10.1071/PVv2015n176p46

The application of geophysics to the sport of cricket

Tim Dean

Tim Dean[1], Ben McCarthy[2], Pieter Claassen[3] and Rakib Hassan[4]

[1]*Curtin University, Perth*
tdean2@slb.com
[2]*Curtin University, Perth*
BMccarthy@slb.com
[3]*Curtin University, Perth*
P.Claassen@bom.gov.au
[4]*The University of Sydney, Sydney*
rakib.hassan@sydney.edu.au

Dedicated to the memory of Vincent Kong, a great colleague and friend, whose inquisitiveness encouraged us in our endeavour.

Introduction

Over the years interest in sports science has boomed with current research in using technology to monitor athlete performance and the motion of balls or other equipment during a game, for example the tracking of golf swings or ball bounces to improve umpiring decisions. The contribution of geophysics to sport is, as far as we have found, only indirect at best (searching within the SEG cumulative index yielded no relevant results). In this paper we detail how we have applied geophysics directly, in particular the seismic method, to the sport of cricket.

Cricket

The game of cricket is relatively straightforward. A *batsman* uses a wooden bat to defend a set of three wooden *stumps* at one end of a *pitch* (ideally made from heavily compacted grass) while a *bowler* attempts to knock them over by bowling a hard leather ball from the other end of the pitch. The batsman aims to hit the ball in order to acquire *runs* without the ball being caught in-flight by a *fielder*. Although the ball can be bowled so that it doesn't bounce on the pitch it typically bounces, or 'pitches' on the pitch before it reaches the batsman. As the combined width of the three stumps is only 22.9 cm and the pitch is over 20 m long, accurate bowling is very important. A fast bowler can bowl the ball at between 135 and 150 km/h, making it extremely difficult to judge with the naked eye where the ball has pitched. Determination of the accuracy of a bowler requires the ability to plot a 'pitch map' showing where each ball has bounced. Such ability is currently offered by a television-based system called Hawk-Eye, which employs six or

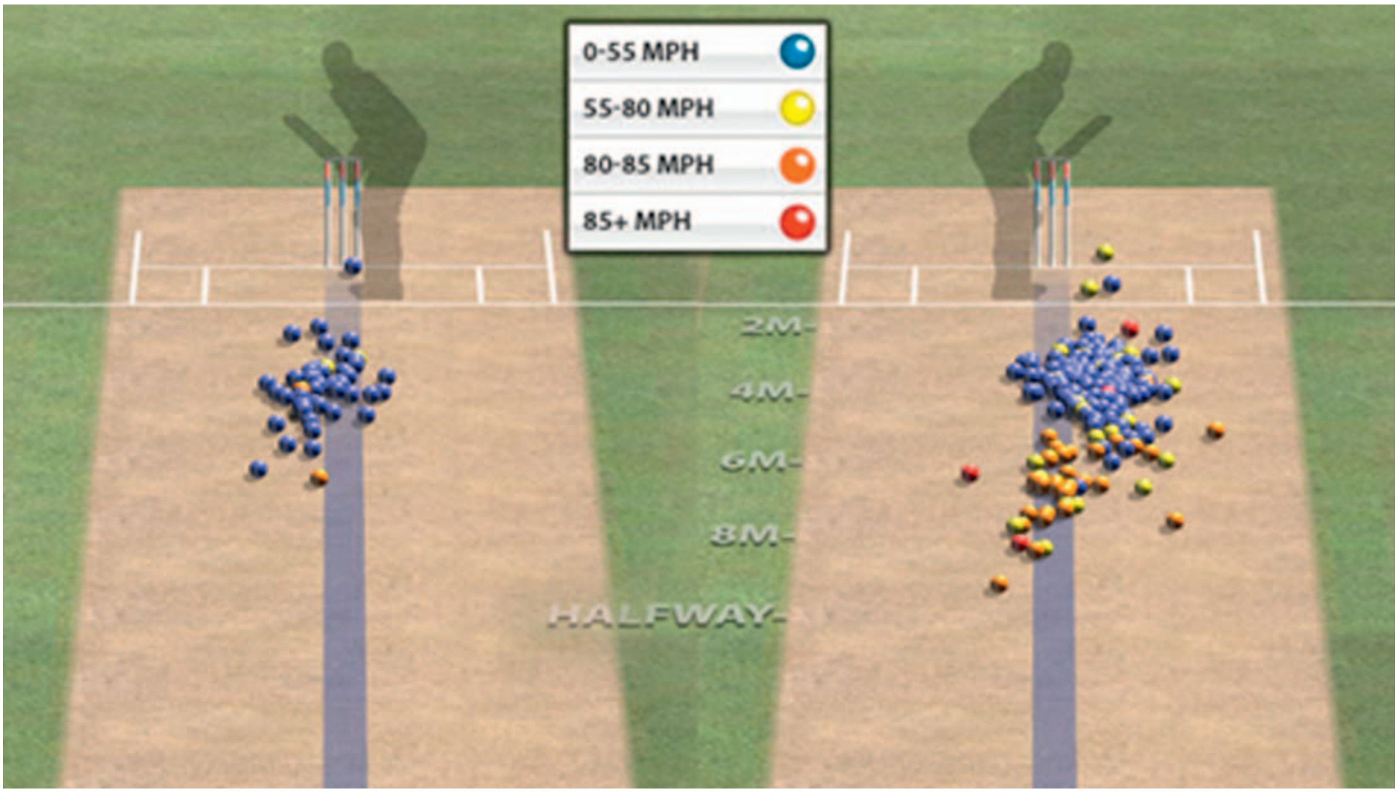

Figure 1. *'Hawk-Eye' pitch map from a match between Australia and Sri Lanka in 2012. Downloaded from www.cricinfo.com.*

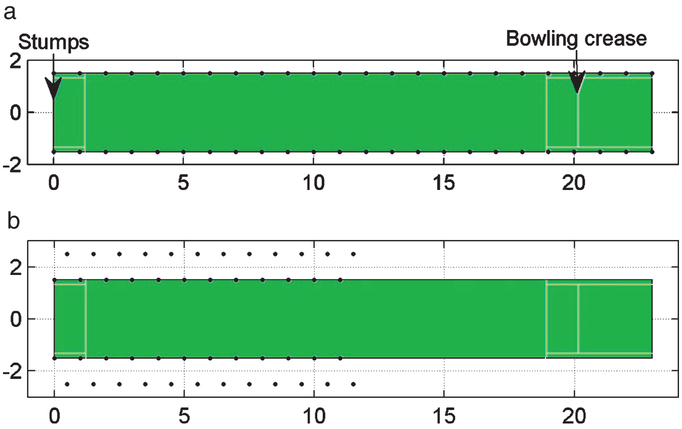

Figure 2. *Diagrams of the layout of our spreads. Each black circle is a geophone position. All distances are in metres.*

seven high speed cameras placed at different angles to track the ball (Figure 1). Unfortunately this system is expensive, often prohibitively so, even for international professional competitions. In this paper we describe the use of a small, low-cost, seismic recording system to determine where a ball has pitched.

Experimental setup

Our initial layout consisted of two lines each of 24 geophones placed either side of the pitch (Figure 2a and Figure 3a). The inline spacing was 1 m and the cross-line spacing 3 m (the width of the pitch). After analysing the results we found that this layout did not have sufficient cross-line sampling to give an accurate cross-line position so we altered it to have four lines

Figure 3. *Photos of the (a) initial and (b) improved layouts. The positions of some of the geophones are indicated by red arrows.*

Figure 4. *(a) Photo of the 'calibration' test with the thrower in the foreground, the target area is between the two red cones. Tests acquired with (b) a bowler and (c) batsman and wicket keeper.*

each of 12 geophones, two either side of the pitch. The lines within each pair were separated by 1 m with an inline separation of 1 m. The two lines were offset in the inline direction by 0.5 m (Figure 2b and Figure 3b).

To determine the accuracy of our method we acquired a 'calibration' test where the ball was thrown at a known target placed on the pitch (indicated using small plastic cones, Figure 4a). For this test the acquisition system was triggered manually but for later tests involving a bowler (Figure 4b) plus both a batsman and wicket keeper (Figure 4c) the system was triggered by the bowler stepping on a piece of wood placed over a geophone. When the ball was being bowled an observer noted where the ball had pitched and this was recorded for comparison with the position estimated from the seismic data.

Processing

When the ball hits the ground it creates a small seismic wave that propagates through the ground in all directions and whose shape in the x-y-time domain is a cone. If we can successfully fit a cone to the recorded data we can infer that the apex of the cone is the position and time at which the ball pitched. The first stage in processing the data was to pick the first breaks. This was done using a simple cross-correlation method, with each trace being correlated with the trace having the strongest amplitude (i.e. that closest to the pitch of the ball). We then fitted a cone to the time picks from traces with an amplitude above a certain threshold (to avoid using traces too far from the pitch of the ball) using unconstrained nonlinear optimisation.

Results

An example record from the calibration test is shown in Figure 5 (the geometry corresponding to this record is shown in Figure 6). The impact of the ball is clearly evident and the hyperbolic nature of the first-break picks indicates that we should be able to identify the pitch of the ball accurately using a conic fit. The results from the calibration test for three different targets are shown in Figure 7. The scatter of the points is affected by the skill of the thrower as well as the uncertainties of the pitch estimation. Overall, however, the pitch of the ball has been estimated correctly to within ±0.1 m (the distance between the pitch estimate and the target). The target near the end of the pitch (the black points) has a larger spread of results as there are insufficient picks on one side of the cone for an accurate fit.

Figure 8 shows the results from the tests where the ball was being bowled, each line connects the 'actual' (we only had an estimate of the position to within ±0.5 m) position with that estimated from the seismic data. The average position error is just over 0.5 m and, given the accuracy of the calibration tests, it is likely that the seismic-derived position is more accurate than that estimated by the observer.

As seen in Figure 9 the presence of a batsman does not affect the success of the algorithm nor does the batsman running down the pitch or the ball landing on the pitch after being hit by the batsman.

Conclusions

A 48-channel seismic acquisition system, coupled with basic processing, proved effective in locating the position at which a cricket ball impacted the pitch with an accuracy of ±10 cm. This method offers the ability to create 'pitch-maps' at a fraction of the cost of television-based systems. We hope that this work will encourage others to look for other ways in which geophysics can be applied to sport.

Acknowledgements

The authors thank Nader Issa for his assistance with the initial test and for reviewing the paper and Aimé Fournier for help with the processing algorithm.

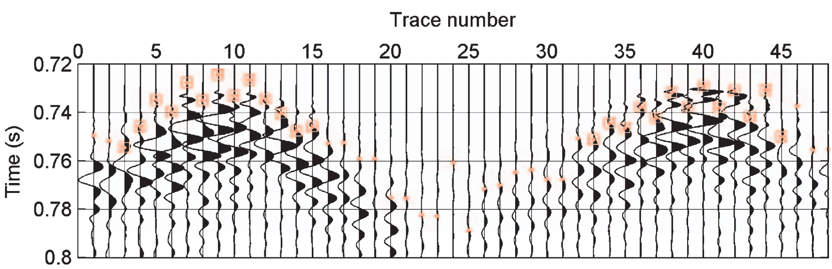

Figure 5. *An example record from the calibration test. The red dots are the first-break picks, the red boxes indicate those picks that were used to determine the pitching position.*

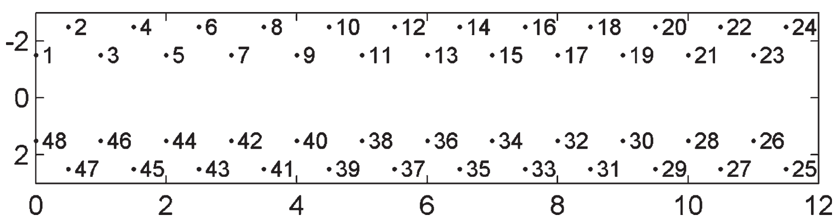

Figure 6. *The geographical position of each trace shown in Figure 5 and Figure 9.*

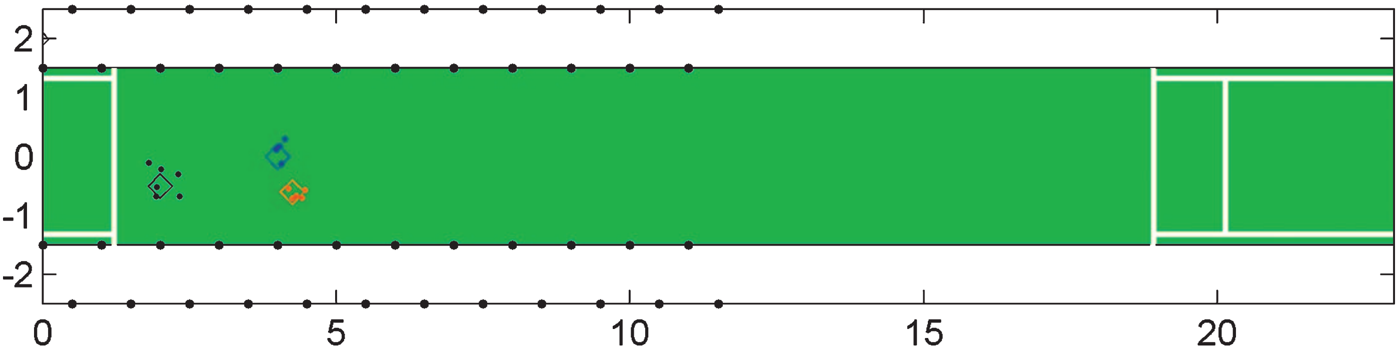

Figure 7. *Results from the calibration test. The position estimated from the seismic data is shown by a coloured point and the actual pitching area by a diamond with corresponding colour.*

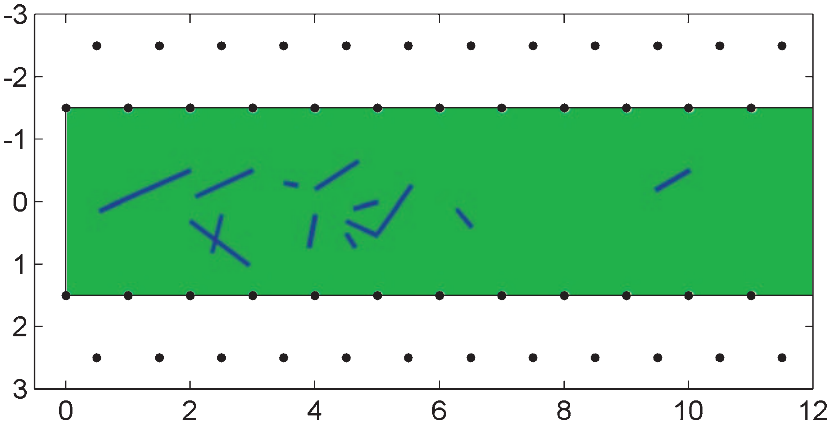

Figure 8. *Results from the bowling test, the lines connect the 'actual' position to that estimated from the seismic data.*

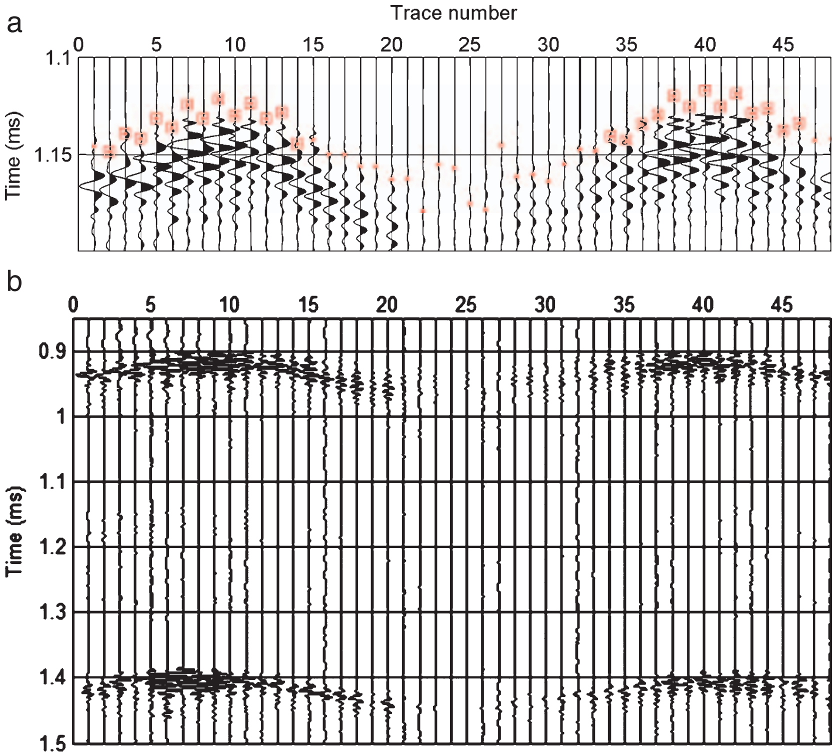

Figure 9. *Example records with (a) a bowler and batsman and (b) an event from the ball being bowled (0.9 s) and being hit down the pitch (1.4 s).*