A Concept to Support Seamless Spectator Participation in Sports Events Based on Wearable Motion Sensors

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Abstract

We present a novel concept for an audience voting system for judged sports events. It is based on wireless wearable motion sensors utilizing the natural behaviour of sports spectators – clapping and cheering. This paper describes initial results from a user study that guided our design process. We further present two preliminary prototypes focusing on hardware and design feasibility respectively. Results confirm our assumption that the system does not provide objective results, but has the potential to increase the spectator experience by giving audience members the feeling of being part of the voting process.

Keywords: Spectator participation, audience participation, spectator experience, wireless motion sensors.

1. Introduction

Traditional electronic devices for audience voting (e.g. voting devices with push buttons) limit spectators in their mobility, distract from the event, and therefore have a negative impact on the experience of the event. Furthermore, they are costly and do not scale for a large audience. These problems are particularly significant for spectator participation in sports events. Advances in pervasive computing motivate a voting system that takes advantage of new technologies in a way to enhance the overall spectator experience. Current research in this area focuses mainly on large group interaction in games or musical performances.

Spectator participation in sports events is especially relevant for sports that are connected to art, like gymnastics, diving, or figure skating. These events cannot be judged by quantifiable means, such as time, height, or range. Therefore, typically a panel of several judges conducts judging. They award points along a predefined scale to the athletes' performance. Nevertheless, the awarded score can be influenced by personal opinions of the judges and is susceptible to human error. For example, during the 1992 Summer Games a judge mistyped a score as 8.7 (on a scale from 0 to 10) when she intended to give a synchronous swimmer a 9.7. Due to this mistake, the athlete missed the gold medal. During the 2002 Winter Games in Salt Lake City, there was another controversy that clearly showed that scores in judged events do not always represent justifiable results. One of the figure skating judges was pressured into voting in a certain way, which did not reflect reality. In both cases the International Olympic Committee (IOC) corrected the judging error and a second gold medal was awarded. Such incidents have cast a negative shadow on specific sports events and on judged sports in general. Giving physically present spectators the possibility to award scores for each performance can possibly improve the acceptance of these sports. However, audience members do generally not have the knowledge to judge highly technical sports performances on a specific scale. Further, audience votes are always subject to group behaviors and therefore will never replace judges, nor can they represent a determining part of the final score. Allowing audience members to cast their vote would however increase the acceptance of the judges' decision and give them the feeling of being part of the voting process.

2. Research Goal

The goal of this work was to develop a concept that allows seamless participation of spectators and can be employed in (large-scale) sports events. The concept is based on the following three requirements.

Unobtrusiveness – The technology should adapt itself to the spectators' behavior and should be intuitive to use and unobtrusive.

Acceptance – The system should provide a low-cost solution to the problems associated with judged sports events to improve the acceptance of these events.

Experience – The spectator participation system should extend the spectator experience through participation and better approval of the score.

We used a user-centered design process, including a user study and the design and implementation of two different prototypes. The final goal is to develop more prototypes that allow the evaluation of the concept in a real context.

3. Concept

Typically, people from various different backgrounds form the audience of sports events. They vary in age, might speak different languages, and live in different cultures. Thus, any interface that requires training or instructions is impractical. We examined how sports spectators currently 'cast their vote' or show how much they like a specific performance. Approval or disapproval is typically shown through applause and cheering – a behavior that is applied in many different cultures and that can even be traced back to sports events in ancient times [7]. This contextual observation motivated the idea of using exactly these two behavioral patterns for an audience voting system that meets the three requirements stated above.

The key element of our concept is a disposable wristband that is handed out to each spectator of a sports event. We propose attaching this wristband to a leaflet that contains directions for use. It is also possible to combine it with the ticket, since there is already a trend towards intelligent tickets for sports events (e.g. tickets for the Soccer World Championship 2006 were equipped with RFID tags).

The wristbands transmit radiofrequency (RF) pulses to stationary mounted receiver stations when people are clapping. Immediate visual feedback is given through a flashing light emitting diode (LED) on the band itself. Microphones, which are integrated into the receiver stations, measure the loudness of the crowd (cheering). Both clapping and loudness values are processed by a computer system (base station), which calculates the audience vote and shows it continuously on stadium displays along with the time left for voting. Thus, multiple seamless and continuous feedback loops are created via connecting the athletes' performances, the individual spectator's impressions, as well as the overall audience vote (see Figure 1).

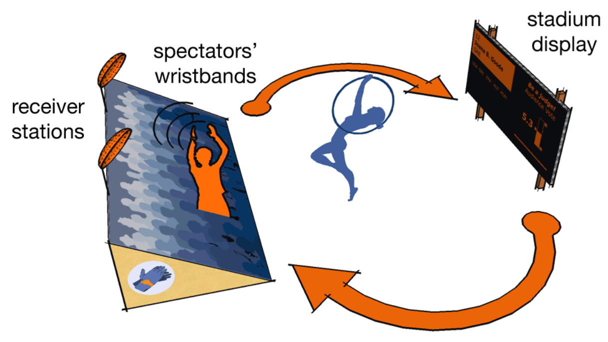

Figure 1. Overview of the spectator participation

3.1. Score Calculation

A central part of the proposed concept is the calculation of the audience vote from clapping pulses and loudness measurements. Clapping is measured in terms of its frequency (number of pulses per time) – the more claps are recognized in the measured time, the higher the vote. Loudness of cheering is measured in terms of its mean value in the measured time span.

Preliminary measurements have been undertaken for validating the feasibility of this approach. The analysis of our measurements, which involved 13 subjects, showed that clapping frequency and scale values are related linearly. For measuring loudness, several different scales could be applied. In the simplest case, the directly measured decibel (dB) values can be used, which is a logarithmic scale [4]. If this method is not appropriate, several other scales that consider the characteristics of the human ear might be used (Phon, Sone). Such scales are well known in the field of psychoacoustics [10].

The calibration of the system represents a quite sensitive aspect of the system. A base calibration can be carried out using two approaches – video recordings of sports events or test settings at sports events. Specific calibration algorithms need to be tested and refined in a real test setting. Because of the fact that each venue is different and different numbers of spectators are involved, fine-tuning of the system before each event will also be necessary.

A further issue, which has to be taken into consideration, is 'booing' as a sign of dislike and representing a negative vote. This can be tackled by recognition of loudness together with no or very little applause, which we consider as booing. Booing, however, is rather uncommon in the settings of judged sports and will not be the focus of our work.

3.2. Wireless Motion Sensor Unit

One of the main objectives of our project was to keep the system simple and the development costs low. Therefore, the system consists mainly of standard hardware, except for the wristbands, which are based on the motion sensors developed by Feldmeier et al. [6]. In our work we use motion sensors to track the clapping of the audience, and RF bursts to transmit the signals. We decided upon an analogue solution for the motion sensor unit, since digital technology would increase production costs considerably. To meet the requirements for an audience in large-scale sports events, we added several features to the motion sensors developed by Feldmeier et al. These extensions support users during the scoring process and provide them with continuous feedback.

The wireless motion sensor unit consists of a piezo sensor, an LED, and an RF transmitter (see Figure 2). The piezo sensor sets a timer that activates the RF transmitter whenever it is accelerated through motion, such as clapping. To prevent the trigger from being set off by normal arm movements, a sensitivity threshold is set. The LED is connected to the timer and is activated simultaneously with the transmission of an RF burst. This provides audience members with direct feedback

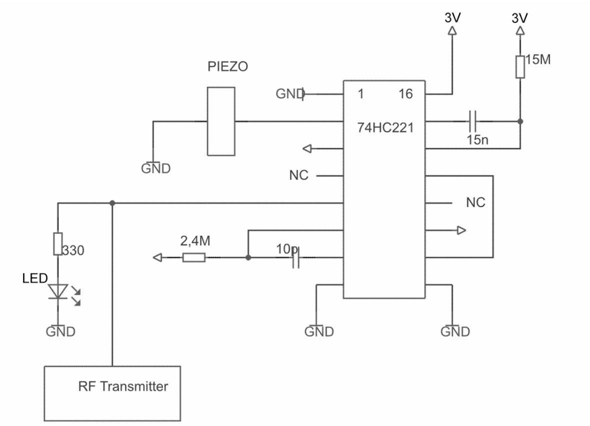

Figure 2. Schematic of wireless motion sensor unit.

about their scoring activity and shows that the device is working properly. The short RF burst duration of 50µs reduces the chance of collisions between signals and allows receiving each participant's activity as a distinct event. Feldmeier et al. showed in their work that the probability of two signals lining up is very low, even if many people are trying to synchronize their movements, which can happen with rhythmic applause [9]. The division of the sports venue into receiver zones (described below) guarantees the scalability of the system. Feldmeier et al. affirmed that the battery would last for a month of continuous usage with two transmissions per second. The integration of an LED increases power consumption only slightly and due to the disposable approach the device will only be operated for single events that typically last for a couple of hours.

The battery cell dominates the size of the entire device. For the prototype we used surface mounted device (SMD) technology to keep the electronic circuit very small. Applying advanced manufacturing techniques, such as wafer level packaging (WLP), would allow even smaller production sizes. The entire motion sensor unit fits into a case that has the size of a standard wristwatch, which is fixed onto disposable wristbands.

3.3. Receiver and Base Stations

The receiver station consists of a low-cost computer, a receiver circuit, and a microphone for loudness measurement. The technical realization of the receiver circuit is described in [5]. Due to the limited transmission radius of the RF transmitter, the entire area has to be divided into zones, with each zone containing a single receiver. The transmission radius and respectively the number of zones can be adjusted to the size of the stadium and audience by simply changing one resistor in the RF transmitter circuit. However, reflections and variations in signal strength make it difficult to determine the exact radius for transmissions. Therefore, we suggest a combination of various frequency channels and a cellular structure for the zones, similar to the architecture used for mobile phone communications. Receiver stations communicate with the base station via a wireless local area network (WLAN).

The base station is an ordinary host computer that collects the data streams received from the different zones. A software program running on the base station is responsible for the loudness analysis. The corresponding change of the audience score is calculated and transferred to stadium displays.

4. User Study

To evaluate our concept we conducted a usability evaluation and interview with a mock-up of the spectator participation system.

4.1. Usability Evaluation

The goal of the usability evaluation was to test the design of the concept regarding the three requirements – invisibility, objectivity, and experience-enhancement. We prepared mock-ups of the wristband, the info card and the stadium display for a sports event (Figure 3). The scenario was set to resemble the 2004 Olympic Summer Games in Athens.

We recruited 13 (6 male, 7 female) voluntary subjects between 17 and 52 years. The average age was 26 years (SD=8.55). All subjects were generally interested in sports. Six out of them stated that they were watching the Olympic Games regularly; four declared that they were watching only some of the Olympic sports events. The remaining three subjects had never watched the Olympic Games before, but did follow other sports events on TV. None of the subjects had any previous experience with the concept of wearable wireless motion sensors for audience participation. However, all of them knew how sports events that cannot be rated by quantifiable means are judged.

The mock-up for the wristband and info card was a double-sided color-printed leaflet. The wristband was separated from the instructions part with a perforation that allowed the participants to easily rip-off the band.

Figure 3. Mockups of the wristband, info card and stadium display.

The wristband contained the name and pictogram of the sports event (rhythmic gymnastics), the description of the round (individual all-around final), and the logo of the 2004 Olympic Games. The front of the leaflet included three illustrations and corresponding instructions that showed how to rip-off the wristband and how to fix it around the wrist and use it. The instructions were in English, Greek, French, and German. The back showed the slogan 'Be a judge!' and a person standing in a crowd and cheering. We designed two mock-ups for the stadium display, which were printed on standard-sized pages. The first one showed a visualization that explained the voting process; the second one contained the name, start number and nationality of the athlete, a timeline, and the current audience score.

We used a scenario consisting of three parts to evaluate the concept – handing out and applying the wristbands, taking seat inside the venue, and voting during a performance. Before handing out the mock-up of the wristband to the subjects we told them to imagine that they were in Athens to attend the 2004 Olympic Summer Games and that they had a ticket for the individual final event for rhythmic gymnastics. We then told them that when they enter the hall where the event would take place they would receive the info card with the attached wristband. At this point we handed out the leaflet to the subjects. Then, we asked what they thought that the leaflet was for and what they would do with it. After the subjects had accomplished to fix the band around the wrist, we told them that they took place inside the stadium and would see the first stadium display. Again, we asked what they thought about the display and what they would do. In the last part of the scenario we told the subjects that the first athlete would start with the performance. We showed the second display mock-up to the participants and asked how they would act. We did not give any hints during the usability evaluation and used thinking-aloud to monitor the participants' behavior.

4.2. Interview

After the usability evaluation, we concluded with a semi-structured interview. The goal of this interview was to obtain information about the subject's acquaintance with the domain and the concept of audience voting. We further wanted to determine what problems the subjects had experienced during the usability evaluation and what they liked or disliked about the concept. This also included emotional aspects.

4.3. Results and Discussion

Our observations showed that the subjects understood the concept easily. Only two participants out of thirteen needed further explanation. Some subjects commented that they were not sure whether they had the knowledge to judge about a performance. The reason for this might be that rhythmic gymnastics are generally difficult to judge.

Though the subjects knew how to employ the device, they had difficulties understanding how the score was acquired. While some of them were comfortable with knowing what they can do with the wristband and how to use it, the majority wanted to know more about the actual realization and how they were able to influence the score. They stated that this information was missing on the info card. Therefore there should be additional information on the info card to help users building a mental model of the voting process.

4.3.1. Learnability of the Wristband. All of the subjects understood very quickly how to use the wristband and that something was triggered according to clapping. This information was obtained from the instruction illustrations on the front of the leaflet. Nevertheless, most of them read the additional instructions below the illustrations. Overall, the results clearly showed that our audience participation system possesses high immediate usability.

4.3.2. Display of the Audience Score. All subjects appreciated having the results displayed on a stadium-sized screen. They clearly understood that the number and scale in our mock-up for the screen showed the audience score. However, they experienced difficulties with the timeline. Most of the subjects did not interpret this scale as the time left for voting. They also had difficulties to grasp what the country abbreviations were for. While it was clear that the abbreviations represented countries, interpretations what they stood for were different. This was due to our mock-up of the display where we showed the country abbreviations without the according scores of the judges.

Only four of the subjects stated that they would prefer to vote during the athlete's performance. Three of them would like to see the results only after the athlete had completed the performance. Positions against a continuous voting process were that the current score might influence spectators, and that it would not be possible to correct previously cast votes (e.g., if the athlete makes a mistake close to the end of his/her performance). Despite these results all subjects liked the idea of getting immediate feedback of their vote when they were first shown the mock-up for the screen. All of them stated that they would follow the audience vote and try to influence it by clapping when they liked a performance. Details of these results need to be clarified in a further evaluation in a real setting.

4.3.3. Acceptance of the Wristband. The subjects that participated in our study did not only state that they would use this system if available in any sports event, but also that they believed this would improve the general acceptance of judged events. Only one subject said that she would only participate if the other spectators do, which clearly shows the effect of group behavior that needs to be considered. Many were doubtful whether the score would represent an appropriate audience vote. In a voting system that is based on clapping and loudness spectators cannot influence the exact score consciously. This is possible in traditional systems for audience participation, such as buttons with a scale, where the user has to push the corresponding button. However, spectators of a sports event generally do not have the expert knowledge to cast a vote that would represent the athlete's performance similar to the judges' scores. The subjects generally appreciated the solution of having immediate personal feedback for the score through the LED.

An often-mentioned argument was that native athletes might get an unequal higher score since the majority of the audience at the Olympic Games will probably come from the host country. A similar argument was that some athletes might have many fans that would dominate the score and also that infamous athletes would be discriminated. To address this we suggest using fine-tuning. Furthermore, spectator experience enhancement was a more important issue than objectivity for us.

The souvenir character of the wristband (spectators can keep the wristband after the event) was appreciated by all subjects and found to be a good idea. Five subjects said that they would not mind to return the item because they did not care so much about keeping it as a souvenir. Few people stated that it also depended on the quality of the wristband whether they would like to keep it or not.

Only one subject stated that she would probably be distracted from following the performance because of the voting process. According to her opinion the reason for this was that she would follow the audience score on the screen, look how other people clap and therefore vote, and try to clap appropriate to the athlete's performance herself.

Our usability evaluation and interviews provided promising initial insights on the practicability and user acceptance of the proposed system. However, in order to get results with statistical significance it is necessary to evaluate a further developed prototype in a realistic setting, where real data is captured in a real event.

5. Prototypes

We built two different prototypes to validate the concept of using wristbands for spectator participation. These prototypes also represent the final outcome of our work so far and aim to inspire and support researchers developing similar systems for ubiquitous environments upon them.

5.1. Hardware Prototype

We built a hardware prototype to prove the technical feasibility of our concept. In particular, this prototype helped us to certify the employment of a motion sensor

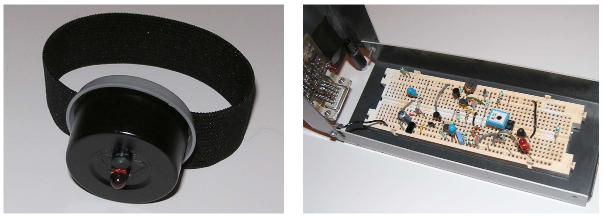

Figure 4. Prototype of the motion sensor and the receiver station.

for measuring clapping. The prototype consisted of the wearable sensor device and a simple receiver unit (Figure 4). The receiver unit can be connected to any standard personal computer via an RS232 interface. For the communication between the wristband and the receiver unit we used an infrared connection, since neither costs nor distance were relevant factors for the realization of the prototype. We assembled the remaining parts of the motion sensor unit as described above, using SMD technology and a piezo motion sensor.

5.2. Design Prototype

We developed a design prototype of the wristband leaflet as a final concept for industrial implementation. This prototype was derived from the initial mock-up and the results gained from the usability evaluation.

We printed the leaflet on synthetic paper, approximately 9 inch long and 4 inch high. The band itself was 1 inch wide and separated from the instructions part through a perforation. On top of the right end of the band we put a double-sided tape that allowed fixing it around the wrist. We used an aesthetic design for the leaflet to avoid that people mistake it for an advertisement. Regarding this it is also important that the leaflet contains an official logo of the sports event as well as a corporate logo. The band contained the name and pictogram of the sports event. For using the wristband in a sports event that consists of different rounds, we suggest to include the name of the round on the band and to print it in different colors.

The instructions printed on the front of the leaflet aim to help people applying the wristband for the first time. They consist of four different illustrations and instruction text. The first illustration shows how to rip-off the band from the leaflet. The second one illustrates how to fix it around the wrist. The last two illustrations explain that the spectators can influence the audience score by clapping and cheering for a particular athlete. This helps spectators to build an internal model of the voting process.

6. Related Work

Feldmeier et al. [6] and Bongers [2] have proposed novel ways of interaction in musical performances. In their work they describe systems that use sensors for motion detection, which can be either held or worn, and directly influence the musical performance. Maynes-Aminzade et al. [8] suggest audience tracking via a camera for interactive gaming. This allows the crowd to influence a system cooperatively, for example in an on-screen game. Such systems support real time interaction of the audience, but do not provide direct control. In contrast, machine vision allows measuring particular actions of each participant, as used for the red-green voting paddles in the Cinematrix Interactive Entertainment System [3]. A drawback of this method is that it requires a line-of-sight from camera to participant. Generally, direct methods such as wearable or handheld sensors are more accurate. A wearable device based on sensors was used for the 'Sophisticated Soiree' installation at the Ars Electronica 2001 festival, where the heartbeats of up to 64 participants were measured to trigger various musical and optical processes [1]. While this is an interesting approach, systems that measure bio-signals are not consciously controllable by participants.

7. Discussions and Future Work

Due to the broad variety of people attending (international) sports events in terms of age, mother tongue, technological knowledge, and knowledge about judging procedures, each participation system that introduces interface barriers or requires essential learning effort is likely to be rejected. Clapping and cheering are the most basic forms of interaction and support, and are used by sports spectators internationally since ancient times. Building upon these habits for a spectator participation system promises to be a good approach that eliminates learning of new technology. Avoiding technological barriers ensures better system usability and accessibility for an international audience. The only thing to learn once is how to apply the wristband and how the voting process works. Both activities are easy to recall and therefore using our voting device is almost as intuitive as buying a drink before a sports game.

The results from our study showed that the proposed concept fulfils the initial goals of invisibility and experience without limiting or distracting spectators. It further relies mainly on standard hardware, which keeps the costs of the entire system low. The production costs for one disposable wristband lies between one and two Euros, depending on the lot size, respectively the size of the sports venue.

Results further revealed that a score derived from clapping and cheering cannot represent an objective audience vote, which means that objectivity cannot be guaranteed. The vote is likely to be influenced by biases of audience members, e.g., audience members that favor one country might cause lopsided voting. It is also an established fact in psychology that crowd behavior can be easily manipulated and therefore leaders of a group can possibly influence the group. Even on-site calibration of the system cannot counterbalance these influences caused by group behavior. The audience vote therefore cannot be used as a determining factor for the final score of judged sports events such as the Olympic Games. It might however be possible to use it in smaller sports events and especially for other events that include audience voting (e.g., band competitions). The participation system further gives each audience member the subjective feeling of being part of the voting process and therefore increases the spectator experience, even if the audience vote has only a minor impact on the final score. This also represents an important advantage to 'clapometers', which display a visual score based on the loudness of studio applause.

Nevertheless it is necessary to build the entire system for evaluating the concept under natural conditions. We are currently in search for a partner to produce a first lot of wristbands, which would allow evaluating the system in a local sports or competition event. From this, we hope to gain more insights about the technological side (e.g., scalability) as well as the acceptance of such a system by audience members.

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