A CHILDREN’S MUSIC EDUCATION SUPPORT SYSTEM USING SENSOR DATA, VIDEO IMAGES, AND SOUND DATA

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ABSTRACT
In kindergartens and nurseries, music is an especially important activity for improving children’s self-expression abilities. However, for inexperienced teachers/nurses, it is very difficult to observe every child while playing the piano. To solve this problem, this paper proposes a children’s music education support system that uses sensor data, video images, and sound data. The proposed system focuses on the motion of a baton equipped with an LED and an accelerometer. A child shakes a baton accompanied by a piano. Marker tracking results and accelerometer output are represented graphically: the horizontal and vertical axes are time and observed values, respectively. An experiment at a kindergarten showed that inexperienced teachers recognize more detailed and rich information from data in a graphical format than observation with the naked eye.

KEY WORDS
Children’s Education, Music, Marker Tracking, Baton, Accelerometer

1 Introduction
The music activity of children promotes language ability and physical development. In the education of children with music, the development of personality is very important. Careful observation of every child to guide and shape individual personalities is strongly required. However, music class is a group lesson during which the teacher often has to play the piano. Thus, it is hard to observe the behavior of each child and retain such observations, especially for inexperienced teachers who usually cannot grasp the personality of each child.

A conventional approach for such children observation is the use of a TV camera, which are captures the children. The resultant scenes are manually analyzed. However, such a TV camera approach is limited because observations are subjective, not qualitative. Another limitation is the difficulty of extracting a target scene from a large amount of accumulated videotapes. Teachers have to spend time and make an effort to analyze the videotape. A TV camera approach cannot be applied in daily use.

This paper resolves the above problem by proposing a new music education support system for children that uses sensor data, video images, and sound data. The proposed system focuses on the motion of a baton equipped with a red LED and a 2-axial accelerometer. A child shakes a baton accompanied by a piano. Marker tracking results and the observed accelerometer voltage are represented graphically: the horizontal axis is time, and the vertical axis is the observed values.

A LED marker results in reliable tracking. Also the children’s detailed motion can be extracted from the accelerometer data. Thus, the personality of individual children can be easily grasped without special skill. An experiment at a kindergarten showed that an inexperienced teacher can also recognize the more detailed and rich information from the data in a graphical format than observation with the naked eye.

Section 2 shows the conventional approach and a prototype experiment before the new system proposal. Section 3 proposes a new system, and Section 4 shows experimental results. Finally, Section 5 concludes this paper.
2 Conventional Approach and Prototype Experiment

2.1 Music in the Education of Children

Music is often employed in the daily life at kindergartens and nurseries [3, 4]. Figure 1 shows a music education scene at a kindergarten where each child has a baton whose motion is timed to the piano.

The music education of children has two major purposes: “by myself” and “expressing pleasure.” The following points are important.

1. Children feel the pleasure of exercise.
2. They feel rhythms and tempo.
3. They enjoy music.

For children, it is important to express and recognize rhythm and tempo. Teachers should never inculcate “technique” upon children. Teachers must guide each child to enjoy music. Since children are also often physically undeveloped, teachers have to grasp the physical development level of each child. Subjective observations are often misleading.

Let’s assume that a child cannot control his/her baton. This doesn’t mean that this child’s ability is low. Children often cannot control objects if their physical coordination is low or at an early stage. This means that the ability to control a baton should be evaluated over a long time span. Objective and quantitative evaluation is strongly required. In other words, extracting quantitative information from the objective analysis of children’s movements becomes the major purpose. A new tool or approach is expected to extract qualitative information from the activities of children.

2.2 Input from a Veteran Music Teacher

To design a new tool, the authors interviewed a veteran music teacher to learn what kind of attention he paid to his music class students. Field research showed the following major results:

1. It is difficult even for a good, experienced teacher to observe each child in a variety of scenes because a teacher is required to simultaneously observe all the children.
2. Since a teacher cannot take notes during class, she has to mentally store impressions concerning the achievement levels of each child. Thus, records are often vague, incomplete, or lost.
3. A teacher has to judge whether his/her teaching is effective. But that decision is subjective and not qualitative.

Figure 2. Time Difference between Baton and Music (Child A).

Figure 3. Time Difference between Baton and Music (Child B).

Figure 4. Time Difference between Baton and Music (Child C).
Video recording is an effective tool from some points of view because it makes a physical and non-volatile record that assists a teacher’s recollection of the actual scenes. However, teachers often depend on their “impression” of the video image, which can be misleading and is dependent upon the skill of the teacher. But, the major limitation is that a video image has no qualitative measure.

The above discussion suggests that qualitative and objective measurements should be introduced into the long time observation of the music education of children. If a qualitative measurement is introduced, the following information may be extracted from the data.

1. What kind of expression does each child make while listening to music?
2. What kind of music should be selected to develop activities of self-expression?
3. How can a child’s expression be analyzed to show personal growth?
4. Does each child realize an action level that the teacher plans for the music class?
5. What kind of detailed support can be realized by analyzing the child’s behavior that the teacher cannot detect with the naked eye?

2.3 Pilot Experiment for Proposed System

First, before the proposal of the new system, the authors designed a pilot experiment whose purpose was to confirm the kind of information that could be extracted. We focused on baton shaking in music class. Each child was given a baton at the top of which was a marker for marker tracking. In this case, the marker was a table tennis ball. “Baton shakes” were shot with a TV camera, and the video images were source data for automatic marker tracking.

Marker tracking was, strictly speaking, quite difficult because of the natural lighting conditions of the music room. The daytime sunshine caused brightness changes in the room. The automatic marker tracking often failed, and manual tracking was required.

The height of the baton marker position was determined as shown in Figures 2, 3, and 4. The x-axis is time progress. The y-axis is the difference between the measure (bar) length of the piano and the child’s measure calculated from the marker tracking data. Thus, these figures show the difference between the baton’s beat and the “accurate” teacher’s beat.

Figure 2 is the graph of child A. In this case, the authors felt from watching the video image in the pilot experiment that child A matched the rhythm. The experienced music teacher agreed. The observed difference value almost meets a base line, meaning that child A matched the beat and that the naked eye observation was also correct.

The curve of Figure 2 shows that short and long periods appear alternatively. Short period means that the arm muscles are strong, and the longer one denotes weakness. Generally speaking, movement from outer to inner is high because the downward muscle is strong and develops quicker. On the other hand, movement from inner to outer is slow because the lifting muscles are weak and develop more slowly. In other words, this graph shows the development stage of the child’s muscle.

Figure 3 is the graph for child B. In this case, the authors felt that the child was cheerful and correct. But, the expert music teacher didn’t agree. The curve of Fig.
gradually falls to the lower right, and the shake amplitude becomes smaller. The boy apparently shook his arm as if swinging a baseball bat. This is an example of how an inexperienced person misunderstands. By graphing the marker tracking results, it is possible to overcome such misunderstandings of inexperience.

Figure 4 is the graph of child C. The authors felt that she didn’t keep the rhythm, but instead she followed her her own sense of time. But the music teacher disagreed, arguing that she nearly matched the rhythm. Figure 4 shows roughly shifted movement. Except for the illegible parts, the graph is nearly identical to child A (Fig. 2), a skilled student. This means that child C almost matched the rhythm. The expert teacher recognized that conclusion from the beginning, but the authors (inexperienced persons) misunderstood.

2.4 Results of Pilot Experiment

The pilot experiment showed that baton marker tacking is effective. An inexperienced teacher or students can understand the children at an expert’s skill level by using the tool. But, the proposed approach has some problems. First, achieving marker tracking accuracy was problematic because a store-bought video camera has difficulty tracking baton motion. This reflects the slowness of the TV camera frame rate. Next, there is a lot of obstruction with similar colors in marker tracking.

Moreover, a problem exists when selecting the standard measure (bar) length. Fortunately, the song in the pilot experiment had a constant speed. But, generally speaking, the measure (bar) length of songs is not constant. It is desired to get the length of one beat from the sound of piano.

3 A New Children’s Music Education Support System

Based on the pilot experimental results, this paper proposes a music education support system that uses sensor data, video images, and sound data. The proposed system can track the marker position in a wide variety of lighting conditions. Figure 5 shows an overview of the system, which used the following compositions to realize the functions:

1. Marker tracking with a red LED maker.
2. Detection of detailed baton motion with a 2-axis accelerometer.
3. Recording piano sounds by microphone and extracting the measure (bar) to automatically detect the head of the measure from those sounds.
4. A commercial Hi-Vision (HDTV) camera for ease of operation in the classroom.
5. An LED time stamp marker that blinks every 10 seconds to create a time stamp important in multisensor environments.
To overcome lighting condition limitations, an infrared LED is often used as the marker. In this case, an infrared filter for TV cameras and a “nightshot mode” are required. But, such an infamous “surreptitious shot” camera is not applicable to kindergartens and nurseries because of concerns of privacy.

Therefore, we employed a red LED as the marker. The Hi-Vision camera has a red filter. Figure 6 shows a video image sample. With the filter, only the marker of the baton and timestamp stand out, and the background is dark. Therefore, robust detection of the baton position becomes possible by making binary images in the brightness and calculating the center of the gravity in the white area.

To extract the measure (bar) from the piano sound, the proposed system employs wave envelope analysis, not such frequency spectra analysis as FFT. It detects percussion peaks in the waveform. However, since the algorithm does not detect all the peaks, manual analysis is sometimes required. As mentioned below, an experienced music teacher adjusts the timing while watching the child’s response. The measure (bar) of the piano sound is not ideal, and so it doesn’t depend upon the original music score.

4 Experimental Evaluation

The authors implemented a prototype system and introduced it to a music class of five-year olds at the Tokiwakai Junior College Kindergarten in Hirano-ku, Osaka, Japan. The children sang songs of two beats and shook batons to piano accompaniment. The scene was shot by a High-Vision (HDTV) video camera. A DAT recorder recorded the piano with a small microphone inside the piano. The above Figure 1 is the experiment scene.

4.1 Circuit Design of Baton

The system’s main device is the baton equipped with a 2-axis accelerometer and a red LED. When shaken intensely, the direction in space of the baton is not constant. On the other hand, the emitting angle of LED is generally narrow. Therefore the authors selected a full color LED manufactured by Nichia Corp., NSTM515AS [6]. The red LED was activated in this system. Five LEDs are attached to the baton’s top. The accelerometer is “ADXL202E” of Analog Devices [7]. The bandwidth is up to 6kHz from DC. The bandwidth is 10 to 100 times wider than a TV camera.

These accelerometer outputs are amplified by two OP-amps: one has unit gain, and the other is an inverter. The baton is several meters from the computer. Therefore, to get lower signal impedance, balanced transmission is employed. The electric power for the LEDs and the sensor is supplied by a computer that employs a five-leads shielded cable for transmission, which prevents noise. These five LEDs, a sensor, and operational amplifiers are composed on one small universal circuit board.

Marker tracking is reliable. By using a red LED and red filter for the TV camera, only the markers and the timestamp appeared, and so positions can be automatically detected. But, if the TV image gets direct sunlight, it is difficult to track the marker.

4.2 Experimental Results

Figures 7 and 8 are the marker tracking results for the teacher and the children. The y-axes show the height of the marker in the video image. There doesn’t seem to be major difference in their action. The authors and an expert music teacher could not find differences in the classroom, either.

However, the above subjective impressions were misleading. Figures 9 and 10 show a major difference in accelerometer data between an experienced teacher and a child respectively. The y-axis is the output voltage of the sensor. The teacher’s data (Fig. 9) has a cycle and many peaks with constant intervals.

On the other hand, the child’s data (Fig. 10) has no peaks. The length of one measure (bar) is not constant. The child doesn’t take the rhythm to the bottom point of the baton movement. The child is following the teacher’s movement. Maybe the child is very clever, but she can’t successfully keep the rhythm. She is following the teacher as hard as she can. But she doesn’t seem to enjoy the music or the baton shaking. This example clearly illustrates that
Figure 11. Time Difference between Piano and Children

we can observe more information with the accelerometer than with marker tracking.

This accelerometer system has one problem. The sensor’s axis is perpendicular to the baton when it is intensely shaken. The sensor output signal value has an indirect relationship to the camera image. It is necessary to improve this limitation of the baton.

Finally, baton movement was compared with the measure length calculated from the piano sound data as shown in Figure 11. The Y-axis values are the measure length of the piano musical score, the experienced teacher, and the child. Figure 11 shows a very interesting phenomenon. The playing speed of the teacher does not equal the values of the musical score. The interval of the measure often varies. Since the teacher is very skilled, this is not his mistake. He adjusts the tempo while observing the children. If the children cannot follow him, he delays the beat. The children notice the tempo changes and shake the baton faster. In this performance, the baton became up-tempo after the first twenty beats.

5 Conclusion

This paper proposed a music education support system for children. An inexperienced teacher can observe and understand individual children at kindergartens or nurseries by using this proposed system. The personality and activity of children can be minutely understood by marker tracking and sensor data.

In an experiment at a kindergarten, marker tracking data showed that a cheerful child shook his baton with an original and inconsistent tempo. These results agreed with the expert’s opinion. However, inexperienced teachers (the authors) regarded this child as skilled in the classroom. Also, the accelerometer detected drastic differences between the baton shaking of a teacher and a child. Observations using marker tracking could not detect any differences. In some cases, the accelerometer offered richer information than marker tracking.

The system employed automatic extraction of measure (bar) from the piano sound. However, not only is the extraction technically difficult but also the expert music teacher varies the tempo on purpose. The expert teacher controlled the song speed of the children by tempo deviation. This means that the tempo of the teacher’s piano is not a good example for automatic personality analysis.

References


