System for Audience Participation in Event Scoring at the 2004 Olympic Games

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Abstract
In this paper we describe a system for audience participation in gymnastics and diving events scoring at the 2004 Olympics in Athens, Greece. The proposed system has six primary design goals: ease-of-use, scalability, low cost, scoring accuracy, portability and resistance to tampering. The system provides a simple and portable system that can be used for any sporting event where judge scores are reviewed by an audience. The supporting database design provides for statistical analysis and portability as well by providing a generalized database structure that can be easily adapted to any event as necessary. By using off-the-shelf technologies and open-source software, the solution provides for simple implementation, inexpensive hardware requirements, and easy software development.

Categories & Subject Descriptors
H5.m. Information interfaces and presentation (HCI): Miscellaneous.

General Terms: Design, Human Factors.

Keywords: Vote casting system, System design.

INTRODUCTION
This paper discusses a system for audience participation in gymnastics and diving event scoring at the 2004 Olympics in Athens, Greece. However, the system is flexible enough to be used for other events such as synchronized swimming, ice skating, etc., without any modifications. The paper is organized as follows: 1) Requirements for diving and gymnastic events are discussed in the Event Requirements section; 2) The system is discussed in detail, including networking infrastructure, operation of the system, hardware devices, database design, and scoring algorithm in the System Architecture section; 3) Cost analysis is presented in the Cost Analysis section.

EVENT REQUIREMENTS
The specified problem requires that the system be usable in two specific sporting arenas. Each arena has different requirements including venue size, event overlap and venue layout. In addition, each event has unique scoring requirements.

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Diving Events
The Olympic Aquatics Center will host the diving events. The Center consists of two outdoor and one indoor pool. The indoor pool, where the diving competition will take place, seats 6,500 [1].

In standard diving competitions, divers perform and are judged on multiple dives. The judging panel consists of between five or seven judges and scores range from zero to ten [1].

In synchronized diving competitions, a pair of divers performs and is judged on multiple dives. A panel of nine judges scores each dive. Dives are marked by judges based upon dive execution, technique, and team synchronization [1].

Gymnastic Events
Artistic gymnastics and trampoline events will take place in the Olympic Indoor Hall at the Athens Olympic Sports Complex. Seating capacity will reach 15,000. Rhythmic gymnastics events will take place in the 6,000 seat Galatsi Olympic Hall. Gymnasts may compete individually and as part of their national teams [1].

Apparatus-oriented events (artistic gymnastics) are scored by eight judges and a Chair of the Apparatus with scoring based upon the content, degree of difficulty, special requirements and bonus points of the exercise. Deductions are made according to the implementation of the program [1].

Trampoline competitions are judged by nine judges with scores based upon the difficulty level and execution quality of the performance [1].

Rhythmic Gymnastics performances are evaluated based upon the composition (accompanying music and choreography), overall degree of difficulty, execution, and technical faults of the performance [1].

Other Events
While not part of the contest specification, it is likely that the IOC would desire to use the audience participation system for other events in future Olympics.

SYSTEM ARCHITECTURE

The basic system architecture is a network of data gathering nodes, an administrative terminal, and a central data processing server. Audience participants are issued handheld devices for event scoring and an event administrator is responsible for activating the system at the appropriate times to allow audience voting (Figure 1).

Network Infrastructure

The network consists of one primary server, an administrator workstation, N nodes (where N is determined by the size and layout of the sporting arena), and an optional scoreboard interface (may require both networking hardware and customized software). 802.11b is used for the network infrastructure because of its low cost and long broadcast radius, making it easy to place data-gathering nodes and the administrator terminal in their proper locations for the event arena. A commercial wireless router with an integrated Dynamic Host Configuration Protocol (DHCP) server should be sufficient for establishing the local wireless network. Wired Equivalent Privacy (WEP) security protocol and Secure Sockets Layer (SSL) are recommended for reasonably secure data communications and resistance to tampering [2,3].

Event Administrator

The event administrator is responsible for starting the voting clock for any given event and displaying the voting results once they are calculated. After an event is scored by the judges and the scores are presented to the audience, the audience is given a timeframe (30 seconds) in which to score the event. When the timeframe expires, voting is closed for the event and the audience score is calculated. Because of the sensitive nature of audience scoring and the possibility of startling contestants if audience votes are displayed at an inappropriate time, the administrator has the option to display the audience scores on the arena scoreboard at a time of his or her choosing.

Audience Voting Interface

Each audience member who wishes to participate in event scoring is issued a wireless handset. Each handheld device has three buttons with the following values: judge score is too high (-), judge score is accurate (0), judge score is too low (+). In addition, each handset has a unique identifier that is broadcast when its results are sent to a data gathering node. The simplicity of the handset makes it easy to operate and encourages audience participation.

Because of their low cost, both Infra-Red (IR) and FM-band radio are technology options for the voting devices. IR is more desirable, as it requires line-of-sight access to function, ensuring that all captured votes originated from within the arena.

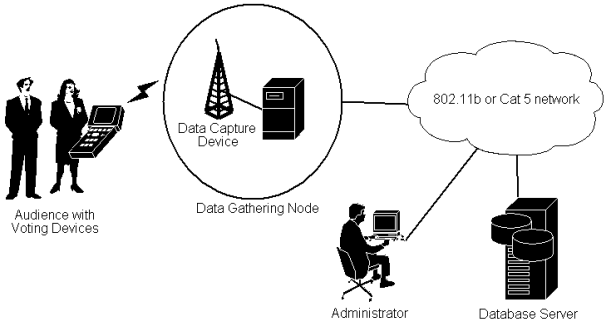

Figure 1. System logical architecture.

Data Gathering Nodes

Commodity x86 Linux computers with attached voting capture devices are used at the collection nodes. The node requirements are fairly straightforward and node computers may be diskless/run off of a CD-ROM boot disk. The nodes must have 802.11b network interfaces and be configured to use the local wireless network and DHCP server (on the wireless router) placed at the athletic venue. Because votes are entered within specific timeframes, it is imperative that all node system clocks be synchronized. Periodic updates with a Network Time Protocol (NTP) daemon running on the main database/Web server will be used to ensure clock synchronization. When not in vote polling mode, nodes will perform periodic requests for work, i.e. scheduled voting times, from the central server. If work has been scheduled, server polling is stopped and the data gathering device is polled for audience votes. When a specified voting "stop time" is reached, polling of the data gathering device stops, each vote is recorded along with its timestamp and unique device identifier, and the results are forwarded to the central server for processing.

Database Server

The primary server runs database software (PostgreSQL), a Web server (Apache/SSL), and NTP on the Linux operating system. A Web-based graphical user interface (PHP) is provided to the administrator to start and stop voting and assist in presentation of voting results. The central database provides data storage and retrieval capabilities and acts as a communication nexus between the nodes and the central server processes. When a vote is scheduled, a row is inserted into the database with an event identifier, voting start time, and voting stop time. A process runs on the database that will wait for all devices to report successful voting before performing vote analysis. Once the votes are successfully inserted into the database, the process will select distinct device identifier records and discard all but the last vote as determined by timestamp (different nodes may have recorded votes for the same device). The average vote value can be tabulated through a simple SQL select statement and will be used to determine the audience score.

Optional Components

Because of its modular nature, the system's functionality can be expanded with ease.

Judges' Terminals

The system is capable of capturing and storing judges' scores, eliminating the inconvenience and administrative overhead of running multiple systems. Should the system be used to capture judges' scores, additional terminals and network connections are needed for each judge. Moreover, additional user interface screens need to be developed.

Scoreboard

As most sporting venues include a large electronic scoreboard, a scoreboard is considered optional equipment for the system. There is no reason to believe that the system cannot be integrated with any programmable scoring display.

Database Design

In keeping with the open-source software design of the system, PostgreSQL will be used as the back-end database. While free, PostgreSQL provides high-performance, robustness, SSL capability and easy integration with Apache/PHP [4].

The database consists of 11 tables: Sports, Events, Athletes, Couples, Venues, Score_Types, Event_Participants, Judges, Event_Judges, Judges_Scores and Public_Scores (Figure 2).

Venues Table

The Venues table stores data about all venues. Each venue is uniquely identified by a value of the venue_id column (primary key). In addition, the name of the venue and its capacity are stored as well.

Sports Table

The Sports table stores data about all sporting activities. Each sporting activity is uniquely identified by a value of the sport_id column (primary key). The name of the sport is also stored.

Events Table

The Events table keeps track of all sporting events. Each event is uniquely identified by a value of the event_id column (primary key). In addition, the event name, event type (individual or team competition), date, time, venue, and sport that the event belongs to are stored. This table has two different foreign key columns: venue_id and sport_id. These foreign keys reference the venue_id column in the Venues table and the sport_id column in the Sports table respectively.

Athletes Table

The Athletes table stores data about all athletes. Each athlete is uniquely identified by a value of the athlete_id column (primary key). Last name and first name of an athlete, his/her gender, country, and the name of the coach are stored as well. The country column is used to group athletes into teams and calculate teams' scores for team competitions.

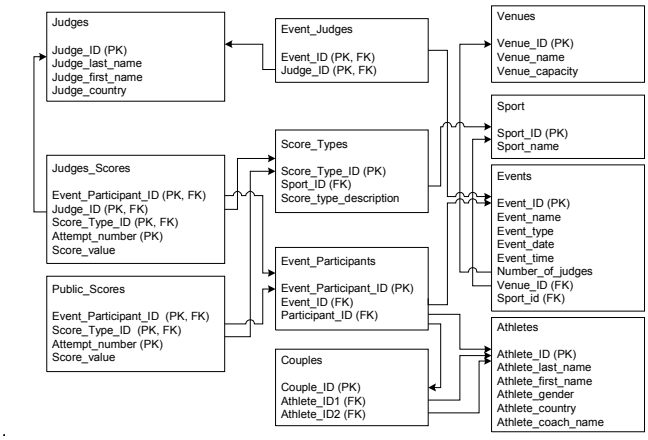

Figure 2. Relational database design diagram.

Couples Table

Some competitions, such as synchronized diving, involve two athletes (or couples) performing simultaneously. The Couples table stores data about all athlete couples. Each couple is uniquely identified by a value of the couple_id column (primary key). Identifiers of both athletes are stored as well. Both of these identifiers are foreign key columns that reference the same column (athlete_id) in the Athletes table.

Event_Participants Table

The Event_Participants table stores data about all participants (athletes) in a specific event. Each row in this table is uniquely identified by a value of the event_participant_id column (primary key). Note that the primary key in the Event_Participants table is a surrogate key. The other two columns of this table are event_id and a participant_id. An event_id column captures an event in which a participant participates. It is a foreign key that references the event_id column in the Events table. A participant_id column identifies either an athlete or a couple depending on the type of the event. It is a foreign key that references the athlete_id column in the Athletes table or a couple_id column in the Couples table.

Judges Table

The Judges table stores data about all judges. Each judge is uniquely identified by a value of the judge_id column (primary key). Last name and first name of a judge and his/her country are stored as well.

Event_Judges Table

The Event_Judges table stores data about judges participating in specific events. Each record is uniquely identified by a combination of an event_id and a judge_id, forming a composite primary key. Each of these columns also represent two separate foreign keys: event_id column references the event_id column in the Events table and judge_id column references the judge_id column in the Judges table.

Judge	Score 1	Score 2
1	5.8	5.8
2	5.8	5.8
3	5.5	5.8
4	5.6	5.8
5	5.4	5.7
6	5.8	5.9
7	5.7	5.8
8	5.6	5.7
9	5.7	5.7
10	5.6	5.8

Table 1. Sample event scores.

Property	Score 1	Score 2
Judge Average (JA)	5.65 (5.7)	5.78 (5.8)
Standard Deviation (SD)	0.135	0.063
Theoretical Max Score	6.055	5.969
Theoretical Min Score	5.245	5.591

Table 2. Judge score analysis.

Score_Types Table

The Score_Types table stores data about different types of scores and their applicability to a particular sporting activity. This table is essential for sporting activities such as figure-skating when judges issue more than one score for each performance. Each score type is uniquely identified by a value of the score_type_id column (primary key). A sport_id column identifies sporting activities related to this score type. This column is a foreign key that references the sport _id column in the Sports table. In addition, a description of a score type is also stored.

Judges_Scores Table

The Judges_Scores table stores scores issued by judges for a particular performance. Each record is uniquely identified by a combination of an event_participant_id, judge_id, score_type_id, and attempt_number (composite primary key). An event_participant_id column links a specific participant performing during a specific event to the score being issued by a judge. This column is also a foreign key that that references the event_participant_id column in the Event_Participants table. A judge_id column identifies the judge who issues a score and is a foreign key that references the judge_id column in the Judges table. A score_type_id column identifies the type of a score being issued and is a foreign key that references a score_type_id column in the Score_Types table. Several sporting activities such as diving require athletes or couples to perform more than once during the same event. Therefore, an attempt_number column is necessary to distinguish scores for different attempts or performances by the same athlete or couple. Finally, the value of an issued score is stored as well.

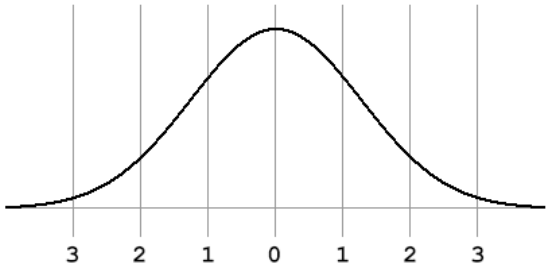

Figure 3. Standard deviation normal curve.

Public_Scores Table

The Public_Scores table stores total scores issued by the audience for a particular performance. Each record is uniquely identified by a combination of an event_participant_id, score_type_id, and attempt_number (composite primary key). An event_participant_id column links a specific participant performing during a specific event to the score being issued by the audience. This column is also a foreign key that that references the event_participant_id column in the Event_Participants table. A score_type_id column identifies the type of a score being issued and is a foreign key that references a score_type_id column in the Score_Types table. An attempt_number column distinguishes scores for different attempts or performances by the same athlete or couple. Finally, the value of an issued score is also stored.

Scoring System

The complexity of scoring each of the diving and gymnastics events requires either an extremely complex solution or an astoundingly simple one. We opted for the latter.

The scoring system uses statistical standard deviation (Figure 3) as a basis for calculating the audience score, leveraging the expertise of the judges when the audience vote is tabulated (Table 1). By using standard deviation, the audience score will closely resemble the judges' score if the audience perception is that the judges' score is correct, while it may be significantly different from the judges' score if the audience perception sharply differs from that of the judges. Based upon the amount of disagreement between the judges, the possibility for dramatically different scores between the judges and the audience increases, as the statistical basis of the audience score is that the judge score is reasonably accurate. The more disagreement between judges, the more likelihood that the

Property	Score 1	Score 2
Audience Size	6500	6500
Votes: -1	1000	1000
Votes: +0	2000	2000
Votes: +1	3500	3500
Audience Avg. (AA)	0.385	0.385
Audience Score	5.805 (5.8)	5.853 (5.9)

Table 3. Audience score analysis.

judges' score (a simple arithmetic mean) is not an accurate representation of the quality of the athletic performance.

The standard deviation of the judges' scores is calculated (Table 2), resulting in a number that represents the quantifiable bounds of inaccuracy of the judge scores. The audience then votes "-", "0", or "+" based upon their perception of the accuracy the score submitted by the judges. An individual audience member may score a "-" if they believe that the judges scored too high, "0" if he or she agrees with the judges' decision or a "+" if the judges' score was too low. The arithmetic mean of the audience scores is determined (positive and negative votes have a value of 1 and –1 respectively), multiplied by 3 (once for each standard deviation) and finally multiplied by the standard deviation itself. The product, which may be a negative number, is added to the judges' score to determine the audience score (Table 3).

The scoring system can be represented mathematically as:

$$s = j + 3ad$$

Where "s" is the final audience score, "j" is the judge score, "a" is the audience vote (between –1 and 1), and "d" is the standard deviation.

Acknowledgment of Partial and Incomplete Solutions

The technical specifics about the audience voting devices have been left purposefully vague, as the technologies used should be based upon actual device cost. Additionally, the scoring methodology is flexible enough that other audience voting mechanisms. One option is for the audience to use color-coded cards to vote. At vote time, each audience member would hold up the color card corresponding to their vote and a digital photo would be taken of the audience. The audience vote could be determined by using digital photo processing to determine color variance off of a previously calibrated mean. Ultimately, one of the strengths of the system is it is not bound to any specific audience voting interface, but can be adapted as funding and event-types allow.

The design details of the vote capturing and transferring software have not been described. There is no reason to believe that the system data processing applications could not be written a high-level scripting language, such as Perl or Python. The most complicated software element, the data capture device driver, needs to be written as a Linux kernel loadable module in C or C++.

COST ANALYSIS

The handheld devices represent the primary system cost, but the simple 3-button interface reduces the cost of such devices dramatically. Similar commercial off-the-shelf products, such as garage door openers and IR remote controls, have a unit cost of around $10 USD. According to the Olympic daily competition schedule gymnastic events do not overlap [1]. Therefore, only 21,500 handsets are needed. Considering the need for spare handsets, 22,000 units would suffice, representing a total cost of $220k USD.

Data gathering nodes with data capture devices can be purchased for well under $1000 USD each. The central server has no special requirements and could also be sourced inexpensively, costing no more than $2000 USD. Wireless routers generally cost less than $200 USD each.

It is highly unlikely that the system hardware and installation would cost more than $300k USD in total. Factoring in software development time, it is possible that the entire implementation could cost around $400k USD.

CONCLUSION

The system leverages the specific strengths of each of its three contributors: the judges for their expertise, computers for their data processing capability and the audience for its perception of entertainment value and scoring fairness. The intuitive three-button handheld device provides an enjoyable way for audience members to participate in event scoring, while requiring no specific event knowledge or technical skill on their part. As a result, the system can be deployed for use at other sporting events, beyond gymnastics and diving, with no additional development effort or audience education required. Given its low cost, ease-of-use, statistical accuracy, high "fun-factor", and event portability, the proposed system is an ideal choice for audience participation in event scoring at the Olympic games.

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