begin to act, with some degree of effectiveness, before being really competent... (the student) thereby eventually comes to gain competence through trial, error, and feedback" [12].

Individual, small group, and large group practice (problem iii) is supported. Each mobile device is equipped with a headphone for private use, and (at the teacher's option) can be networked to peers in a small group. Students in the same group can hear each other's sound via their headphones without being distracted by sounds from other groups. The devices can connect wirelessly to a server and loudspeakers if a class-wide performance is desired.

MOGCLASS provides tools for effective classroom management (problem iv). The teacher's mobile device controls students' mobile devices, specifying which actions students are allowed to perform. These controls include muting student devices (to allow the teacher to talk without distractions), setting devices to a specific instrument (to focus on a particular musical genre), or permitting all actions (to allow students to freely explore more creative possibilities). The teacher may also select whether students will practice individually (no shared sound), work together in small groups (shared sound within groups via headphones), or allow the entire class to play together (shared sound via loudspeakers).

Study results showed that MOGCLASS system is effective both in motivating students' interest and collaboration in music as well as helping teachers' classroom management.

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2. RELATED WORK

MOGCLASS draws upon three concepts: mobile devices, music-making, and classroom music education. Previous work has combined two out of these three, but not all three.

2.1 Music-Making with Mobile Devices

Music-making with mobile devices (e.g., PDAs, smartphones, electronic music players) is a hot topic in current research. NIME (New Interfaces for Musical Expression) [3] regularly includes papers about hardware-customized mobile phones, and MMW (Mobile Music Workshop) [2] is a conference devoted entirely to this subject. There is an EU project SAME [4] focusing on mobile active music experience. Prime examples of such work include Shamus [10], the combination of a Nokia 5500 with an additional accelerometer with higher fidelity, and Audioscape [21], a combination of mobile devices to create shared 3-D virtual environments.

There are numerous commercial applications which transform a mobile device (such as the Apple iPhone) into a virtual musical instrument. For example, Cosmovox [1] allows the user to play notes with 45 different musical scales. Smule's famous Ocarina [5] mimics the ancient flute of the same name, allowing users to play with four tone-holes.

2.2 Mobile Devices in Classroom Education

Using mobile devices for educational purpose has been attempted in the past few years. *Meaning* [16] uses mobile devices to present children's activities in kindergartens to parents, allowing increased communication within families. *Explore!* [9] is a mobile-learning system which helps students acquire historical knowledge. *LeafView* [20] is a tablet PC application which aids identification of botanical species, aiding student field trips.

2.3 Technology-Enhanced Music Education

Multiple research projects for enhancing music education have been developed in the past few years. Family Ensemble [17] increases student motivation by providing an easy way for beginning piano students to play piano duets. Non-musicians (such as parents or siblings of a student) may perform the secondary part by merely tapping the rhythm; the computer automatically fills in the correct notes so that the secondary part always matches the student's part.

Many technological projects for classroom music education have been attempted in recent years; a good survey is presented in [19]. Students have considerable interest in technology-enhanced music lessons, as shown by a recent survey of almost two thousand students in Shanghai secondary schools [13]. The Princeton Laptop Orchestra (PLOrk) [18] teaches undergraduates a combination of computer programming and music.

However, few technology-enhanced projects involve young children performing instruments; most focus on composition, listening, or instrument-neutral performance skills. One rare example of instrument performance (which still includes a strong component of composition and listening) is the Continuator [11]: a student plays a short musical phrase, then the computer plays a "continuation" of that phrase.

Since MOGCLASS system was created specifically for children in the context of classroom music education, these individual virtual instruments are impractical. More work needs to be done in analyzing teachers' classroom practices, children's requirements, and the current music curriculum.

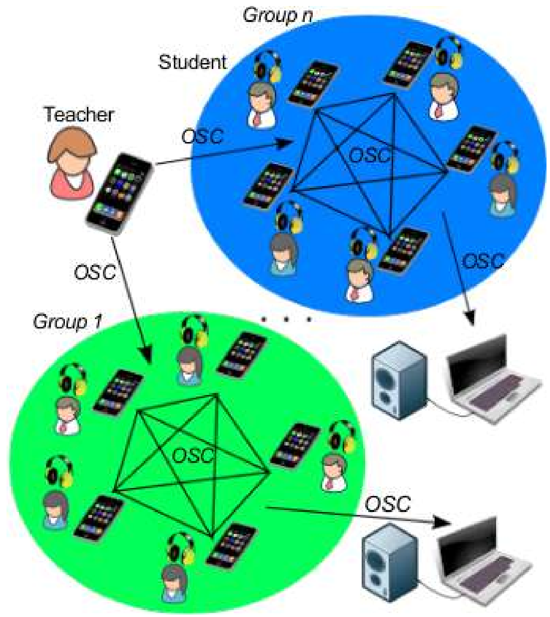


Figure 1: System architecture

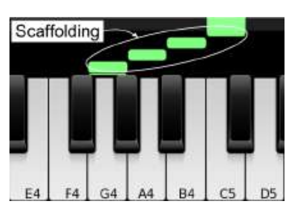
3. MOGCLASS DESIGN

In this section, we will briefly introduce our system architecture and its key components. The system architecture (Figure 1) places the teacher in the center of a collection of distributed P2P clusters, providing overall control while still allowing each group to work independently.

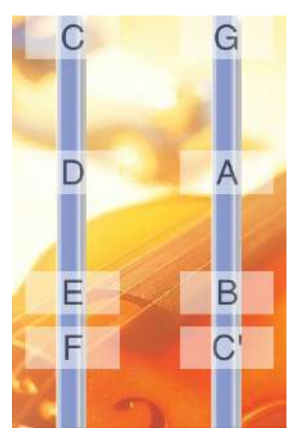
3.1 Student Interface

Three interfaces (hitter, tapper, and slider in Figure 2) are designed to support students' body percussion (clapping, stamping feet, etc) with untuned and tuned instruments and string instruments mentioned in the local music curriculum[6]. Each interface can simulate a range of instruments, such as drums (hitter), xylophones (tapper), and violins (slider). Drums and xylophones are commonly used in the primary music classroom; the slider is created for a more advanced level of playing, as the variable-pitch interface can be used to explore more advanced music concepts.

(a) Hitter interface



(b) Tapper interface with scaffolding



(c) Slider interface

Figure 2: Student interfaces in MOGCLASS

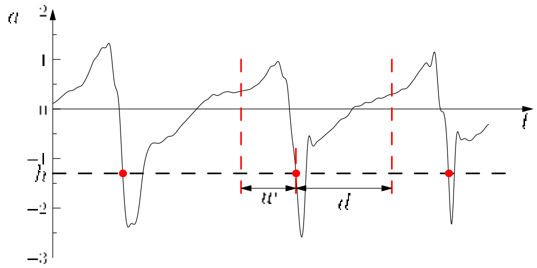


Figure 3: Analysis of accelerometer data for shake detection

3.1.1 Hitter

This interface uses accelerometer data to trigger an event: students use the iPod like a drum stick. The first version was implemented using threshold-based detection, but we discovered that students naturally had stronger or weaker shaking. Tuning the threshold for individual students would require too much setup, so we chose to employ a machine learning method to train a generic model to recognize shakes.

Figure 3 shows the acceleration (in one axis) of a typical series of shakes. We define a_t as the acceleration at time t along that axis. h is a threshold value; we only test for a shake when a_t passes from above h to below h. Once that condition is met, we examine the previous w samples as a vector $\boldsymbol{s_t} = [a_{t-w+1}, a_{t-w+2}, \ldots, a_t]$.

We extract the mean, variance, maximum, minimum, and energy of $\boldsymbol{s_t}$ as the feature vector $\boldsymbol{x_t}$, which is fed into the kernel function $K(\boldsymbol{w}, \boldsymbol{x_t})$. After several experiments, we chose to use a linear kernel in the trained SVM model. This algorithm is expressed in Equation 1.

$$(a_{t-1} \geq h) \wedge (a_t < h) \wedge (K(\boldsymbol{w}, \boldsymbol{x_t}) + b > 0) \qquad (1)$$

The trained SVM model detects a shake point slightly ahead of the “bottom” of the shake. However, this “pre-detection” combines nicely with unavoidable sound synthesis and network delay, resulting in barely any perceptible lag.

Training was performed by two subjects who imitated various types of shakes and indicated the “bottom” of a shake by clicking a button on the touchscreen. We used libSVM[8] to train the model. Our dataset contained 1083 features; 503 features are positive examples while 580 are negative. The average precision of the 10 folds cross-validation is 97.8%.

To reduce CPU consumption, we ignore the next d samples after a shake was detected. We determined that children cannot shake faster than 10 Hz, so since the accelerometer gives us 100 Hz, we set $d = 10$.

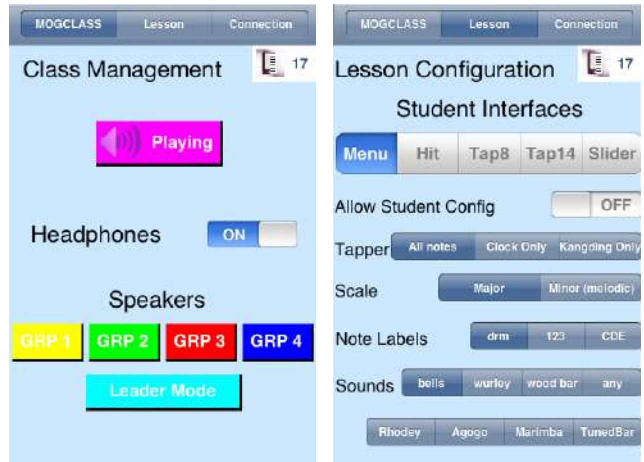
3.1.2 Tapper & Slider

Tapper and Slider interfaces are the same as the interfaces in MOGFUN [23]. However, in order to support collaborative music composition with five students at once, we cache sound buffers in memory to lower the CPU load.

3.1.3 Scaffolding / Synchronization

The scaffolding (Figure 2b) uses stored MIDI files on the student devices; these are parsed with libjdkmidi [14]. Since MIDI is a widely-used music format, teachers can produce new songs using existing music composition software.

When the system begins, all clocks are synchronized to ensure that the students see hints at the right time. The teacher device sends 10 timestamps to the student devices. Each student device calculates the difference between its local time and the time sent by the teacher. We consider the minimum of all those time differences to be the amount of clock drift. The average delay in our wireless network is 2.6ms (discussed in Section 3.3); this amount of error is acceptable for the visual hints.



(a) Class Management (b) Lesson Configuration

Figure 4: Teacher interface

When the teacher initiates a class-wide performance of a song, the teacher device sends the starting time of its local time plus two seconds to all students. This gives the network (and students!) time to receive the message, prepare everything, and then begin playing together.

3.2 Teacher Interface

There are two different displays (Figure 4) in the teacher interface, allowing the teacher to control the student iPods.

The “Class Management” display (Figure 4a) contains the most common commands. The teacher can mute / unmute the entire class or specific groups of students, enable / disable the headphones, and activate or deactivate “Leader Mode” which only unmutes the first student of each group.

The “Lesson Configuration” display (Figure 4b) contains options which are typically used once or twice during a class. The teacher may choose which interface students use, which type of sounds will be played, which labels will be displayed on notes, and which type of scale to apply. The “Allow Student Config” option passes the control of changing instruments to the students.

3.3 Sound Production and Network

We use Bonjour for service discovery, while P2P communication is done via OSC [22]. The iPod touch uses a low-power WiFi (802.11 b/g) protocol. To prevent the device from going into low-power mode, we send a “keep-alive” message every 20ms. These messages reduce the maximum and mean delay from $>$ 100ms and 40ms to $<$ 50ms and 2.6ms.

Most importantly, this redesign added *shared soundspaces*, where a group of students can share their sounds through their headphones. The teacher interface sets up a shared soundspace for a group by sharing the IP addresses between all student devices in the group. The student device then set up UDP sockets to send OSC messages within their group.

These soundspaces allow a classroom full of students to play music in small groups without hearing sound from other groups. This is impossible to achieve with acoustic instruments without using multiple physical classrooms, and opens new possibilities for music education.

4. EVALUATION

Two rounds of evaluations were conducted to iteratively refine and validate the design of MOGCLASS. The first round of evaluations consisted of using MOGCLASS in four separate music lessons with 3 classes of students, allowing us to revise the design of MOGCLASS. The improved system was then evaluated in a between-subject controlled study against recorder (a commonly used traditional music instrument) using two groups of elementary school students under the same 5-lesson mini-course. Study results showed that the MOGCLASS system is effective both in motivating students' interest and collaboration in learning music as well as helping teachers' classroom management. Due to the page limitation, the detailed iterative evaluations will be presented elsewhere.

5. CONCLUSION

Based on careful considerations of music education needs in schools, we developed MOGCLASS, a collaborative system of networked mobile devices which enables creative music-making and engagement through a broadening of the music classroom sound palette by means of active listening, composition, and performance, allowing for music lessons to be actively engaged, fun and effective.

Taking children's distinctive characteristics into consideration, the interfaces (for the teacher and students) are designed to allow students to learn in a collaborative setting while creatively exploring music in groups or as individuals. It provides a wide-ranging palette of musical instruments and lowers the physical skills and time required to become proficient in traditional musical instruments. Guided by the principle of learning by playing, MOGCLASS was developed to provide an active and motivating learning environment for children, while providing the teacher with an effective class management tool.

Although MOGCLASS is currently focused on children, it could inspire adults to become involved in community music making. We will investigate this option in our future work to allow for broader application impact.

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