Analyzing tennis game through sensor data with machine learning and multi-objective optimization

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Problem

- Wearable sensors in sports found increasingly valuable and popular
- Tennis-specific solutions too limited (wrist devices) or too cumbersome and expensive (video systems installed at courts)
- Commercial devices offer rich information on movement and effort, but lack tennis metrics

Solution

- Use a commercial device (Catapult Sports S5), and add tennis metrics
- Step 1: detect shots and classify them into serves, forehands and backhands
- Step 2: detect active play to know how long each rally is (the time from serve to a point scored), and to disregard other activities

Shot detection – machine learning

Inputs: accelerometer, gyroscope and GPS data from real matches of five professional players

Features:

- Average, variance and standard deviation for each accelerometer and gyroscope axis for window sizes of 0.8 s and 1.2 s
- Movement speed from GPS
- Strength of peaks in gyroscope signals
- Areas between gyroscope signals related to back swing, shot and return to default possition

Algorithm: Random Forest

Evaluation: Leave-one-player-out cross-validation

	Precision	Recall
Forehand	91.5 %	90.5 %
Backhand	93.6 %	90.6 %
Serve	99.8 %	98.2 %
All	95.0 %	93.1 %

Active play detection – optimization

Inputs: accelerometer data as for shot detection

Features:

- Modified variance emphasizing large variations:

$$var^* = \frac{\sum_{i=1}^{N}(x_i - \bar{x})^4}{N}$$

- Back variance (*BV*) and forward variance (*FV*): sum of var^* before and after a potential beginning or end of a rally
- Difference between the variances *DV* = *BF* – *FV*

Rules to detect a rally:

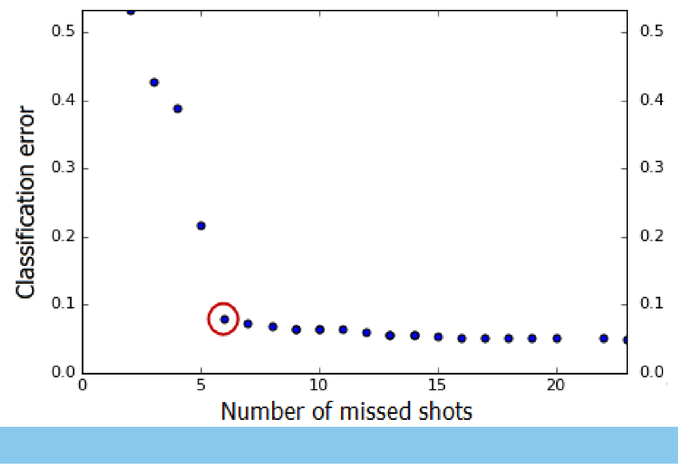
- Beginning: (*DV* > *p*1) & ((*BV* < *p*3) || (*FV* < *p*4))
- End: (– *DV* > *p2*) & ((*BV* < *p*3) || (*FV* < *p*4))

Big difference between a rally and inactive play

There should be little activity before beginning and after end of rally

Multi-objective optimization: Find such *p*1, *p*2, *p*3 and *p*4 that active play is recognized accurately, and few shots are outside active play.

Evaluation:



Game analysis

Graphical presentation:

- Green = heat map of player location during active play
- Blue = forehand, red = backhand
- Size of points = shot strength
- Dashed line = area with more forehands vs. more backhands

Analysis: More aggressive (= closer to the baseline) on the left. Less aggressive on the right, but more forehands (= better shots) to control the game.