ism: Improvisation Supporting Systems with Melody Correction and Key Vibration

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Abstract. This paper describes improvisation support for musicians who do not have sufficient improvisational playing experience. The goal of our study is to enable such players to learn the skills necessary for improvisation and to enjoy it. In achieving this goal, we have two objectives: enhancing their skill for instantaneous melody creation and supporting their practice for acquiring this skill. For the first objective, we developed a system that automatically corrects musically inappropriate notes in the melodies of users' improvisations. For the second objective, we developed a system that points out musically inappropriate notes by vibrating corresponding keys. The main issue in developing these systems is how to detect musically inappropriate notes. We propose a method for detecting them based on the N-gram model. Experimental results show that this N-gram-based method improves the accuracy of detecting musically inappropriate notes and our systems are effective in supporting unskilled musicians' improvisation.

1 Introduction

Music, especially a jam session, is an important and exciting form of entertainment. The widespread participation in this type of entertainment is so prevalent that there are many studies on jam sessions being facilitated through the use of computers. For example, jam session systems [1–3] construct virtual musicians in computers and provide us with environments for jam sessions with the virtual musicians. *Open RemoteGIG* [4] enables geographically diverse musicians to join a worldwide jam session using the Internet. Furthermore, various novel electric musical instruments, including a PDA-based portable one [5] and a wearable one [6], and new jam-session styles using these instruments have been proposed.

These studies were geared toward enabling a new kind of jam session for experienced, skilled musicians, not for supporting a jam session for people who cannot improvise. Since improvisation is musical performance style that involves creating melodies while playing, becoming a skilled improvisational player requires further training even if the musician can play an instrument with a score.

There will therefore be many people, called *non-improvising players* in this paper, who can play a musical instrument but cannot improvise. Providing such players with environments that will enable them to enjoy improvisation is an important goal that should be achieved.

The reason why improvisation is difficult for such musicians is their lack of skill in instantaneously creating melodies. To help them learn and enjoy improvisation, therefore, computing technology should enhance this skill or support their practice for acquiring this skill. In this paper, we seek to create an environment where players can enjoy improvisation by proposing two systems that address the issues explained above. For enhancing the skill, we propose a system that automatically detects musically unnatural notes of played melodies and corrects them to musically natural ones. This system hides musically unnatural or inappropriate melodies from the audience, hence enables inexperienced musicians to easily enjoy improvisation. It would therefore contribute to increasing their motivation for learning to improvise. For supporting the practice, we propose a system that points out musically unnatural notes to the player. If a played melody contains musically unnatural or inappropriate notes, the system points them out to the player through vibrating corresponding keys in real time. Using this system, inexperienced players can practice improvisation efficiently and in an enjoyable manner because the system, instead of the players, determines whether a melody is musically appropriate or not, which could be very difficult for them. We call the two systems ***ism*** and ***ism$_V$***, respectively.

The main issue in achieving these systems is how to detect musically unnatural or inappropriate notes. We propose a method for detecting them based on the N-gram model. Our method uses N-gram probabilities calculated from a large-scale melody database to determine whether notes are appropriate or not. This N-gram-based determination makes it possible to solve the problem of judging actually appropriate notes to be inappropriate.

The rest of this paper is organized as follows: Sect. 2 discusses requirements for improvisation supporting systems and proposes an improvisation supporting system ***ism*** according to the discussion. Sect. 3 proposes the N-gram-based correction method which is necessary for ***ism***. Then, Sect. 4 presents the implementation and evaluation of ***ism***. Sect. 5 proposes the system, called ***ism$_V$***, that points out musically unnatural notes to the player through key vibration. Finally, Sect. 6 concludes the paper.

2 *ism*: An Improvisation Supporting System that Automatically Corrects Musically Unnatural Melodies

The aim of our study is to provide people who cannot yet improvise musical solos but want to try doing it with an environment that allows them to enjoy it. When we design a system for achieving such an environment, we should take into consideration the following requirements:

1. **Same playing method as a normal instrument**
   Because the final goal of our target users is to enable improvisation without

any supports (*i.e.*, using a normal instrument), the system should not specify a playing method. To allow users to make good use of experience in using the system when trying improvisation with a normal instrument, it should emulate the same playing environment as a normal instrument.

2. **Avoidance of over-supporting**
   Even if players do not have adequate ability to create melodies, they do not always create musically unnatural/inappropriate melodies[1]. The system should not therefore provide unexpected support while the player creates appropriate melodies.

Although some musical performance supporting systems have been proposed, these systems do not satisfy the above requirements. For example, *Coloring-in Piano* [7] is a musical device that corrects players' incorrectly played melodies using score information provided before the musician attempts the piece. This method is applicable for non-improvisational music, but it is not applicable to our purpose because scores of improvisation cannot be provided beforehand. *RhyMe*, which is a subsystem of *MusiKalscope* [8], is an improvisation supporting system based on a fixed-function mapping. The fixed-function mapping is a new method for mapping between keys and notes according to the functions of the notes, which depend on the context of the chord progression. This novel mapping can make it easier to choose keys that produce musically natural melodies. The instrument using this mapping method may be effective if the goal of the users is to enjoy improvisation solely with this instrument. However, it would not be effective for people whose goal is to enjoy improvisation with a conventional musical instrument. *INSPIRATION* [9] is an improvisation supporting system that corrects all of the notes out of the available note scale. Because these notes do not necessarily produce musically unnatural melodies, it is not desirable to correct all of them.

In this study, we propose a novel performance supporting system called ***ism***, which detects unnatural notes in melodies based on the N-gram model and corrects them (Fig. 1). Because this system is used with an existing MIDI controller (typically a MIDI keyboard), the experience of improvisational playing enabled by this system will not be useless when trying improvisation with a conventional musical instrument. In addition, because this system determines whether notes should be corrected by comparing their N-gram probabilities with a threshold, the player can control the strength of melody correction (*i.e.*, how frequently melody correction occurs) by adjusting the threshold.

3 N-gram-based Melody Correction Method

The main issue in achieving ***ism*** is how to detect notes requiring correction. One possible solution for this may be to correct all the notes (called *out notes*) that

[1] Our investigation using 10 beginning and 15 intermediate players show that the rates of unnatural/inappropriate notes in the melodies of their improvisation are 12.03% and 8.22%, respectively.

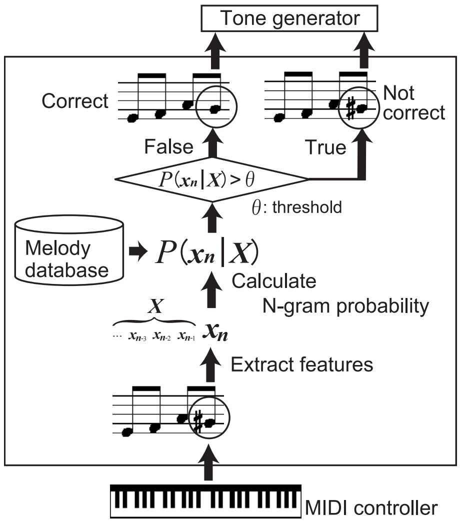

Fig. 1. Overview of ***ism***. The system first calculates N-gram probabilities of played notes and then corrects only notes with low N-gram probabilities.

are out of the *available note scale*, which is a series of notes that can produce harmonic sounds, depending on the key and the chord of the accompaniment. However, all of these notes do not necessarily produce disharmonious sounds, and they are frequently used in actual musical pieces. This method, therefore, causes unexpected correction and is unsuitable.

In this paper, we propose a novel method for determining notes requiring correction based on the N-gram model. This method captures the tendency of note transitions by N-gram probabilities and determines, when there are notes with low N-gram probabilities, that such notes should be corrected.

Step 1 Feature extraction.

The 4-dimensional feature vector listed in Table 1 (see Fig. 2 for examples) is extracted from each note in a melody of improvisation. These features were selected under the restriction that they can be extracted right after the note on (therefore they do not include the note length) for realtime melody correction. Let "note $\boldsymbol{x}$" be the note with feature vector $\boldsymbol{x}$.

Step 2 Modeling melody by N-gram.

The appropriateness of note transitions in a played melody is modeled by the N-gram model. This model gives the probability $P(\boldsymbol{x}_n|X)$ in which the note $\boldsymbol{x}_n$ exists behind the note sequence $X = \boldsymbol{x}_1 \cdots \boldsymbol{x}_{n-1}$. The N-gram model assumes that this probability is fixed by the $N-1$ notes $\boldsymbol{x}_{n-N+1} \cdots \boldsymbol{x}_{n-1}$ and calculates it by the following equation:

$$P(\boldsymbol{x}_n|X) = P(\boldsymbol{x}_n|\boldsymbol{x}_{n-N+1} \cdots \boldsymbol{x}_{n-1}) = \frac{P(\boldsymbol{x}_{n-N+1} \cdots \boldsymbol{x}_n)}{P(\boldsymbol{x}_{n-N+1} \cdots \boldsymbol{x}_{n-1})}.$$

Table 1. Elements of a feature vector.

[1]	The kind of the note (chord tone, key tone, etc.)
[2]	The interval between the note and the last note (m2, M2, more than m3)
[3]	Whether the note is on eighth-note-level beats
[4]	Whether a rest exists between the note being played and the previous note

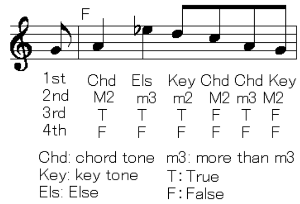

Fig. 2. Examples of feature vectors.

Step 3 Determining the notes to be corrected.
When the out note $\boldsymbol{x}_n$ follows the note sequence X, its appropriateness is given by the N-gram probability $P(\boldsymbol{x}_n|X)$ calculated with a large melody database. In other words, if $P(\boldsymbol{x}_n|X)$ is high, $\boldsymbol{x}_n$ frequently follows X in melodies of actual musical pieces. Our method therefore determines that the out notes that have lower N-gram probabilities than a threshold should be corrected.

Step 4 Determining the after-correction pitch.
The pitch maximizing N-gram probabilities, within an interval of major 2nd of the original note, is determined as an after-correction pitch.

4 Implementation and Evaluation of *ism*

4.1 Implementation

We built a prototype system of ***ism*** using the C language on Microsoft Windows. To construct a melody database, we used 208 songs' melodies of standard jazz. The total number of measures, which are segments of notes within a song, and individual notes of this database are 6,836 and 18,897, respectively. We adopted both the bigram model ($N = 2$) and the trigram model ($N = 3$) as the N-gram model because of the limitations of the database size (*i.e.*, using a number greater than 3 will cause the data sparseness problem). The threshold is 0.10.

This system has accompaniment data as standard MIDI files. While an accompaniment is played, the user plays improvisation along with this accompaniment using the MIDI keyboard connected to ***ism***. Then, ***ism*** corrects the player's melody and the MIDI tone generator plays the corrected melody.

4.2 An Example of melody correction

Fig. 3 shows an example of melody correction. The top score is a melody before correction. The middle and bottom scores are melodies corrected by the proposed method and the all-correction method, which corrects all of the out notes, respectively. The marks in the figure represent notes that are out of the available note scale before correction, each of which makes an interval of minor 2nd with

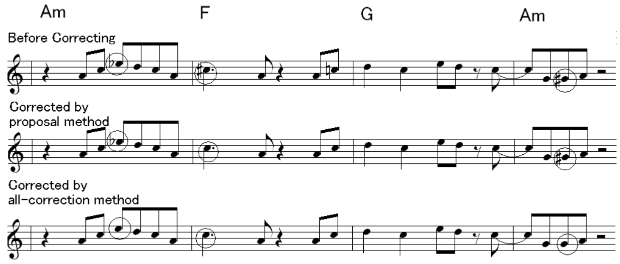

Fig. 3. An example of melody correction.

a note of the simultaneously played chord. In general, when a note in a melody makes an interval of minor 2nd with a note of the simultaneously played chord, it does not usually produce a disharmonious sound if it is an approach note. The second marked note is not an approach note, and actually produces a disharmonious sound. This note was corrected by both methods. On the other hand, The first and third marked notes are used as an approach note or a blue note, and actually do not produce a disharmonious sound. These notes were not corrected by our method, whereas they were corrected by the all-correction method.

4.3 Evaluation of Determination of Notes to be Corrected

We conducted experiments on determining whether notes in melodies should be corrected or not. The 37 non-improvising players listed in Table 2 first played using an improvisational style, and then the melodies of their improvisation were recorded. For each note in the melodies, we manually labeled whether it should be corrected. The melodies were then corrected both by the proposed method and by the all-correction method, and finally the appropriateness of the correction was evaluated using recall rate R, precision rate P and F-measure F, defined by the following equations:

$$R = \frac{\text{Number of correction-requiring and actually corrected notes}}{\text{Total number of correction-requiring notes}},$$

$$P = \frac{\text{Number of correction-requiring and actually corrected notes}}{\text{Total number of actually corrected notes}},$$

$$F = \frac{2 \times R \times P}{R + P}.$$

Table 3 shows experimental results. Our method based on the bigram and trigram models improved the F-measure by 0.1093 and by 0.1080, respectively. Although the recall rates of the proposed method were 1–2% lower than those of the all-correction method, the precision rates were about 13% higher. These results mean that the proposed method achieved an improvement in over-correction, that is, correcting notes that should not be corrected.

Table 2. Details of subjects and labeled notes in Sect. 4.3.

	# of players	Measure / player	Total notes	Correction-requiring notes
Beginning (under 1 yr.*)	10	64	3,108	12.03%
Intermediate (3–5 yrs.*)	15	64	3,177	8.22%
Advanced (over 5 yrs.*)	12	64	2,660	3.38%
Total	37	64	8,945	8.11%

*Experience in playing musical instruments.

Table 3. Experimental results of determining notes to be corrected.

	Whole			Beginners		
	R	P	F	R	P	F
All-correction	0.7822	0.3636	0.4964	0.7005	0.4242	0.5307
Ours (bigram)	0.7737	0.4977	0.6057	0.6628	0.5066	0.5743
Ours (trigram)	0.7682	0.4982	0.6044	0.6190	0.5078	0.5579

	Intermediates			Experts		
	R	P	F	R	P	F
All-correction	0.9123	0.5131	0.6568	0.7072	0.2012	0.3133
Ours (bigram)	0.9099	0.6622	0.7665	0.7072	0.2985	0.4198
Ours (trigram)	0.8969	0.6585	0.7594	0.7072	0.3032	0.4244

The accuracies for the intermediate group with all the methods were high. Because many players in this group know that notes in the available note scale produce natural melodies, their out notes mainly appeared as a result of mistouching or a failure of challenging an advanced melody. The proposed method detected such clearly unnatural out notes with accuracy.

On the other hand, the accuracies for the expert group were not high enough. This insufficient accuracy was caused by the mismatch of players and the melody database; the melody database was constructed using jazz melodies whereas many players of this group have experience in classical music. It can be improved by constructing genre-dependent or player-dependent melody databases.

4.4 Questionnaire Evaluation

We conducted evaluation of users' feelings of our system by questionnaires. The subjects are three people, listed in Table 4, who can play an instrument but have little experience in improvisation. They first played improvisation using our system and then answered the following questions:

Q1 Do you think the correction of your melodies was appropriate?
Q2 Did the system allow you to improvise without feeling a strong sense of strangeness?
Q3 Did you enjoy the improvisation with this system?
(7: Definitely Yes, 6: Probably Yes, 5: Possibly Yes, 4: Neutral
3: Possibly No, 2: Probably No, 1: Definitely No)

Table 4. Musical experience of the subjects for the evaluation in Sect. 4.4.

	Playing	Composing	Improvising
A	12 yrs. (Piano)	Yes	No
B	11 yrs. (Electone)	No	No
C	6 yrs. (Keyboard)	Yes	No

Table 5. Questionnaire results.

	Q1			Q2			Q3		
	all	bi	tri	all	bi	tri	all	bi	tri
A	5	4	6	5	4	7	4	5	5
B	5	7	6	1	4	6	6	6	7
C	3	4	7	2	2	4	5	5	5
Av.	4.3	5.0	6.3	2.7	3.3	5.7	5.0	5.3	5.7

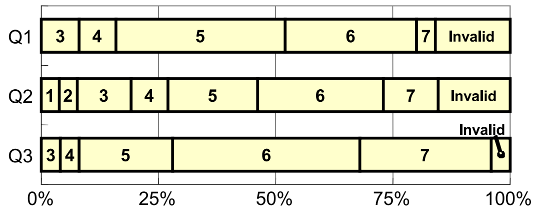

Fig. 4. Questionnaire results in WISS 2003.

Table 5 shows the results of the questionnaire. For all questions, the proposed method was superior to the all-correction method on the average of the three subjects. In particular, all the subjects answered that the trigram-based correcting method was better than the all-correction method.

The results of the trigram-based system were better than the bigram one. This is because the trigram model captures the tendency of note transitions better than the bigram model since the former uses longer note sequences.

Subject A did not highly evaluate the bigram-based system in Q1. This is because the chromatic phrases frequently used by this subject were corrected by the system. However, some listeners say that the corrected melodies are more natural, so that this correction is not necessarily redundant.

When we focus on Q2, Subjects A and B evaluated our trigram-based system highly. They have long experience, more than 10 years, in playing instruments. It means that the melody correction by the proposed method does not give a strong strangeness feeling to players even if they have long experience in playing musical instruments.

We also obtained from subjects the opinion that it was good to hide their failure from listeners when they failed in improvisation. This opinion suggests that our system achieved mitigating their hesitation toward trying improvisation.

4.5 Demonstration in WISS 2003

We demonstrated our system in the 11th Workshop on Interactive Systems and Software (WISS 2003), which is one of the biggest domestic workshops on human-computer interaction in Japan. When demonstrating the system, we asked attendees to use the system on trial and to answer the same questions as those in Sect. 4.4. Unlike Sect. 4.4, they used only the system using the trigram-based correction method, so that they did not compare it with the one using the all-correction method. The questionnaire results are shown in Fig. 4. For every question, the average of answers was more than 5.00. In addition, they gave us many comments such as the following:

– “I want to do more improvisation using this system.”
– “That is very interesting. Even if I play it without thinking, it produces appropriate melodies.”
– “This system is good for unskilled people.”
– “I can enjoy improvisation although I am a beginner.”
– “It would be more interesting if other instruments also had such a melody correction function.”

These results mean that many people have good impression on our system and hope for further development of our study. On the other hand, some people answered that they felt a sense of strangeness when a tone different from the pushed key was played. Reducing this kind of strangeness sense is an important future issue.

5 ***ism_V***: An Improvisation Supporting System that Points Out Unnatural Melodies with Key Vibration

In this section, we propose a system, called ***ism_V***, that points out musically unnatural notes in real time with key vibration. Previous methods for supporting musical practice (e.g., melody navigation with lighting keys, automatic tablature generation for guitars [10]) did not deal with improvisation, because they focused on supporting users who cannot read scores. Our system, ***ism_V***, detects musically unnatural notes in improvisation using the above-mentioned N-gram-based melody appropriateness determination method and points them out through vibrating the corresponding keys in real time.

5.1 Overview

The system described here is another version of the ***ism*** series, which vibrates keys instead of the correction methodology employed by ***ism***. The user plays improvisation on a keyboard called *Buru-Buru-kun*, which has built-in vibrating motors (Fig. 5, Fig. 6). The system detects musically inappropriate notes based on the method described in Sect. 3 and points them out by vibrating the corresponding keys. Because this system enables users to instantaneously learn that they are hitting inappropriate notes, it contributes to achieving efficient improvisation practice for people who cannot fully judge melody appropriateness.

Using key vibration in order to point out unnatural notes is because auditory, visual and other indication methods are unsuitable for the following reasons. Auditory indication means generating some sounds and it disturbs the performance. Visual indications such as LEDs demand that the user is always looking at the indicatiors while playing. As another approach for providing information to the player, heating keys has been proposed [11], but it takes a long time (approximately two seconds) from starting to heat them to the player feeling the heat.

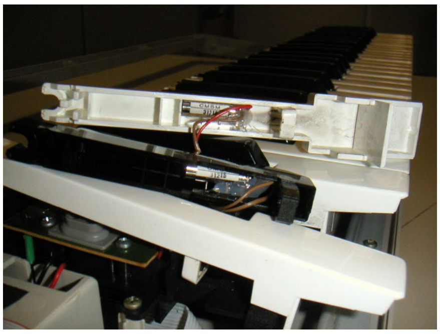

Fig. 5. Built-in vibrating motor in each key.

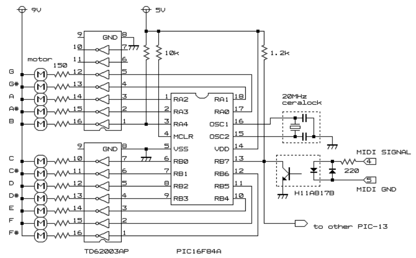

Fig. 6. Circuit diagram of *Buru-Buru-kun*. The PIC analyzes signal received from the MIDI IN port, and controls built-in vibrating motors.

5.2 Questionnaire Evaluation

To evaluate the effectiveness of ism_V, we administered questionnaires to users, comparing improvisation practice methods using ism_V and a normal MIDI keyboard. The subjects were 16 beginning level musicians, divided into four groups (A–D). Each subject tried both practice methods and then answered questions for each practice method. To avoid the influence of trial orders, the subjects in Groups A and C first used ism_V and then used the normal keyboard, whereas those in Groups B and D used them in the reverse order. In addition, we used two different accompaniments (I and II), which had different keys and chord progressions, between two trials. Accompaniment I was used for the first trial of Groups A and B and the second trial of Groups C and D, and Accompaniment II for the rest. The questions used are as follows:

Q1 Do you think you can improve your improvisation skills with this method?
Q2 Do you think this practice method is efficient?
Q3 Did you enjoy the practice?
Q4 Do you think you will continue this practice method?
(7: Definitely Yes, 6: Probably Yes, 5: Possibly Yes, 4: Neutral
3: Possibly No, 2: Probably No, 1: Definitely No)

The results are listed in Table 6. For every question, the average answer for ism_V was more than 5.0 and was 1.7–3.5 higher than that for the normal keyboard. The results of paired t-tests show that ism_V is superior to the normal keyboard with a significance value of 5% (Details are omitted due to lack of space). Table 7 shows comments made by participating subjects. As shown in Table 7, many subjects gave us positive comments such as "I can easily recognize which notes are wrong" and "This is revolutionary." These results indicate that many people deemed it to be a good tool to help them practice improvisation easily and in an enjoyable manner. On the other hand, most comments for the practice using the normal keyboard were negative such as "too difficult for beginners" and "boring." These comments indicate that the normal method is difficult to continue the practice, although continuous practice is the most important for improving improvisation.

6 Conclusions

This paper has addressed the issue of helping inexperienced musicians in improvisation. Although improvisation is one of the most exciting entertainment forms, many people have given up learning improvisation due to the difficulty of instantaneously creating melodies while playing. To tackle this important issue, we developed two systems: ***ism*** which automatically corrects musically unnatural notes to natural ones and ***ism***$_V$ which points out musically unnatural notes with key vibration. Through these systems, users can not only easily enjoy and attempt improvisation but also practice improvisation efficiently and in an enjoyable manner. We believe that these systems make a significant contribution to music entertainment and music education.

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Table 6. Questionnaire results of ***ism_V*** evaluation

	Q1		Q2		Q3		Q4	
Subjects	***ism_V***	normal	***ism_V***	normal	***ism_V***	normal	***ism_V***	normal
A1	5	3	7	1	5	2	6	2
A2	5	3	4	2	5	6	3	4
A3	5	6	4	2	6	6	4	4
A4	5	3	7	1	7	6	5	4
B1	6	5	7	4	7	4	6	4
B2	6	5	5	2	7	2	5	3
B3	6	2	6	2	6	5	7	4
B4	6	5	6	2	4	5	6	6
C1	6	5	7	3	4	7	6	3
C2	4	3	5	2	6	6	5	5
C3	5	3	5	3	6	4	4	4
C4	5	1	7	1	7	1	6	1
D1	6	5	6	3	6	3	6	4
D2	6	3	6	3	4	1	7	1
D3	4	2	3	2	4	2	4	3
D4	6	4	6	2	4	7	3	5
Av.	5.4	3.6	5.7	2.2	5.5	3.8	5.2	3.3
SD	0.72	1.4	1.3	0.83	1.2	2.0	1.3	1.5

Table 7. Opinions obtained from subjects after evaluation

ism_V
This is helpful because I can quickly get feedback on which notes are inappropriate.
This system allows me to easily recognize wrong notes from vibration.
This is a good system because it indicates melodies that are more appropriate than the ones I have generated on my own.
By comparing my melodies with the ones corrected by the system, I can learn more about the mistakes I make.
It is efficient at telling me when my playing is not in line with the accompaniment.
This is revolutionary!
I have no time to correct my errors even if the system points out the notes that need to be corrected in real time.
Although it is useful for creating melodies that are harmonious with the accompaniment, it is still difficult to use it for creating beautiful melodies.
A normal MIDI keyboard
It takes a long time to learn from the system because I cannot quickly recognize wrong notes.
I cannot understand which notes are inappropriate.
If users do not have a good sense of music, this practice method is inefficient, because they have to evaluate everything with their own ears.
This practice method will reach a plateau because it does not provide objective advice.
It is difficult to determine whether my melodies are good or not.
It is too difficult for beginners.
This is boring.