Instrumented Sports Equipment: Performance Analysis for Athletes Coaches and Spectators the Future of Sports Technology

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Abstract

Instrumented sports equipment aims to reveal equipment-related data, which represent the performance of an athlete. The instrumentation of F1 racing cars is common and the data collected is visualized on the TV screen. Instrumentation of other sports equipment is sometimes limited by the size of the sensors as well as rules and design. The aim of this project was to 1) develop instrumented sports equipment with embedded sensors and modular design, which allows for simple and quick changes of the configuration based on the athletes requirements and which allows for simple and quick changes of the configuration based on the athletes requirements and which maintains the shape, mass, and inertial properties, 2) design means for data transfer and visualization of data, and 3) identify suitable performance indicators and parameters. In this specific project, a bowling ball and a climbing wall were instrumented with 3D force transducers, 3D accelerometers, and 6DOF force/moment transducers respectively. Both the ball and the wall are designed with modular components which allow flexibility of usage. The performance indicators of ten-pin bowling, identified with the instrumented ball, are the peak finger forces, the duration of the forward swing, the magnitude of impulse and moment applied to the ball. The performance indicators of sport climbing, identified with the instrumented wall, are the contact time, the normalized mean and maximal force, the impulse, the friction coefficient, the smoothness factor, the movement of the centre of pressure, and the fractal dimensions of the signal. Instrumented sports equipment intends to make sports more effective, scientific and interesting. The athlete benefits from instrumented sports equipment through optimizing the training process and improving the performance. The coaches and the sports science community benefit from data, which are accessible for analysis. The spectators benefit from exciting displays of data, which can only be captured with instrumented equipment. The huge business factor of instrument sports equipment is evident, as it is not only related to the number of product sold, but it also increases the number of spectators and participants. Instrumented sports equipment although still in its infancy, expected to significantly contribute to the future of sports technology.

Key words: Instrumented sports equipment, Sports technology, Performance analysis

Introduction

Online broadcasting of data during F1 racing (e.g., speed, position, throttle, brake, g-force etc.; Figure 1) has become a standard nowadays, due to the availability and wireless transmission of data. In other sports disciplines, data is not at hand due to lack of instrumentation. Although ubiquitous and pervasive computing, e.g. sensors embedded in smart products, is a well-established field, it enters the sports scene only very slowly. The reason for this is that instrumentation of equipment, and instrumentation of athletes is impeded by the size of suitable sensors.

Advanced performance analysis is based on continuously measuring the performance throughout the exercise or competition, rather than relying on a single value (winning time, jump height, etc.), or very few measurements (split times) representing overall performance.
Instrumentation in general for sports purposes extends to wearing and using sensors, as well as imaging (sands 2008). In other words, we can instrument the athlete, the sports equipment, and the environment (sports facilities). The latter is simply achieved by TV cameras, high speed video cameras, etc. The former two, however, are the challenges of sports technology and the data to be obtained constitute a personal value for the athlete, result into a business factor through attracting spectators, and serve the research within the sports community.

Specifically, the targets are; access to databases, injury prevention and treatment, improvement of information quality of life broadcasts, and quantification of performance and improvement of training through continuous online monitoring. The aim of this project is to

1) Develop instrumented sports equipment with embedded sensors and modular design, which allows for simple and quick changes of the configuration based on the athletes' requirements and which maintains the shape, mass, and inertial properties

2) Design means for data transfer and visualization of data, and

3) Identify suitable performance indicators and parameters

Figure-1

Live and Online Data Display during F1 Racing

So far several equipment have been instrumented by our research group, among these are table tennis bats, badminton racquets, racing wheelchairs, martial arts punching shields, bowling balls and climbing walls. The application of the latter 2 will be presented in this paper.

Equipment Design

a) Bowling ball; a conventional bowling ball was equipped with three 3D force transducers, a 3D accelerometer and a wireless data transmission system (figure 2).
The finger and thumb holes were replaced by tubes, connected to the force transducers serve to measure the forces and moments applied by the fingers to the ball during the swing; the accelerometer records the kinematics during the swing and the sliding/rolling/spinning motion after the release of the ball. The modular design allows for adjusting of the finger and thumb holes (spacing, angle), depending on the bowlers requirements. The ball is balanced and reproduces the same COM- offset and RG-differential.

b) Climbing wall and holds; conventional climbing holds were connected to a 6DOF force/moment transducer and there by transformed into a mini-force plate. The transducers, in turn, were connected to a climbing wall. The flexible design allows arranging the design allows arranging the climbing holds for any possible climbing holds for any possible climbing route (Figure 3).

**Figure-2**

**Design of the Instrumented Bowling Ball and the Final Product**

**Figure-3**

**Instrumented Climbing Wall**
Results

a) Ten-pin bowling: the performance indicators identified with the instrumented ball are the peak finger forces, the duration of the forward swing, the magnitude of impulse and moment applied to the ball. In better bowlers, the duration of the forward swing is relatively longer, the peak forces are relatively larger, and impulse and moment are relatively higher during the forward swing, with a good correlation of r>0. (Fuss et al. 2006, Khan, Fuss 2007). The larger forces are attributed to the relatively stronger grip during the forward swing in better bowlers.

Figure-4

Finger Forces; B& F=Back and Forward Swing; T, M, R=Thumb, Middle and Ring Finger; Left Beginner, Right; Elite Bowler

Figure-5a

Force Vector Diagrams, Straight Shot; Top Row; Elite Bowlers, Bottom Row; Beginners
b) Sport climbing; the performance indicators in sport climbing are the contact time, the normalized mean and maximal force the friction coefficient, the smoothness factor, the movement of the centre of pressure, and the fractal dimensions of the signal. The better the climber, the shorter the contact time, the smaller the forces, the impulse and the fractal dimensions, and higher the friction coefficient and the smoothness factor (Fuss et al. 2003a, 2003b, Fuss and Nigel 2006, 2007). The smoothness factor reflects how smooth the force is applied to the hold, and the fractal dimensions (Hausdorff-Besicovitch dimension) quantity the chaoticness of the signal. The difference between more and less experienced climbers is clearly visible in Figure 5a and b; in Figure 5a, the magnitude of the force vectors is smaller, the centre of pressure (origin of the force vectors) moves continuously over the surface of the hold, the force vectors are of almost the same length (smoothness), and the vectors are well inclined (high friction coefficient). The 3D force vector diagrams of a bouldering circle are indicated in Figure 5c.
Discussion

Instrumented sports equipment intends to make sports more effective, scientific and interesting.

The athlete benefits from instrumented sports equipment through optimizing the training process and improving the performance. The coaches and the sports science community benefit from data, which are accessible for analysis. The spectators benefit from exciting displays of data, which can only be captured with instrumented equipment.

The huge business factor of instrumented sports equipment is evident, as it is not only related to the numbers of spectators and participants. Further advantages of instrumented equipment are;

- Quantification of performance through other than conventional means (e.g., height, speed), as conventional means (result of a competition) measure the effect of the energy released to the environment (= performance). Instrumented equipment, however, measures the cause of the energy released.

- Quantification of energy transfer (conservative / non-conservative)

- Online measurement of performance with biofeedback support for improvement of consistency and optimization of motion and position.

Literally any equipment can be instrumented, provided that the sensors do not alter the shape, mass, and inertial properties, nor distract the athlete. A typical example is the adidas_1 Basketball shoe which provides intelligent cushioning through a magnetic sensor at the heel, a magnetic sensor at the heel, a microprocessor, and a motor-driven spring. Unfortunately, the data is not stored and subsequently lost. It would be of advantage to store the data and to analysis those as to the activity pattern of an athlete, or as to causes of injuries.

The same principle applies to common exercise machines, which are instrumented to a certain degree, but do not allow to retrieve the data for further analysis. Exercise machines equipped with a USB port and standardized software for data analysis would optimize the work-out and contribute to global health.

Instrumented sports equipment is still in its infancy but will significantly contribute to the future of sports technology.

References

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