Saltate! – A Sensor-Based System to Support Dance Beginners

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Abstract

We present Saltate!, a wireless prototype system to support beginners of ballroom dancing. Saltate! acquires data from force sensors mounted under the dancers' feet, detects steps, and compares their timing to the timing of beats in the music playing. If it detects mistakes, Saltate! emphasizes the beats in the music acoustically to help the dancing couple stay in sync with the music.

Keywords

Dancing, wearable computing, wireless sensor system, motor skill learning.

ACM Classification Keywords

C.3 [Special-purpose and application-based systems]: Real-time and embedded systems; H.5.2 [Information Interfaces and Representations – User Interfaces]: a – Auditory feedback, p – Training, help, and documentation.

Introduction

Learning to dance is difficult for many people: In order to dance correctly, a dancer has to detect the underlying rhythm of a music piece and synchronize his or her movements to it. This double task of detecting beats and executing new movements is mentally very demanding for people who, unlike musicians, have little prior experience in beat or rhythm detection.

In courses, dance teachers oftentimes count along with the beats of the music. This greatly reduces the mental effort of detecting the rhythm of a song for those couples who have problems with it.

For couples with good beat detection capabilities this would not be necessary. On the other hand, it is very hard for couples with bad beat detection capabilities to exercise outside of a course.

A wearable system could provide individual support for those couples who need it. We set out to investigate whether such a system could be designed.

In domains other than dancing, sensor-based systems to support beginners are already researched. The main difference between dancing and most other domains is that, in dancing, movements have to be synchronized to external acoustic stimuli. This leads to requirements that are different from those of trainees in other domains.

Related work

In martial arts, Takahata et al. [4] developed a system for karate training. Feedback is given acoustically and helps trainees to learn the correct timing of a specific punch. The system uses acceleration sensors on wrists, ankles, and waist.

Spelmezan et al. [3] developed a snowboard training system that uses, among others, force sensors in the shoes to calculate the weight distribution of snowboarders. Feedback is provided by small vibrating actuators mounted on several parts of the user's body.

In dancing, Nakamura et al. [2] developed a training system that uses vibrating devices to indicate the timings at which the dancer of a Japanese folk dance has to move her or his arms. As there are no sensors included in their system, it cannot react to a trainee.

Cognitive psychologists have researched effects of different variables on motor skill learning. The most interesting ones for a dance training system are concurrent feedback and the focus of attention:

Concurrent feedback usually increases performance but decreases learning. Winstein et al. [5] showed this with a partial weight bearing task, Linden et al. [1] with a force exertion task. Other researchers achieved similar results with different tasks. It is important to note that feedback presence in their experiments was not depending on the trainee's performance. In how far concurrent feedback influences learning if its intensiveness is adapting to a trainee's performance is still largely unknown.

Gabriele Wulf researched the influence of an internal and an external focus of attention [6]. If users adapt an internal focus of attention, they concentrate on their movements. If they adapt an external focus of attention, they concentrate on the effect of their movements. Experiments in domains such as golfing, balancing, basketball, and many others, showed that an external focus of attention is superior to an internal focus of attention, both for performance and for learning.

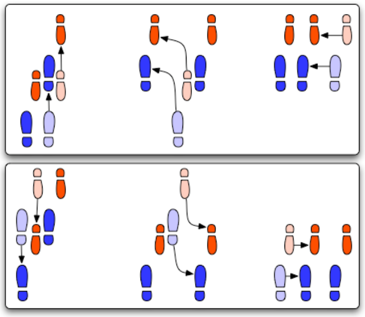

Figure 1. A graphical representation of a Slow Waltz' basic step: Steps performed during the first bar are shown in the top row, steps performed during the second bar in the bottom row.

Slow Waltz: Basics and common problems

As we chose to implement support for Slow Waltz first, we shortly present its basic step and natural turn. Slow Waltz is performed in closed dance frame to music in ¾ time at a tempo of 28 to 30 bars per minute. In closed dance frame, the dance partners stand in front of each other, each positioned slightly to the left of their partner, so that each one's right foot can move between the partner's feet.

During a basic step, the man performs a step forward with his right foot on the first beat of a bar, a step to the left with his left foot on the second beat, and a closing third step with his right foot on the third beat. During the next bar the man starts with his left foot backwards followed by a step to the right and a closing step with the left foot. The woman's steps mirror the man's steps.

In a (simplified) natural turn, the first two steps are executed into viewing direction of the man, and during the closing third step a clockwise rotation of 90 degrees is performed. During the second bar, the movement is performed into the woman's viewing direction. The rotation is always performed clockwise.

We interviewed dance teachers to find out what the main problems of beginners are, and what could be done to help them. They considered developing the trainees' "inner clock" to be the most important step. Beginning dancers are usually occupied too much with dancing in time to put, e.g., advice about smaller corrections of posture into action. Counting the beats of the music is a common approach of dance teachers to help beginning dancers, as, for most dances, is slowing down the music.

Hardware

We developed sensor boxes based on Arduino Minis[1] and XBee modules[2] to wirelessly transmit sensor data to a computer. A force sensing resistor is positioned under each foot's ball and heel. We kept the hardware small and lightweight in order not to disturb dancers in their movements. The sensor boxes are 8.6cm x 6.5cm x 2.7cm with an overall weight of 119g. A flexible ruler is used to easily attach the box to a shoe with shoelaces. The sensors are fixed underneath a shoe insole that is put into the dancer's shoe.

Figure 2. One of our sensor boxes attached to a shoe. The box is held in place by a flexible ruler that is secured underneath the shoelaces.

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[1] http://www.arduino.cc/

[2] http://www.digi.com/

Software

Saltate! synchronizes the sensor boxes' clocks to the program clock, and sensor data is then transmitted together with time stamps. Based on calibration data taken from the dancers prior performance, Saltate! analyzes sensor data in two steps:

First, based on raw sensor data, Saltate! decides whether a single sensor is touching the ground or not, and generates *ball touch, ball leave, heel touch,* and *heel leave* events.

Next, these events are transformed to *ball* or *heel taps*, *forward steps*, and *backward steps*.

Each tap and step is then matched to the beat within the music to which it has the smallest time difference. We manually marked the timing of each bar's first beat. The timings of the second and third beat are calculated automatically from this before the music starts.

Once a beat has been played, Saltate! analyzes the steps performed to this beat: For each beat, we expect a step with the man's right and the woman's left foot (or vice versa), alternating with each beat.

Thus, Saltate! decides for each beat whether the couple has danced correctly to it or not. If it has, the number of the steps performed is calculated as well: If steps have been detected with the man's left foot and the woman's right foot to the second beat of a bar, the couple has danced the second step of a basic step. If the steps were made with the man's right foot and the woman's left foot, the couple has danced the fifth step of a basic step or natural turn.

Feedback

As a supporting function, Saltate! emphasizes the music beats if a couple dances out of synch with the music. We use a soft bass drum sample for the first, and a soft high hat sample for the second and third beat of each bar. For each incorrectly danced beat, the feedback's volume is increased linearly, from zero to a hundred percent over a period of ten beats. For each correctly danced beat, the feedback volume is decreased linearly, from a hundred percent to zero over a period of 18 bars. Music volume is set to 80 percent.

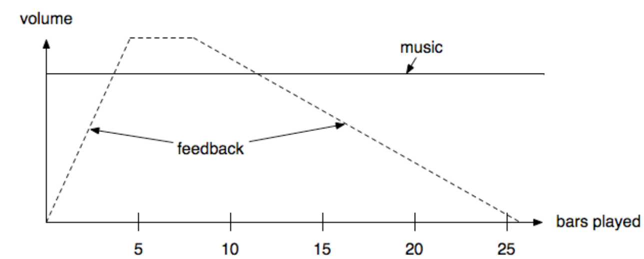

Figure 3. Feedback volume over time: In this example, the couple started to dance with the eighth bar of a song, and danced correctly from then on.

While relatively simple, this feedback style has several advantages. Feedback sound becomes dominant only if a couple doesn't start to dance correctly for at least three bars. It fades out rather slowly and thus avoids to disturb the dancers' attention at a point in which they do perform without mistakes. The sound samples chosen fit into the characteristic sound of a typical Slow Waltz.

Pilot study

We conducted a pilot study to determine beginning dancers' acceptance of our hardware and feedback, and to acquire step timing data: For all steps, i.e., the first to sixth step of a basic step, and for all feet we calculated average timing differences to their closest beat, and the dancers' standard deviations. The percentage value of danced steps performed correctly was calculated as well.

Our study was conducted with the help of eight couples of volunteers. Four of them had no experience in dancing, the other four considered themselves beginners, although at least one of them visited a dancing course before.

Each couple danced in two blocks with five songs each. During the second to third song, we either activated the feedback or not, depending on the experimental group the couple was in. The first and the last song were used for performance measurements only.

The statistical data from the more experienced couples wasn't usable to investigate the effect of Saltate!'s feedback functions: They performed too well for it to activate. The data from our four couples without dancing experience showed to great parts what we expected: The amount of correct steps performed increased, and the standard deviation of the dancers' step timings decreased. Differences between the feedback and no-feedback group were small, but the group with feedback improved more than the group without feedback. The fact that in the last song the feedback group's performance was comparable to that of the control group is a strong indicator that we successfully avoided one effect of concurrent feedback: decreased learning.

We handed out a questionnaire to our participants to evaluate their impressions of the system. Using a Likert scale from one to five (strongly disagree, disagree, neither agree nor disagree, agree, strongly agree), we found a high acceptance of our system: Our participants agreed that the sensor modules were comfortable to wear (average 4.31, standard deviation 0.7), the extra beats were helpful (4.38, 0.62), they came at appropriate times (4.06, 0.68), and participants believed that this kind of support would help beginning dancers (4.31, 0.7). These values were calculated using the questionnaire results from all 16 participants.

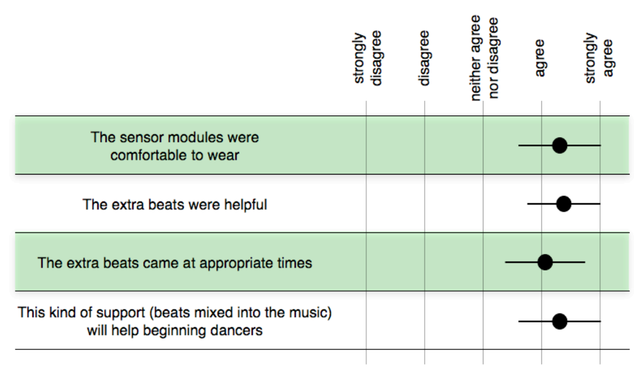

Figure 4. Our subjects' opinions about Saltate!. The thin horizontal lines indicate the standard deviation from the average value.

Lessons learned

Our data indicated that the standard deviation of step timings is a good value to determine the experience of a dancer: Values for experienced dancers which we invited before our pilot study were in the range of 50ms to 75ms, while the values of participants in our study decreased from about 130ms to 80ms. The average difference to the music's beats is much less suited to determine the experience of a dancer: This value fluctuates greatly from song to song. Thus, it is hard to determine a "correct" average time difference.

During our pilot study we discovered a typical error Saltate! cannot detect automatically right now: Three of the eight couples danced several songs "in time" with the music, but incorrectly: They performed the first step of a basic step to the second or third instead of to the first beat of a bar.

Future work

In order to determine the effects of Saltate!'s feedback on learning, a study with more couples without dancing experience is necessary.

The system's error detection can be improved: The typical mistake of some couples, which danced the first step to the second or third beat of a bar, cannot be detected right now, as Saltate!'s force sensors do not allow a reliable decision into which direction a step is made. Additional acceleration sensors can help to solve this problem. Since two of the three couples who made this mistake were from the more experienced group, an automatic detection of this mistake would not only improve the system for dancers without any dancing experience, but also increase Saltate!'s potential target group to dancers with at least some experience.

Overall, Saltate! has turned out to be a promising step towards helping beginning dancers improve their technique.

Acknowledgements

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References

[1] D.W.V. Linden, J.H. Cauraugh, and T.A. Greene. The effect of frequency of kinetic feedback on learning an isometric force production task in nondisabled subjects. *Physical Therapy 1993*, APTA Vol. 73, 79––87.

[2] Akio Nakamura, Sou Tabata, Tomoya Ueda, Shinichiro Kiyofuji, and Yoshinori Kuno. Multimodal presentation method for a dance training system. *Extended Abstracts of CHI 2005*, ACM, 1685––1688.

[3] Daniel Spelmezan and Jan Borchers. Real-time snowboard system. *Extended Abstracts of CHI 2008,* ACM, 3327––3332.

[4] Masami Takahata, Kensuke Shiraki, Yutaka Sakane, and Yoichi Takebayashi. Sound feedback for powerful karate training. *Proc. of NIME 2004*. ACM, 13––18.

[5] C.J. Winstein, P.S. Pohl, C. Cardinale, A. Green, L. Scholtz, and C.S. Waters. Learning a partial-weight-bearing skill: effectiveness of two forms of feedback. *Physical Therapy 1996*, APTA Vol. 76, 985–993.

[6] Gabriele Wulf. *Attention and Motor Skill Learning*. Human Kinetics, 2007.