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A Music Performance Algorithm Based on Leap Motion and Piano Interface

CHI ZHANG, MING ZHEN FENG, MING KUN DU, DI AL, QI JI and XIN GUAN

Abstract

The multimedia applications based on Human computer interaction devices are now widely used in all aspects of our daily life. Leap Motion, a kind of somatosensory recognition equipment, is getting familiar by now. Leap Motion has great application value in the field of music creation for its portability and high identification accuracy. The paper proposed a music creative algorithm (Leap Music) based on Leap Motion sensor and the model of piano performance. The advantages of this algorithm are that the performance form is simple, the same performance form can output different music quality and tone notes, and equipment is more portable. Meanwhile, music composition created using Leap Music was analyzed. Leap Music algorithm can be used instead of the piano performance.

Keywords: Leap Motion, music performance, Human computer interaction (HCI), somatosensory recognition

1. Introduction

Leap Motion is a somatosensory recognition device that was released in 2013, and therefore not much scientific work has been published yet [1]. Leap Motion focus on high precision recognition in a small space with sub-millimeter accuracy, and provides the original data of 30 frames per second, including Palm Position, Palm Velocity and Tip Position and other relevant additional

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information. In addition, Leap Motion can recognize gestures such as Screen Tap, Key Tap, Circle and Swipe. The Leap Motion represents a major leap in input technology that could, with its enhanced interaction possibilities, trigger a new generation of far more useful 3D displays and possibly surpass the mouse as a primary input device [2,3].

In this paper, we provided a music creative algorithm, Leap Music, which was based on the somatosensory recognition device of Leap Motion and piano performance interface. The algorithm denoised the original data obtained from Leap Motion, and built gesture transition model by the judgment of relative position for fingertip coordinates and piano interface. Finger location Algorithm was used to calculate performance notes and output music.

2. State transition and key algorithm

2.1 Basic gesture and state transition model

Since the original data of Leap Motion input device is complicated, the data is usually classified into a few simple categories. In order to easily design develop program, the state transition model was used to abstract simple elements from the device behaviors.We designed the following state transition model according to the characteristics of music composition based on Leap Motion sensor (Fig. 1).

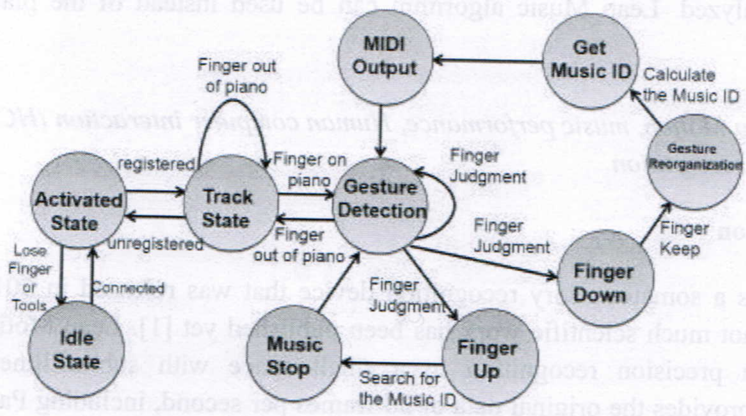

Figure 1. The state transition model of Leap Music.

2.2Denoising algorithm

The recognition precision of Leap Motion sensor can theoretically reach 0.01 mm. However, the hardware of Leap Motion sensor uses a resolution of 640 × 240 two high frame rate cameras and causes unstable recognition phenomenon during identification tracking. Component resolution, thermomagnetic noise, hand shaking, visual occlusion, and singular values of numerical calculating generates noise signal [4]. The method of self-adaptive cut-off frequency of the low pass filter used in this paper was proposed by Casiez et al[5]. The cut-off frequency of the low pass filter can be real-time changed by detecting the fingertip position. Formula (1) gives the parameters expression and calculus of self-adaptive filter.

$$\hat{D}_i = \alpha D_i + (1-\alpha)\hat{D}_{i-1} \tag{1}$$

Where $D_i$represents a high-dimensional vector composed of coordinates and vector value when Leap Motions sensor returned to i-th finger, $\hat{D}_i$represents a vector by self-adaptive filter, α represents a smoothing factor in the range of [0,1], $\alpha = 0.85$ in this algorithm.

2.3 Fingertip coordinate judgment algorithm

Leap gesture components in the SDK only provide a gesture recognition feature, but the time of finger pressing or lifting could not be calculated. This is very different from usual music performance. The performance generally has different note length, so appropriate performance judgment algorithm need to be designed.

If fingertip coordinates is $\hat{y}_i < H$ and $\hat{y}_i - \hat{y}_i' < -2cm$ after denoising, it is determined that the finger make pressing action, then continuous output of note happens, where H is the relative height of the piano in Leap Motion coordinates, $\hat{y}_i$ represents the y-coordinate value of the i-th finger, $\hat{y}_i'$ represents the y-coordinate value of the i-th finger at previous moment. If fingertip coordinates is $\hat{y}_i > H$and $\hat{y}_i - \hat{y}_i' > 1.5cm$after denoising, it is determined that the finger make lifting action, then output of note stops.

2.4 Finger location Algorithm

Assuming the finger coordinates on the piano plane surface is (x, z), L_W and W_W represent length and width of the ivory keysrespectively, and L_B and W_B represent length and width of the ebony keys respectively (Fig. 2). If finger were in the range of formula (2), thei-ththe ebony key should be pressed.

$$\left\{(x,z)\middle| L_W - L_B < z < L_W \text{ and } iW_W - \frac{1}{2}W_B < x < iW_W + \frac{1}{2}W_B,\ i = 1,2,4,5,6\right\}$$

(2)

If the (x, z) is not in this range, the linear scan should be performed. If finger were in the range of formula (3), the j-ththe ivory key should be pressed.

$$\{(x,z)|0 < z < L_W \text{ and } jW_W < x < (j+1)W_W,\ j = 0,1,2,3,4,5,6\}$$

(3)

Note ID was distributed basing on pressed keys, and was used for subsequent music output.

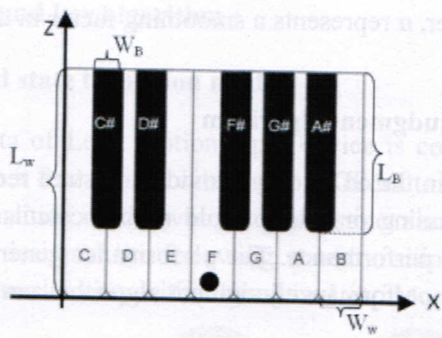

Figure 2. The finger coordinates on the piano plane surface.

3. Implementation steps and methods

Step 1: Key images and palm models were drawn from graphical programming interface such as OpenGL or Direct3D. Note the relationship between key position and Leap Motion coordinates.

Step 2: Connect Leap Motion device and denoisethe data of fingertips' coordinate positions and record the previous time, we can obtain (x_i, y_i, z_i), then record the present time and obtain (x_i', y_i', z_i'), where i is from 1 to 5.

Step 3: Calculate and analyze the obtained data by judgment algorithm of fingertip coordinate, and judge whether fingers should make keystrokes. If keystrokes were made, step 4 should be performed. If keystrokes were not made, step 2 should be repeated.

Step 4: Analyze (x'_t, z'_t) in the present data, and determine whether the pressed position is on the keyboard. Detect keystrokes position, and then convert it to corresponding music note code.

Step 5: Music notes were played by the way of MIDI output interface or mp3 player.

4. System testing and analysis

The graphical drawing interface used in the experiment was OpenGL. Fig. 3 gives the reference interface of piano performance.

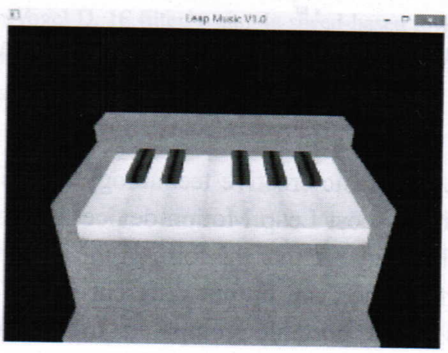

Figure 3. The reference interface of piano performance.

In order to verify the validity and accuracy of the algorithm, we designed the following two examples:

Experiment 1: we invited 15 Leap Music experimenters, who carry out music performance using software developed by Leap Music algorithm. Each experimenter played about 50 notes, and all experimenter played 768 notes, in which 736 notes were correctly played. The accuracy of experience reached 95.83%. Although there is a certain gap between Leap Music and piano performance, but considering the hardware error of Leap Motion device, the accuracy of Leap Music experience is considered to be very high.

Experiment 2:Music played using Leap Music algorithm and by piano was simultaneously carried out spectral analysis.The results show in Fig. 4, where the left is piano performance, the right the music of Leap Music, and where signal waveform, power diagram and frequency alias amplitude diagram array from top to bottom. As can be seen, there is nosignificant difference between sound frequency of Leap Music output and frequency component of piano performance.Therefore, we can draw the conclusion thatLeap Music algorithm can be used instead of the traditional piano.

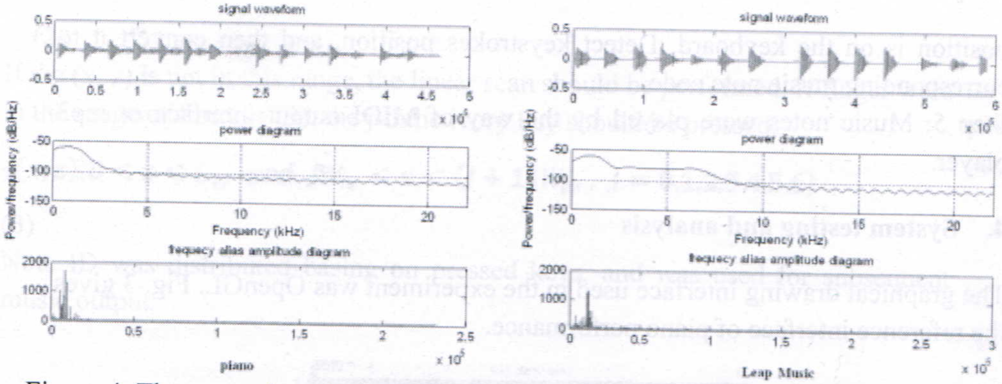

Figure 4. The spectral analysis of Leap Music playing music and piano music.

5. Conclusions

The research provides a Leap Music creative technology that is a more efficient and accurate way based on low-cost Leap Motion device for piano performance. The advantages of this technology are that the form of the performance is simple, the same form of the performance can output different music quality and tone notes, and equipment is more portable compared to the traditional piano. Beginners will be able to create simple music and do not need a long time to learn the piano playing. Professional musician can simplify creation by somatosensory interaction device such as Leap Motion.

At present, stereo vision and RGB-D technology is getting mature, and related similar non-contact space input devices such as Leap Motion will play a bigger role in our daily life. Therefore, Leap Music technology and related algorithms will have very broad application prospect, and Leap Music will have the following three possible work plans and assumptions: (1) add the frequency analysis function and multi-path synthesis technology, replace FL, Sonar software and creative instruments such as the piano and guitar for mainstream music creation in the future; (2) add the music recording and broken points replaying function, modify the music composition for creators; (3) add the form of music teaching for beginner learning related program to create.

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