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Development of an automated scoring system for amateur boxing

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Abstract

The scoring process in amateur boxing is subjective, and this has caused a litany of problems for the sport. We have developed an automated scoring system that offers complete objectivity. Equipment worn by boxers during competition is instrumented to enable impact detection. Information on impact events is transmitted via Bluetooth to a ringside computer, where customised software applies temporal criteria to identify valid scores. The system has undergone multiple iterations over time based on outcomes of laboratory and field trials, and its potential to enhance amateur boxing is now worthy of attention.

Keywords: Amateur Boxing; Olympic Boxing; Scoring; Wearable Sensors; Smart Textiles; Technology;

1. Introduction

Amateur boxing was admitted to the Olympic Games at St Louis, USA, in 1904. It has been included in every subsequent Summer Olympics, except for 1912 [1]. The sport is fundamentally different from professional boxing, with contests of much shorter duration (currently three 3-minute rounds) and a greater emphasis on safety. In the modern form, head guards are worn, and the rules provide for early cessation of bouts if a competitor is clearly outclassed [2]. Retirement from the sport is compulsory upon reaching the age of 35 years [3]. Of a total of 1506 bouts held over the past five Olympic Games (1992 to 2008), 1246 – or approximately 83% - were decided on points, as opposed to ending inside of their scheduled duration. At the 2008 Beijing Olympics, almost 93% of contests were decided on points. This contrasts with a report from Balmer et al [4] on professional boxing, where

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about 50% of 788 European championship bouts held between 1910 and 2002 were found to have been determined by knockout or technical knockout.

When contests run their allotted time, there obviously needs to be a method to identify the winners. The scoring methodology used in amateur boxing has evolved considerably over the years. For the most part, the boxer considered victorious by a majority of judges has been declared the winner. Originally, there were 2 judges (with the referee having a casting vote if necessary), but the number subsequently increased to 3 and then 5. The judges awarded points at the end of every round, with the perceived winner given 5, 10 or later 20 points and the loser a lesser number intended to reflect the extent of the loss [3,5]. In theory, the progression to a higher number of available points provided scope for finer scoring differentiation.

Despite the incremental changes to judging procedures, amateur boxing has been troubled by scoring controversies throughout its history [6]. Dissatisfaction reached a critical point at the 1988 Seoul Olympics, when there were several dubious results. In particular, American Roy Jones Jr appeared to dominate his final against a South Korean competitor, only to lose the decision when 3 of the 5 judges voted against him. Post-bout video analysis indicated that he had landed 86 scoring punches during the 3 rounds and taken only 32. Regardless of his loss, which was alleged to be due to corruption, Jones was declared the outstanding boxer of the Olympic tournament [7].

The problems in Seoul stimulated the introduction of a new, computerised scoring system that remains in use today. Under this system, each of the 5 judges is provided with equipment incorporating 2 electronic buttons – one for each contestant. When a judge perceives that a contestant has achieved a valid impact, he presses the corresponding button. If 3 of the judges record the same perception within one second, a point is awarded to the identified boxer.

While the attempt to find a technological solution to the scoring issue has been commendable, it has become clear that the computerised system has serious limitations [8]. A boxer cannot score more than once per second, whereas punches may actually be landed with a much higher frequency. The scores are dependent on the visual acuity of the judges and on their ability to rapidly and accurately process complex visual information. The judges need to have good hand-eye coordination to ensure that the correct button is pressed. In practice, they seem to more consistently detect impacts to the head than to the torso, and many impacts clearly visible to spectators fail to register scores. The fact that scores are still determined by subjective inputs leaves considerable scope for error and manipulation. The definition of a valid impact is open to interpretation, and it seems likely that interpretations have varied across time, since the mean number of points scored per completed bout was 48 at the Athens Olympics in 2004 but only 16 at Beijing in 2008. An independent-samples t-test conducted on log-transformed data showed the difference between the two Olympics to be highly significant ($P<0.0001$).

There is evidence that in subjectively judged sports home competitors may have a considerable advantage, possibly due to the influence of crowd noise on judges [4]. Colours of athlete uniforms might also have an effect. In amateur boxing competitions, one contestant traditionally wears red and the other blue, and a study conducted with Tae Kwon Do has suggested that in such a situation judges may tend to favour the red [9]. It also seems that subjective scoring may be affected by the knowledge of judges concerning the prior records of athletes [10].

To date, the computerised scoring system has not overcome the scoring challenge, and controversies have occurred at every Olympic Games since its implementation. There have been cases in which all five judges have individually recorded more impacts for a particular boxer than for his opponent, only to have the opponent win due to timing factors associated with the pressing of buttons [11]. At the 2004 Athens Olympics, there were several apparently anomalous decisions, and the International Olympic Committee temporarily withheld a payment of $9 million to the International Boxing Association (AIBA) pending appropriate attention to ‘general judging issues’ [12]. In Beijing in 2008, a camera system was introduced to improve surveillance of judges but disputes still arose [13].

It would be ideal to have a fully automated scoring system to ensure complete objectivity. We are currently working toward development of such a system.

2. Methods

Our approach involves instrumentation of boxing equipment to enable automated impact detection. The technology has undergone numerous iterations over 7 years, with refinements based on outcomes of repeated laboratory and field trials, and on feedback from boxers, coaches and, on one occasion, members of the AIBA Referees and Judges Commission.

The general configuration of our scoring system has remained relatively constant. It is designed to record points when impacts to a boxing glove of one competitor and the target area of the other competitor occur within a specified brief time window. Sensors embedded in the boxing equipment generate voltage changes upon impact. Small transceivers connected to the sensors detect the signals and use customised algorithms to discriminate impact events. The transceivers send time-stamped event information via Bluetooth to a ringside computer where a dedicated software package applies temporal criteria to determine whether scores should be allocated. Scores can be displayed in real time.

Throughout much of the history of our project, polyvinylidene fluoride (PVDF) piezoelectric sensors have been used to detect impacts. These sensors were incorporated into boxing gloves, head guards and specially constructed vests. For the vest, at least 16 sensors (22 for larger vests) were attached to a polycarbonate film substrate that was then sandwiched between two layers of polyurethane foam, over which a removable knitted cover (either red or blue) could be fitted. There were multiple small holes in the garment to minimise its weight and its influence on thermoregulation. For the gloves, four sensors were inserted at the point of manufacture by Ranson Sports Industry (Jalandhar, India). In the case of the headguards, at least nine sensors were used and were either incorporated during manufacture or attached afterwards. Head guards with cheek protectors were deployed to ensure that all received impacts were likely to hit a sensor area.

When incorporated into moulded foam boxing gloves of the type used at major amateur boxing competitions, the PVDF sensors were found to be insufficiently sensitive. We therefore implemented a different method for detecting glove impacts, making use of accelerometers contained within our transceiver units. The transceivers are now placed in flexible wrist bands that include Velcro attachments to ensure tight fitting. Glove impacts are identified when changes in acceleration exceed a predetermined threshold. This approach provides high sensitivity, and eliminates the need for specially manufactured gloves.

Some difficulties also were encountered in relation to the employment of PVDF sensors in the vests. The normal torso movements of boxers cause deformation of the sensors and generate signals, even in the absence of any impact. We therefore needed to develop algorithms to differentiate impact signals from background ‘noise’. An algorithm that examined the rate of voltage change generated by the PVDF sensors proved quite effective. A more discerning method was established based on monitoring the harmonics of the PVDF sensors, but could not be immediately implemented as it required processing power greater than that available in our transceivers.

Another problem associated with the use of PVDF sensors in vests concerned the potential for blocked punches to score, since force from a punch striking a blocking arm could be transmitted through the arm and still cause deformation of the vest. This was largely overcome by setting a very narrow time window (<20 milliseconds) to define ‘simultaneous’ contact between the glove of one boxer and the head guard or vest of the other, so that force transmission time typically exceeded the window. However, false positive impacts were still occasionally recorded when the blocking arm was held hard up against the target zone.

At an early stage, it was found that force ‘waves’ resulting from a single impact could progressively excite several vest PVDF sensors, and cause registration of two or even three points. Consequently, it was necessary to implement (in software) a minimum time between registration of successive points. In general, the duration of this

'hold-off' period was set at 200 milliseconds, meaning that it was still possible for a boxer to register up to five legitimate impacts per second.

Despite the efforts to optimise the design and construction of the vest, the need to protect the electronics and polycarbonate film substrate by including polyurethane foam layers caused many boxers to note that when worn during sparring the vest felt heavy and hot. Fitting of the vests, which involved the use of straps and clips, was also a logistical issue.

A breakthrough in the project recently occurred with the production of a new vest that closely resembles a standard boxing singlet [14]. This vest incorporates smart textiles that generate electrical signals when contacted by a conventional glove that has been modified to include a conductive scoring region. The modification to the glove entails only the attachment of a conductive patch to the glove surface. Detection of impacts based on direct contact, rather than on vest deformation, has removed many of the problems inherent in the earlier vests, and has assured that blocked punches and impacts landing outside of the valid target area cannot score. In addition, there is no possibility of points being awarded for impacts landed with the incorrect portion of the glove, since only the conductive portion can interact with the smart textiles in the vest to trigger signals.

Initial experimentation has been carried out with incorporation of the smart textiles also into head guards, with promising results, but this work has not yet extended to substantial field trials.

The smart textiles are presently able to indicate only that they have been struck by a glove, and do not yield information as to which glove. The use of data from wrist-mounted accelerometers therefore remains necessary as a source of the latter information, and is critical to avoiding the possibility of a boxer providing a point for the opponent through inadvertent self-contact.

We have investigated the practicality of using rates of change in wrist acceleration to estimate impact forces, at least in terms of five broad categories, but a comparison of the rates with force data obtained through striking a wall-mounted force plate revealed a very low correlation. Accordingly, we are now exploring the feasibility of assessing impact forces through application of pattern recognition techniques to the wrist accelerometer signals. The matter does need to be successfully addressed as the rules of amateur boxing mandate that only reasonably forceful punches should score.

Over the past few months, we have carried out a number of laboratory and field trials that seem worthy of particular note. In January 2009, we operated our automated scoring system during a 'competition sparring session' held at the Australian Institute of Sport (AIS) in Canberra, Australia, and involving boxers of national standard. The competition sparring was closely akin to full competition. At the time, we were still using the vests incorporating PVDF sensors. The computerised scoring system was employed at the same event, enabling a direct comparison of results, although it should be noted that the judges were mostly AIS boxers and coaches, rather than officials of international standing. In addition to the trial at the AIS, we used the automated system on several occasions throughout 2009 to support a modified form of boxing competition called Box'Tag® [15]. The object of Box'Tag® is to record as many impacts as possible to clearly delineated scoring regions on an opponent's torso and shoulders. Impacts to the head and those above a moderate level of force are penalised, so that there is minimal risk to contestants. Although Box'Tag® competitions are currently confined to a small geographic region in and around Sydney, they have proved quite popular across a broad spectrum of the population, attracting substantial participation of juveniles, females and people aged 35-55 years. At most of the Box'Tag® events that we supported during 2009, the old vests were used, but during December the new vests and conductive glove patches were employed, allowing us to gather some valuable feedback. Finally, we have also been able to recently carry out some basic laboratory trials with the latest version of the automated system.

3. Results

The trial involving comparison of results produced by the automated scoring system with those yielded by the existing computerised judging system included 8 contests. The scores recorded are shown in Table 1.

In all but Bout 7, the boxer identified as the winner by the judges also scored better on the automated system. The judges gave Bout 7 to the blue boxer by a small margin but the automated system indicated a clear win to the red boxer.

A striking feature of Table 1 is the difference in the absolute magnitudes of the scores obtained by the two methods. The total number of points scored per bout averaged 20 for the computerised system and 164 for the automated system. A question obviously arises as to which figure is closer to being correct. We have been unable to locate any published scientific literature concerning detailed video analysis of amateur boxing to determine the number of punches typically landed per round. However, a system called Compubox has been used to estimate the number of punches thrown and landed in many professional boxing matches over the past 25 years [16]. The system requires two operators, who each watch one of the contestants and manually press buttons to record punches. There are four buttons – jab connect, jab miss, power punch connect and power punch miss. While the method may have considerable scope for error in any individual case, it might be expected that errors would randomise out during the collection of large volumes of data over a prolonged period, making mean values instructive. The Compubox database indicates that leading professional boxers throw an average of 56 punches per 3-minute round, and that 18 of these hit the target zone [17]. On this basis, it could be predicted that amateur boxers competing over three 3-minute rounds would on average land a combined total of about 108 scoring punches per bout, but that estimate might be somewhat low, as the restricted duration of amateur contests probably leads to more intense activity within the available time.

Table 1. Comparison of results recorded by the current computerised judging system with those obtained using the automated scoring system. The column headed 'Red' indicates the score for the boxer from the red corner, while that headed 'Blue' is the score for the boxer from the blue corner. 'Total' is the sum of the scores of the two boxers.

	Computerised Scoring System			Automated Scoring System		
Bout	**Red**	**Blue**	**Total**	**Red**	**Blue**	**Total**
1	15	3	18	121	51	172
2	8	2	10	140	101	241
3	11	4	15	69	27	96
4	14	17	31	78	102	180
5	12	7	19	63	34	97
6	11	15	26	58	78	136
7	12	13	25	140	80	220
8	6	8	14	70	103	173

It is almost certain that we recorded some false positive scores, as we were using the old vests that contained PVDF sensors, and had previously shown that these could yield occasional scores for blocked punches. Also, our inability to accurately quantify impact forces could be expected to have led to counting of some punches that were too light to be scored under current amateur boxing rules. On the other hand, the number of false positives may well have been less than the number of false negatives associated with the computerised judging system. Furthermore,

the advent of the new vests is likely to significantly reduce the incidence of false positives produced by the automated system, enhancing its overall performance.

Across the 8 bouts listed above, there was no correlation between the two scoring methods in terms of the total number of points recorded (r= -0.06). Consequently, a bout that yielded high scores under one system did not necessarily do so under the other. There was, however, moderate agreement between the two systems with regard to the margins between contestants – when points for the red boxer were expressed as a percentage of those for the blue the correlation between results of the computerised and automated systems was 0.65 ($P<0.10$), and when the percentages were converted to rank order the correlation rose to 0.78 ($P<0.05$).

Testing of the new, singlet-like vests is at an early stage, but some work has been carried out in laboratory settings involving the delivery of impacts to manikins. In the most recent trial, hundreds of impacts were dispensed. With the automated scoring system in full operational mode, more than 90% of impacts delivered to the target area of the vest were correctly detected, and no false positives occurred. Impacts to an arm held hard against the vest never scored. The same was true for impacts delivered with non-scoring regions of the glove, and for punches directed to areas of the vest outside the designated target zone. The effects of profuse sweating on the performance of the vest remain to be thoroughly tested, but the outer surface of the target zone has been chemically treated to make it highly water resistant. The vests have been found to still work effectively after being washed and dried, but the number of wash cycles that can be tolerated has not yet been determined.

The recent field trials in the Box'Tag® setting have produced very encouraging outcomes. Throughout 2009, no major technical problems were encountered. Occasional difficulties were experienced with drop-out of Bluetooth receivers, failure of transceivers and breakage of electronic adaptors, but these issues could be easily addressed if the project were to enter an intensive product development phase. Such a phase clearly would be necessary as a prelude to adoption of the technology for use in major amateur boxing competitions.

Employment of the new vests in Box'Tag® events held during December 2009 greatly facilitated participant preparation and enhanced the aesthetics of the modified sport. The participants provided highly favourable feedback in regard to the performance and comfort of the vests, and considered them a substantial advance on the previous version.

4. Conclusion

The automated boxing scoring system has reached a point where it merits serious consideration as a possible solution to the scoring problems that have long beset amateur boxing. The system has already been successfully deployed in challenging competitive environments. Numerous technological hurdles have been overcome, and the recent development of new vest technology promises to address most of the remainder. Investment will be needed in a concerted product development phase if the full potential of the system is to be realised. That phase will have to include establishment of a mechanism for accurately estimating impact forces. To facilitate uptake of the system, there will need to be ongoing focus on minimising requirements for any change to the manufacture of standard boxing equipment.

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