Deriving Pauses for Obtaining Fundamental Movements in Traditional Skills

Teruhisa Hochin and Hiroki Nomiya

Abstract This chapter tries to derive pauses in order to obtain fundamental movements, which are considered to be important for transmitting traditional skills, from the movement of a worker or a player. This is due to the observation that the fundamental movements may relate to pauses. The fundamental movements are captured as similar changes of the speeds appearing everywhere. The movement is represented with a sequence of the sum of the speeds of the parts of a body in this chapter. Subsequences are cut out from the whole sequence. The similarity of two subsequences is judged in the frequency domain. It is experimentally shown that pauses can easily be obtained by adjusting several parameters of the similarity test. The typical fundamental movement is tried to be obtained.

Keywords Pause · Traditional skill · Fundamental movement · Frequency

1 Introduction

There are many traditional crafts and industries in Japan. In almost all of them, things are made by hand, without the use of machinery. The craft workers joining traditional industries have special techniques and skills. It takes a long time to obtain them. It is, however, becoming difficult for the next generation to inherit them because young people seldom join the traditional crafts and industries [1, 2]. Analyzing the techniques and skills may clarify their important points. These points could make the learning time shorter than usual. This will make it easy and quick for young people interested in the traditional crafts and industries to learn such techniques and skills.

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In order to transmitting traditional techniques and skills from the current generation to the next one, several efforts have been made. These include the analysis of the movement of craft work [1–3], the construction of skill training system based on data mining and visualization [4], that of the prototype self-training system using a three dimensional depth sensor and a camera [5], that of an interactive multimodal motion learning system [6], and that of the augmented practice mirror learning support system [7].

Recently, the pause, which is called "Ma" in Japanese, has been focused on in order to derive the skills from the master's movement, and to transmit them to the next generation. The movements of a craft worker have been analyzed from the point of view of the pause [3]. A method of representing the pause has been proposed [8].

Here, Nakamura has intensively studied the pause especially in speeches and music pieces [9]. Nakamura defined the pause. She emphasized that a pause is not merely a silent period, but gives some impression to an audience. She revealed the characteristics of the pause mainly from the points of view of the impression and the aspect of physiological psychology [9].

Various pauses have been clarified in various performances [10]. Pauses in speeches, music pieces, and actions have been obtained. We have categorized the pauses into several types from the various points of view: the presence of sound, that of movement, that of a pose, the time duration, and the aim of a pause. It has also been pointed out that there is a negative pause, whose time duration is shorter than the usual one. It is shown that short pauses are considered to be important for transmitting traditional skills.

This chapter tries to derive pauses for obtaining fundamental movements often appearing in the movements of traditional workers. They are derived by using the frequency characteristics. It is experimentally shown that they can be derived by choosing several parameters of the similarity test.

The remaining of this chapter is as follows: Sect. 2 describes the related works on the pauses and the frequency analysis. Section 3 describes the tea ceremony, whose movements we treat as the traditional work in this chapter. Section 4 experimentally derives pauses. Some considerations are made in Sect. 5. Finally, Sect. 6 concludes the chapter.

2 Related Works

2.1 Pauses

Pauses in speeches and music pieces. The pause means no movement. It is the temporary stop. Nakamura revealed and emphasized its importance [9]. Nakamura defined the appropriate pause of a speech and/or a music piece as the time required and sufficient for understanding the contents and the meaning of the phrases and/or notes preceding it, for connecting to the next phrases and/or notes, and for representing some impression and receiving it.

Nakamura also revealed the relationships between the pause and the breath [9]. It has experimentally been revealed that the length of a pause is based on that of a breath. Synchronizations of the breaths of a music player and an audience, and those of a speaker and a listener are shown.

Pauses in traditional skills. Tanaka et al. have studied on the pauses in the knitting of wire netting [3]. The purposes of their study were to find the pauses in the knitting process of wire netting, and to reveal their effect. A knitting work is composed of the main tasks and the secondary ones. The main task is the movement of the knitting. The other movements are included in the secondary ones. The main tasks alternate with the secondary ones.

Pauses were tried to be found when fingers stop in knitting wire netting. Fingers, however, did not stop in the task. They defined a pause as the duration when the acceleration of the motion of a finger is in some range. According to this definition, pauses could be found in around 15–40 % of the time after a main task started.

They concluded that the pauses appeared in the working time, and that the pauses were related to short breaks of finger's motion. These pauses are important for skilled workers to repeat the same movement for a long time.

Kinds of pause. Pauses have been categorized into several types from the following points of view: the time duration, the presence of sound, that of movement, that of a pose, and the aim of a pause [10].

Time duration. Pauses are divided into three categories in the point of view of the length: short, normal, and long pauses. The duration of a normal pause is about 1 s, which corresponds to one breath. That of a short (long, respectively) pause is shorter (longer) than 1 s. Short pauses appear in work, e.g. the knitting of wire netting. On the other hand, long ones appear in performances, e.g. speeches, music pieces, and Kabuki performances.

Sound. Pauses are categorized into two types according to the accompaniment of sound: a pause without sound, and a pause with sound. The former is an ordinary pause. A pause of a speech is an example of this type of pause. An example of the latter type of pause is the note with a fermata.

Movement. In actions, there are two types of pause: a pause without movement, and a pause with movement. The former means there is no movement. An actor stops his/her motion. This type of pause is an ordinary pause. On the other hand, the pauses in the knitting of wire netting are of the latter type of pause because fingers move.

Poses. There are two types of pause on the existence of a pose: a pause with a pose, and a pause without a pose. The former is a usual pause in an action. An actor stops his/her motion. The latter type of pause has two meanings. One includes neither movements nor poses. An actor does not do anything. The other includes movement. The pauses of the knitting of wire netting are of this type of pause.

Aim. Pauses could further be divided to two types according to the aims of pauses: a pause for an audience, and a pause not for an audience. The former is for giving some impression to someone. A player gives an audience some impression. The pauses in speeches and music pieces are of this kind of pause. The latter is not for anyone. The pause of the knitting of wire netting is of this type of pause. A skilled person does not intend to give any impression to anyone.

2.2 Deriving Patterns from Time-Series Data

For the purpose of deriving patterns from time-series data, similarity of two sequences of data must be judged. There are two major approaches in judging the similarity of the sequences. One compares two sequences directly in the time domain [6, 11–13]. The Adaptive Piece-wise Constant Approximation (APCA) [11] approximates a sequence into a sequence of steps, and uses the areas between the steps and the axis. The Multi-resolution Vector Quantized (MVQ) [12] divides a sequence into segments, and approximates it by using a sequence of the representative values of the segments. The ratio of the representative values of a candidate sequence to those of a key one is their similarity. These methods, however, could not properly handle the sequence slightly different from the one in the time direction. For example, the similarity of a sequence and the slightly shifted one becomes very low. In order to adapt this situation, the dynamic programming approach is often taken. The Dynamic Time Warp (DTW) e.g. [13] is a popular method. Ozaki and Oka followed this approach to extract knacks of skills [6].

The other approach compares two sequences in the frequency domain [14–16]. The sequence of data is transformed to a set of data in the frequency domain. The Fourier transformation is often used as such a transformation. It has been shown that similar sequences can be retrieved by using a few Fourier coefficients [14]. This also brings the dimensionality reduction. We can construct an index for fast retrieval by using only these coefficients [15, 16].

By applying Fourier transformation to a sequence of data, Fourier coefficients are obtained. These except for the 0th one are complex numbers, which is composed of a real number and an imaginary one, while the 0th coefficient is a real number. The 0th coefficient represents the mean value of the data in the sequence. By using these coefficients, we could compare two segments in the frequency domain. The coefficients of low orders correspond to those of low frequencies, while those of high orders correspond to those of high frequencies. By using coefficients of several lowest orders (all of orders, respectively), we could approximately (precisely) compare two segments.

In general, we could define and use the distance between two segments. The distance is the dissimilarity of two segments. We can use the distance in judging whether they are similar, or not. We could decide two segments are similar if the distance is less than a value, which is usually called the threshold value. It is the boundary of deciding whether two segments are similar, or not.

When the time series is very long, we often use the window to obtain their subsequences. The Fourier transformation is applied to a subsequence in the window. The subsequence is called a segment. In the window approach, segments are obtained by shifting the window. The amount of the shift of the window *Ls* as well as the width of the window *Lw* should be considered. When *Ls* is larger than or equal to *Lw*, there is no overlap between two windows. There are some overlaps among windows when *Ls* is smaller than *Lw*.

3 Tea Ceremony as Traditional Works

The movements of tea ceremony are used as those of traditional works. After the summary of tea ceremony is presented, the pauses in tea ceremony are described.

3.1 Tea Ceremony

In tea ceremony, a host serves cups of tea for guests. There are strict rules on how to prepare, make, and serve tea. Tea ceremony consists of many steps.

Scenes of tea ceremony are shown in Fig. 1. These are of the preparation phase of making a cup of tea. A host makes the instruments used in the tea ceremony clean by using Fukusa, which is a sheet of cloth. The host begins to prepare (Fig. 1a). He takes the Hishaku, the ladle for scooping water, up (Fig. 1b), and puts it down (Fig. 1c). He bows to the guest (Fig. 1d). He puts a tea container down in front of him (Fig. 1e). He opens Fukusa (Fig. 1f) to fold it. This action is called the Fukusa-sabaki. The tea container is purified (Fig. 1g). He puts it down in front of a water jug (Fig. 1h). He opens Fukusa to begin Fukusa-sabaki again (Fig. 1i).

3.2 Pauses in Tea Ceremony

There are two kinds of pause. Motions entirely stop in one kind of pause, while there are some movements in the other kind of pause.

In the former kind of pause, a host intends to make pauses, and to divide the series of actions. A host may take a breath at this kind of pause. The scenes of these pauses are those shown in (Fig. 1a, b, d, f). A kind of impression is received at these scenes. The length of the pause is from a half to one second. This pause corresponds to the normal pause.

On the other hand, a host does not intend to make pauses in the latter kind of pause. These are considered to be stays rather than pauses. These pauses do not divide the series of actions. The scenes shown in (Fig. 1c, e, g–i) are of this type of pause. A host may not take breaths at these pauses. These are caused by that a host politely treats the instruments. These pauses are shorter than the former ones. This pause is considered to be the short pause.

The sums of the speeds of the twenty-nine parts of the body are shown in Fig. 2 in the normalized form. There are many periods where speeds are equal to zero. These periods are considered to be of both types of pause. These types, however, could

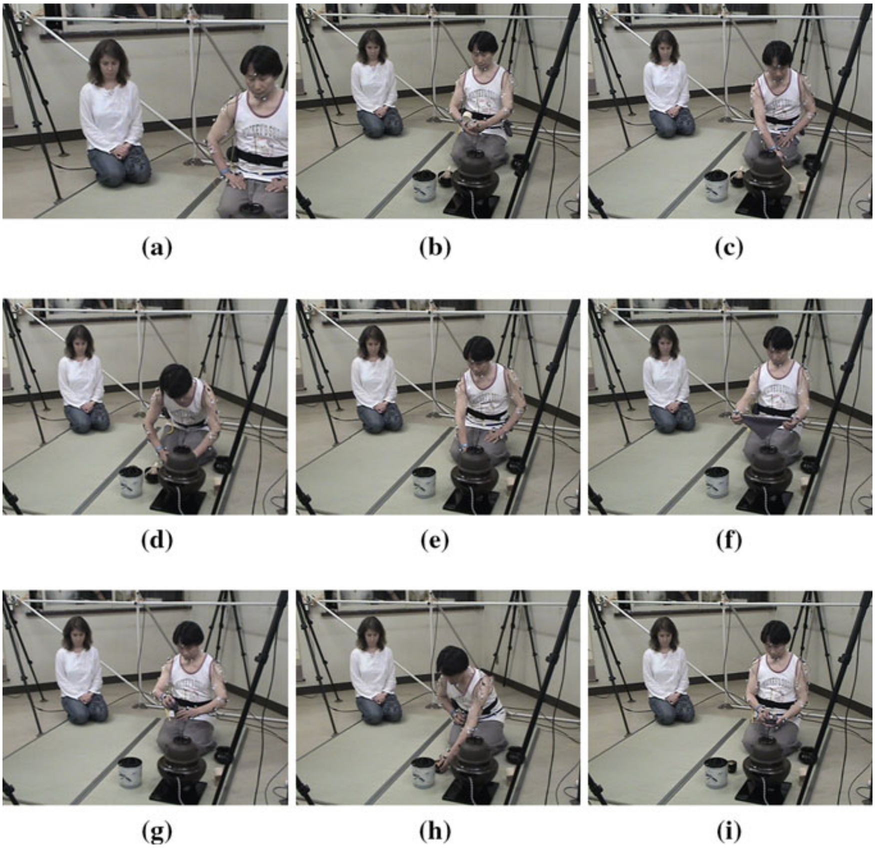

Fig. 1 Scenes of tea ceremony: **a** Beginning, **b** Kagami-Bishaku, **c** Putting Hishaku down, **d** Bowing, **e** Putting a tea container down in front of a host, **f** Fukusa-sabaki, **g** Purifying a tea container, **h** Putting a tea container down in front of a water jug, and **i** Opening Fukusa again

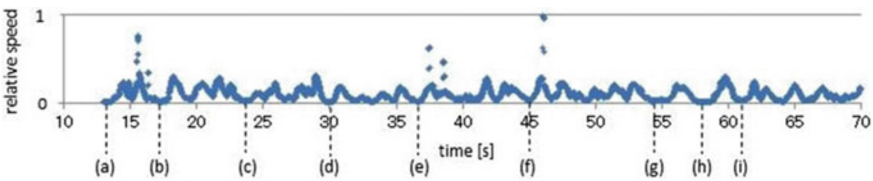

Fig. 2 Normalized speeds of movements of tea ceremony

not be distinguished each other only by considering the length of a pause. This is because the time duration of the longest short pause is very close to that of the shortest normal one [10]. It has been shown that the scenes of the normal pauses could be distinguished from the short pauses by using the fact that the host straightens himself or bows in the normal pauses [10]. Here, both types of pause are tried to be derived.

4 Derivation of Fundamental Movements

Fundamental movements of tea ceremony are tried to be obtained by focusing on pauses. Here, we follow the approach comparing sequences in the frequency domain. The Fast Fourier Transformation (FFT) is applied to the time series of speeds. As the whole of the movements of tea ceremony is very long, the window method is used.

4.1 Experimental Methods

The sampling frequency of the three-dimensional motion captured data used in the experiments is 100 Hz. The duration of a time slice is 0.01 s.

We conduct three experiments. The first is to decide the appropriate width of the window *Lw*. The second is to decide the number of Fourier coefficients used in calculating the similarities of segments. The last is to determine the threshold value in judging the similarity of two segments.

The segment of the movement (e) of Figs. 1 and 2 is used as a key segment of retrieval because this is a typical one of the pauses not for an audience in tea ceremony. The segments similar to the key segments are retrieved.

In the last two experiments, the goodness of the selection of the value of the parameter is evaluated by using the measures of precision, recall, and F-measure. These are calculated as

precision = *Ncr*/*Nr*,
recall = *Ncr*/*Nc*, *and*
F-measure = 2*precision*recall/(precision + recall),

where *Ncr* is the number of the correct segments retrieved, *Nr* is the number of the retrieved segments, and *Nc* is the number of the correct segments. The correct segments are manually decided by one of the authors. In the experiments, the number of the correct segments is sixteen because there are fifteen segments similar to the key segment, which is the segment of the movement (e) of Fig. 2.

Experiment 1. As described in Sect. 3, it is considered that fundamental movements exist in short and/or normal pauses. The duration of a normal pause is about 1 s. The candidate widths of the window *Lw* are 32, 64, 128, and 256. Here, we use the numbers of powers of two because the number of points must be a power of two in using FFT.

We adopt the width of the best retrieval as *Lw*. In this experiment, we set *Ls* be 10.

Experiment 2. It is experimentally decided the number of Fourier coefficients used in calculating the similarity of segments. The number is varied from two to four. Adopting two coefficients means that the 0th and the 1st coefficients are used. We use 128 as *Lw* because it gives the best performance as described later. The goodness of the number of Fourier coefficients used is evaluated through precision, recall, and F-measure.

Table 1 Precision, recall, and F-measure against the number of Fourier coefficients used

Number of Fourier coefficients	Precision	Recall	F-measure
2	1.00	0.81	0.90
3	1.00	0.94	0.97
4	0.89	1.00	0.94

Table 2 Precision, recall, and F-measure against threshold values

Threshold value	Precision	Recall	F-measure
1,000	1.00	0.63	0.77
1,500	1.00	0.94	0.97
2,000	0.88	0.94	0.91

Experiment 3. We experimentally decide the threshold value. We try 1,000, 1,500, and 2,000 as the threshold values. Three Fourier coefficients are used because they attain the best as described later. The goodness of the threshold value is evaluated by using precision, recall, and F-measure.

4.2 Experimental Results

Experiment 1. The results are shown in Fig. 3. The sequences of bold red squares show the candidates obtained by the retrieval. In the cases of 32 and 64, many sequences do not become the candidates similar to the key sequence. These lengths seem to be too short to capture the waveform of the key sequence. In the case of 256, the length of the segment is too long to represent the waveform of the key segment. On the other hand, the similar waveforms are obtained in the case of 128. It is considered that 128 is better than 32, 64, and 256.

Experiment 2. The results are shown in Table 1. In the case of two and three coefficients, several subsequences do not become the candidates similar to the key sequence. In the case of four coefficients, the sequences not so similar to the key sequence are obtained. Totally, the best performance could be obtained when the three coefficients are used. We decided to use three coefficients.

Experiment 3. The results are shown in Table 2. In the cases of 1,000 and 1,500, several sequences do not become the candidates similar to the key sequence. In the case of 2,000, the sequences not so similar to the key sequence are obtained. Totally, the best performance could be obtained when the threshold value is 1,500. The value 1,500 is adopted as the threshold value.

The segments of bold red squares shown in Fig. 4 are those obtained when the window size *Lw* is 128, three coefficients are used, and the threshold value is 1,500.

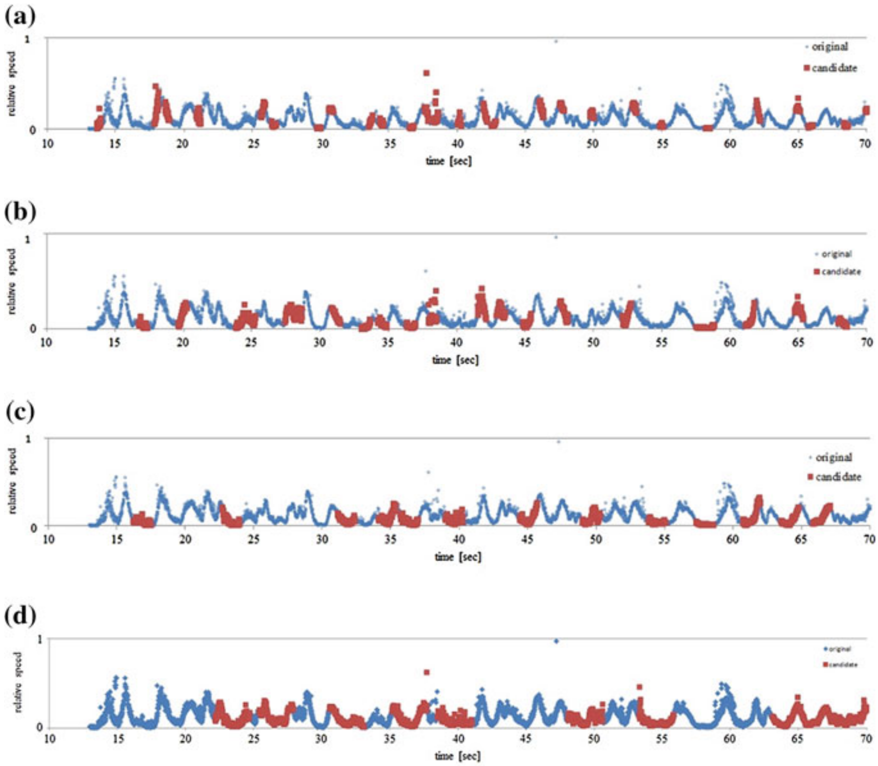

Fig. 3 Movements similar to the one of the scene **e** shown in Figs. 1 and 2. Window widths *Lw* are **a** 32, **b** 64, **c** 128, and **d** 256

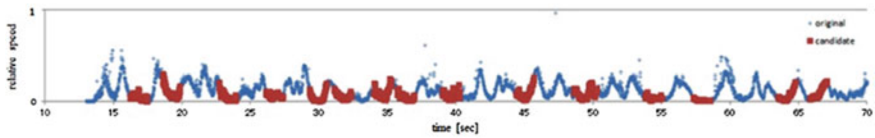

Fig. 4 Segments obtained by the retrieval when the window size *Lw* is 128, three coefficients are used, and the threshold value is 1,500

5 Considerations

When we use 128 as the window size *Lw*, the best performance could be obtained. As the length of a normal pause is about one second, and the sampling frequency is 100 Hz, this value is considered to be appropriate. When four Fourier coefficients were used in calculating the distance between two segments, the precision degraded. As the third coefficient is a high frequency component, it is considered that the effect of the high frequency component is not good in calculating the distance between segments.

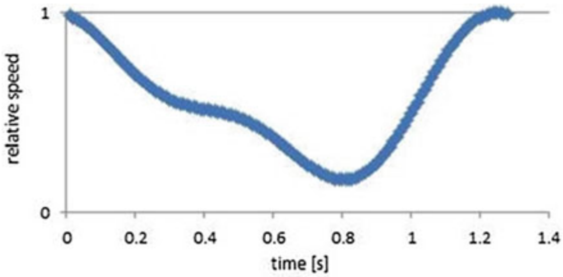

Fig. 5 The waveform obtained through the inverse Fourier transformation only with the three coefficients used in comparing segments

As the three Fourier coefficients are used in comparing segments, we could obtain the waveform used in the comparison. That is, the waveform used in the comparison can be obtained through the inverse Fourier transformation only with the three Fourier coefficients used in the comparison. The waveform obtained is shown in Fig. 5. This is of the key segment used in the experiments, the segment of the movement (e) in Fig. 2. It can be seen that the relative speed slowly decreases and then increases. The duration of the slow-down phase seems to be longer than that of the speed-up one. This movement may be considered to be the fundamental movement of tea ceremony.

It can easily be seen that the fundamental movements appear everywhere in the movements of tea ceremony. Even if the actions are different, the patterns of the movements are quite similar. It may be one of the skills in tea ceremony.

The method described in this chapter could derive fundamental movements of tea ceremony. These are in both of normal pauses and short ones. The normal pauses can be identified by using the fact that the host straightens himself or bows in the normal pauses [10]. Therefore, we could distinguish the fundamental movements of the normal pauses from those of the short ones.

Fundamental movements could easily be obtained. We treat only one kind of speed, the sum of the speeds of the parts of a body. We did not treat the speeds of each part of a body. This might make it easy to get fundamental movements.

We decided to use three Fourier coefficients and 1,500 as the threshold value. We may, however, use four Fourier coefficients and 2,000 as the threshold value. The values within some range may be acceptable.

6 Conclusion

This chapter tried to derive pauses in order to obtain fundamental movements from the movement of a worker or a player. The movement is represented with a sequence of the sum of the speeds of the parts of a body. The similarity of two subsequences cut out from the whole sequence was judged in the frequency domain. It was experimentally shown that pauses could easily be obtained by adjusting the width of the window, the number of Fourier coefficients used, and the threshold value in judging the similarity of two segments. The typical fundamental movement in tea ceremony was tried to be obtained.

Only the part of the preparation phase of tea ceremony was treated in this chapter. Treating the whole of tea ceremony is in future work. The movements treated in this chapter are represented with sequences of the sums of the speeds. The movements of each part of a body are not considered. A part of a body resides at a point in three-dimensional space. We may have to treat the movements as those in the spatio-temporal space. Spatio-temporal analysis of the movement is also in future work. Tea ceremony is treated in this chapter. Trying other traditional works is also included in future work.

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