Exploring Rhythmic Patterns in Dance Movements by Video Analysis

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Abstract. Treatments of coordination disorders may be benefit from modern assistive technologies by achieving effective feedback that improves the rehabilitation protocols. In this paper, a method to identify movement patterns from video sequences is presented, providing acoustic stimuli by means of sounds generated from motion analysis. The method explores rhythmic patterns in movements, through fundamental concepts as: motion detection and analysis, Principal Component Analysis (PCA) and frequency analysis. The proposed method was evaluated by using four (4) dance steps, used typically in Latin music, showing good performance in detecting and reproducing acoustic beats.

1 Introduction

The rhythm has an important role in human life by enhancing perceptive functions and sensitivity. Especially, corporal rhythm contributes to the improve motor, visual and auditory skills [1] and hence the physical and social-emotional development.

Previous researches have demonstrated that rhythm is typically developed between 4 and 8 years of age [4]. To be able to keep musical rhythm with body motion means perceiving changes in the cadence or sound type. However, some people have limitations to coordinate any movement, because their cognitive, psychological and motor processes are not developed. In children this is known as Developmental Coordination Disorder (DCD), which includes limitations in the three process mentioned previously [5]. This trouble makes it difficult to perform the required corporal expression on some activities such as dance where it means be able to perceive changes in speed and sound types. The objective of this work is to bring support to people who have some coordination troubles in dance, especially keeping the musical rhythm with their body, by means of a feedback i.e. to give the possibility for people to listen their sound pattern based on their movements, through computer technology by using interaction techniques based on computer vision algorithms, signal processing and audio synthesis.

This paper is organized as follows. The Sect. 2 displays the related work in musical applications interaction. The Sect. 3 focuses on the explanation of the proposed method. In Sect. 4, a results and evaluations are presented. The Sect. 5

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shows a discussion of experimental results. The Sect. 6 contains the conclusions as well as the future work directions. Finally, acknowledgements section displays the Acknowledgements.

2 Related Work

Researches have pursed different approaches regarding musical applications that use the human-computer interaction and specifically corporal motion and audio synthesis. One of those which was development by Chattopadhay [11], taking available technologies as Microsoft Xbox Kinect to label some body positions in musical notes through tracking in real time of human skeleton. Another research made by Shiratori [13] which the main target is to realize an audio synthesis based on a dance perform video, using relationships between corporal motion and musical rhythm and comparing speed of both respectively. Also, several works have been analysing the human being motion, specially approached to aspects like a treatments for gait rehabilitation in Parkinson's Disease [12] analysing the gait patterns of a person with Parkinson's disease and another person without this disease.

In this paper, It's presented a method that makes an approach for analysis of rhythmic patterns in dance movements based on segmented video input. Unlike most previous methods where to the problem of rhythmic stimulation was included using available technologies or computer vision techniques without auditory response, this approach generates an audio response which perform as rhythmic auditory feedback, from input parameters extracted of motion periodic patterns.

3 Proposed Method

Interaction process starts by recording a video of an individual dancing a specific latin music step. Sequences of periodic movements of both lower limbs in the video are analysed to find motion patterns and finally produce a rhythmic sound using the workflow, Fig. 1. Next, the process that shows the hypothesis, is presented with its corresponding description.

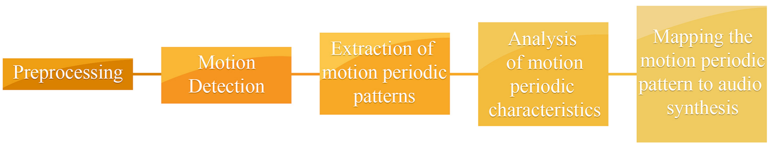

Fig. 1. Work flow proposed method

3.1 Preprocessing

Starting from a video input, the first step corresponds to filtering and color transformation. The video is transformed to grayscale using RGB to YUV transform. Additionally, a Median filter is set to reduce the noise in the video.

3.2 Motion Detection

In order to segment the video by extracting the background. The Sigma Delta proposed by Manzanera [6], algorithm was used. For the initialization, the method reads the video frame by frame, each one represented as $I_t(x)$ and the initialization it's matched with estimated background value, described as $M_t(x)$. The same way, the algorithm update the estimate using the sign function Eq. 2, which returns three values depending the input value, and the estimate varies a bit. So, each frame, the estimate is simply incremented by one if it's smaller than the sample, or decremented by one if it's greater than the sample.

$$sign(n) = \begin{cases} -1 & \text{if } n < 0 \\ 1 & \text{if } n > 0 \\ 0 & \text{if } n = 0 \end{cases} \tag{2}$$

Once the background is estimated, the next step is to calculate differences between consecutive frames with the background. Finally, the algorithm considers a thresholding process for rendering the detection. Algorithm 1

The result, as shown in Fig. 2, presents motion detection of the lower limbs.

Fig. 2. Motion Detection results with an image sequence making

3.3 Extraction of Motion Periodic Patterns

After the pattern is determined, and the characteristic that define the motion type is obtained, the method consists in analyzing the video to find profiles for the X and Y directions, Fig. 3. The goal is to determine the motion in each specific direction. A normalized image is created with the profile values for each axis. As an example, Fig. 4 shows the patterns for a step side by side. Colors represent intensity values of the frequency of movements, i.e. if the colors tend to red there is many motion times.

Algorithm 1. The $\Sigma - \Delta$ background estimation

Initialization
for each pixel x **do**
  $M_0(x) = I_0(x)$
end for
For each frame t
for each pixel x **do**
  $M_t(x) = M_{t-1}(x) + sign(I_t(x) - M_{t-1}(x))$
end for
For each frame t
for each pixel x **do**
  $\Delta_t(x) = |M_t(x) = I_t(x)|$
end for
For each frame t
for each pixel x
if $I_t(x) < \Delta_t(x)$ **then**
  $D_t(x) = 0$
else
  $D_t(x) = 1$
end if

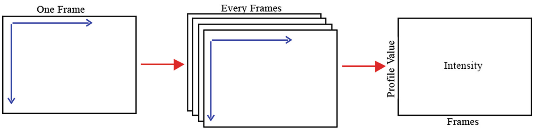

Fig. 3. Representation of profile sum for each frame

3.4 Analysis of Motion Periodic Characteristic

To extract periodicity information in figure a dimensionality reduction is performed using the Principal Component Analysis (PCA) method [7,9], which projects data in a new subspace Fig. 5. The most powerful ingredient that has PCA is to keep the same relationship in the new data set. One side maximizes the variance of projection data for each component and another side reduces the error rate of reconstruction.

For example, given a data set belonging to $\mathbb{R}^p$ space:

$$x_1, x_2, \ldots, x_n \in \mathbb{R}^p \tag{1}$$

PCA defines data reconstruction in $\mathbb{R}^q$ to $\mathbb{R}^p$ as

$$f(\lambda) = \mu + \upsilon_q \lambda \tag{2}$$

Being $\mu \in \mathbb{R}^p$ and υ_q a $p \times q$ matrix taking q as orthogonal unit vectors. Also, $\lambda \in \mathbb{R}^q$ is new data of projected dimensionality. An important factor making process of dimensionality reduction is to minimize the reconstruction error shown in Eq. 3.

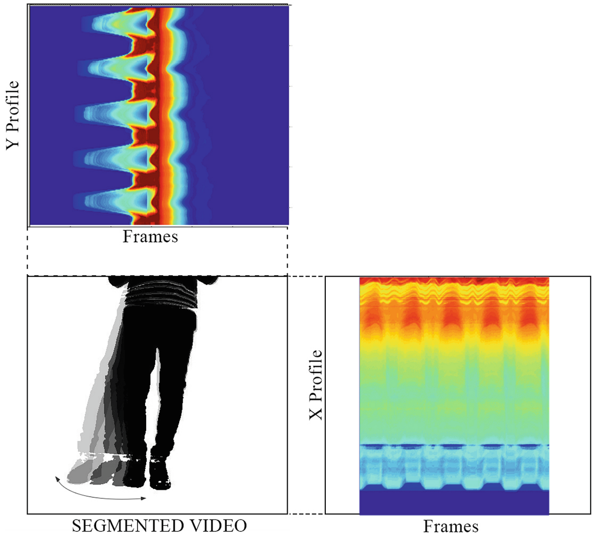

Fig. 4. Representation of a extraction of motion periodic patterns. The lower left box displays the segmented video with the dance movement. The upper left box shows the profile extracted from video for Y pixels and the lower right box shows the profile for X pixels. The upper right box displays 3D image taking the intensity value.

$$\min_{\mu_1 \lambda_1 \ldots N \upsilon_q} \sum_{n=1}^{N} \| X_n - \mu - \upsilon_q \lambda_n \| \tag{3}$$

For this case μ is intersection point between subspace and original space. The above defines a $\mathbb{R}^p$ using μ and υ_q as is shown in Fig. 5.

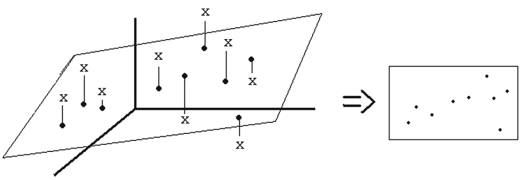

Fig. 5. Data projection with PCA, projecting $\mathbb{R}^3$ data to $\mathbb{R}^2$, made by Blei [9]

The Fig. 6 has three parameters (x, y, z), which represent frame number, profile value and pixel intensity respectively, i.e. data set $(x, y, z) \in \mathbb{R}^3$. When the dimensionality reduction is made, the result is a signal, i.e. data set $(x, y, z) \in \mathbb{R}^2$ with the same periodic pattern like the image created.

To determine the periodicity value, a frequency analysis of the resulting signal is performed, in order to find the fundamental frequency (Fig. 7).

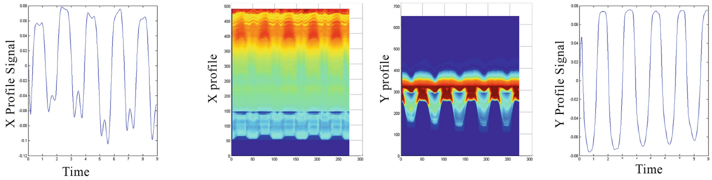

Fig. 6. Image with profile values. Two left images represent the X pixels analysis, and the two right images show the Y pixels analysis

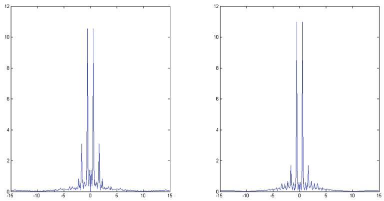

Fig. 7. Signal in frequency domain

3.5 Mapping the Motion Periodic Pattern to Audio Synthesis

Once obtained the results of frequency analysis, The feedback audio is produced to create a beat which reflects the periodic pattern according to video input parameters at the cadence of the dance steps. Thus, audio produced offers the possibility to the person of listening with how often the the movement is realized, which it's a feedback that makes understand the speed of dance movement in progress (Fig. 8).

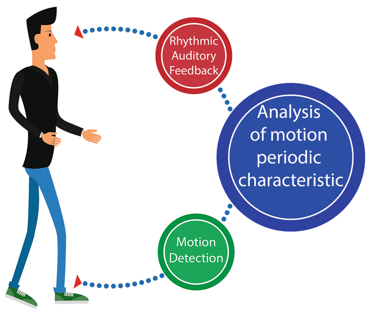

Fig. 8. System structure

4 Results and Evaluations

The method effectiveness was assessed by determining variations between control and the automated groups. The performed evaluation aims to verify that

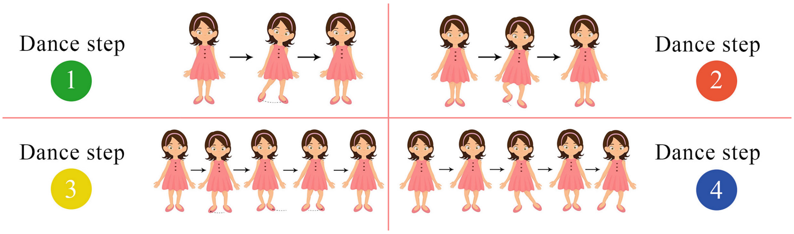

Fig. 9. The basics 4 dance steps established. 1 shows the first step, which it's characterized to carry the right or left foot to the side, then return it to the starting position and repeat the process. 2 the movement is to raise the left or right foot. 3 the person must move from side to side to make the step correctly. 4 provides the ability to perform it with more rhythmic expression because it contains two times; the first is to alternate between right and left foot and the second is the kick.

the produced sound is consistent with the motion. Forty-eight (48) videos were used for testing, recorded from twelve (12) persons, each with four (4) dancing steps (Fig. 9). From each video, the beat is extracted and compared with reference values manually selected by an expert. The objective is to measure the misalignment between periods in both signals in milliseconds. Table 1 shows the results value and the Fig. 10, shows that results measuring each person and the difference range in miliseconds.

Table 1. Table of difference value between method and control values on milliseconds (ms). The control values were established based on expected data for each dance step, in this case the expected data were defined taking information of one person who doesn't have troubles keeping time of the rhythm. If the difference among Control Value and Result tends to zero, the method is most accurate.

User	Step 1	Step 2	Step 3	Step 4
1	0.177	0.057	0.005	0.612
2	0.095	0.323	0.152	0.211
3	0.118	0.296	0.005	0.612
4	0.019	0.091	0.188	0.410
5	0.073	0.295	0.071	0.143
6	0.004	0.043	0.118	0.217
7	0.019	0.081	0.066	0.457
8	0.011	0.096	0.112	0.746
9	0.113	0.032	0.081	0.621
10	0.007	0.103	0.045	0.132
11	0.012	0.067	0.184	0.383
12	0.080	0.096	0.055	0.486

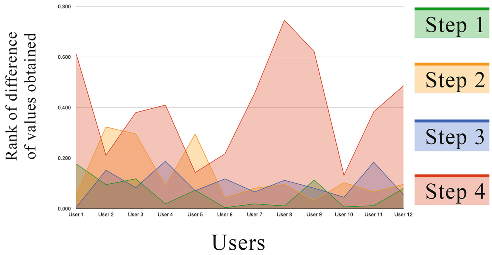

Fig. 10. Graph of difference value between method and control values, it based on table presented in Table 1

5 Discussion

Analyzing the obtained results, the method works correctly when simple movements are performed. The first three steps show among 58 % and 75 % of accuracy, i.e. the margin of difference is lower than 0.100ms. However, for complex steps (4), the method precision is lower. (Fig. 11)

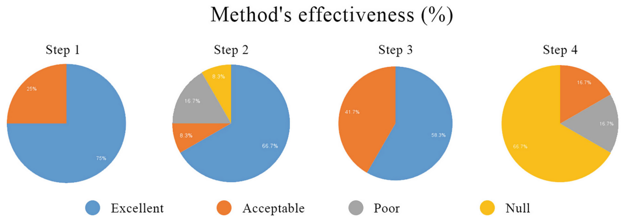

Fig. 11. Percentage of Method's effectiveness for each dance step. The blue colors represent higher accuracy and the yellow colors represent lower accuracy. (Color figure online)

When each movement was analysed, it was checked the pattern that defines the characteristic of the motion came from Y profile image. Also, it was proved that the most dance movements created an sinusoidal waveform, because the movement is constantly repeated.

6 Conclusions and Future Work

This work presents a method that determines, from a video sequence, the beat associated to the body motion. The proposed method is useful at identifying periodic patterns in actual motion. This study marks a starting point with the proposed motion analysis in dance steps. However, for complex movements it is necessary to improve the method.

The study of human movement will always require more optimization in terms of processing, systems interaction, etc. The proposed method is made available to be used in more aspects of people's life, not only for entertainment purposes. It can also be used for patients who suffer diseases such as Parkinson, supporting treatments related to gait analysis.

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