Exploring Spatio-Temporal Patterns in Sport Movement Observations

Kimia Amouzandeh*, Farid karimipour*, Seyed Hossein Chavoshi*, **, Havard Tveite**

*School of Surveying and Geospatial Engineering, College of Engineering, University of Tehran
**Department of Mathematical Sciences and Technology, Norwegian University of Life Sciences

Abstract. Analysis of movement data is becoming more popular in several applications. Most of the attempts that has been made on this line of research to analyze movement sport data have focused on spatial aspects of the movement to extract some movement characteristics, such as patterns and similarities. In this research, we propose examining the behavioral movement patterns of athletes by analyzing changes in different movement attributes (e.g., speed and heart rate), which is categorized under the general term of "analysis of movement observations". An example data set of the movement observations acquired during the "orienteering" sport is presented and shortly discussed.

Keywords. Spatial movement analysis, Movement observations, Spatio-temporal patterns, Orienteering.

1. Introduction

The spatio-temporal analysis of movement data is a recent trend of research in GIScience. Recent and emerging positioning technologies have resulted in significant increases in the availability of highly accurate data on moving phenomena (Gudmundsson et al. 2011). Thus, new exploratory tools and knowledge discovery techniques are required to extract meaningful infor-

Published in "Proceedings of the 13th International Conference on Location-Based Services", edited by Georg Gartner and Haosheng Huang, LBS 2016, 14-16 November 2016, Vienna, Austria.

mation, discover interesting patterns, and explore the dynamic behavior of moving objects. Especially, analysis of movement observations, which contain information about the movement of each individual entity and the underlying mechanisms, are of great interest. These observations are key to the study and understanding of movement (Dodge et al. 2016). In this case, in addition to the positional movement data, some set of ancillary observations that describe objects behavioral and cognitive proceeds are employed to study the behavioral movement patterns and their impacts on the target object.

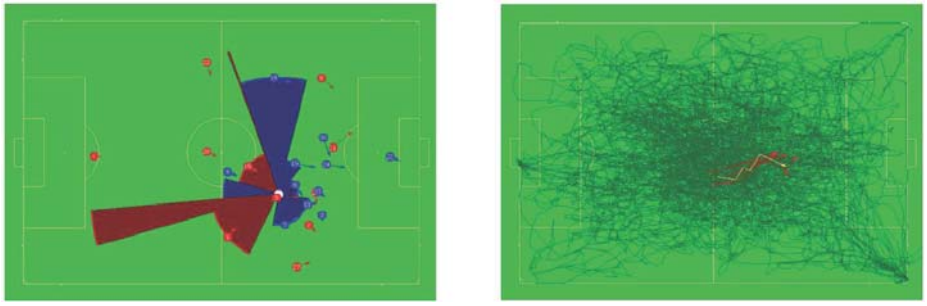
Analysis of movement data is becoming more popular in several applications. In particular, attempts have been made to analyze movements in sport scenes (Gudmundsson and Wolle 2010; Memmert and Perl 2009; Taki and Hasegawa 2000). However, they have mostly focused on spatial aspects of the movement to extract some movement characteristics, such as patterns and similarities. This research proposes examining the behavioral movement patterns of athletes by analyzing changes in different movement attributes (e.g., speed and heart rate) of each individual athlete through a competition. We believe analyzing the athletes' movement observations in terms of space (x, y, z) and time (t), through considering movement attributes of each athlete and contextual information (e.g., the environmental information such as temperature) will direct us to better understanding of behavioral movement patterns of athletes. In other words, we aim to identify the effect of athletic status (e.g., elite vs. amateur) and of surface (e.g., road vs. path vs. forest) on the movement patterns. As the first step, this paper considers movement observations of "orienteering" sport and visually analyses them to discover simple movement patterns. The initial results verify that such movement observations contain a significant level of information in order to be exploit in extracting more sophisticated behavioral movement patterns.

The rest of the paper is organized as follows: Section 2 shortly reviews the previous efforts to analyses sport movement data. In Section 3, orienteering sport is introduced and an example data set of the movement observations acquired during the orienteering task is presented and shortly discussed. Finally, Section 4 introduced the future line of the research.

2. Analyses of Sport Movement Data: A Review

Movement is a key element of many processes and activities. Understanding of the movement itself, as well as the patterns of movement is very important in many areas of science and technology (Dodge 2011). Capturing of trajectory data at fine temporal and spatial granularities has allowed representation, and concequently analysis, of detailed geospatial lifelines. Especially, coupling such data with field observations enable ex-

traction of movement patterns that contain information about preferences regarding individual decision-making and locational choices.
Professional sports have widely been influenced by such analyses. For example, Gudmundsson and Wolle (2010) deployed trajectory clustering techniques to study frequent movements of an individual football player and groups of players (Figure 1). In the same regards, Taki and Hasegawa (2000) analyzed the movement of each player and extract the players' dominant regions, i.e., the area where a player has priority over others. They then analyzed the distribution of dominant regions. This model has been extend by Fujimura and Sugihara (2005) and by Kang et al. (2006) by including an advanced modelling of human movement. Even, some software has been developed to automatically provide basic statistical information (e.g., speed of players, player average position, number of passes performed by players), which are then used by coaches to analyze the performance of the players and choosing the best strategy.



(a) (b)

Figure 1. (a) Passable regions visualized with red (to players in the same team as the ball holder) and blue (to players in the opposite team); (b) Movement of a player, and a cluster of frequent movements highlighted in red (Gudmundsson and Wolle 2010).

As discussed, the previous efforts to analyses sport movement data have mostly focused on spatial aspects of the movement to extract some movement characteristics, such as patterns and similarities. An exception is Hollman et al. (2007), which examined the effect of age on gait velocity and stride-to-stride variability during normal and dual task walking conditions. There are also research that studies the effect of different situations on runners' biomechanics (Bert-Losier et al. 2015; Hébert-Losier et al. 2014).

3. Spatio-Temporal Patterns in Sport Movement Observations: The Case of Orienteering

This research proposes examining the behavioral movement patterns of athletes by analyzing changes in different movement attributes (e.g., speed and heart rate). Orienteering is selected as a case study. Orineterring is a family of sport that requires navigational skills using a map and compass to navigate from point to point in diverse and usually unfamiliar terrain, and normally moving at speed. There are two major forms of orienteering competition (Scouts 1995):

- *Score (- or free) orienteering:* Here, many checkpoints are placed in an area of 1 to 2 kilometers around the starting point, which is also considered as the finish line, with different scores depending on the distance to the start point or the level of difficulty to find. Competitors have a set time to find as many checkpoints as they can (in any order they wish) and earn as large a total score as possible. Therefore, they must judge the time well and evaluate their abilities to run and read orienteering map to score.
- *Cross-country (- or point-to-point) orienteering:* In this case, every competitor must visit the same checkpoints in a numerical order, and as quickly as possible. This form of orienteering is a challenge in route choice and stamina.

In the both forms of orienteering, competitors choose their route around the course. Hence, they confront many possible challenges such as terrain barriers or obstacles, artificial features, level of physical fitness and so on. For instance, if a hill sits between competitor and the control exists, a good rule of thumb is that 15 meters of climb is equal to running about 100 meters on flat ground. Hence, a 45-meter hill will be equivalent to running 300 meters; and if the competitor can contour around the hill in less than 300 meters, then he should choose around rather than over.

Figures 2 and 3 respectively illustrate the path taken by an orienteering athlete, and its corresponding movement observations, including altitude, heart rate, speed, as well as the land cover. We have divided the path into several sections based on the land cover, and computed the duration, distance, and thereby, the average speed of each section, hoping that relations can be found between these parameters in (1) an individual section, (2) sections of the same type, and (3) the whole path. This will be performed in the next steps of the research through extensive computational analyses. However, for the time being, some relations can be seen visually. For example, the heart rate has significantly increased at the very start of the path; Or in the first half of the section 3, where the land cover is forest, the altitude is

ascending, which caused an increase in the heart rate although the speed is reducing. However, in the second half of this section, the altitude is descending, thus it does not influence the heart rate; instead the heart rate is in direct relation with the speed.

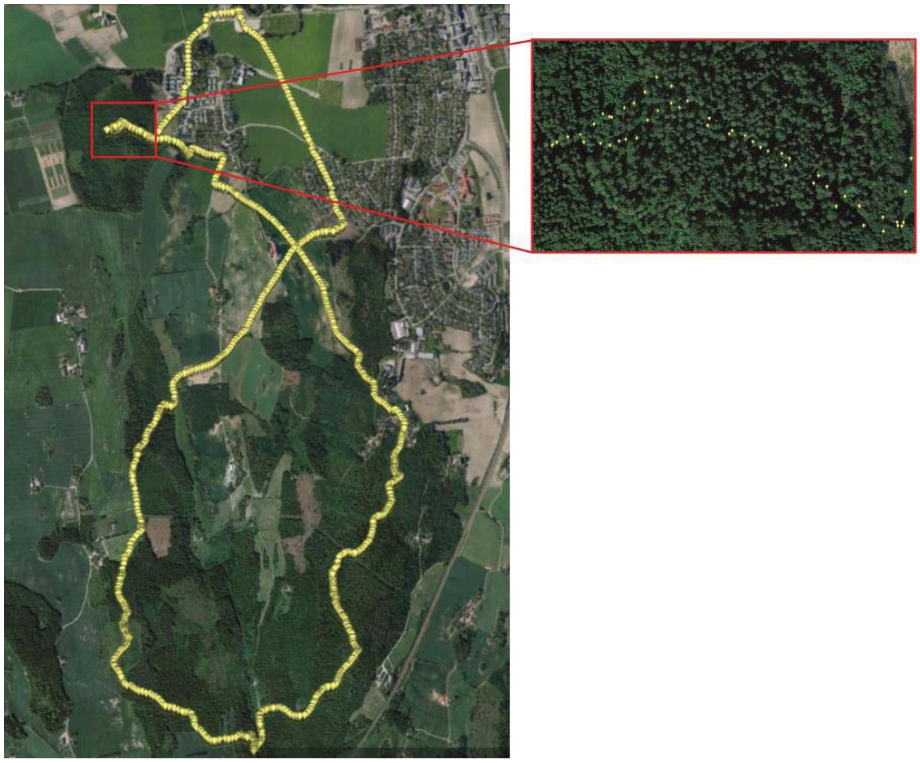


Figure 2. The path taken by an orienteering athlete. Right figure shows the path corresponded to the Section #3 in Figure 3 in more details.

4. Future Research's Direction

This paper proposed the idea of examining the behavioral movement patterns of athletes by analyzing changes in different movement attributes (e.g., speed and heart rate), which we believe leads to better understanding of behavioral movement patterns of athletes. Here, we only presented a type of such information for a path taken by an orienteering athlete, in which some patterns can be visually detected. However, complete exploration of the patterns needs sophisticated computational analyses. For example, we are going to take advantage of sequence analysis techniques to investigate and explore transformed movement data into time-dependent sequences.

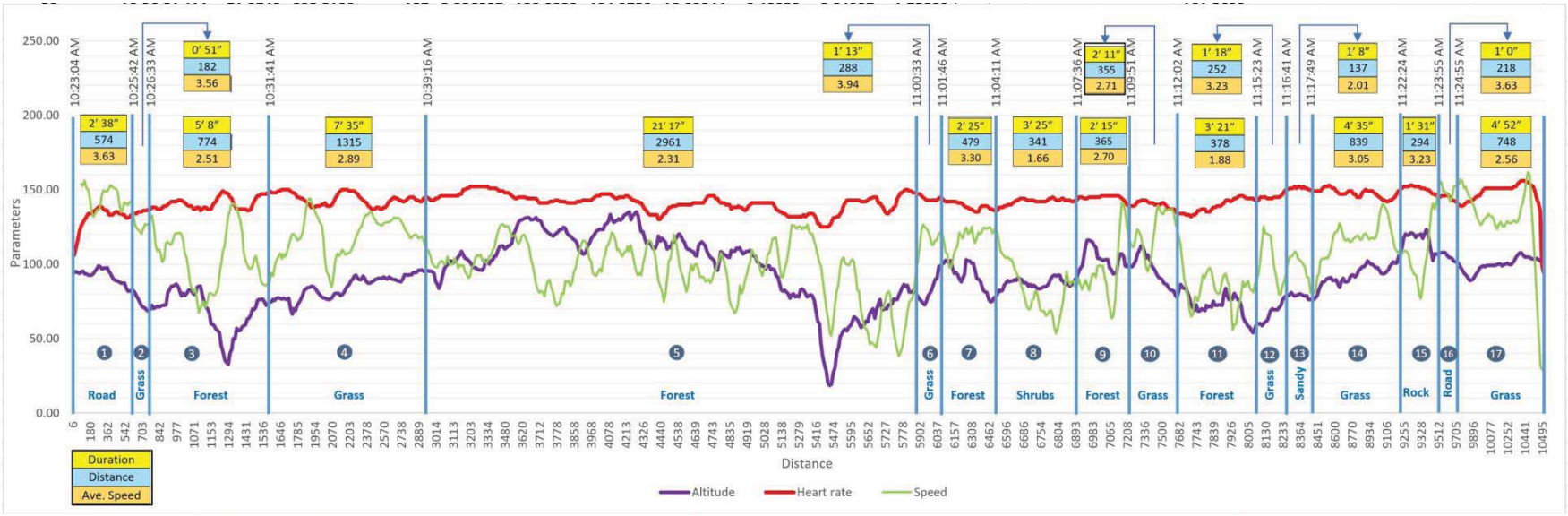


Figure 3. Movement observations corresponded to the path illustrated in Figure 2, including altitude, heart rate, speed, as well as the land cover.

References

Bert-Losier, K., L. Mourot, and H.-C. Holmberg. 2015. Elite and amateur orienteers' running biomechanics on three surfaces at three speeds.

Dodge, S. 2011. Exploring movement using similarity analysis.

Dodge, S., R. Weibel, S.C. Ahearn, M. Buchin, and J.A. Miller. 2016. Analysis of movement data. *International Journal of Geographical Information Science* 30: 825-834.

Fujimura, A., and K. Sugihara. 2005. Geometric analysis and quantitative evaluation of sport teamwork. *Systems and Computers in Japan* 36: 49-58.

Gudmundsson, J., P. Laube, and T. Wolle. 2011. Computational movement analysis. In *Springer handbook of geographic information*, 423-438: Springer.

Gudmundsson, J., and T. Wolle. 2010. Towards automated football analysis: Algorithms and data structures. *Proc. 10th Australasian Conf. on mathematics and computers in sport*.

Hébert-Losier, K., K. Jensen, L. Mourot, and H.C. Holmberg. 2014. The influence of surface on the running velocities of elite and amateur orienteer athletes. *Scandinavian journal of medicine & science in sports* 24: e448-455.

Hollman, J.H., F.M. Kovash, J.J. Kubik, and R.A. Linbo. 2007. Age-related differences in spatiotemporal markers of gait stability during dual task walking. *Gait & posture* 26: 113-119.

Kang, C.-H., J.-R. Hwang, and K.-J. Li. 2006. Trajectory analysis for soccer players. In Sixth IEEE International Conference on Data Mining-Workshops (ICDMW'06), 377-381: IEEE.

Memmert, D., and J. Perl. 2009. Game creativity analysis using neural networks. *Journal of sports sciences* 27: 139-149.

Scouts, B. 1995. Orienteering(Merit Badge). *Irving, Texas*.

Taki, T., and J.-I. Hasegawa. 2000. Visualization of dominant region in team games and its application to teamwork analysis. In Computer Graphics International, 2000. Proceedings, 227-235: IEEE.