Analyzing performance in Orienteering from movement trajectories and contextual information

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Abstract. This paper presents a framework to automatically analyze the performance of elite orienteers under the consideration of the slope and of a wide-range of vegetation types. We test our approach using data of four different competitions of the European Orienteering Championships 2018. Two use cases of the framework are presented: first, the analysis of the speed and slope on a competition level and second, the analysis of the speed as a function of the vegetation type either on a competition level or on an individual athlete level. The presented framework can be used efficiently across multiple data sets and by coaches and athletes to develop new strategies for training or competitions.

Keywords. orienteering, data analytics, context

1. Introduction

The monitoring of sports activities in amateur and professional settings has become ubiquitous due to the availability of small and low-cost GPS receivers. In orienteering, a sport where an athlete runs at speed from control point to control point using a map and compass, the tracking serves two main purposes: For live coverage of events to make the invisible runners visible for spectators and moderators, and for post-analysis of the athlete performance. In the second case, the availability of high-resolution data, topographic maps, and further contextual data, allows to reconstruct the race, analyze route selection decisions and compare the performance to other competitors (Gasser, 2018).

Despite these advantages, the ubiquity of GPS tracking results in large data quantities requires automated data processing methods for efficient analysis. In orienteering, performance of orienteering athletes based on context data

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focuses mainly on tests under laboratory conditions (Lauenstein, Wehrlin, & Marti, 2013; Zürcher, Clénin G, & Marti, 2005) or in the outside on prepared test courses (Amouzandeh & Karimipour, 2017; Hébert-Losier, Jensen, Mourot, & Holmberg, 2014). Furthermore, studies often do not consider vegetation context in their analysis or only consider few vegetation types (Hébert-Losier et al., 2014). For further information on related work, we refer to the review done by (Amouzandeh, Karimipour, Chavoshi, & Tveite, 2016).

Here we present a framework to analyze the performance of orienteers in competitions under the consideration of a large variety of vegetation types and the slope of the terrain. Our framework provides the means to compare the vegetation type dependent performance to athletes of the same race.

2. Methods

To analyze the context dependent performance of elite orienteers, raw tracks are enriched with context data. We assume that the individual trackpoints consist of timestamps, geographic coordinates and the current speed. Vegetation data comes from the same topographic maps that are used by the orienteers during competition. These orienteering maps provide information about control points.

For the context integration, we represent vegetation and terrain type information as polygons or lines, and the tracking data as a set of trajectory segments by connecting consecutive tracking points of the same athlete. To join the line segments with the context information, we perform the following data preparation steps:

- **Streets**: Streets are encoded as a line geometry. To account for imperfect GPS accuracy, we apply a 10m buffer around all road types.
- **Overlapping vegetation**: The geometries of the available vegetation data can overlap. To enable the association of a trajectory segment with a unique context type, we define a matching hierarchy[1] and associate each trajectory segment only with the vegetation type with the highest priority.
- **Non-unique relations**: Each trajectory segment can span over multiple vegetation types. To associate line segments with a unique vegetation type, we split the trajectory segments whenever they cross the boundary between two polygons. Therefore, a new tracking point is created at the

[1] Vegetation types (see footnote 6) ordered by their priority (20 = highest priority). Priorities are printed in boldface - 1:405; 2:401; 3:402; 4:403; 5:404; 6:310; 7:407; 8:409; 9:414; 10:406; 11:408; 12:410; 13:411; 14:508; 15:507; 16:506; 17:505; 18:504; 19:503; 20:502

boundary of the polygons, and it is associated with the average speed of the two original trackpoints.

- **Slope information**: Every trackpoint is associated with the elevation information from the digital elevation model swissALTI3D[2] with 2m resolution. The slope of every segment is calculated as $\frac{h_{i+1}-h_i}{dist(t_{t+1},t_i)}$, where h_i is the height of the i^{th} trackpoint and $dist(\cdot,\cdot)$ calculates the Euclidean distance between two trackpoints.

The line segments can then be associated with the context type using a simple spatial join. The result of this process is that each trajectory segment is associated with information about the vegetation type, the average speed and the average slope.

3. Case Study

To test the framework, we apply the segmentation method described in section 2 to four different competitions of male elites, which all took place during the European Orienteering Championships 2018 (EOC18) in Ticino, Switzerland[3] (Table 1).

Competition	Carona (c1)	Serpiano (c2)	Capriasca (c3)	Capriasca (c4)
Date / Weather	08.05.2018 / dry	09.05.2018 / dry	12.05.2018 / dry	13.05.2018 /dry
Type	Middle quali	Middle final	Relay	Long
Tracks	10	19	52	31
Segments	3692	18545	55414	78864

Table 1. Orienteering Data Sources of EOC2018

Tracking data from the EOC18 was recorded per competition and athlete with a sampling rate of 3 seconds using GNS 3301 receivers and are available online[4]. We discarded invalid tracks (e.g. multiple large jumps) based on visual inspection, parsed all tracks in a PostgreSQL database with PostGIS extension, and deleted all points that were recorded before the first or after the last control point. Furthermore, we deleted all trackpoints with implausible running speed (> 8 m/s) and points that are not within the competition area. As a source for the vegetation data we used the official competition maps that were provided in the OCAD format by the EOC18 organizers. The maps are based on the schema of the International Orienteering Federation (IOF). We exported vegetation and terrain type including their geometry as a shapefile

2 https://shop.swisstopo.admin.ch/en/products/height_models/alti3D
3 http://www.eoc2018.ch/eoc2018/news.html
4 https://www.tulospalvelu.fi/gps/?year=2018

and merged underrepresented categories with similar ones (IOF terrain type code[5] in parentheses), e.g., we merged paved area (501) into wide road (502). Furthermore, the forest (405) is not explicitly drawn on the map but corresponds to the background color. Therefore, we define all areas that do not explicitly belong to IOF-categories as forest (405).

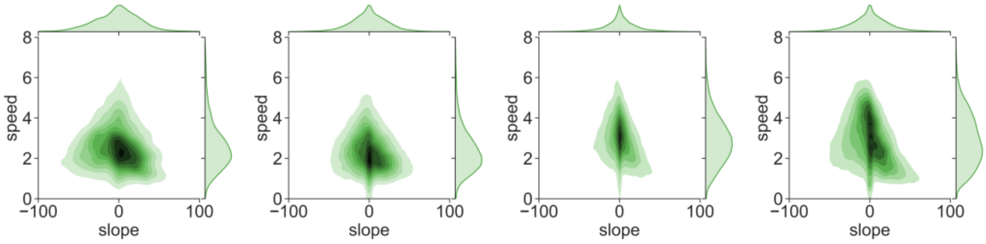

Figure 1. Speed-slope distribution for the different competitions (L to R: c1, c2, c3, c4; speed in m/s, slope in %).

3.1. Speed vs. Slope

Figure 1 shows the joint distribution of running speed and slopes of all segments for the different competitions as well as their marginal distributions. The joint distribution shows the expected correlation between running speed and slope. However, this dependency is not linear but shows an optimal slope between -3% and -7% depending on the competition.

3.2. Speed vs. Environment Type

Figure 2 shows a box plot to visualize the speed distribution of all segments depending on the vegetation type. The plot is from Capriasca (c4) and consists of fast segments (slope between -25% and 5 %, and median speed > 3 m/s). The median values show that the better the ground (streets) the better the performance. While indistinct marsh (310) shows unexpectedly good values, easy to run forest (405) shows unexpectedly bad values compared to paths, roads and open areas. Vegetation resulted mostly in worse performance. An additional value for orienteers is the possibility to compare their performance to their peers. Figure 2 shows the median of the best athlete (blue) and the median speed of a randomly selected athlete (pink) as line plot for every vegetation type. The graph demonstrates that the best athlete

avoided less distinct small footpaths (507) and performed dominantly in difficult to run terrain like undergrowth vegetation (409). The figure shows that

[5] https://www.fiso.it/_files/f_media/2018/02/15021.pdf

the selected athlete (pink), performs significantly worse in (409) and also on footpaths (505).

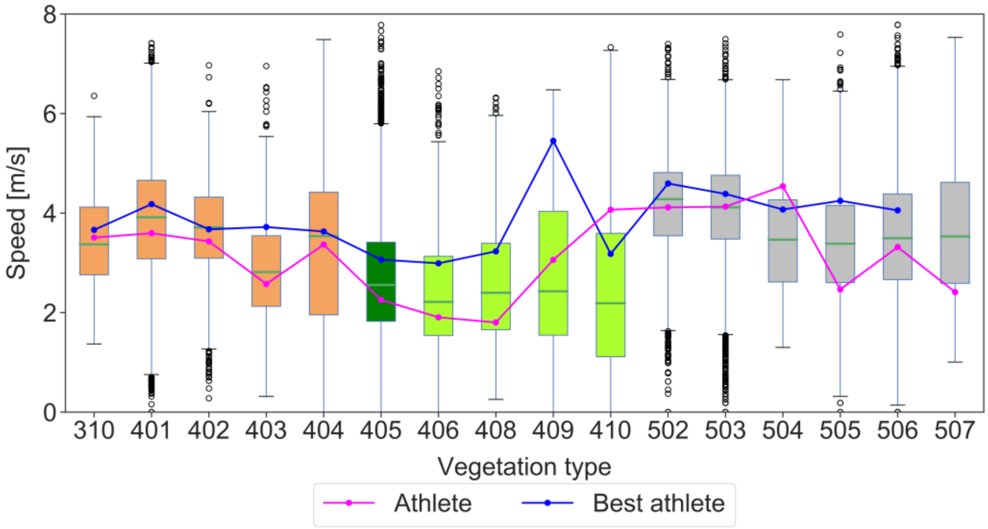

Figure 2. Speed vs. vegetation type[6] by the terrain codes of IOF from Capriasca (c4)

Comparing all four competitions in that way, shows if and where an individual runner has significant deficits. Such findings are important insights for future competition strategies and training plans for coaches and athletes.

4. Discussion and Outlook

The presented approach allows analyzing running speed of all or individual athletes depending on the environment type and slope on a large scale. The automated analysis has the potential to generate new insights for context dependent performance in orienteering. Furthermore, the possibilities to reconstruct the competition and to compare the context dependent performance of individual athletes allows to optimize training sessions and to create better strategies for future competitions.

The possibility to process tracking data of competitions on a large scale and in realtime can revolutionize the experience of spectators in front of the television and on site.

6 **Open Areas**: (310) Indistinct marsh, (401) Open land, (402) Open land with scattered trees, (403) Rough open land, (404) Rough open land with scattered trees / **Forest**: (405) / **Forest Vegetation:** (406) Vegetation, slow running, (407) Vegetation, slow running, good visibility (408) Vegetation, walk, (409) Vegetation, walk, good visibility, (410) Vegetation, fight / **Street**: (502) Wide road, (503) Road, (504) Vehicle track, (505) Footpath, (506) Small footpath, (507) Less distinct small footpath

Most analyses have been made so far based on GPS, slope and environment. Future work could take more context into account such as human biological and cognitive factors, and further environmental factors. This results in an infinite number of further research possibilities in the field of orienteering.

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