ANALYSING LONG TERM SPATIAL MOBILITY PATTERNS OF INDIVIDUALS AND LARGE GROUPS USING 3D-GIS: A SPORT GEOGRAPHIC APPROACH

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ABSTRACT

Individual mobility and human patterns analyses is receiving increasing attention in numerous interdisciplinary studies and publications using the concept of time-geography but is largely unknown to the subdiscipline of sports geography. Meanwhile the visualization and evaluation of large data of individual patterns are still a major challenge. While a qualitative, microscale view on spatial-temporal topics is more common in today's pattern research using mostly 24h time intervals, this work examines a quantitative approach focusing on an extended period of life. This paper presents a combination of time-geographic approaches with 3D-geoinformation systems and demonstrates their value for analysing individual mobility by implementing a path-homogeneity factor (HPA). Using the example of professional athletes, it is shown which groups display greater similarities in their career paths. While a high homogeneity suggests that groups make similar decisions through socially influenced processes, low values allow the assumption that external processes provide stronger, independent individual structures.

Key words: geovisualization; sport geography; time geography; 3D GIS analysis; individual mobility; path analysis

INTRODUCTION

Despite the fact that sport is an omnipresent element of today's society, the discipline rarely finds its way into the academic context. This paper uses pro athletes as the focus group. This may seems atypical but is very useful: Often overlooked as a 'martial' addition to everyday life, sport is a ubiquitous societal phenomenon that offers numerous opportunities for geographical research. The analyses and data can therefore be linked to the field of sports geography. This little-known subdiscipline of geography focuses on the interaction between sports and space (Rooney 1975; Bale 2003). In this context, sport is to be understood as a socio-cultural or spatial movement practice of modern societies. The essential task of a modern sport geography is the mutual interpenetration of sport, space and society. It deals with the interdependence of those socio-cultural and spatial mechanisms that have an effect on sporting practice and thus condition the constitution of sporting space (Peters & Roth 2006). A major element of sport geographic research is the analysis of mobility of athletes and other professionals in sport (Bale 2003). Especially in professional, highly skilled sports, participation in the competitive Market and the development of individuals is linked to a high degree of social and spatial mobility (Snyder & Spreitzer 1975). The migration of athletes

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therefore plays a major role in the global sports business (Elliott & Maguire 2008).

Geographic analyses of actors mobility in the field of sports geography are characterized by predominantly descriptive approaches, even though theoretical approaches from the field of sociology are increasingly gaining ground in the discipline (Elliott & Maguire 2008; Poli 2010). A deeper understanding of structures and phenomena of spatial movement can be gained by considering time as well. Therefore, spatio-temporal geography offers a rich toolbox that is very well suited to study mobility of highly skilled athletes. The method used in the paper presents a form of spatio-temporal path analysis that goes beyond the previously dominant short time intervals by using the career paths of high skilled athletes.[1] This offers opportunities for comparison and analysis of the spatio-temporal movement of individuals and groups over a large period. Highly skilled athletes in particular are increasingly prominent in the media and their career paths can be retrieved from various databases. Therefore this group is ideally suited for testing the intended method. For the particular case of professional athletes, greater similarities in movement patterns may indicate similar decision-making behaviours or influences, while low resemblance allow the assumption that external processes provide stronger, independent individual structures. Although mobility decisions of an individual can be influenced by a variety of different factors (e.g., money, law, ethical and social factors) and actors (e.g., agents, supervisors, family), the paper shows a method to find exactly such structures from a large amount of data over a longer time span. Thus, not only the previous sport geographic research is enriched by a very useful approach, but also the time geographic research.

The paper first aims to connect sports geography with methods of spatial-temporal geography. In particular, the field of mobility research of athletes is enhanced by a new, comprehensive approach. The aim is to establish a new method for the evaluation of mobility influences and the identification of noticeable structures in large groups beyond the previously dominant descriptive methods. Second, the method of 3D space-time geographic path analysis used for this purpose is methodologically extended and specified using a path comparison analysis. The approach aims to contribute to previous work in time-geography, since both a larger time horizon is taken into account and the previously dominant focus on individuals is extended by focusing on groups and their relational movement patterns.

SPORTS GEOGRAPHY AND ATHLETE MOBILITIES

Studies that combine geography and sports rarely receive serious support, either financially or through motivation from supervisors. Despite the fact that sports geography is a serious discipline, there is a lack of research publications (Koch 2017). In general, there are some publications relate to the topic of sport with classical geographic characteristics like space, time and mobilities. Bale and Dejonghe (2008) summarized work published by geographers and Bale (2000) gathered additional studies published by non-geographers. Furthermore, a broad review of currently existing sport geography studies is provided in Wise and Kohe (2018). Still researchers often position their work rather in the mainstream subfields than in the academic debate (Koch 2018).

The essential conception and definition of sports geography goes back to Rooney (1975) and Bale (2003). Bale, in particular, broadened the understanding of sport geography and thus ushered in the postmodern phase of the discipline. As a result of the efforts to not only describe spatial regularities, but to be able to explain them, as well as a stronger orientation of the scientific view towards human action, sport geography increasingly dropped its descriptive character (Bale 1988, 2003; Peters & Roth 2006). However, there is still no robust discipline, because sport is constantly used as a subject of other disciplines (Koch 2017).

A fundamental part of sports geography research are analyses of athlete mobility (beyond the playing field) (Maguire & Bale 1994). The high pressure to perform for clubs in the world's major sports leagues, as well as the development opportunities and potential fame that individuals can achieve

in them, ensures a high and widespread mobility of talent. Work in this field has existed in both, academic and mainstream contexts since the beginning of the debate surrounding the discipline itself. Early work dates back to Lehmann (1940), Jokl (1956) and later Rooney (1974), who looked at the origins of athletes in North America and the Olympics. Following a few other similar publications, Bale and Maguire (1994) published a comprehensive work on Athletic Talent Mobility. Several authors have since published works that attempt to capture and explain the complexity of today's athlete mobility.

Research on migration in sport geography also draws attention to political and legal frameworks, as these are often what have a lasting impact on migration movements (Maguire & Falcous 2010; Chatzigianni 2018; Waite 2020). In addition, recent studies focus on the comlex field on motivation of highly skilled athletes (Magee & Sugden 2002; Elliott & Maguire 2008; Waite & Smith 2017). Carter (2011) emphasizes the influence of both macro-scale processes, such as population migrations or global governance, and micro-scale factors, such as the influence of social networks.

Social networks have become highly relevant in postmodern society. They play a major role in numerous contexts of social coexistence and are also important for the occurrence of migration. Thus, network research is also gaining importance in migration research (cf. Castells 2000; Weyer 2014; Fuhse 2016). While networks used to be seen more as loose connections between actors in the migration process, today they serve as a fundamental explanation, a link between micro- and macro-scale phenomena and build a bridge between individualistic and structural explanatory approaches (Schnegg 2010, p. 67, Hillmann 2016, p. 72ff.).

The chosen movement strategy depends on a variety of factors. It is not only the pull factors of successful and financially well-positioned associations that initiate mobility; personal experiences and the social network play an important role within this process (Carter 2005, 2011). Waite (2020) also argues that the process of migration of highly skilled athletes is very complex and involves numerous institutions and actors at micro-, meso- and macro-scales, both at the destination and at the origin. After the original strongly descriptive work and micro-scale approaches, individual decisions, and the actions of individuals are now increasingly becoming the focus of research on sports migration. Poli (2010) first called for such a shift in sports migration analyses. He extended the existing approach of identifying macro-scale movement patterns by including an individual perspective in order to gain a better understanding on processes of transnational movements (Carter 2011, p. 11). Carter (2011) highlights the role of new theoretical approaches, such as those of biographical or network research, when analysing player movements. Thus, a change in perspective can be observed, through which henceforth movement patterns are less inferred from groups of actors to individuals, but rather larger movement flows are explained by individual actions. This is exactly where this paper can contribute: First a method for the analysis of larger groups is presented. Second, the method also helps to identify individuals whose mobility characteristics can be used to describe higher-scale processes.

TIME GEOGRAPHY AND INDIVIDUAL PATH ANALYSIS

Individual mobility and human patterns analyses is receiving increasing attention in numerous interdisciplinary studies and publications. A fundamental approach for the comprehensive analysis of spatio-temporal movement of individuals is the field of time-geography developed by Hägerstrand and his colleagues (1970). Weichhardt (2015) claims that the initial idea of the theory can be linked to Greek philosophers and their concept of using the combination c*horos* for space and *chronos* for time. The broad theoretical assumption is the indivisibility of space and time (Hägerstrand 1970). It is well known that the temporal dimension of research in geography has many beneficial effects (Kwan 2013). Time geography is a very useful concept because it combines a temporal component and a spatial approach of human activity

patters in one analytical framework (Kwan & Lee 2003; Weichhart 2015). Further it points out the value of time for a better knowledge of the geographies of everyday life (Cullen *et al.* 1972).

An essential and often used tool of time geography are space-time path (STP) analyses of individual mobility. The basic elements of the STP analysis are the spatial origin and destination of a movement as well as its duration and the period of activity at a certain place between movements. The spatial information forms the two-dimensional basis and is supplemented by the third, temporal dimension (Kwan 2004; Huang & Wong 2015).

Focusing on a wide range of human spatio-temporal activities (daily habits, commuting, shopping etc.) time related geographical approaches usually represent a temporal sequence of 24 hours (Kwan & Lee 2003; King *et al.* 2006; Huang & Wong 2015). The fact that time geography can also be usefully applied to the research of longer time spans is often neglected. Especially for human activities that are far-reaching and happen over a longer period of time (e.g. migration), the approach is rarely used (Liversage 2009). Due to the emergence of useful methods, technics of GIS-technologies and detailed individual pattern data, a more detailed analysis of human activity patterns is possible today (Rey & Janikas 2005; Neutens *et al.* 2011; Gu *et al.* 2016). Data or data collection for spatio-temporal studies are diverse. For daily mobility, survey or GPS-based data are often used (Wang *et al.* 2019). Such data provide deep insight into everyday human activity patterns and their influences (Kwan & Lee 2003). Spatiotemporal visualizations, especially in interactive form, can also support the analysis of dynamic networks in order to identify temporal paths of individual actors or groups of actors (Bach *et al.* 2014). However the evaluation and visualization of large data sets of individual patterns is still a major challenge.

There are several recent studies that use these techniques precisely. The highest number of publications certainly exists in the field of microscale analysis of everyday mobility (e.g. Scholten *et al.* 2012; Lee & Miller 2019; Peterson *et al.* 2020; Yang *et al.* 2020). A recent work in the area of everyday human mobility using Big data is the analysis of Ebrahimpour *et al.* (2020). The benefits of spatio-temporal analyses are also applied in other fields such as economic geography (Gu *et al.* 2016) and inequity research (Li & Wei 2010; Liao & Wei 2012; Liao & Wei 2015). Jen *et al.* (2010) use a macroscale analysis method to identify spatio-temporal trends at the country level based on characteristics at different points in time. Spatio-temporal analyses can be used to achieve performance improvements, especially in sports science applications, and thus maximize the chances of success (Narain 2017). Various studies use running paths of athletes during competition as basic data. For instance, Kotzbek and Kainz (2014) investigate the action spaces of soccer matches based on tracking data of players. In numerous papers, they emphasize the interdisciplinary value added of a synergy between sports-related studies and GIS technology, especially in the field of soccer (Kotzbek & Kainz 2015a, 2015b; Kotzbek 2016). Another micro-scale study focused on the tennis finals of the London Olympics. Here, it was shown at which locations on the court point wins were achieved at which time. It was also possible to show the type of each shot in a located manner (Damej 2012). While mainly macroscale studies use spatio-temporal tools manly for visualization purposes and only a few micro-scale studies characterize mobility in detail, the method shown in this paper provides a way to combine these different scales.

METHOD

The method used aims to find homorganic mobility structures within the study group of highly skilled athletes by using vitae data (career paths) and 3D-GIS. In the field of time geography these structures are called bundles. Homorganic structures within the career paths of individuals are here defined as activities at the same sports club over at least a 12-week span. In this case it can be assumed that individuals build a certain social relationship (whether good or bad) which can lead to decision influences on further mobilities. Here, similar to the discipline of quantitative social network analysis, actors and

their relationships are initially understood as simple entities to acquire an understanding about the structure of a system (Jansen 2006; Fuhse 2016).

Space-time visualizations can be very complex. Challenges are the high computational effort, as well as the difficult orientation and interpretation of the depicted structures for the viewer (Gahegan 1999). The space-time path and the space-time cube are used for explorative visualization of individual-based objects, events and activities (Nara 2017). There are different techniques to simplify the complex visualization for the audience, which are also used within this paper (e.g. extraction of single groups) (Bach *et al.* 2017). The geovisualization of activity paths aims to represent actual movement patterns and their spatio-temporal structure in order to gain a better understanding of possible influences. Two different approaches have been used in previous studies: A raster-based approach that represents the three-dimensional space by cells and a vector-based approach that represents movements by lines (Neutens *et al.* 2011). For the visualization and comparison of a smaller number of actors' paths, the vector method is more appropriate. This technique is well known and often used for analysing individual movement patterns (Kwan & Lee 2003; Huang & Wong 2015). In 24-hour-timed visualizations the movement between two stations plays an important role. Therefore, the exact path and the potential range of movement can be analysed using a space time prism (e.g. Kwan & Lee 2003; Winter & Yin 2011; Demsar & Long 2016; Liao 2019). In this study, the analysed timeframe includes multiple years. The actual time needed for the movement between stations is irrelevant. Therefore, the analysed paths represent the stay and movement of an individual athlete over his career (competition-based activity not included).

Case study: patterns of professional athletes – Soccer is one of the most popular sports in the world. Especially in Germany, the discipline has a very high reputation in all aspects of society (DOSB 2021). Players in the higher divisions are in the media spotlight. Numerous online databases collect data on the characteristics of careers. This also includes career histories, i.e. at which time a player was active at which location. Collecting data of such a high value is often very challenging for research purposes. However, the quality and amount of spatio-temporal information available in highly skilled soccer is very well suited for quantitative time geographic studies.

The data set used in this study includes all players of the German DFL (Deutsche Fußball Liga – first and second German soccer league) in October 2015 representing the state of a squad at the beginning of the 15/16 season, as no transfers were possible to that point (Ligainsider 2015; Transfermarkt 2015). The first German Bundesliga is considered part of the BIG 5 (Germany, France, England, Spain, and Italy) in soccer. Unlike the other countries, however, Germany has less strong historical ties to certain regions in the world, which have shaped migration channels to the present day, including in soccer (for example, Spain – Latin America or France – Africa) and thus form the leagues' player landscape (Poli 2010). Due to these lower dependence relationships, the Bundesliga is particularly well suited to test the following method. In total 36 teams, with an overall of 998 players were analysed. In order to achieve the desired comparison between different groups of individuals, two distinctions were focused. At first, all players of the 18 teams of first German soccer league were used. Every team had at least 22 actors, 506 in total, and the player's age and career structures within any team is very similar to all others and therefore comparable in this study. Secondly, all actors of the two leagues were grouped by their representing agency at the time of the analysis. In the following, agencies mean both individually acting representatives of players and alliances of player advisors. Due to the heterogeneous structure of these groups and to allow a comparison between the agencies, young individuals with shorter career paths (less than one year) and agencies with less than 4 players were not included, which resulted in 52 agencies and 488 carrier paths. In addition to an actor's professional stations, the locations of former youth clubs were also included (also international athletes and stations). Unfortunately, it

was not possible to investigate whether players had changed agents during the study period. There was also no information available on the respective start of the cooperation between the agency and the player, so that it was not possible to say without a doubt when the agencies influence on the mobility of the player began. Nevertheless, it can be assumed that the current agents had a greater influence, especially in the final years of the study.

Homorganic path analyses – The career paths of all players were plotted in a sociomatrix to analyse the mobility paths of every pair of individuals. By using all the documented stations of the 998 players examined, a total of 6939 values were determined. Each station of a player was compared to each potential contact resulting in a 6939 × 6939 matrix. The matrix allows to select and compare groups of players based on their team, representing agency or other attributes. In order to operationalize the concept of homogeneity, a benchmark was developed that indicates the ratio of bundles, i.e. player relationships at the same location in relation to all other career paths within a group, by using the following formulation:

$$H_k = \frac{\sum (A_{ij} * 2) / \left(z_i + z_j\right)}{\left(\frac{(A_n^2 - A_n)}{2}\right)}$$

The homogeneity H of a group k is defined by the ratio of the time two actors i and j spent together at one location (A) and their individual career length (z). The sum of all these bundles is normalized with the total potential number of relationships within a group. The value of the calculation ranges from 0 (no shared stations and activities throughout the careers) to 1 (identical paths throughout the careers).

The main factors in the homorganic path analyses (HPA) that can have an influence on the homogeneity value H is the number of investigated actors n within a group as well as the total career period ($z_{max} - z_{min}$) within the group. However, a correlation of the following results and of these two factors does not show a significant influence. This shows that above a certain number of individuals and at a certain spatio-temporal activity both small and larger groups of actors can be compared with the help of the method. High values in the HPA therefore can show higher cohesion or a bigger potential influence within the group. Furthermore, a comparison between different groups of actors can be carried out.

Visualization – The visualization was realized using ESRI ArcGIS. In the three-dimensional visualization of STP, the analysed paths are composed of geo-referenced points connected by lines (Kwan 2004; Huang & Wong 2015). First, all stations within Germany were given spatial coordinates (X & Y values). All stations abroad received a fixed location outside the study area, since the focus of the analysis was on the DFL. This simplification is only done for visualization purposes. The internationality of professional soccer is taken into account, as all stations of a player with their real location are considered within the HPA. Then, the career information was converted into three-dimensional paths. The z-values of these points are calculated on the basis of a reference value. The furthest date in the past and therefore the earliest start of an actor's career was 7.1.1991. This date corresponds to the Z-value 0. All other values are based on the time interval to this reference value in weeks. The highest value represents the data access date of 15.10.2015 1292 weeks after the start of the research period. This value represents the final date of all players analysed. Each player was given two points per station for visualization purposes: One for the beginning of the activity and one for the end. If a spatial change to another club took place, the end point of the previous period had the same z-value as the starting point at the new station, since the transition period was not relevant. This was done for all career stations of every player. The points were then connected by lines which resulted in the mobility paths. This procedure was translated into a script that automatically converted the career information into three-dimensional GIS data for each player analysed.

RESULTS

Within the following sections, the overall results are presented first. Using HPA the

similarities in the movement behaviour of the players within the teams of the first German soccer league are examined before the paths of players grouped by their representing agency are analysed. Subsequently, examples of different degrees of homogeneity among groups of actors are presented.

Homogeneity of mobility paths within the first German soccer league – At the time of the study, the players analysed (506) have already had some time of joint activity at their respective team, as the season has been underway for several weeks. Table 1 shows the calculated values, the cumulative shared periods of player pairings at a location, and the total career length of all players.

The mean value for H is 0.2905[2] with a standard deviation of 0.0766. Since none of the teams examined has replaced its entire squad, the values are above zero. There are also no examples of a homogeneity higher than 0.5. The highly competitive nature/character of professional soccer in the first German soccer league forces clubs to always achieve maximum performance.[3] While one way is to optimize the existing squad, another way is to replace individuals. The second way is always associated with a certain risk, but can lead to success faster. In addition, players are not further employed due to their age or injuries. Teams with high values are characterized mainly by the fact that they have made few changes to their squad in the recent past. Furthermore, high values are favoured if several players were already active together in the youth section of the location and have now made the leap into the professional team. Hannover 96 has the longest cumulative relationship between its players. This can be attributed primarily to five players who were active together for five seasons without a spatial transfer. Players from clubs such as Hamburger SV show a very high spatial activity and only few shared activity phases. Overall, it can be seen that clubs that are less established in the 1. Bundesliga (e.g. Hamburger SV and SV Darmstadt 98) have lower values. And 3 of the bottom 9 teams have played in a lower division at least once in the past 3 years. In contrast, 1 of the top 9 teams has not been in the first division during the same period. Since each team consists of at least 22 players, a visualization in a spatio-temporal diagram does not add any value in this particular case.

Homogeneity in the mobility behaviour of players by agency – Agents as intermediaries on the national and global player market have a major influence on the course of players' careers and their choice of stations

Table 1. *Homogeneity values for the teams of the first league.*

Team	Cumulative relationship periods (in weeks)	Cumulative career length (in weeks)	***H***
Werder Bremen	194.51	13,533	0.4472
Hannover 96	207.15	11,892	0.4176
Borussia Mönchengladbach	107.08	12,911	0.3879
Eintracht Frankfurt	142.23	11,966	0.3762
VfL Wolfsburg	137.42	12,095	0.3385
FC Augsburg	169.73	14,019	0.3215
Hertha BSC	119.04	11,345	0.3149
FC Schalke 04	126.10	12,591	0.3106
Borussia Dortmund	98.03	10,360	0.3016
TSG 1899 Hoffenheim	109.44	12,287	0.2895
1. FC Köln	65.19	11,835	0.2823
Bayern München	98.93	12,636	0.2819
FC Ingolstadt 04	85.34	11,438	0.2626
VfB Stuttgart	92.99	11,026	0.2460
Bayer 04 Leverkusen	96.53	12,439	0.2378
1. FSV Mainz 05	102.37	12,862	0.2351
SV Darmstadt 98	82.05	11,874	0.2021
Hamburger SV	59.81	13,279	0.1840

(Lanfranchi & Taylor 2001; Bale 2003). Using the HPA (for 488 players), it is also possible to investigate whether individual player agents have preferences in the selection of clubs for their clientele or whether they in particular use close contacts with individual clubs. These close contacts corresponds to high values of the homogeneity index. Considering a completely free transfer decision, H tends to 0, which can be seen by the lower values in that case. In contrast to teams, agents rarely involve collective thinking in the management of player mobility. Although the subgroup of players used within an agency's analysis is comparable in quality, most agencies are looking for the best possible individual growth scenario for themselves and their clients. Therefore, values can differ significantly.

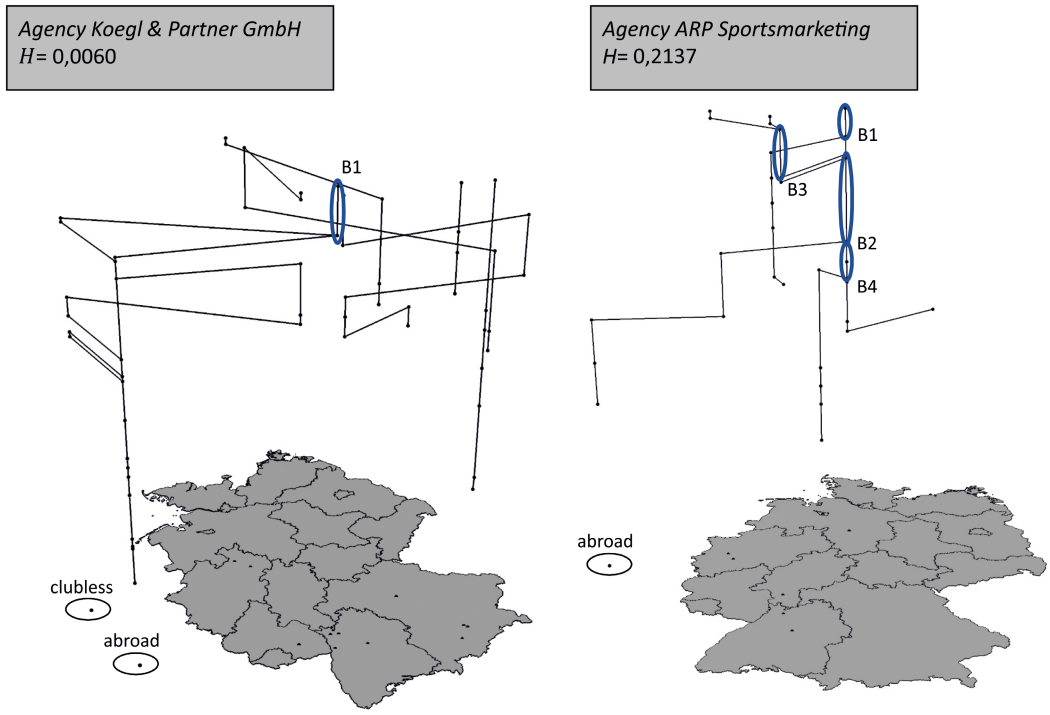
The mean value of the distribution is 0.0435 with a standard deviation of 0.0645. Only a few agencies contract their clients with the same clubs. Only five agencies have recorded a homogeneity value above 0.1. Table 2 shows both the five agencies with the highest and lowest scores (but with at least one relationship).

Of the 52 agencies considered, 7 agencies have a homogeneity value $H = 0$, which means that none of the players they represent have ever been active at a station together with another client. This indicates strongly situational and individual decisions in transfer influence and behaviour. Apertura Sports GmbH shows the highest value. The low cumulative career length indicates that the clients are younger players with a short professional career so far. In addition, three of four players from the Apertura Sports GmbH agency were under contract with FC Augsburg at the time of the analysis. This means that the players with short professional careers were also active at the same location. Next, two examples of high and low homogeneity are visualized and analysed in detail.

A deeper look at the paths and the actors associated with them can help explain the visualisation. In the space-time diagram of the player agency Kögl & Partner GmbH (Figure 1 left), very heterogeneous paths of the players can be observed. The agency represents five players who were or still are active at past stations of Ludwig Kögl, one of the agency's partners and a former soccer player himself. This allows the conclusion of a close relationship that is still maintained with these clubs and that players are intentionally signed there or transferred to these clubs. However, within this group, only one bundle (B1) can be identified at SV Sandhausen. All other paths within the study area run completely independently of each other. The visualization in Figure 1 (right) clearly shows the central bundles of the players. The majority of the players have at least one relationship with another player in the group, which is one of the main reasons for the high homogeneity value. The headquarters of ARP Sportsmarketing

Table 2. *The five highest and lowest agency homogeneity scores.*

Agency or consultant	Number of players	Cumulative career length of all players	H
Highest values for H			
Apertura Sports GmbH	4	1.079	0.3751
ARP Sportmarketing	5	2.489	0.2137
AWM	5	3.132	0.1442
Sports United Sportmanagement	6	2.009	0.1415
Soccer and more	5	2.114	0.1328
Lowest values for H			
SEG	15	7.671	0.0064
Koegl & Partner GmbH	7	4.121	0.0060
JB Sports2Business	5	2.169	0.0043
Boutique Transfers and Management ApS	6	3.194	0.0037
Spielerrat GmbH	5	3.835	0.0019



number of players	7
cumulative career length	4.121
number of relations	1
average Age	25,85
averagenumber of stations	6,57
relationship length	120 weeks
B1 -	Bundle Sandhausen 2 Players, 120 weeks

number of players	5
cumulative career length	2.489
number of relations	6
average Age	27,91
averagenumber of stations	6,5
relationship length	444 weeks
B1 –	Bundle Hannover 2 players, 58 weeks
B2 –	Bundle Hannover 3 players, 208 weeks
B3 –	Bundle Stuttgart 2 players, 92 weeks
B4 –	Bundle Hannover 2 players, 86 weeks

Figure 1. *Example of low (left) and high homogeneity (right).*

Agency is located in close proximity to most of the bundles. This is one possible reasons for the high HPA value.

Investigation of individual path connections – The method allows specific patterns to be identified from the large number of career paths. Some connections between players exist in more than one location. Elliot & Gusterud (2016) have shown that players can have an influence on transfer events and therefore the mobility paths of other players. Signs of such influence can be found by looking at the mobility biographies of individual players, as well as on recurring relationships between players. In total, 1111 relationships of the 998 players are present in two or more different locations (about 2.82% of the 39,350 existing relationships). And 25 relationships are recorded at three different locations. In four cases, the players are managed by the same

agency. By extracting the data of certain players, spatio-temporal visualization can be used to visualize the activity paths of the player dyads.

The following figures show examples of two career paths that were noticeable within the entire data set. In the first dyad, the initial contact was observed at Wolfsburg. Both players went through the club's youth program and played together for the second team. This first bundle (B1) lasts for five years. The second bundle (B2) is with FC Energie Cottbus and lasted about 1.5 years. Both players were loaned out to that club. Most recently, both players have been active together at 1. FC Kaiserslautern (B3). In the process of more in-depth research (various newspaper reports and social media), no deeper connection was identified that went beyond the athletic relationship and thus could have had an influence on the mobility paths. Both players were under contract with the PRO Profil agency at the time of the research. This agency is characterized by a high number of players that are active in many different locations. The relatively low homogeneity value of the agent of 0.03 also proves that there are weaker relationships with specific clubs. The apparently high path dependency could not be proven for this dyad, which suggests that it is a rather random relationship or that the players contributed little to the similarity of their paths.

In contrast, the example of Figure 2 shows that close social relationships between players can indeed have an influence on their mobility biographies. Both players were born in Mannheim in 1991 and started their careers with VfL Neckarau (B1). Afterwards, both entered the youth program of TSG 1899 Hoffenheim at the same time and stayed a total of 3.5 years until January 2011. Player A moved to Karlsruher SC on Jan. 1, followed by Player B on Jan. 26, where they both spent 1.5 years together (B3). In total, the players played 14 years together at the three stations. In 2014, Player B called Player A his 'best

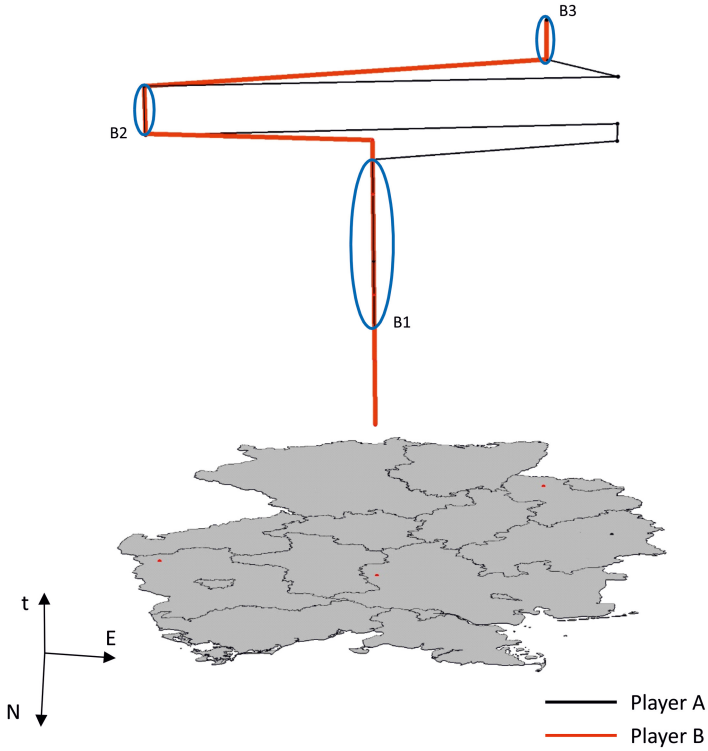


Figure 2. *Space-time paths of two strongly connected individuals without a closer social relationship.*

buddy' in the professional game. The two grew up together and shared an apartment during their time at the Karlsruhe site, which is the main reason for their strong social relationship (Roth 2014). Both players were part of a systematic transfer business of TSG 1899 Hoffenheim, which signed seven players of the junior Team of VfL Neckarau in 2007 (Reich 2020). It can be assumed that the spatial closeness of the stations had a major influence on the transfer business in the first part of their careers.

The early phase of the two players careers (Figure 3) shown a high homogeneity, which can certainly be attributed to their strong social relationship. It was not possible to investigate the actual influence of players on the further transfer process. However, it can be argued that clubs may well plan the composition of their squad in such a way that players are hired who, for example, have a similar athletic education and tactical understanding. As a consequence, if the players' individual performance is higher due to accumulated social capital, a team can benefit from it.

Nevertheless, as the quality of players as well as teams increases, the social relationship with former teammates is likely to be less important while other individual performance criteria gain importance.

DISCUSSION AND CONCLUSION

Within the professional context, only a few players make the leap into the field of highly qualified athletes. Thus, individual performance is an essential component within individual mobility and dictates the opportunities a player has. Nevertheless, social contacts have a significant influence, as well, which has been shown in selected examples.

However, there are some limitations. Critically, it should be noted that in addition to social relationships and the individual

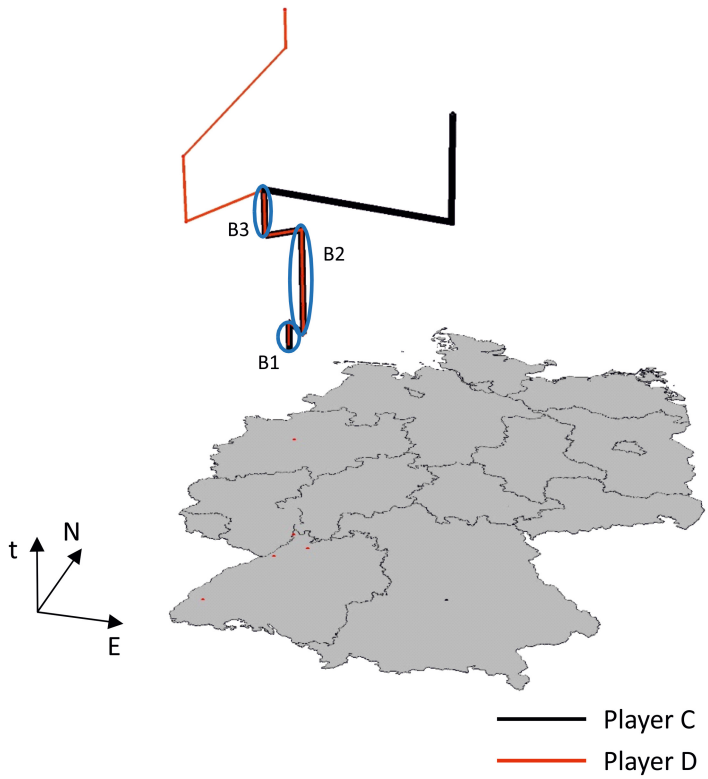


Figure 3. *Space-time paths of two individuals with a closer relationship.*

performance, it is primarily economic factors that contribute to explaining the mobility of highly skilled athletes, but these have been neglected in this paper (Poli 2010; Carter 2011). A major factor for many players are those earning opportunities that Maguire and Pearton (2000) refer to as 'following the money.' Often the amount of an offer has a lasting impact on the decision to switch locations, and this becomes increasingly important as players get older (Magee & Sugden 2002). While the observation made in this paper does not allow us to say what triggered an actor's mobility in particular, it can explain how it formed existing relationship structures (Buffington 2019). In the decision-making process of a professional athlete to move to a new location or club, information and relationships with the target region/club are also very important. An exchange of information can take place between the players themselves, their agents or agencies, the coaches and the responsible club employees (e.g. managers). HPA is one technique that can help identify certain phenomena and path correlations between these individuals within a large set of data. In order to gain a comprehensive view of the mobility of such a large study group, this complex system was analysed in a simplified way. The analysis is based on the assumption that the actors studied are simple entities (like in quantitative social network analysis). This simplification ignores a variety of social and economic aspects. Furthermore, such influencing factors are by no means constant over a career and change, just like individual decisions, based on previous experiences and current circumstances. Also, no information about the strength of a social relationship was included in the calculation. Since only those players were considered who were part of the system at the time of the study, no previous players or agents were taken into account, who may well also have a major influence on a players mobility. Team-building factors, such as what position a host club requires, were also not considered in the analysis.

The objective of the overall approach is to identify noticeable structures in the movement paths. Furthermore, it is also possible to make general statements about the systems analysed. Within the soccer market, a growing trend of de-territorialization has been observed in recent decades. Increased mobility of players and shrinking contract periods result in a decreasing presence of players raised by the club. Given the identification role of clubs in the local context, Poli (2007) takes a highly critical view on this phenomenon. By switching teams and looking for the best overall situation for themselves (financially and athletically) actors pursue the goal of participating in the highly skilled competition for as long as possible.

In this study it has been shown that there are teams that have more homogeneous structures in their rosters than others. These clubs initiate lower numbers of player movements. Established squads that are active together over a longer period of time seem to be more successful or rather manage to achieve the goals set by the club. In addition to the pure performance component, there are also other factors for the transfer management of the teams and the resulting mobility and paths of the players. There are some clubs (especially financially weaker ones) that develop players at their location and then transfer them to secure their economic existence. Nevertheless, H does not necessarily provide information about the success or failure of a team. The factors that influence the success of a team are very diverse. With the help of H, certain market strategies in relation to transfer activity can be obtained, which can be a significant factor for success. There is a potential for future studies to assess whether there is an actual relationship between transfer policy and success that can be measured using HPA.

Agency H values also vary widely. This is due to the fact that agencies mostly seek individual development paths suited to their clients. Still, with the help of the HPA, specific patterns could be revealed that are caused by personal preferences. Consequently, there are agencies that choose their clients to match the teams they work frequently and well with.

By implementing a path-homogeneity factor using HPA, the analysis allows to compare different groups of actors based on mobility paths. Using the example of the highly specialized group of professional athletes, it was shown which groups of actors display greater similarities in their career paths. While a high homogeneity in any case reveal that players share more time overlaps throughout their career, it also can show that certain groups make

similar decisions through socially influenced processes. Low values show mostly independent processes and allow the assumption that external processes provide stronger, independent individual structures.

In the field of time geography analysing and interpreting a large number of individual mobility paths are always a major challenge. Interactive, digital visualizations can help to get an inside view on individual connections. The method used presents a form of spatio-temporal path analysis that goes beyond the previously dominant short time intervals and thus offers opportunities for comparison and analysis of the spatio-temporal movement of individuals. By identifying noticeable structures in large groups of actors, the HPA can provide a systematic overview on which basis in further research the system influencing dynamic aspects of social and economic nature can be incorporated. The methodology can be used as a core instrument of early stages of individual mobility and path analysis and in combination with qualitative methods, it provides comprehensive opportunities to analyse individuals in detail in order to identify their motives for moving. Dividing career paths into different action periods using more in-depth qualitative information can provide additional insight here. Another potential application of the method is the movement of consumers of sports. Even though data acquisition might be even more difficult than in the example shown, promising opportunities emerge for economic geography issues. The example of professional athletes shows many similarities with other disciplines. Since especially the highly professional sports and the clubs are managed like international companies. Thus, it is possible to transfer individual results to other fields of the labour market, in particular to the segment of highly qualified workers. In addition, a transfer of the methodology to different spatio-temporal scales is possible as well as the consideration of other groups of actors. Therefore, the method of HPA can also be used in other research, if an appropriate data basis is available. On the one hand, the paper introduces a new method (HPA) in the field of space-time geography and on the other hand, it establishes a connection of this approach with the field of sports geography. The work has also shown that these two fundamental approaches can mutually benefit from each other. In professional sports, movements of athletes are well documented in the micro, meso and macro scale. Influences on the movements can therefore be understood quite well. The discipline therefore offers very rich data bases for studies in space-time geography.

The still rather raw discipline of sports geography has so far mostly lacked sophisticated spatial analysis methods. Spatio-temporal analysis methods as used in this paper can initially assist in the visualization of actor mobility. However, the quantitative approach can help to identify systematic structures and central actors. The results obtained help to link the subdiscipline of sports geography more closely with previous research on mobility and migration, and to gain a better understanding of the processes in sport itself. The paper makes a significant contribution to mobility research in the field of sport geography. This work furthermore aims to move sport geography more into the centre of geographical research and to encourage authors in the future to use their extensive knowledge and methodological skills from various disciplines in order to explain and understand so far unexplained but socially highly relevant phenomena of the 'martial' discipline.

Notes

[1] The method used in this paper was first introduced in Rauch (2020).

[2] Since even small fluctuations in the value allow an interpretation, the results will be given with 4 decimal digits.

[3] In the German soccer league system, the decision whether a team remains in a division or is promoted or relegated to a different league is based on the athletic performance of the teams/the players.

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