Change of Direction Analysis Using Foot-Mounted Sensors

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1. Introduction

In recent years, as sports are being ushered into the big data era [2], the attitude towards athlete training and classification and talent identification leans towards scientific analysis and data-driven decision making, rather than subjective interpretation.
This approach, though proved to provide important insights, is still somewhat limited due to lack of some key features affecting the athlete's physical conditions. For example, in football (soccer), current match analysis is mostly based on velocity and accelerations in a linear model, while running forward in a straight line. In this article a new layer of analysis is introduced: Turns and change of directions.
These elements were chosen due to their significance in analyzing athlete motion in a dynamic sport such as football [3,4,5,6]. Turns are considered a high-load motion [7], where most acute changes of direction apply great forces to the feet, knees, tendons and muscles, as the motion is often not planned and comes as a quick reaction to events on the field [1].

Traditionally, the ability to efficiently change direction, sometimes referred to as agility, is tested with short-termed, high-intensity drills [4,5]. As those drills are some of a benchmark for numerous talent identification processes, they usually rely on time measurements of specific motion segments, and they are performed in a supervised, controlled manner. As the controlled scenarios are not taken from real match scenarios, it is difficult to use this data to make any assumptions on the relation between recorded controlled performance and uncontrolled match scenarios. Analyzing a player's dynamic behavior, specifically change of direction, during match time, may reveal important information about how players play the game.

2. Methods

For this project, 12 different users were recorded, each wearing two Playermaker sensors, one on each leg. These IMU sensors report all the strides performed by the users as well as stride parameters such as distance, duration, contact time and angles. It also provides the user speed and information regarding the user ball possession and handling. The users are from a youth male academy team. In the data at hand, the players are taking part in a training match, which lasts for 60 minutes.

Change of direction in this work is defined as a combination of two parameters: angle of rotation and entry speed. As a preliminary step, Playermaker’s motion parameters allow for the detection of turns in each of the user sensors’ signals. This was developed by comparing the sensors’ output and predefined validation videos captured with video cameras. An example for a turn is shown in figure 1.

Here, a turn is defined as a sequence of strides that starts and ends with a forward stride and has an intermediate change of direction phase. The change of direction phase may include multiple strides. As with the turns, forward strides are automatically detected with high accuracy, which helps framing the desired events.

The turn rotation angle is defined as the difference in motion angles between the first stride of the segment and the last one. The entry speed is the speed at the first stride of the segment.

Changes of direction were also compared with and without the ball, utilising the touch detection algorithm [9]. In the three photos below (Figure 1), the motion of a 180-degree turn is described. The first photo shows the approach towards the turn - The body decelerates and the entry speed is extracted. The second photo shows the actual rotation phase during the change of direction. One foot is used as a pivot as the body turns. This foot experiences the highest load during the entire motion flow. The third photo shows the player after the rotation is complete.

Figure 1 – Diagram of general 180-degree change of direction during the 5-0-5 drill

In the following sections we show the data that was extracted using Playermaker's sensors that is relevant to this research, and discuss the applications that this and future work may support.

3. Results

Figure 2. shows the number of turns, as defined in the methods, for each participating player in the match.

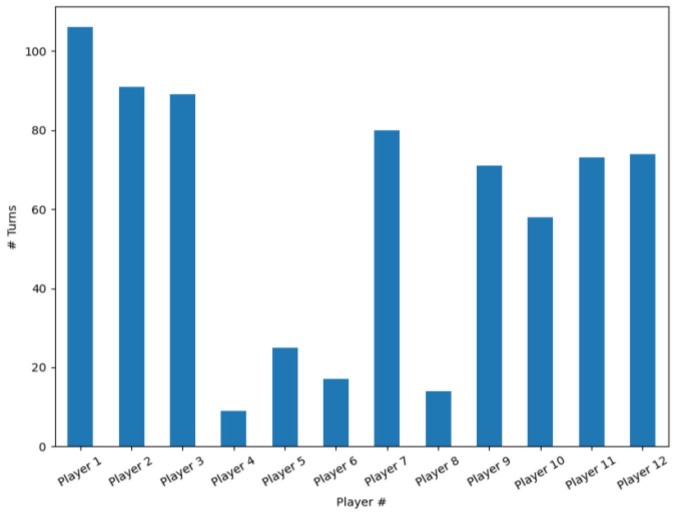

Figure 2 shows 8 out of 12 players (75%) performed over 50 turns during the session, while the others show less than half of that. The difference between players may raise several questions, with different applications for different answers: what role did the player play? As goalkeepers are less active than midfielders that run up and down the pitch. What was the number of turns per player per minute of play time? Differences between players are either due to less turns taken during play time by some players, or because some players played less minutes than others. In this case, the four players with the least number of turns played only one half-time.

Significant reduction in the number of turns have a number of potential implications depending on the information provided by coaching staff and club practitioners. It is therefore recommended to add context into future analysis for clubs in order to decipher if these reduced turns are a consequence of fatigue, load management, strength/ ability to perform turns or perceived effort of the player. Understanding the required turns performed in a match for each player, can help present this data relative to the capabilities or demands of match play on that player.

As discussed in the methods, in this work turns are defined using two parameters - entry speed and angle of rotation. Figure 3 shows the relation between the rotation of the turn and the entry speed coming into the turn. The frequency of turns (between 0-90 degrees) is reduced when a player turns at a larger angle of rotation and approaches at higher velocities (Figure 3).

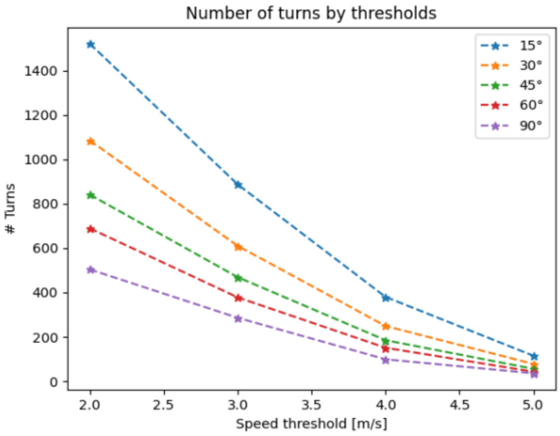

Figure 3 - Number of turns as a function of entry speed and angle of rotation.

Figure 4 shows the two dimensional polar histogram of turn rotation angle and entry speed at all angles and speeds observed. The user approaches the turn from below ("-180 degrees") and then turns at the center of the circle. This plot shows turns from 180 degrees to the right (clockwise, negative values) up to 180 degrees to the left (counter clockwise). The warmer the color, the more prevalent the parameters' combination is in the data. In figure 4, most data points are between -45 and +45 degrees, but vary in speed. The wider the angle of rotation, higher speeds are less common.

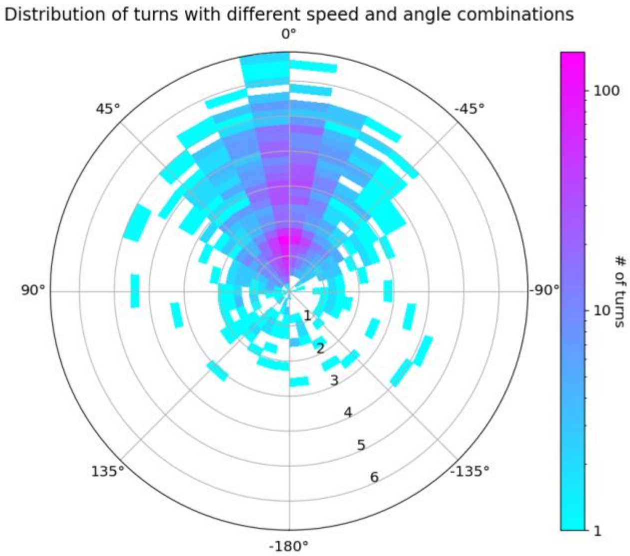

Figure 4 - 2-D histogram of turns parameters. The color represents the frequency of observations in the data. The width and length of each colored rectangle represents a range of angles and speeds the observations cover.

To provide an example for the interpretation of figure 4, the area around the digit "3" represents turns in which the entry speed is 3 m/s and the rotation angle is about
155 degrees, clockwise. The faster a player approaches the turn, it is less likely that they will rotate sharply within this example.

As this was within a training environment of young players, it is unlikely to see players bringing themselves to the extreme. In a formal match, one would expect to see more effort being put into turns, which will increase the frequency of sharp and quick turns, which in turn expands the variation we see in this figure.
Another interesting analysis is comparison of the performance with and without the ball. Since players most of the time move without the ball, the number of turns with the ball is typically a small fraction of the total number of turns. In order to compensate for this bias, the turns frequency is compared rather than the total turns count. The

turns frequency of each player is defined as the number of turns divided by the total distance.

The frequency was calculated for individual ball possessions and for the complementary times, when the player didn't possess the ball.

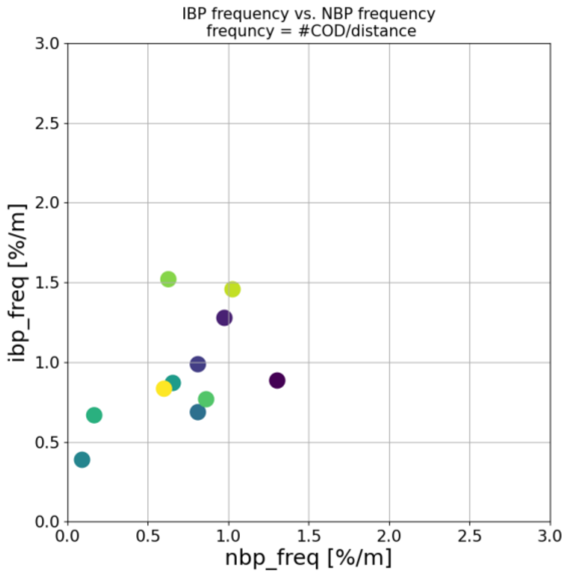

Figure 5 - Relation between frequency of turns with and without the ball, per player.

Figure 5 shows the relation between individual ball possession frequency (ibp_freq) and the complementary frequency (nbp_freq).
It is observed that the data is between 0.0 - 1.5 [%/m] for both dimensions.

9 out of the 11 recorded players are clustered between [0.5-1.4, 0.6-1.6].

This mapping can be used to compare between players in a single team or between teams.
Higher frequency in times of ball possession may suggest a higher level of technical skill.
Higher frequency in times without the ball may suggest a higher level of physical stamina.
This information may also be used as assessment for injuries, whether as a prevention tool or some reference for recovery.

4. Discussion

The main conclusion from this work in the mind of the writer of these lines is the emerging relation between how fast a player approaches a change of direction, and how intense the rotation might be. This of course is highly dependent on athletic ability, physical build, fitness level and age of the player.

Building on top of the idea suggested in [1], in the figure below (figure 6) we try to visualize the relation between speed, rotation angle, and change of direction strain on the player.

The angle is the turning angle when the athlete approaches from below and turns on the center of the circle. The innermost circle represents jogging speed while outer rings represent higher speeds. The colors represent different load levels: Green, yellow and red for low, medium and high change of direction load, respectively. The areas used in this plot are only for visualization.

The outer circles depict higher speeds, wherein the intensity is higher for a wider range of angles.
This plot is merely how we see the combination of speed, rotation and load intertwine to lead players to a more sustainable training and performance policy. Different players have different techniques for turning. Different techniques result in different loading mechanisms on the muscles, tendons and bones. On a wider perspective, the data necessary to build such a plot for each individual, relies on the speed and angles of rotation as we showed in this work, and on top of that some calculation of forces acting on the feet. With this information we can find correlations and causality between speed, rotation angle and load.

This information may help monitoring players' effort and strain over time, trying to avoid injuries and allow necessary resting periods. It can also provide a more comprehensive understanding of a match's physical demands, thus improving the training session planning to better prepare the players for the match.

If a player made X turns in high intensity (the red zones in figure 6) over a period of time, they might be considered to spend more time resting, stretching and treating specific muscles that worked extra time.

This work is a base for future projects regarding load estimation, injury prevention and recovery, and physical and technical evaluation for football players.

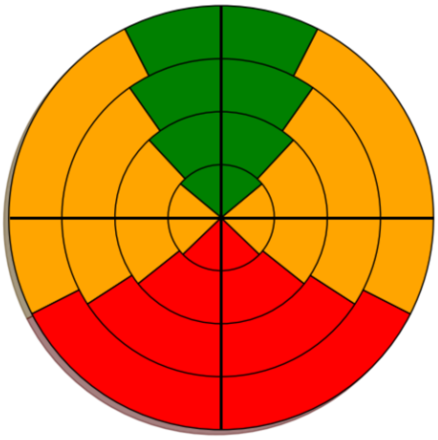

Figure 6 - Qualitative description of the relation between entry speed, angle of rotation, and physical load.

The results we show in this work align with previous projects in this field of sports science. In [8] the authors describe a similar relationship between speed during turns and the angle of rotation, using a positioning system. This is another validation to Playermaker's sensors, able to extract both correct and reliable data from the feet of athletes.

Playermaker, with its innovative motion features, is attempting to analyze the actual motion parameters that take part in achieving an efficient change of direction, in an uncontrolled environment, where athletes perform in their most intense yet natural way.

Being informed on the way athletes, whether they are professionals, semi-professionals, or youth academy individuals, change direction may provide ways to both improve performance and maintain it over time.

Understanding how this speed-angle-load tradeoff looks for different athletes with vs. without the ball and over time, will yield important value to squads and individuals in their perspective on physical and technical performance, improvement, and identification.

5. References

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