CO-215

# How to grasp the geographic movement? A heuristic guide for its cartographic representation

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## INTRODUCTION

"Geographical movement is critically important". This sentence often found in Pr W. Tobler's works expresses an essential preoccupation of today: how to grasp the movement. Understanding should be aided by cartographic representations; yet the phenomena's numerical expression increases exponentially as the number of concerned places does, so that most of the usual solutions are very often illegible and inappropriate. The multiplication of movements is a fundamental fact of globalization and investigating visualizations that will forward its understanding has become inevitable.

The aim of this paper is to propose an aid to cartographic representation of movement in the form of a heuristic guiding grid with queries that assist the selection within a range of cartographic solutions that include new technologies. This reasoned process helps with decision-taking at each design stage of a product. Examples will continuously back the guide's answers as well as those connections that unfold.

## 1. FROM IDENTIFYING THE ITEM TO BE STUDIED TO THE SPACE-TIME DATABASE

Identifying the "movement" item means determining its specificity and the dimensions attached to it.

### *1.1. Definitions*

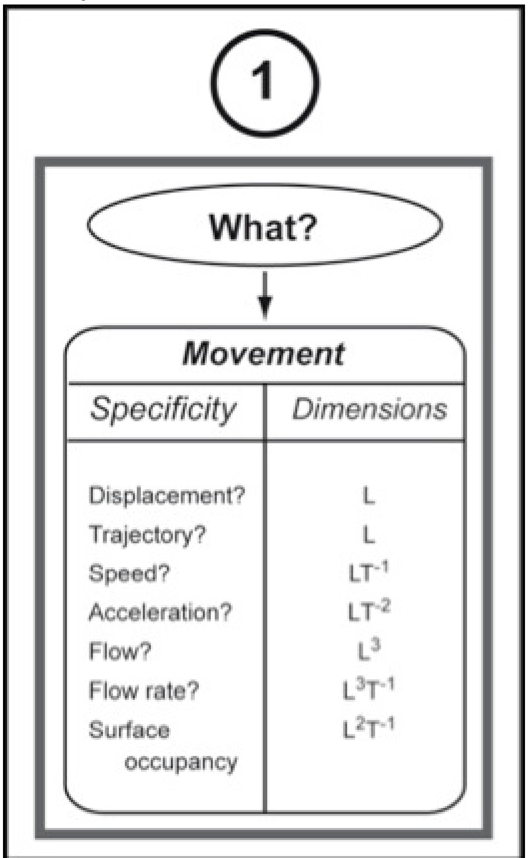



*Figure 1*

The definitions make up the answers to the first query of the diagram, "What?" (Figure 1).

– A movement is a change of position in space and time, within a given frame of reference, that "involves both space and time, being a natural synthesis of both concepts" [Auffray, 1998].

This change of position requires further precisions and a terminology adapted to the specificity of the movement.

– A displacement is a movement where an object or a person goes from one point to another.

– A trajectory is the line made by a material point as it moves [Petit Larousse, 2005].
– Speed is the ratio of a covered distance (in other words, space) to the time it takes to cover it [Petit Larousse, 2005]; acceleration is the changing rate of speed of a movement during a given period of time.
– Flow is a mass moving between a point of origin and a destination following a trajectory, concretely expressed or not.
– A flow rate is a volume or quantity of matter by a unit of time.

Surface occupancy is the space where the movements occur, whatever their specificity. This paper will highlight the trajectories of displacements, accessibility as allowed by speed, flows and surface occupancy.

Depending on the specificity ascribed to the movement, geometrical dimensions vary as well as the accompanying cartographic representation; it furthermore implies the association of its heuristic corpus.

### *1.2. Heuristic corpus*

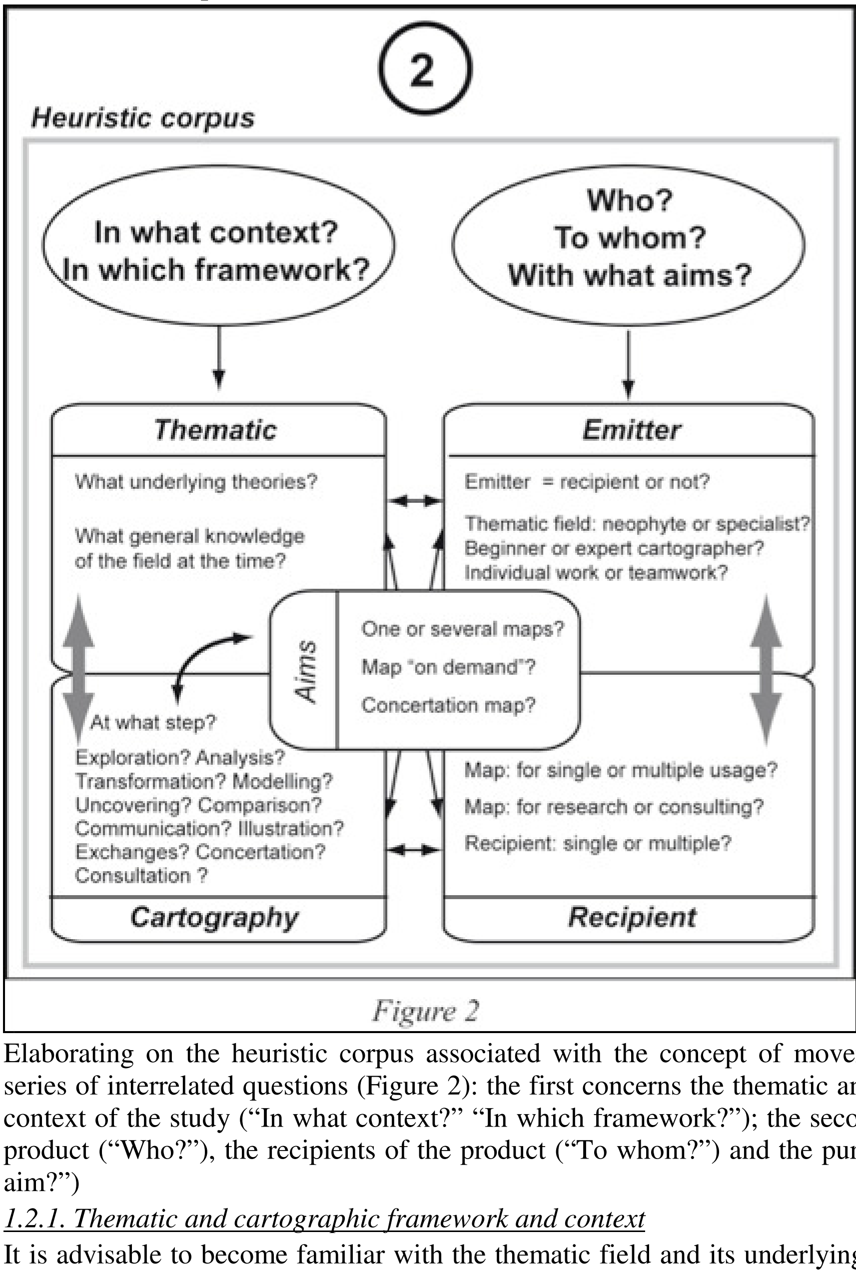



Figure 2

Elaborating on the heuristic corpus associated with the concept of movement supposes answering two series of interrelated questions (Figure 2): the first concerns the thematic and cartographic framework and context of the study ("In what context?" "In which framework?"); the second concerns the authors of the product ("Who?"), the recipients of the product ("To whom?") and the purpose of the study ("With what aim?")

#### 1.2.1. Thematic and cartographic framework and context

It is advisable to become familiar with the thematic field and its underlying theories prevalent at the time of the study: for instance, here, the studies on "Time-geography" [Hägerstrand 1970, 1985] concerning trajectories, or the research on diffusion models [Hägerstrand, 1967] for surface occupancy.

Cartographically speaking, it is necessary to determine which step in the development of the study has been reached, an exploration or a comparison not leading to the same possibilities. The final objective must be well understood: flows presented singly will be appropriate for a detailed study whereas a vector field will highlight trends.

*1.2.2. Emitter, recipient and objectives*

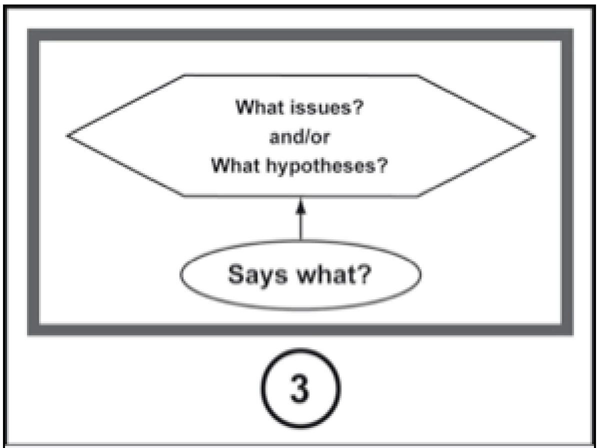



*Figure 3*

Depending on whether the cartographer is already familiar with the theme, works alone or with others, decisions will differ and come more or less easily. Again, knowing the recipient and the final objective of the study will produce distinct solutions.

Only by answering these questions will we be able to determine potential issues and hypotheses that will guide the process along and lead to, in turn, answering the "Says what?" query in H. Lasswell's diagram [1968] (Figure 3).

From then on, and from then on only, can setting up and constructing an appropriate database be considered

***1.3. Space-time database***

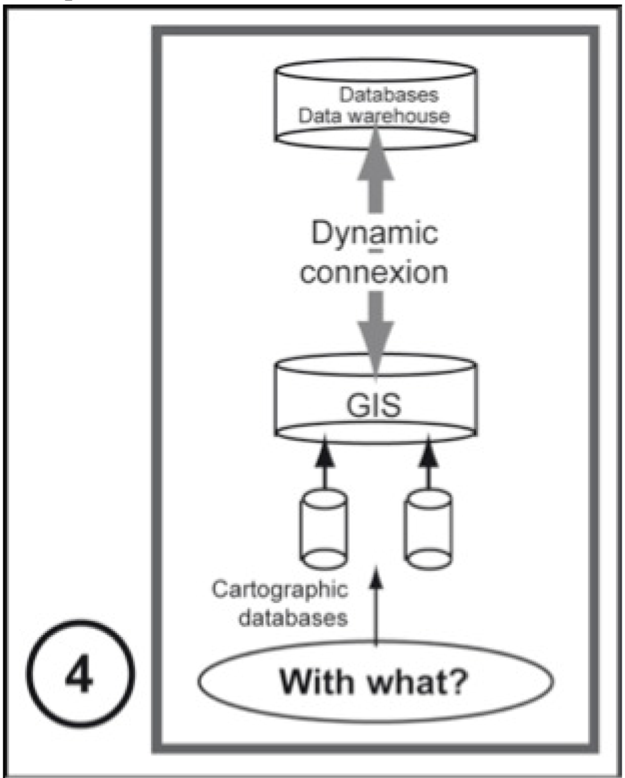



*Figure 4*

Data relative to movement ("With what?") must be organized, which means with an appropriate structure, to be exploiter (Figure 4). This transformation simplifies the ulterior operations and modelling needed to build relevant representations.

These data being intrinsically both spatial and temporal, a particular attention must be brought to bear on the three fundamental dimensions at the heart of space-time models [Peuquet, 1994]: space (from where? to where?), theme (what subject?), time (when? how fast/how long?). This basic structure forms the skeleton of all databases which include movement, permitting an organisation whatever the specificity of the movement (displacement, trajectory, flow, speed…) with specific adjustments linked to future visualizations [Klein, 2010].

Numerous cartographic representations become possible with such a tool: classical operations but also W. Tobler's applications or developing novel solutions based on the more recent technologies

## 2. FROM CLASSICAL SOLUTIONS TO MODELLING

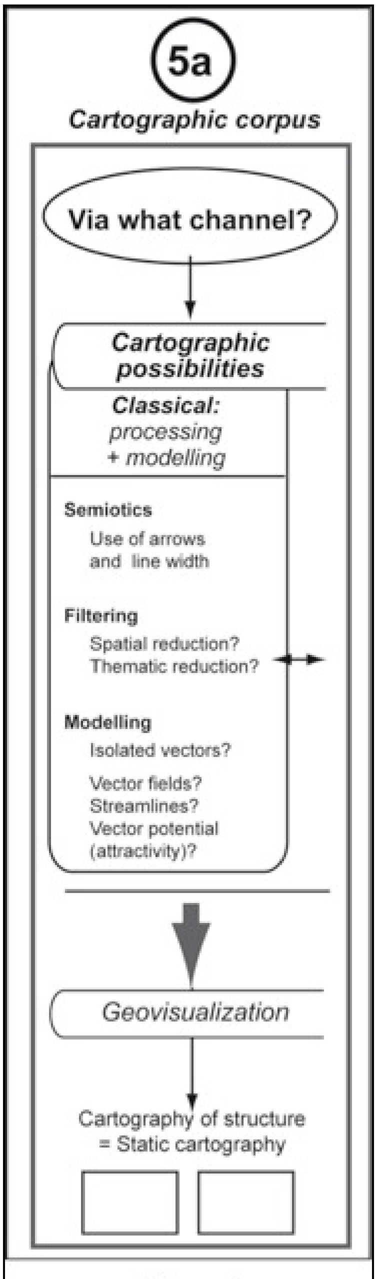



Figure 5

The possible representations, which means the channel through which the answers are conveyed, have been regrouped into three families, each resting on different principles (Figure 5) ; associated examples bear mainly on flows:

– semiotics, with numerous possibilities of classical representations;

– filtering, which offers a partial answer to the profusion of information in movement matrices

– modelling, which proposes explanatory derivated representations.

### *2.1 Semiotic possibilities*

Choosing a semiotic solution depends on criteria that first implicate what one wishes to represent, i.e. those elements described in the first part of the text: the route, its direction line, its way; the significance of its extremities (point of origin and point of arrival); its significance (geometrical dimensions).

Where flows are concerned, a semiotic answer is found, among others, with "Flowmapper", a program with many possibilities developed by W. Tobler [1979]. It must be noted that, for these maps, grammatical rules often have to be reversed if the representations are to express the thematic contents correctly. But this program goes a lot further as it also allows filtering.

Our examples refer to daily migrations between Luxembourgian cantons in 2001 and outline the graphic problems presented by those flows considered as foremost (Figure 6).

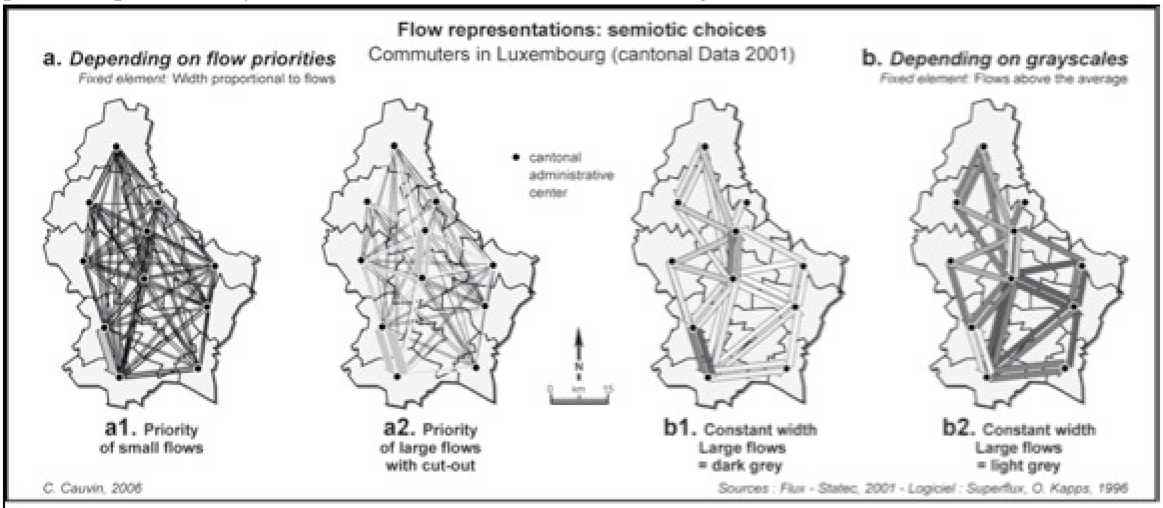



Figure 6

## *2.2. Filtering*

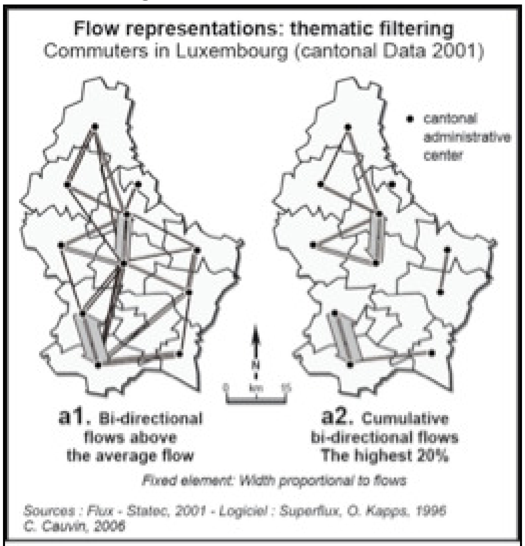



Figure 7

The difficulty in representing movements and flows comes mainly from their multiplication as the number of places increase. Solving this problem requires reduction which consists in operating either thematic (quantitative threshold of flow appearance) or spatial (regrouping spatial units) filtering (Figure 7).

Examples are numerous but often need an accumulation of maps to fully express the phenomena.

## *2.3. Modelling*

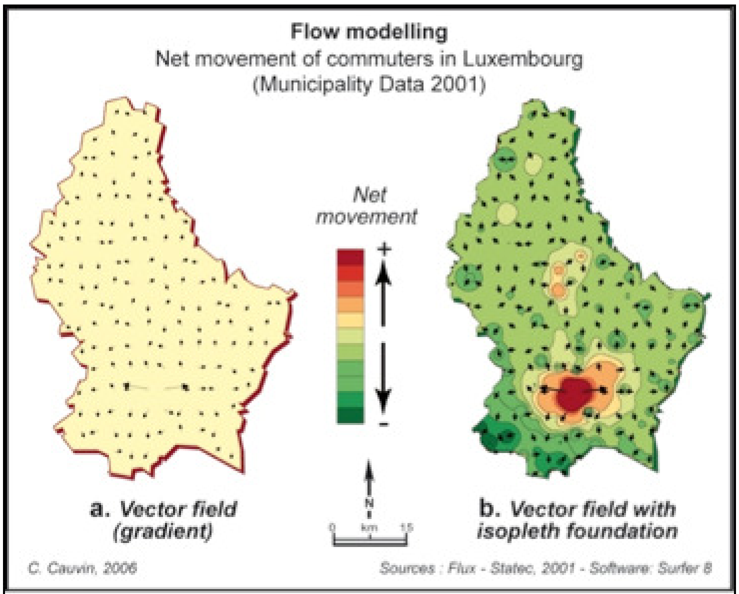



*Figure 8*

Modelling movement with a visual representation, and those of flows in particular, was mainly developed by W. Tobler [1978, 1981], S. Lavin et R. Cerveny [1987], G. Turk et D. Bank [1996], D. Phan et al. [2005].

Three types of representation dominate: isolated vectors, vector fields and streamlines (Figure 8) to which attractivity potential derived from vector fields (Tobler) and unit-vector density method (Lavin et Cerveny) can be added.

These three representation families essentially produce static maps, expressing structures. Only with the help of new technologies can we go further.

**3. THE CONTRIBUTION OF NEW TECHNOLOGIES**

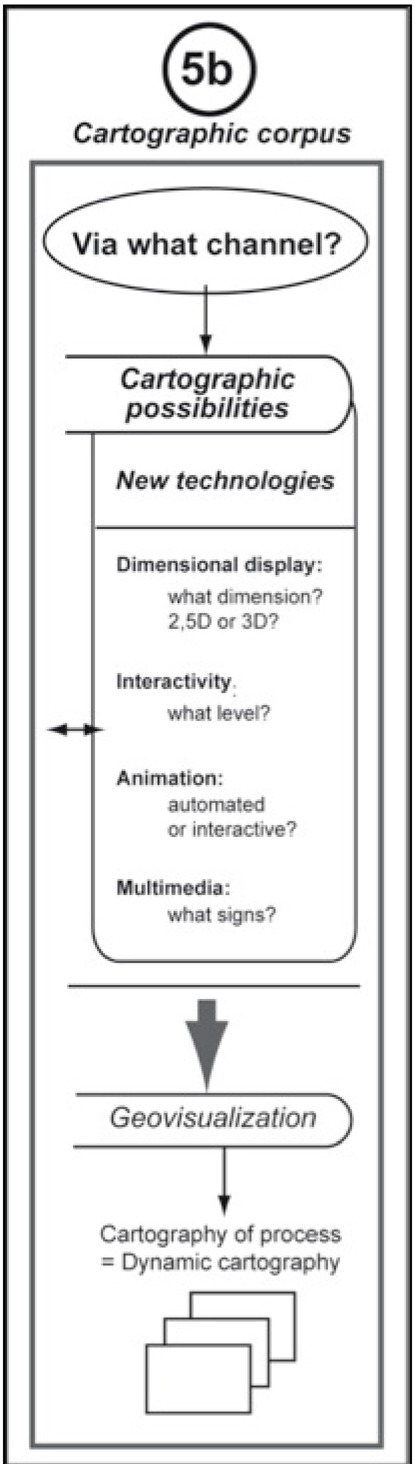



*Figure 9*

New technologies (Figure 9) have been sorted into four groups of possibilities: 3D, interactivity, animation and multimedia (Figure 10).

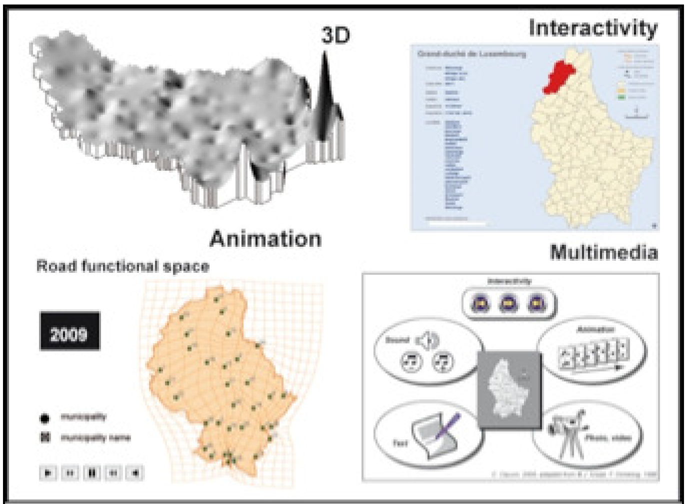
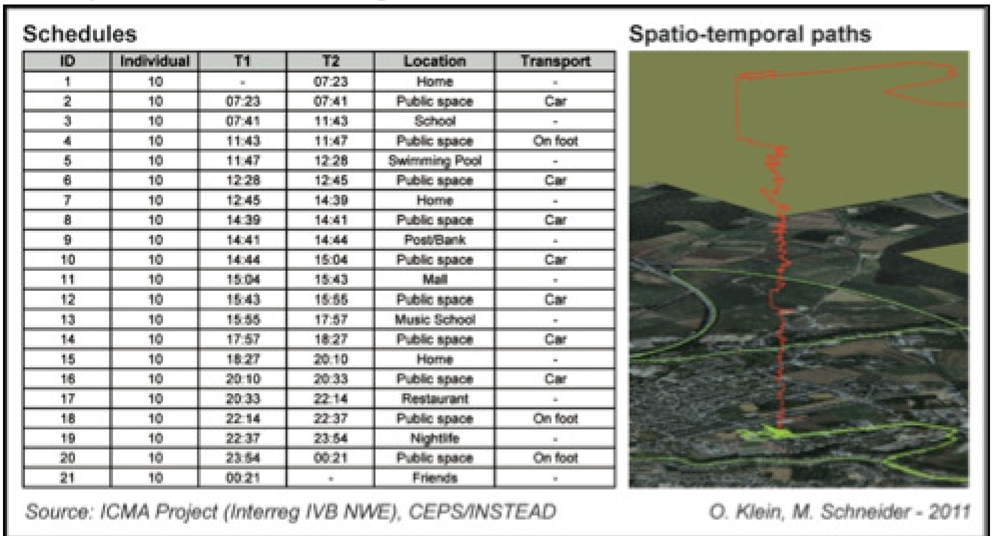



*Figure 10*

Separately, these processes would be of limited use for expressing movement. A simultaneous grasp is required, taking into account what is needed and what phenomenon are expressed through movement.

***3.1. Trajectories, 3D and mobile points***




| ID | Individual | T1 | T2 | Location | Transport |
|---|---|---|---|---|---|
| 1 | 10 | - | 07:23 | Home | - |
| 2 | 10 | 07:23 | 07:41 | Public space | Car |
| 3 | 10 | 07:41 | 11:43 | School | - |
| 4 | 10 | 11:43 | 11:47 | Public space | On foot |
| 5 | 10 | 11:47 | 12:28 | Swimming Pool | - |
| 6 | 10 | 12:28 | 12:45 | Public space | Car |
| 7 | 10 | 12:45 | 14:39 | Home | - |
| 8 | 10 | 14:39 | 14:41 | Public space | Car |
| 9 | 10 | 14:41 | 14:44 | Post/Bank | - |
| 10 | 10 | 14:44 | 15:04 | Public space | Car |
| 11 | 10 | 15:04 | 15:43 | Mall | - |
| 12 | 10 | 15:43 | 15:55 | Public space | Car |
| 13 | 10 | 15:55 | 17:57 | Music School | - |
| 14 | 10 | 17:57 | 18:27 | Public space | Car |
| 15 | 10 | 18:27 | 20:10 | Home | - |
| 16 | 10 | 20:10 | 20:33 | Public space | Car |
| 17 | 10 | 20:33 | 22:14 | Restaurant | - |
| 18 | 10 | 22:14 | 22:37 | Public space | On foot |
| 19 | 10 | 22:37 | 23:54 | Nightlife | - |
| 20 | 10 | 23:54 | 00:21 | Public space | On foot |
| 21 | 10 | 00:21 | - | Friends | - |

*Figure 11*

Movements are usually expressed on a two dimensional plane. Time set on the ordinate in T. Hägerstrand's representations offers another visual expression of the phenomena, as seen in Figure 11 where a child's trajectory among his/her daily lifeplaces, tracked by GPS in the city of Luxembourg, is shown.

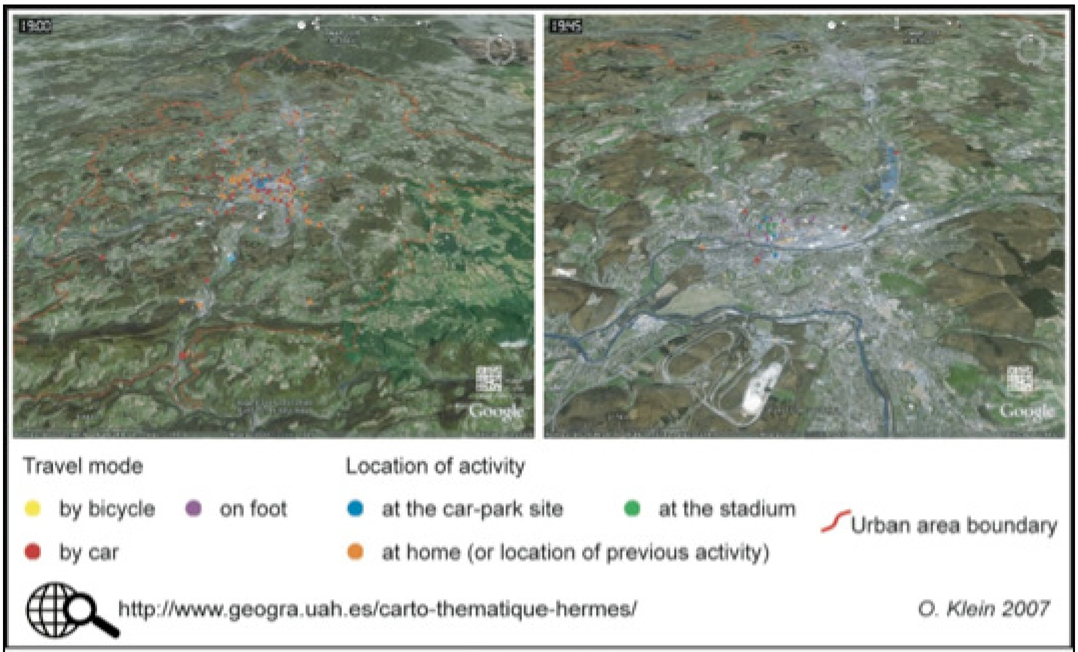



*Figure 12*

Another possibility for expressing trajectories is to use the moving points method. With this category of representation, the end-user will be able to directly analyze the movements through a specific space or on a specific route according to the hours of the day. This approach will allow him/her, for instance, to understand the emergence of traffic jams. Such a representation can be very useful in the field of transports, and when combined with MAS modeling, can be even used to simulate the development of road infrastructures.

The figure 12 represents the movement related to a soccer match at the Bonal Stadium in Sochaux-Montbéliard.

### *3.2. Flows and new visualization*

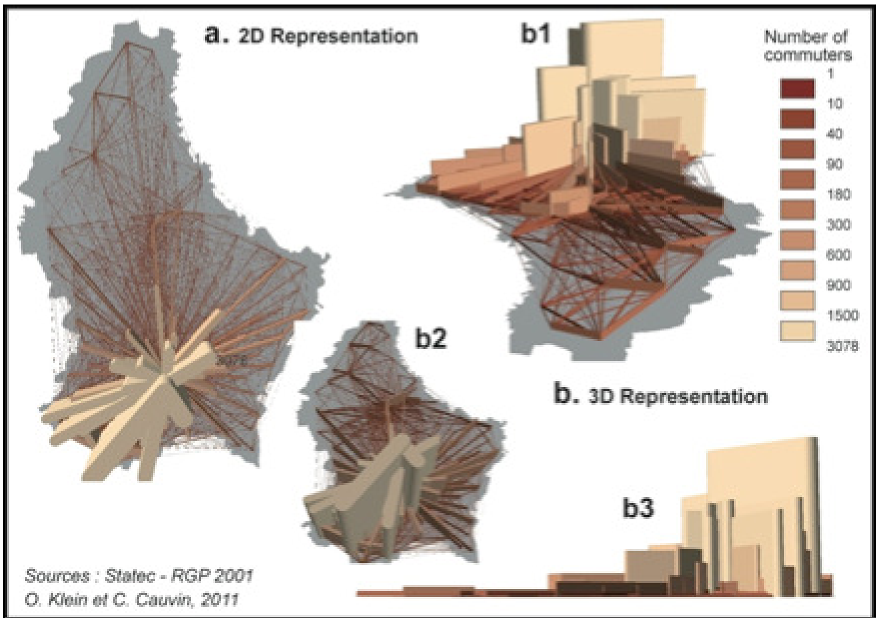



*Figure 13*

Flow representation can be improved with a descriptive approach using 3D, the third dimension expressing the importance of the flow. Combined with animation and interactivity, a map can then show flows from various angles at the rhythms required for their study, and a finer analysis then becomes possible. Here we have the daily movements between home and workplace in the Grand Duchy of Luxembourg (Figure 13).

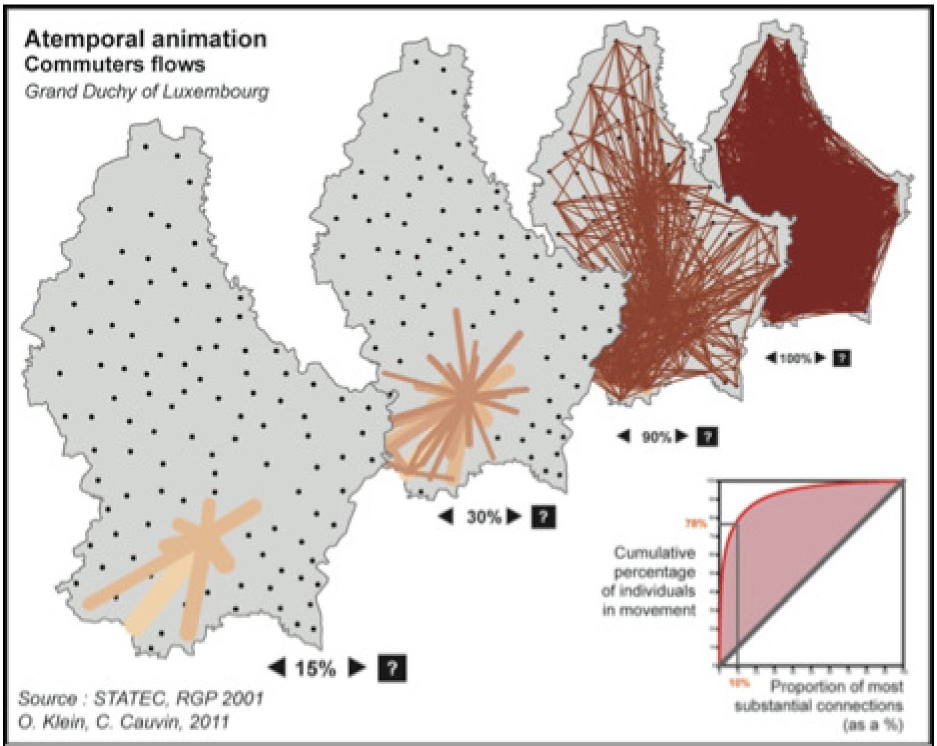



*Figure 14*

Interactivity benefits filtering by allowing the flows to appear successively as desired (Flash animations), either in a increasing or decreasing order. Here the animation simulates changes at a structural level instead of the temporal one (Figure 14).

These new technologies can also benefit the vectorial representation of flows, whether vector fields or streamlines.

### *3.3. Surface occupancy and dynamic densities*

Surfaces occupied by the daily displacements between home and workplace can be expressed through interpolation; but they vary from hour to hour, which multiplies the number of maps and doesn't make their study any easier, as shown in Szegö's works [1987].

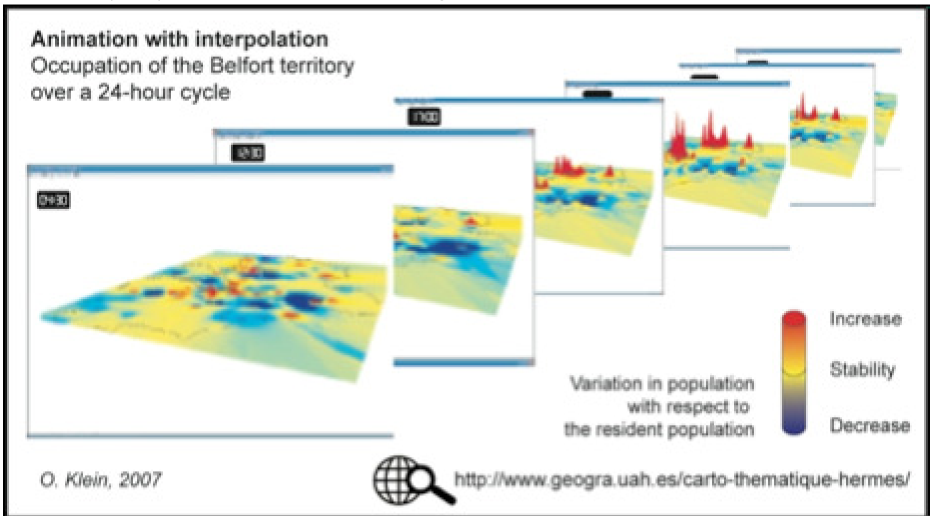



*Figure 15*

Animation will compensate for this overabundance of maps and – especially if 3D is used – display a "breathing" surface. An example is given here with the daily movements in the Belfort-Montbéliard area (Flash animation) (Figure 15).

This process could also be used to visualize the diffusion of a disease or of any other phenomenon that varies spatially in time.

## CONCLUSION

These different stages each correspond to different queries, the answers to which would direct the decisions as to the visualization of the phenomenon, but as shown in the following diagram, they are interrelated, no choice can be made independently.

This guide to movement representation (Figure 16), with its many retroactive effects, points to the importance of exchanging information with the recipients as well as with the specialists of the field concerned, and to its consequence on the selection of geovisualization.

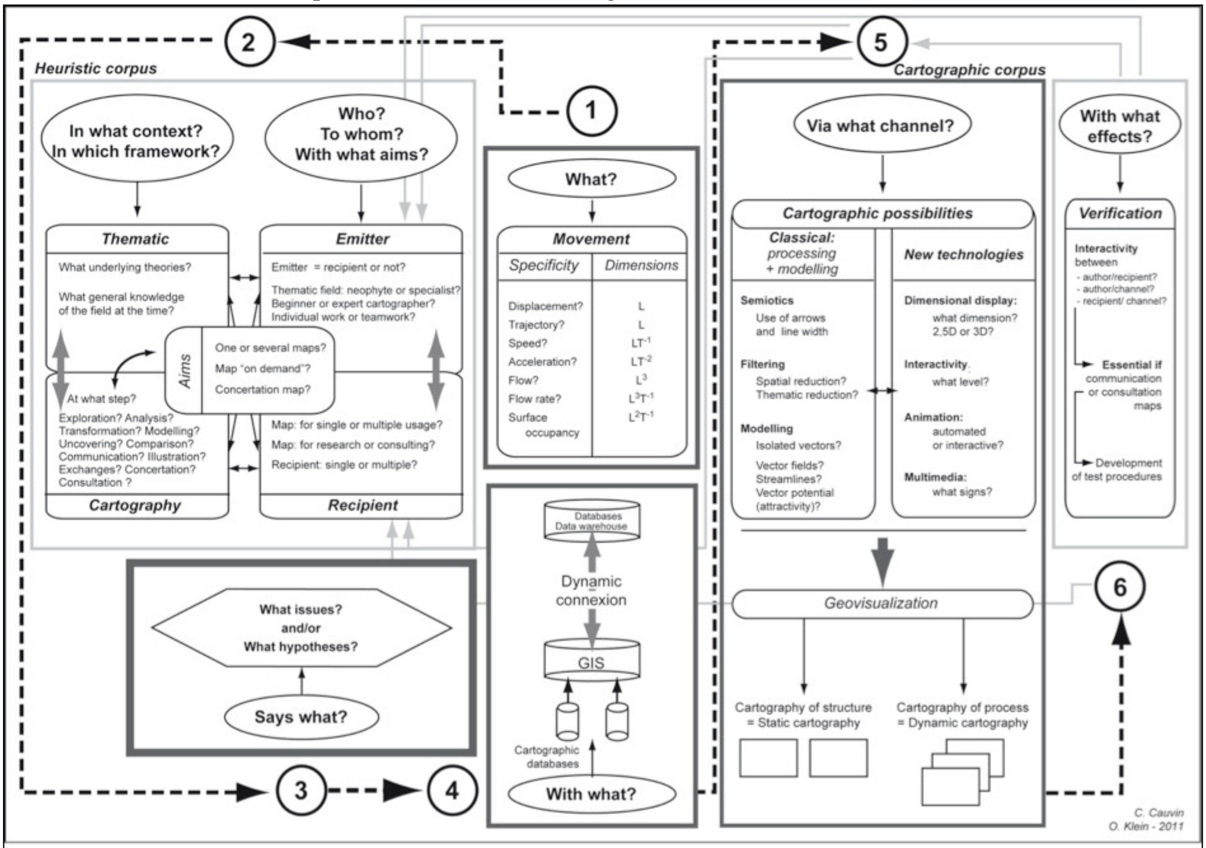



*Figure 16*

On the one hand, relations and discussions, at all levels, between map authors – those working in the field being studied and/or the cartographers - and all of the recipients of the map, with a defined purpose in mind, promotes participation. Thus, such a guide leads to concertation cartography, in full expansion nowadays.

And on the other, exchanges that were very limited yesterday between, here, geographer and cartographer, will induce a geo-cartographic or carto-geographic reflection that should lead to extending geographical studies

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