ADVANCES IN ATHLETE TRACKING TECHNOLOGY

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Athlete tracking is increasingly ubiquitous in elite sport. For most practitioners this involves using data from heart rate sensors, GPS or video based tracking for velocity and distance and increasingly some basic accelerometer derived parameters. However the questions that coaches want to answer from athlete tracking technology continue to evolve and become more sophisticated. This paper discusses some advances in software and hardware from Catapult Sports in Australia that are keeping pace with those emerging issues. They include a practical solution to ball tracking in team sports, and a method of using inertial sensors to better measure the non running part of an athletes activity.

KEY WORDS: Force plate, accelerometer, GPS, ball tracking, gyroscope, inertial movement analysis, team sports.

INTRODUCTION: An evidence based approach to preparation of athletes requires measurement tools. Many of the tools deployed in this application start in the laboratory- meaning that you can obtain useful metrics for the athlete, but only if you interrupt his training, take him into an artificial laboratory environment and usually get him to do things he wouldn't normally do in the course of training or competition. As a result of these limitations, groups like the Australian Institute of Sport and Catapult Sports have been at the forefront of trying to move more instrumentation out of the laboratory and back onto the field. Innovations like wearable, high speed, sports specific GPS tracking have consequently added huge insights into activities like team sports.

Initially, practitioners in this space were interested in answering the first obvious question in the 'chaos' of team sports movement: How far is an athlete travelling over the course of a match? While GPS was able to answer this question, for many practitioners their thinking quickly evolved to new questions. For example:

a. How many high velocity efforts were achieved or how much time was spent at high speed?
b. What high accelerations and decelerations were achieved? And what impact does this have on the recovery strategies for each individual athlete?

The answers to these have arguably provided more enduring value in designing better training practises and managing match day loads.

However, it would be obvious to sports scientists that these questions are only describing the running based activity in a sport. There is an enormous amount of additional (non running) activity that is of interest. Collision sports like Rugby are a great example of this. Whereas the running portion of the activity is interesting for fitness coaches, measuring the collision part of the game is equally important for conditioning, recovery and long term player welfare. For this purpose, Catapult uses some unique algorithms that combine information from accelerometers, gyroscopes, GPS and more to detect and quantify work around a tackle in the minimax athlete tracking system.

However our view is that this example is just the tip of the iceberg in terms of the potential for additional sensors to start "fleshing out" the quantitative athlete tracking information available from team sports. The purpose of this paper is to describe 2 new innovations in this space from Catapult's research team:

1. Ball tracking
2. Inertial Movement Analysis (IMA)

1. Ball tracking

Its clear that tracking balls in team ball sports would be enormously useful in understanding the context of the athlete tracking data being collected, the cognitive and instinctual decision making of athletes during performance and understanding tactically how the ball is moving.

For example, for those interesting in counting high velocity efforts in a sport like Australian Rules Football, it's interesting to note that a lot of players have a large effort running off and on the field from the bench. While this is not unimportant, its usually not very game defining when compared to the effort a full forward might make in leading hard to successfully mark the ball. So in both cases, athlete tracking records a large velocity effort, but adding ball tracking to the picture would enable automatic differentiation between the two. In the case of the Full Forward ball tracking would enable answers to questions like:

1. What percentage of leads from a forward get him in proximity of the ball (ie how often does he lead in the right direction)?
2. What percentage of leads actually result in a possession?
3. Therefore how effective are these efforts (or which efforts are linked to game defining results)?

Another example is comparing the work rate of a team when in possession (attacking) vs when the opposition is in possession (defending). Does a team not work as hard in defence? Is this a mental challenge?

The challenges with implementing a ball tracking solution are:

1. Balls are consumables that must be inexpensive (even for elite clubs). So it's not practical to deploy very expensive sensors in balls routinely
2. Balls experience high impact which is extremely challenging for sensor electronics
3. Since balls have no fixed orientation, conventional antennas and radio frequency designs don't work
4. Whatever hardware is deployed in a ball must be very light weight to avoid comprimising ball performance

Catapult's' Smartball technology uses a small electronic beacon that mounts inside the bladder of footballs. Weighing approxiately 6 grams, it makes negligible difference to the weight or performance of the balls. In a recent study with professional AFL players in a blind test, no players were able to distinguish between instrumented and non instrumented balls (Hewitt, 2011).

This beacon can be detected by any athlete's minimax tracking unit that is within a specified range. The minimax units then send this information in real time to a computer on the sidelines that can then determine who has the ball, pass chains, ball velocities in passes and other parameters. The second generation of this product is expected to additionally distinguish both the player in possession, and players in close proximity allowing automatic detection of things like contested or inside possessions vs possessions in open space.

Catapult can currently provide match grade Smartballs for AFL, Rugby League and Rugby Union.

2. Inertial movement analysis

One of the classic biomechanics tools used in a laboratory are force plates enabling measurement of ground reaction forces. The obvious limitation is that you can't deploy this measurement tool in games or real training environments, and you certainly cant deploy it routinely for a full list of athletes at a football club. Force plates are useful in a way that GPS can never be – they measure forces, or by extension, consequent micro movements that can never be detected by a 'gross' positioning system.

To put it another way, we see GPS providing the scaffolding for athlete tracking (covering gross movements across the field), but for a complete tracking solution, these micro or local movements need attention. They are enourmously relevant for skill execution, work rate, fatigue, recovery and more.

Inertial sensors have the potential to fill this need. The analogy isn't perfect, but it's a little bit like being able to take your force plates onto the field. However there have been fundamental problems in using inertial sensors this way. The principle problem is that gravity is an

acceleration that is always acting, but in an unknown direction on any wearable device. In other words, although measuring real acceleration with an accelerometer would be a great start in analysing those micro movements described above, since the athlete is in constant motion, it's hard to subtract the 9.81m/s^2 of gravity because you don't know which way is down.
Catapult Sports has developed a new software tool that uses an Unscented Kalman filter to take gyroscope, accelerometer and magnetometer information and build a gravity model that enables subtraction of the gravity vector. While this sounds a bit obscure, it opens up enormous possibilities to then build models of human movement from the minimax platform that detect these small motions.
To illustrate the utility of this in a practical way, lets consider basketball. Normally played inside, there is no GPS tracking data available. In asking practitioners in basketball what sorts of things they would like an athlete tracking system to measure, we typically get the following list:

1. Jumps
2. Accelerations
3. Decelerations
4. Intense direction changes (lateral accelerations, lunges)
5. Some measure of impact or physicality of the game
6. Free running events (eg unimpeded running from one end of the court to the other)

The Inertial Movement Analysis tool that Catapult has built using the method described above, we are now able to provide metrics around each of these categories. For instance jumps can be detected and categorised into low, medium or high. Intense direction changes can be detected and described in terms of their direction and magnitude. Decelerations leading to eccentric loading can be quantified even if they are very small movements (although sometimes very high G). Even if GPS was available in this environment, such decelerations would not be detected.

Summary
This paper has outlined two examples of innovations in athlete tracking technology from Catapult Sports. Catapult's ultimate goal is to measure everything about athletic performance that practitioners are interested in – especially in applications like team sports. Tracking balls and tracking small movements using inertial sensors are two very significant and innovative steps in this direction.
Further work is required for independent validation of these new tools in an elite sports environment.

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