Performance Visualization for Hearing-Impaired Students

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ABSTRACT

We have been teaching computer music to hearing impaired students of Tsukuba College of Technology for six years. Although students have hearing difficulties, almost all of them show an interest in music. Thus, this has been a challenging class to turn their weakness into enjoyment. We thought that performance visualization is a good method for them to keep their interest in music and try cooperative performances with others. In this paper, we describe our computer music class and the result of our preliminary experiment on the effectiveness of visual assistance. Though it was not a complete experiment with a sufficient number of subjects, the result showed that the show-ahead and selected-note-only types of performance visualization were necessary according to the purpose of the visual aid.

Keywords: Hearing Impaired, Computer Music, Music Performance, and Visual Feedback.

1. INTRODUCTION

We have been teaching computer music to hearing impaired students of Tsukuba College of Technology (now National University Corporation, Tsukuba University of Technology) for six years. Students with the hearing impairments of more than 100 decibels are qualified to enter the college and get a quasi-bachelor degree in three years. They learn architecture, design, computer software, or computer hardware according to their major to obtain useful skills. This style resembles that of Gallaudet University and the National Technical Institute for the Deaf at the Rochester Institute of Technology (NTID).

There are many professional musicians with visual impairments, moreover, there are several activities to assist those people with computer software such as WEDELMusic [1]. Though it is not surprising that there are very few professional musicians with hearing impairments, the number of them is not zero. Some of them are talented deaf musicians, like Evelyn Glennie, a famous percussion soloist, who even has absolute pitch.

The computer music class is open to students of all specialties but mainly those of the computer hardware course have taken the class. This is not a required subject. Not necessarily all the professors at the college agree on the importance of the class. On the other hand, we came to know that not a small number of students have an interest in music, independent of the degrees of their handicap and personal experience with music. Thus given the computer assistance for them to understand and enjoy music, their quality of life (QOL) is considered to be improved. We thought performance visualization would be a good method for such assistance. Since the research of performance visualization is not a mature area and currently there is no suitable user interface to assist students, we need a good performance visualization system for them. In order to design and build such a system, we conducted a preliminary experiment on cooperative musical performance using visual assistance.

2. COMPUTER MUSIC CLASS

We set the purpose of the computer music class to allow students to understand and enjoy music in order to broaden their interest [2]. In other words, the class was more music oriented (and amusement oriented), not computer oriented. Considering that the class should meet the requirements of the college, especially for the computer hardware course, the purpose above is not necessarily appropriate. The reason for setting such a purpose is to get rid of the difficulty of keeping students' interest, especially in an area that they have not experienced much in their lives. If we start teaching them from computer perspective such as the structure of synthesizers or the format of Musical Instrument Digital Interface (MIDI), a digital format for performance data, they will have conversations in sign language, or even worse, no students may register for the class.

Making students continue to move their bodies with music is the most effective way to keep the class active. Thus, the computer has been used as a tool for assisting them in enjoying music in the class, not as a tool with which to develop new computer music software or hardware systems.

Materials

Because it was not possible for teachers who did not receive special education in music to teach conventional acoustic musical instruments to students, we benefited from the newly developed MIDI instruments. Furthermore, we were able to connect several machines and instruments with MIDI. A MIDI instrument generates MIDI data when a player plays it. It has a MIDI terminal to connect with another MIDI instrument or a PC. It needs a sound generator either inside or outside the instrument.

Figure 1. Taiko performance with Miburi

Figure 2. Batucada performance

The following are the hardware and software systems we used in the class.

- Miburi R2 (Yamaha): A MIDI instrument with sensors. Sensors are attached to a shirt which a performer puts on. When a performer moves his/her elbows, shoulders, wrists, and legs, sound that corresponds to the position and its movement is generated from the sound generator of Miburi. The sound generator provides several drum sets, tonal sound colors, and SFX sound (murmuring sound of a stream, the sound of gun fire, a bird song, etc.).

  The good points in using Miburi for students were as follows:
  - With simple body movement, you can generate music.
  - It is a new instrument in which playing methods are not difficult and not established.
  - Miburi performers can communicate by looking at each other's movement.
  - Since MIDI data is generated by playing the Miburi, their movement is reflected synchronously to visualization if systems are connected. Through the visualization, students understand their movement and its result as music.
- XGWorks (Yamaha): A sequence software system to make performance data in MIDI.
- VISISounder (NEC): An animation software system whose action is controlled by MIDI data. It prepares several scenes and animation characters beforehand. For example, a frog at a specific position in the display jumps when a sound “C” comes, while another frog jumps with “G.” Using this software, students were directly able to feel their performance with Miburi through visualization. They liked it very much.
- MIDI drum set and MIDI keyboard (Yamaha): MIDI instruments.
- Music table (Yamaha): A MIDI instrument, originally designed for music therapy for elderly people. Pads are arranged on the top of the table on which people pat. There is a guide lamp for indicating the beat.

Though we tried an actuator that is used inside a speaker system for the haptic feedback purpose, it was not suitable to use because it heats up as sound was generated.

An unfortunate thing in using these products is that some of them had a short life. In the past six years when we taught the class, Miburi and VISISounder, which were the most suitable materials for the class, disappeared from the market. Although there are several other MIDI instruments and animation systems with MIDI data at the research level, products are more reliable and end user oriented.

Students' presentation

The class is held in a school term. There were ten or eleven weeks in a term. Every year we asked students to make a musical presentation at the final class. The following is an excerpt from the list of students presentation.

- A dramatic play using Miburi. Accompanied by SFX sounds, a student played out her daily life in sign language. For example, the barking of the dog was heard accompanying the sign language for a dog made by wrist movement.
- A music performance using Miburi. With a tonal sound, a student played the “Do-Re-Mi song.” Her performance controlled characters of VISISounder.
- A Japanese Taiko (drum) performance using Miburi. Figure 1 shows the performance. Though it is a completely virtual performance, the change of drum sets was musically very effective. Usually a Taiko player uses one to three Taikos in an actual play, a player with Miburi can use many more types of Taiko as if all of them are around him/her.
- Samba performance using a Music table and a drum set. Seven students played three different rhythm patterns that cooperatively made Samba percussion performances (Batucada). Figure 2 shows the performance. One student stood up and played as a conductor by performing a basic rhythm pattern. Playing Batucada gave students the sense of unity in music.
- Some students used sequence software in order to perform accompaniment music for Karaoke. They sang using the sign language accompanied by the music.

After their presentations, many students indicated on a questionnaire that they would like to play in an ensemble or they enjoyed playing with other students.

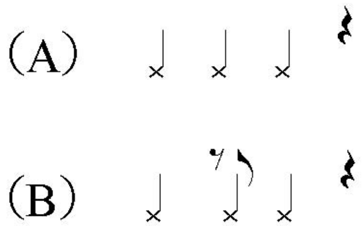

Figure 3. Rhythm A and B

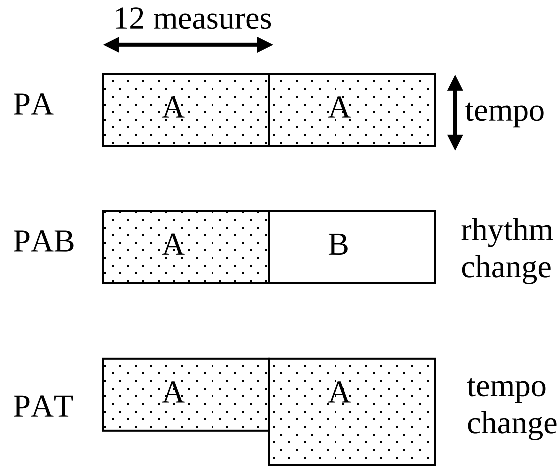

Figure 4. Three types of model performance: PA, PAB and PAT

3. RELATED WORKS

Although there are several studies of aiding visually handicapped people in their musical activities, there are very few for hearing impaired people. We conducted the experiment described in Section 4 from the viewpoint of performance visualization. Thus, in this section, we describe research on performance visualization.

Sobieczky visualized the consonance of a chord on a diagram based on a roughness curve [3]. Hiraga proposed using simple figures to help users analyze and understand musical performances [4][5][6]. Smith proposed a mapping from MIDI parameters to 3D graphics [7]. Foote's checkerboard type figure [8] shows the resemblance among performed notes based on the data of a musical performance. 3D performance visualization interface is proposed for users to browse and generate music using a rich set of functions [9][10].

These performance visualization works have different purposes such as for performance analysis and sequencing. So far, there has been no work for cooperative musical performance.

4. EXPERIMENT

Outline

In order to determine a more suitable visualization interface for performance feedback to support cooperative musical performances by hearing-impaired people, we investigated the characteristics of animated performance visualization proposed by commercial systems and a prototype system by a student. The investigation was done by a usability test of each performance visualization.

The purpose of the test was to see the playing timing of each subject with a guided animation that is controlled by MIDI data of a model performance. Namely, subjects played a MIDI instrument looking at the animation and their performances were recorded, then we compared the performances with a model performance. The time differences were calculated between the onset time of subjects' performances and the model performance. Onset time is the moment a note is played by a keyboard or a drum. It is the time of a MIDI message of "Note On" is generated. The message includes the note number (pitch) and the velocity (volume) of the note on. We can see from the note number which drum pad is patted or which key on a keyboard is played.

Subjects

Three students (call them SA, SB, and SC) and a technical staff member (call her SS) were the subjects of the experiment. Students were in a sense exceptional among all students regarding their musical experience because two of them were members of a pop music club and had performance experiences, and the other had been learning play the piano for six years. They were assigned different instruments and tried to play cooperatively with a model performance using feedback.

Model performances

We used two rhythm patterns, A and B (Figure 3), then prepared three types of model performance, PA, PAB, and PAT, by combining them (Figure 4). PA repeats rhythm A for twenty-four measures with tempo MM=108. MM=108 means that there are a hundred and eight beats in a minute, namely a beat takes 0.556 (60/108=0.556) second. The larger the MM number, the faster the tempo. PAB repeats rhythm A for twelve measures then changes rhythm to B for another twelve measures with the constant tempo MM=108. PAT repeats rhythm A for twenty-four measures with tempo MM=108 for the first half, then with tempo MM=140 for the second half.

Feedback types

The experiment used four types of feedback: three types of visual feedback and one type of sound feedback. These feedback types were exclusively given to subjects. They were as follows.

1. VISISounder.

We used a scene that clearly showed the difference among performed notes by the movement of characters (either a monkey or frogs) (Figure 5). A monkey in the center corresponds to the performance of a model performance and frogs to those by subjects. Characters pop up when an instrument is played. Since a frog character was assigned to individual subject, we could distinguish subjects through the animation.

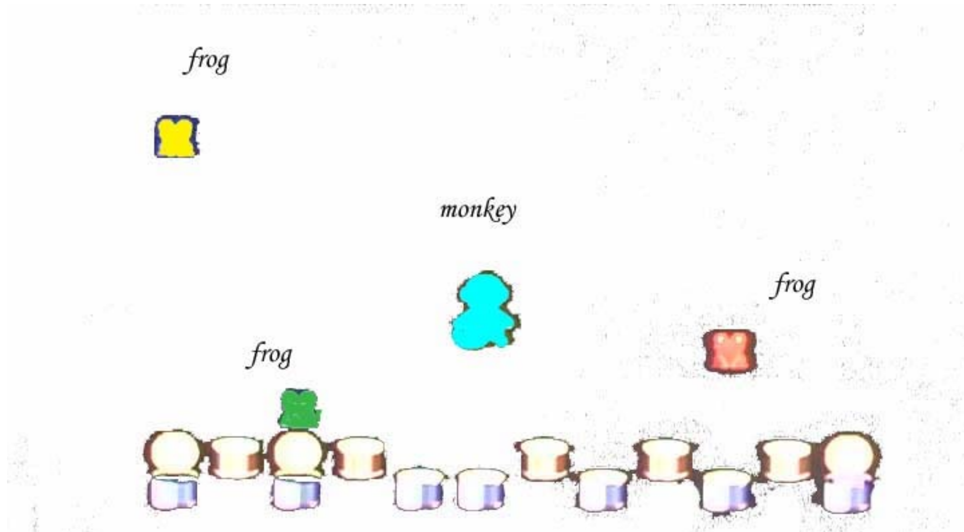

Figure 5. A snapshot of VISISounder, a monkey for a model performance (center) and three frogs for performances by subjects.

2. XGWorks.

Although XGWorks has several visualization forms for performance, we used a “drum window” (Figure 6). In the drum window, each line corresponds to a type of drum, such as a Conga. When a rhythm changes or a tempo changes, a drum used by a model performance changes accordingly. A cursor indicated the place of a model performance on the display.

A big difference in the visualized performance on XGWorks from the other two types of visual feedback is that subjects are able to predict the rhythm (show-ahead feedback). In PAB, the rhythm change from the thirteenth measure was shown on the display, therefore, subjects could see the change of the rhythm before the cursor came to the position. Although the tempo change was also indicated by using a different type of drum, the degree of tempo change could not be shown.

Other differences are that a model performance is shown as continuous cursor movement, and performances by subjects are not shown on the window.

3. Virtual Drum.
Virtual Drum is a program using direct API calls and Mabry Visual Basic MIDI IO controls, originally freeware [11]. A student partially modified the program in order to make it a game program for scoring a performer's playing timing with respect to a model performance.

In Virtual Drum, a model performance appears in the upper boxes and performances by subjects in the lower boxes (Figure 7).

4. Sound only.
The model performance is not visualized but only performed.

Sessions

Combining three types of model performance and four types of feedback, the experiment consisted of twelve sessions as shown in Table 1. Subjects were informed about the twelve sessions and practiced PA, PAB, and PAT only by clapping by themselves without a model performance before the experiment.

5. RESULT

We obtained the time difference between a subject performance and the model performance. The average and standard deviation of time difference for a session were calculated using the performed beats in twenty-four measures by all subjects as shown in Table 2.

The average of the time difference between a subject performance and the model performance for each beat was shown as a line graph for the rhythm patterns of PA (Figure 8), PAB (Figure 9), and PAT (Figure 10). Each line shows a session whose name is specified in Table 1. In the graphs, X-axis showed the beat. Since three notes were performed in every measure of the two rhythm patterns, beat number four was not the fourth beat of the first measure but the first beat of the second measure. Therefore, the beat number thirty seven (the first beat of the thirteenth measure) was the changing point of the rhythm in PAB and the tempo in PAT.

The Y-axis showed the time difference counted by “ticks.” In the experiment, a beat consisted of 480 ticks. Therefore, tempo MM=108 meant a beat was played every 556 ms (60/108=0.556) and a tick roughly corresponded to 1 ms (60/108/480=0.00118).

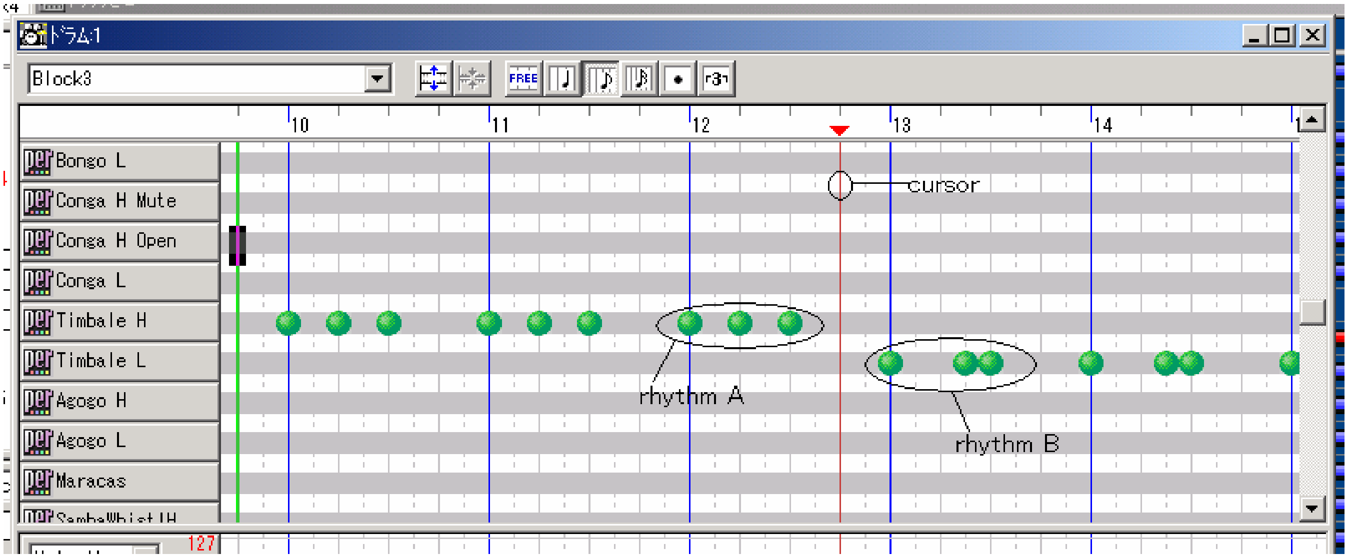

Figure 6. XGWorks. Rhythm changes from A to B at the thirteenth measure

The results from Table 2 and the figures are as follows.

1. VISISounder.
The average and the standard deviation of the feedback of VISISounder are rather large.

2. XGWorks.
Both the average and standard deviation of the feedback of XGWorks compare fairly well to those of other types of feedback.

3. Virtual Drum.
Though with a small average, Virtual Drum has the largest standard deviation. This means the subjects' performances waver.

4. Sound feedback.
The smallest standard deviation value was obtained from the sound feedback for two of the three model performances. This is also found in the small movement of a line for the session A*Sound (* is either null, “B”, or “T”) in the three graphs (Figures 8, 9, and 10). On the other hand, the sound feedback average is rather large.

The average and standard deviation of four measures before and after the rhythm change and the tempo change, namely the ninth to twelfth measures and thirteenth to sixteenth for PAB and PAT are shown in Table 3. Data of the ninth to twelfth measures show the steadiness of subjects performances after performing several repeats of a rhythm pattern with a regular tempo.

For the rhythm change (PAB), ABVISI made a big difference before and after the change, while for the tempo change (PAT), ATXGW made a big difference.

6. DISCUSSION

In discussing the time, we have to notice the basic numbers, such as, we are able to perceive multiple vocalizations when the time lag is over 20 ms or due to MIDI hardware and display redrawing. In the experiment, we do not need to take those numbers into consideration, because the precision of the time is the next step. Here we would like to see the tendency between the subjects' performances and feedback types.

We are able to see that the sound method gives better feedback from the point of view of standard deviation than other types of feedback from the result shown in Table 2. It can be interpreted that once subjects form the performance model of the rhythm and tempo within themselves, it is more comfortable and easier for subjects to keep playing it. Of course, this result comes from the fact that the subjects are less impaired. The next good result is using the feedback of XGWorks. In spite of this, subjects did not appreciate the show-ahead of tempo and rhythm with the moving cursor of XGWorks. On the other hand, we are also able to see in Table 3 that the show-ahead visualization by showing the change in rhythm and tempo is useful as judged from the result of the smallest standard deviation obtained using XGWorks for PAB and PAT. Though with the worse result, they well appreciate the animation of VISISounder. These observations show that it is important to show something fun in the visual aid for cooperative performance.

From the experimental results, we came to the conclusion that the important thing in designing performance visualization for cooperative performance is the show-ahead of the tempo. Animation that shows only the important notes for cooperation concerning musical structure will reduce the physical burden.

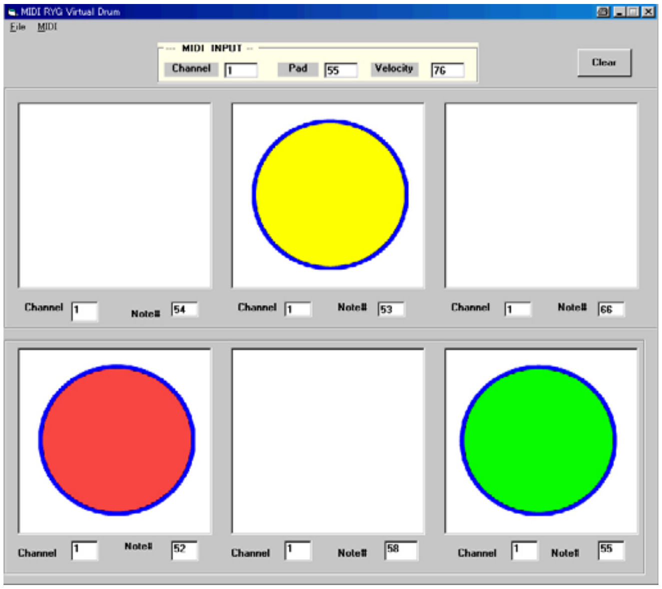

Figure 7. Virtual Drum: a model performance (circle above) and performances by subjects (two circles below)

Visualization with the purpose of game animation is not suitable for accompaniment. Performance visualization should be designed according to its purposes. The new user interface will be the combination of continuous information for the tempo and discrete information of the musical structure. The following is future work.

- Since the experiment was with a small number of subjects and not a variety of subjects, we need to ask more people with different musical experiences and levels of hearing impairment.
- We have to make it clear how long the subjects are affected by the change of rhythm or tempo.
- On the questionnaire after the experiment, subjects made comments on four types of feedback. They say looking at the display for the movement makes them fatigued. Therefore, we should take the physical burden caused by the feedback into consideration. Also, we should notice that animation should not always be given attention.
- Besides, in order to create less physical burden because of the reason above, there are other good reasons to visualize a part of the performance. They are (1) not all notes in a musical piece are given the same role and importance, and (2) a report by a music researcher indicated that a phrase can be analyzed to a tree structure according to the degree of prominence of each note [12]. The prominence of notes gives performers important information on performance. Therefore, a possible new performance visualization could show animation only at important notes, such as the first beat of every or every other measure.
- Though we could see that the showing-ahead type of performance visualization is effective as far as the tempo is regular, the sudden change in the cursor movement of XGWorks according to the tempo change is difficult to follow for subjects. A reason for the difficulty is that the movement is different from that of a human conductor who controls tempo smoothly. It is necessary to suggest the change of tempo in a smoother manner by referring to the movement of a human conductor.

7. ACKNOWLEDGENMENTS

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	VISI	XGW	VD	Sound
PA	AregVISI	AregXGW	AregVD	AregSound
PAB	ABVISI	ABXGW	ABVD	ABSound
PAT	ATVISI	ATXGW	ATVD	ATSound

Table 1. Twelve experimental sessions. Feedback types are abbreviated as follows: VISI for VISISounder, VD for Virtual Drum, and Sound for sound only.

PA (rhythm A, tempo regular)

	AregVISI	AregXGW	AregVD	AregSound
Average	165.36	5.41	21.19	40.69
Std. dev.	77.44	49.28	177.19	55.84

PAB (rhythm A and B, tempo regular)

	ABVISI	ABXGW	ABVD	ABSound
Average	54.39	33.69	-14.65	63.33
Std. dev.	92.12	61.83	122.44	40.74

PAT (rhythm A, tempo changes)

	ATVISI	ATXGW	ATVD	ATSound
Average	70.13	56.23	22.13	79.31
Std. dev.	85.34	64.04	127.87	29.73

Table 2. The average and standard deviation of the twelve sessions.

PAB (rhythm A and B, tempo regular)

measure 9-12					measure 13-16			
ABVISI	ABXGW	ABVD	ABSound		ABVISI	ABXGW	ABVD	ABSound
-16.79	16.23	-11.50	48.11	Average	41.19	69.88	23.94	70.64
51.29	34.40	196.85	11.66	Std. Dev.	151.92	79.07	66.35	82.66

PAT (rhythm A, tempo changes)

measure 9-12					measure 13-16			
ABVISI	ABXGW	ABVD	ABSound		ABVISI	ABXGW	ABVD	ABSound
97.60	26.65	-1.06	54.39	Average	122.75	124.19	64.36	105.31
31.02	30.23	114.63	16.56	Std. Dev.	116.11	69.42	117.20	37.81

Table 3. The average and standard deviation of four measures before and after the rhythm change (above) and the tempo change (below).

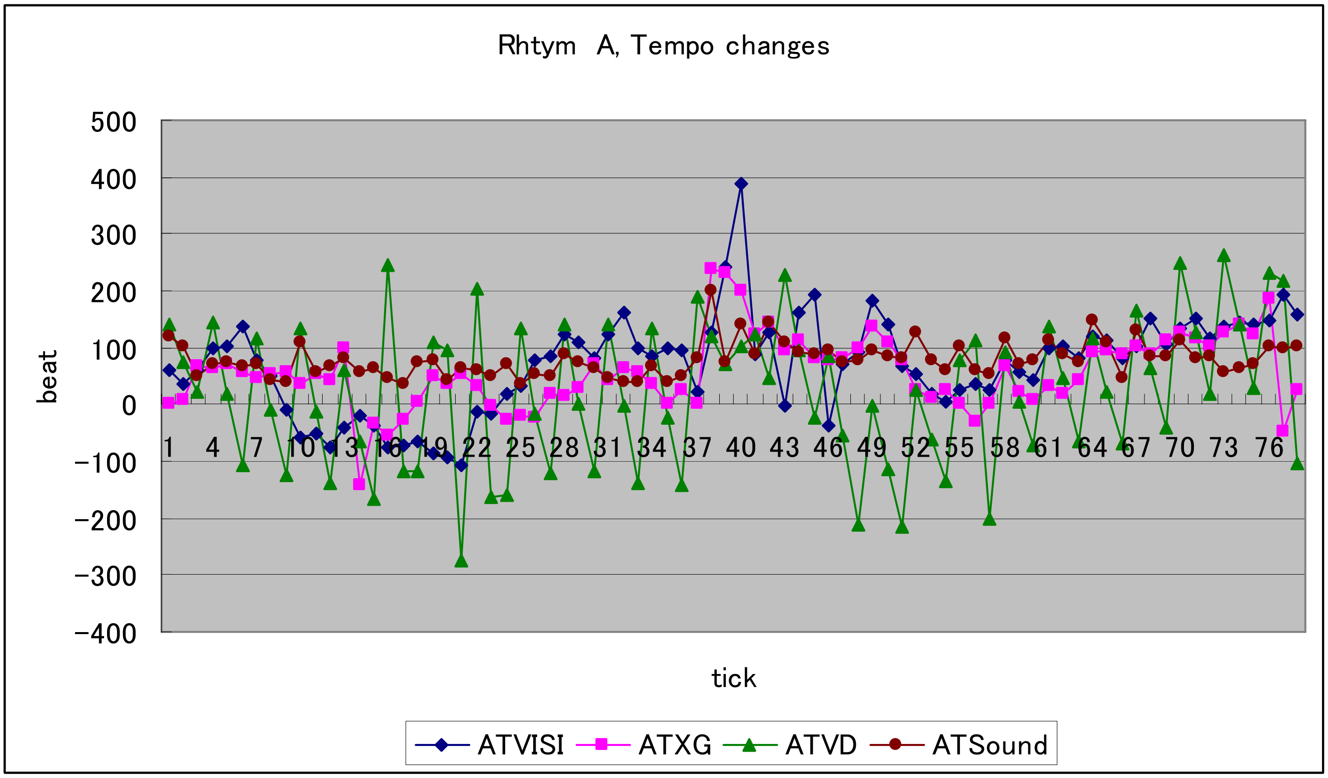

Figure 8. PA (rhythm A, tempo regular)

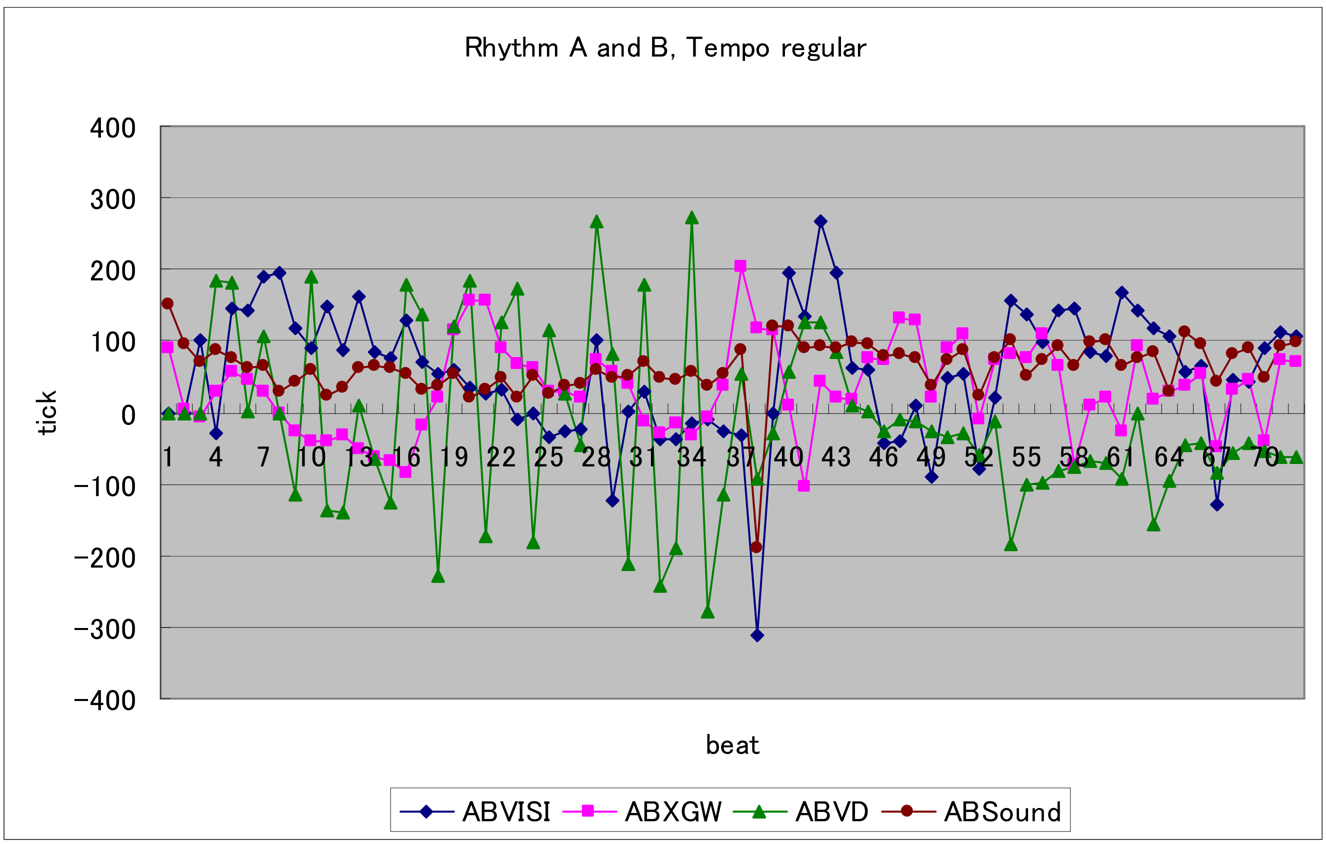

Figure 9. PAB (rhtym A and B, tempo regular)

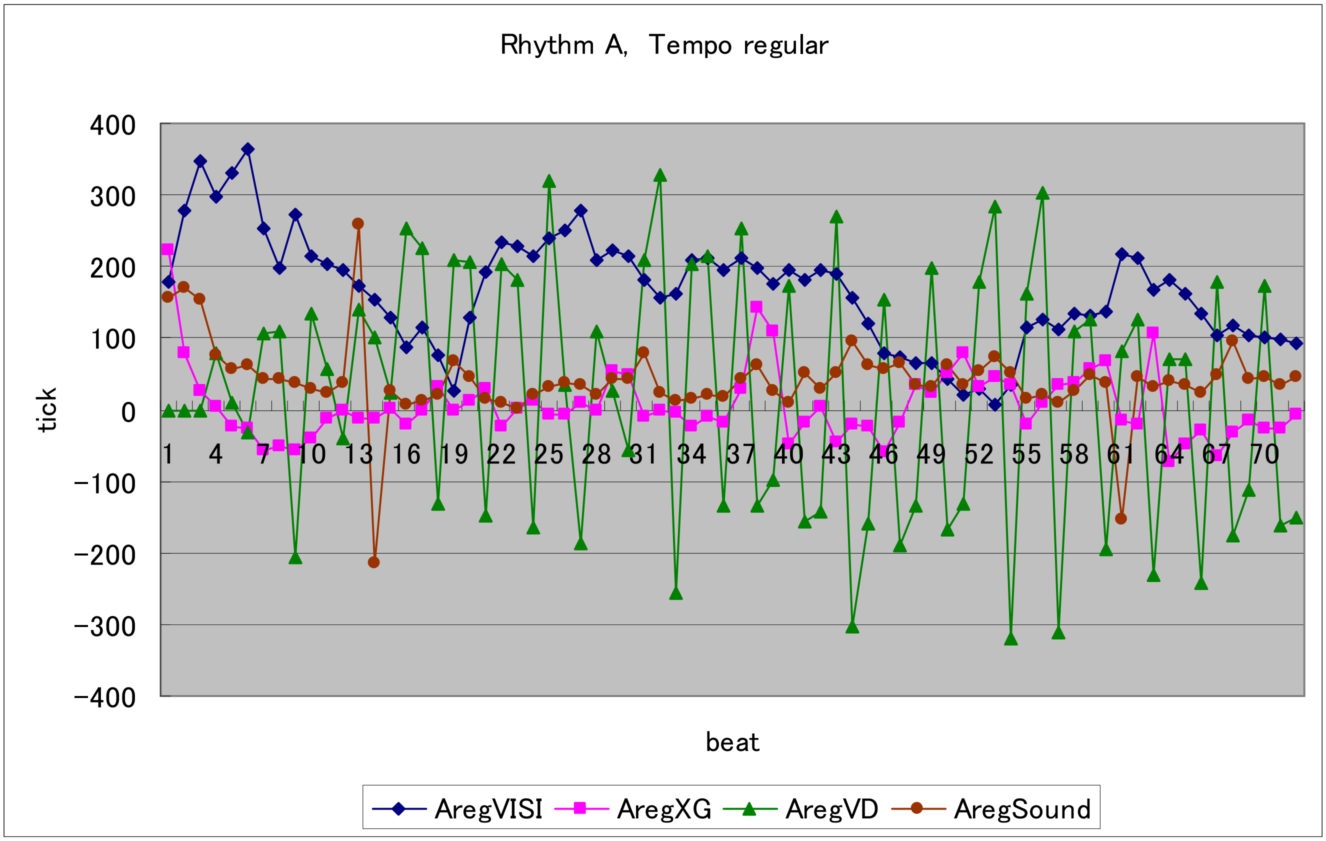

Figure 10. PAT (rhtym A, tempo changes)