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Transportation studies and time geography

The year 2020 marked the 50th anniversary of the founding of the Time Geography movement by Torsten Hägerstrand. It was in 1970 that he wrote his seminal article 'What about people in regional science?' (Hägerstrand 1970). Although disregarded in the 1980s and 1990s, time geographical concepts came in for renewed interest in the early 2000s, not only in the study of human behaviour but also in varied disciplines such as epidemiology, ecology and archaeology. This interdisciplinary trend is related to advances in Geographical Information Science. The latter provides a methodological framework for representing information in space and time. This progress has been the subject of several applications in the study of transport and even more so in the analysis of daily mobility behavior. In fact, we observe a diversification of investigative sources (Zhang et al. 2014). Classical surveys in the mobility field are supplemented by GPS tracking techniques providing an interesting alternative for understanding travel behavior. Recently a wealth of new ICT data collected by cell phone or Internet providers has been made available to scholars. Moreover, micro-simulation models now produce an impressive quantity of information to be managed and understood.

These different tools make it possible to record the rhythms of daily mobilities in both space and time. The analysis of spatial-temporal interactions is certainly relevant for urban studies, but it is now becoming essential for improving urban planning and governance. In this way, we need to take a new step to integrate these new sources and their data models into an analytical framework dedicated to the space-time design of the city. Accordingly we propose a geovisualization tool –named Geographer– capable of linking the theoretical framework of time geography and the power of Exploratory Spatial Data Analysis (Andrienko et al., 2013). Anselin defines ESDA as the collection of techniques to describe and visualize spatial distributions, identify atypical locations and suggest different spatial patterns (Anselin et al., 2010). We have developed this prototype to visualize the level of space-time interactions in terms of densities of activities.

Methodological explanation

To illustrate the potential of Geographer, we use a simulated dataset. This information comes from the Mobisim platform (http://thema.univ-fcomte.fr/mobisim). Mobisim is a Land Use Transport

Interaction model based on household survey, census and geographical data. In this contribution we visualize the control simulation applied to the medium-sized (193,000 inhabitants) city of Besançon (France). The analysis of simulated data makes it possible to work on a complete population and not on a small sample obtained from household surveys. This dataset has the advantage of presenting a large volume and diversity of two main classes of information. The first class defines individuals by their socio-economic characteristics (age, sex, etc.) and motorization. The second class describes space-time paths. In other words, the simulator generates a route over a 24-hour day for each individual. We focus on this part of the dataset for the next visualization.

To synthesize this complex dataset, we mobilize three concepts from Time Geography (Lenntorp 1977). 'Intersection' gives the condition of two or more time-geographic features sharing certain locations in space and time. 'Bundle' reveals the convergence of two or more space-time paths for some shared activity. The most sophisticated concept is Pockets of Local Order (PLO) (Ellegård and Vilhelmson 2004). PLO can be used to define each individual’s potential to reach a given place at a given time to share resources or engage in social interactions in a specific order.

In order to implement these concepts, we situate daily trajectories within a space-time cube. Based on the work of Kraak (Kraak and Koussoulakou 2005), this space is subdivided into small cubes (named Voxels) for a time step. The main advantage of the voxel is that it provides a joint and continuous representation of space and time. This space-time cube is integrated into the classical tools of ESDA. This computing environment makes it possible to compose complex queries in a simple way. For example, it is possible to count and visualize routine behaviour with a few clicks. In the same way, a simple selection on the screen can be used to cross-check socio-economic profiles with travel patterns and trajectories.

Guidelines for observing the space-time cube

The figure shows six space-time cubes for which the x and y axes determine the spatial dimension, while the z axis represents the temporal dimension for a 24-hour day. To guide users in their analysis, the city's main road network has been added to the base of the space-time cube. The voxels summarize the equivalent of 2185 paths derived from the Mobisim simulation model. Their spatial resolution has been defined at 500 metres with a time resolution of 10 minutes. The mapped indicator represents the number of intersections contained in each voxel.

According to the rules of graphic semiology, this absolute value should be represented by a proportional symbol. However, the spatial and temporal resolution selected for this study generates a large amount of data that is difficult to observe in a space-time cube. To solve this recurrent problem of dense visualization in a dynamic network, Bach proposed a set of very interesting solutions in his tool Cubix (Bach et al., 2014). The evaluation of this geovisualization revealed that coloring the voxels was the most efficient means of mapping values located at the edge. This feedback confirms our decision to break the rules of graphic semiology. Thus, blue is used for low numbers of intersections and red for high numbers. Transparency is used to make the block easier to view in three dimensions.

In this space-time cube, we use voxels in which two and five intersections are counted. In accordance with the principle of 'bundles', we select the intersections corresponding to two purposes: Home and Drop-off (children at school or a relative at a medical appointment). It is also possible to select the number of intersections gradually in order to reveal the main clusters. In our example, we observe a dispersion of collocation for low intersections whereas a concentration of movements can be detected in the historical city center.

Conclusion

Through this illustration, we have tried to demonstrate the potential of the space-time cube to capture urban dynamics by mobilizing concepts borrowed from Time Geography. Beyond the very static figure presented in this contribution, our ultimate ambition is to build an interactive geovisualization tool. Without the use of computer coding but with a few clicks on the screen, we can link the space-time cube with other diagrams commonly available in ESDA tools: histograms, box plots, scatter plots, parallel coordinate plots, etc. At present we can manage a large dataset with the POSTGRES database management system connected to a calculation cluster. This solution allows researchers to test many hypotheses without the need for complex queries. As this prototype does not require special computer skills, we hope to make it available to transport planning departments for analyzing household surveys or consulting simulation results. This final stage will require validation work to be carried out with ergo-psychologists in order to ensure that mobility planners can easily appropriate the prototype.

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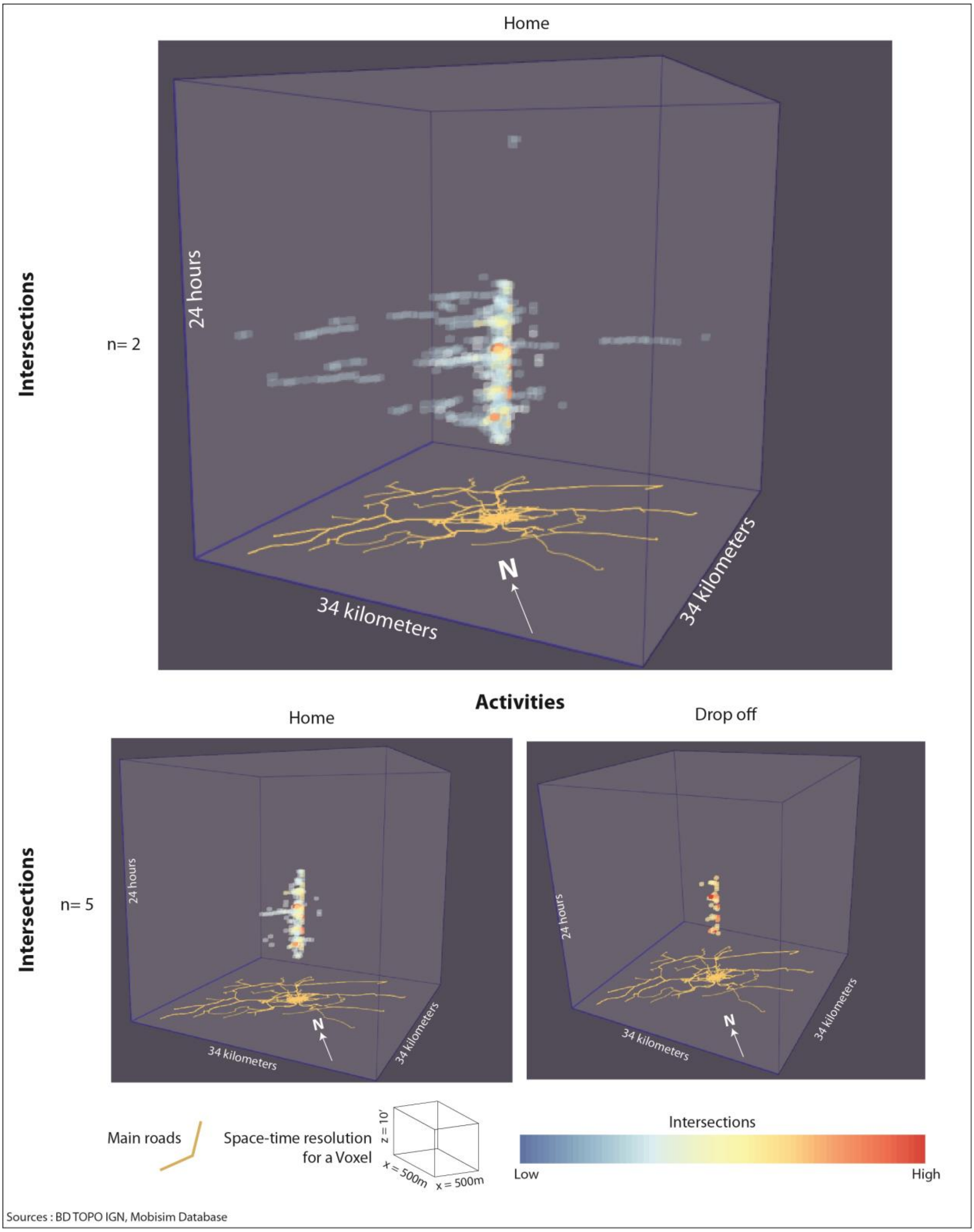
Home
Intersections
n= 2
24 hours
34 kilometers
34 kilometers
N
Activities
Home
Drop off
Intersections
n= 5
24 hours
34 kilometers
34 kilometers
N
24 hours
34 kilometers
34 kilometers
N
Main roads
Space-time resolution for a Voxel
z = 10'
x = 500m
x = 500m
Intersections
Low
High
Sources : BD TOPO IGN, Mobisim Database