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A Human Motion Analysis Using the Rhythm – A Reproducing Method of Human Motion

Kazuya Kojima[1], **Mikiya Hironaga**[2], **Sadahiko Nagae**[3], **Yasuhiro Kawamoto**[4]

[1] *Graduate School of Biology-Oriented Science and Technology, Kinki University*
Nishimitani 930, Uchida-cho, Naga-Gun, Wakayama 649-6439, Japan
email: kkojima@mm.info.waka.kindai.ac.jp

[2] *Faculty of Science and Engineering, Kinki University*
3-4-1, Kowakae, Higashiosaka-shi, Osaka-fu 577-8502, Japan

[3] *Faculty of Biology-Oriented Science and Technology, Kinki University*
Nishimitani 930, Uchida-cho, Naga-Gun, Wakayama 649-6439, Japan

[4] *Toei Kyoto Studio Co., Ltd Toei Digital Film, Kyoto Research Park 1-4-5F*
Awata-cho, Chudouji, Simogyo-ku, Kyoto-city, Kyoto-fu 600-8815, Japan

Abstract. In this study we estimate the postures of a human body in dance images (or repeated motions) recorded in an image database (especially recorded movies). We propose a new method by defining the "Rhythm Points", i.e. equally spaced points on the time axis located at the moment of the start or end of the motion. With these rhythm points we are able to separate each repetition of the motions and to measure coordinates only at the moment of rhythm points and of a few points between (key frames), while coordinates of other frames are interpolated automatically.

We introduced new terms for these variables in the formula of the splines and we designed a new natural spline curve for interpolating the knee-angle. Thus we could improve our previous results. With our method the necessary human work could be remarkably reduced.

Key Words: Rhythm Points, Spline Function, Human Motion Analysis.

1. Introduction

Many studies on human motion have been done lately [1]. Especially dance motions are studied by many people [2].

In this study, we aim to analyse and preserve the traditional Japanese dance motions recorded in the image database shown in Fig. 1. As the database is already built, we cannot use special devices such as the motion capture devices to get the coordinates of each part

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of the body. On the other hand, it would be too much work if we manually pick all the characteristic points in each frame. Thus we need some interpolation. This paper proposes the new interpolation method to reproduce human motion on the target of dance motion (repeated motion).

Figure 1: Ouni dance

2. A sample image

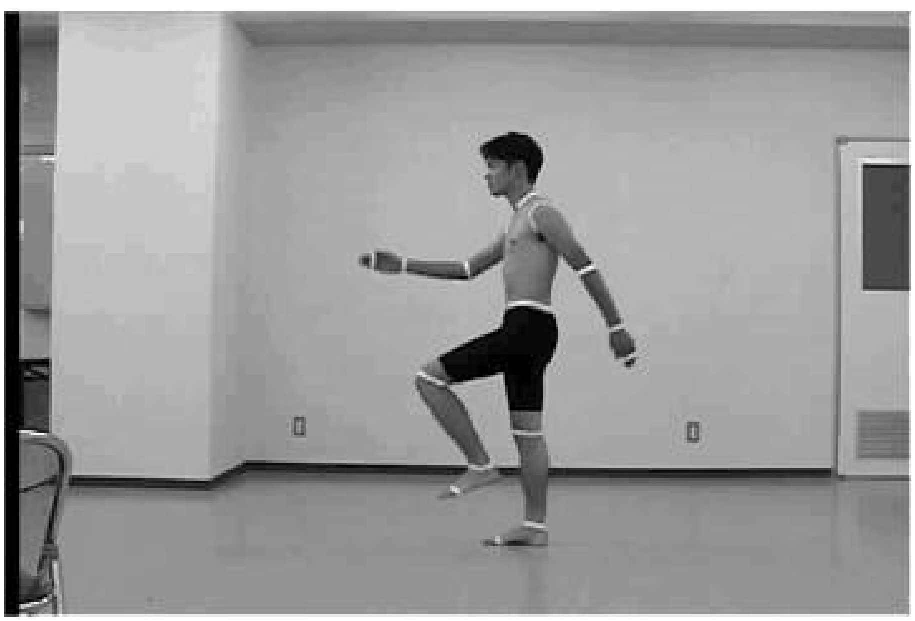

Figure 2: Step motion

As a primitive sample image data, we used a step motion video, motion repeated on metronome sounds (Fig. 2). In this sample, the length of each part of the body is known and we can estimate three-dimensional coordinates of each part of the body by triangulation [3, 4].

3. The relation of the image database and the dance motion

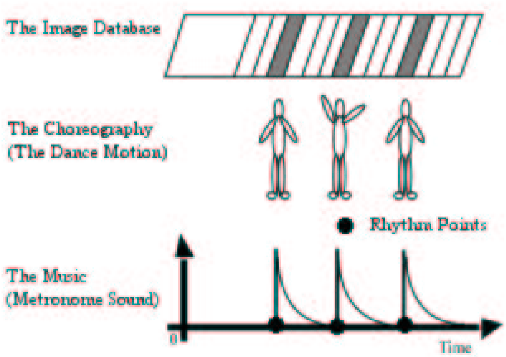

Figure 3: The relation of image database and dance motion

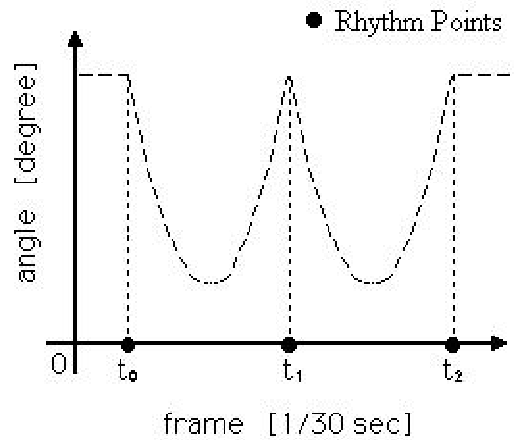

Figure 4: Rhythm points and a change of angle

In this section, we will explain the relation between the image database and the dance motion shown in Fig. 3. The image database has many frames which consist of the choreography or the target motion. As each frame represents any moment of the motion, we utilize the metronome sound to separate every period of the motion. In dance motions, the pose of the body is ruled by the music. The rhythm of the music determines the start and the end of any motion period. Now we call the time of the start and the end of the motion "Rhythm Points". Note that the end of the motion is the start of the next motion. An ideal repeated motion is shown in Fig. 4. The time t_i are the rhythm points. The angles of the joints reach extrema at the rhythm points and they have extrema in between rhythm points.

To reduce human interaction and work to do, we use the frames at the rhythm points as the "key frames" for the interpolation of the joint angles. Figs. 5–8 show how angles of the body vary during the step motion. The vertical lines represent rhythm points made by metronome with tempo 91.6 . Each figure has three repeats. There are about 20 frames between rhythm points.

4. A new spline

To generate a motion of any type, interpolation is often done in animations to reduce human work. In this study, we have defined frames at the rhythm points as the key frames. We add further frames at the middle points between rhythm points. In Fig. 9, the second repeat of the knee's angle is shown. The vertical lines represent rhythm points and the vertical dotted lines represent middle points. This figure has 5 key frames (3 rhythm points and 2 middle points). We interpolated from these points of the whole motion. In this paper, we measured the angular variation in all frames in order to evaluate the error.

Based on three key frames, we started by interpolating with a cubic spline (Fig. 10). The maximal difference between the measured angle and the cubic spline is $-19.525°$ at the 370th

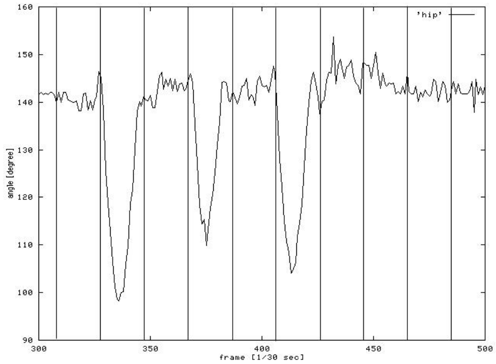

Figure 5: Rhythm points and the change of angle (hip)

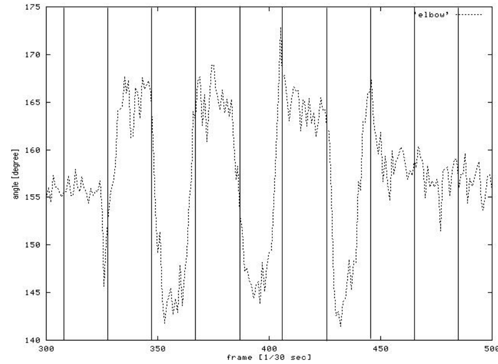

Figure 6: Rhythm points and the change of angle (elbow)

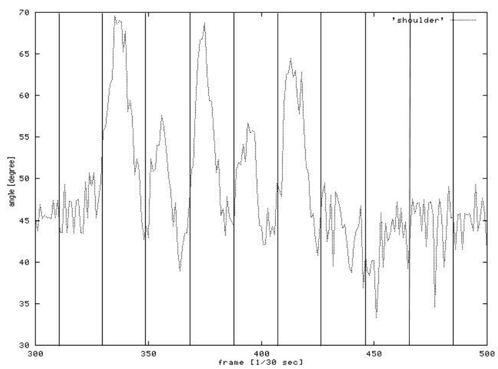

Figure 7: Rhythm points and the change of angle (wrist)

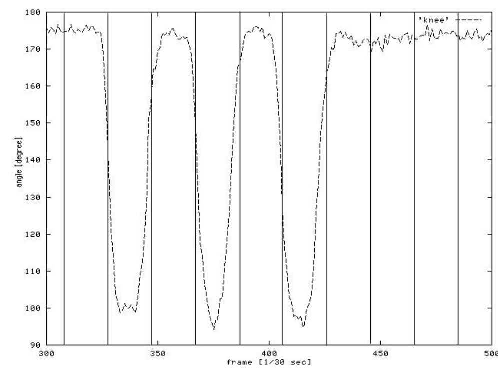

Figure 8: Rhythm points and the change of angle (knee)

frame. Between the 357th and the 367th frame the cubic spline is extremely bigger than the measured angle though the extremum should be at the midpoint between the rhythm points.

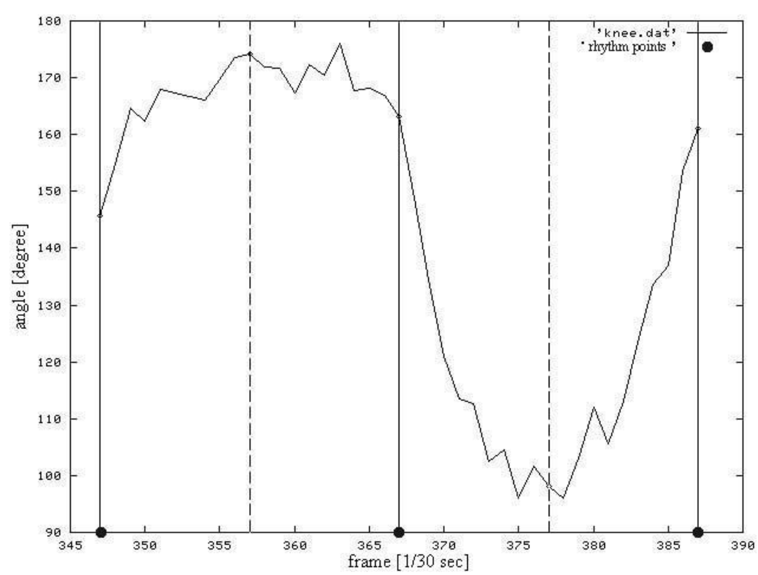

Figure 9: Key frame and a measured angle (knee)

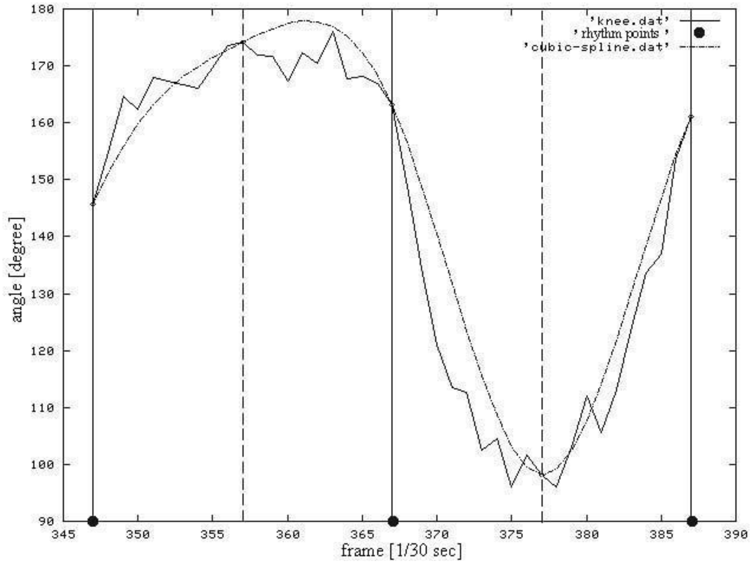

Figure 10: A method of a cubic spline

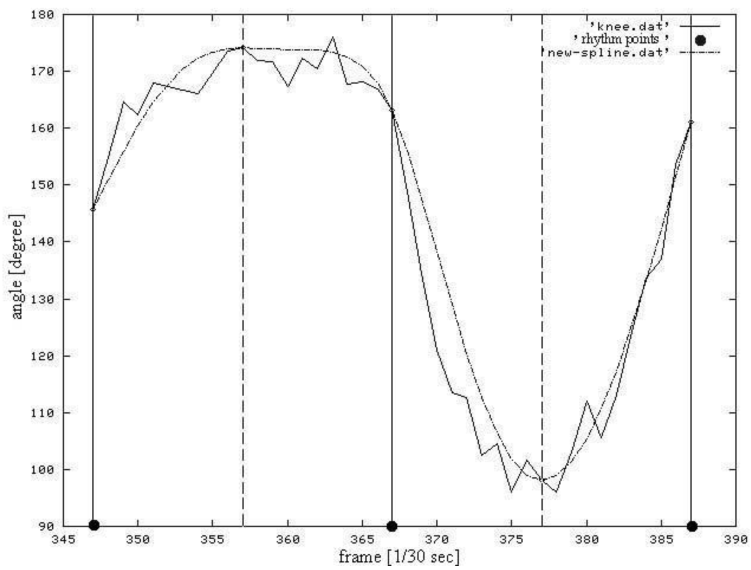

Figure 11: The curve of a new spline

Now we propose a new spline for interpolating dance or repeated motion. This spline is defined by the five conditions listed below.

1. In any interval between key frames the spline function is a polynomial of fourth degree.
2. At both ends of any interval the function equals the measured values.
3. At the border of an interval the 1st, 2nd and 3rd derivatives of the function are continuous.
4. In the middle of the rhythm points the 1st derivative of the function equals 0.
5. At both ends of an interval the 2nd derivatives are 0.

The interpolated new spline curve is shown in Fig. 11. The maximum error of the new spline is $-17.453°$ at the 370th frame. Between the 357th and the 367th frame our curve now fits better to the measured data.

5. Result and discussion

Table 1 shows the sums of the squared errors and the maximum error for both splines. For the new spline the maximum error is 10.6% smaller than that of the cubic spline. The sum of the squared errors decreases by 34.4%. Around the 354th frame, our spline has a slightly (2.3°) bigger error than the cubic spline (Figs. 12–13). But the absolute value of the error is very low. In the range of errors greater than 6.5°, our spline has always smaller errors than the cubic spline. The evaluation function of E (sum of the squared errors) is

$$E = \sum (A - X)^2$$

where A is the measured value and X is the spline value.

Table 1: The sum of the squared errors

	maximal error	*sum of squared errors*
cubic spline	−19.525°	2115.162
new spline	−17.453°	1386.657

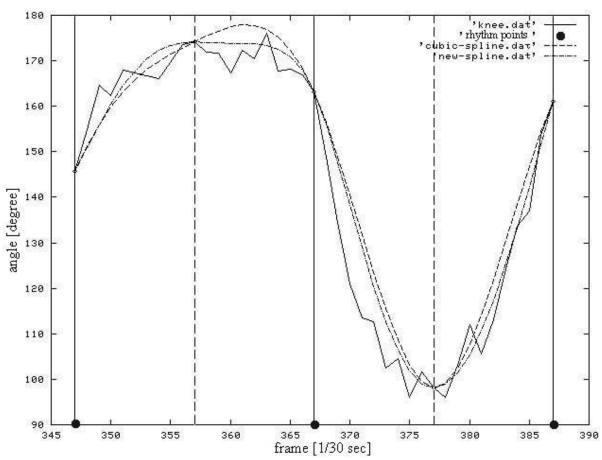

Figure 12: The result of the cubic spline and the new spline

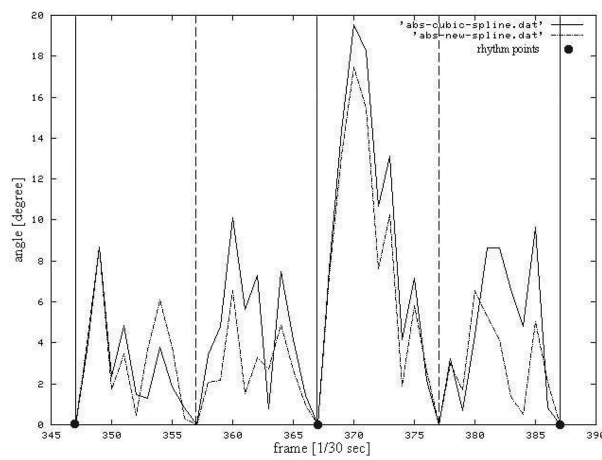

Figure 13: The absolute of the error (the cubic spline and the new spline)

6. Conclusion

We proposed the new spline interpolation method to reproduce human motion in the animation of repeated motion. We tested our method at the movement of the knee. Our spline method approximated the change of the knee's angle better and reduced of the error remarkably. To reproduce the whole motion of the dance, we intend to extend out method to other joints of the body.

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