Socio-Economic Units: Their Life and Motions

Draft for Position Paper

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ABSTRACT

Geographic reality is in constant change but GIS are not well prepared to deal with description of this changing world. The representation of change is difficult at all levels, at the conceptual, verbal, graphical but also at the data storage level. Despite several efforts, general purpose solutions to deal with change of spatial phenomena and data representing change in time, the so called temporal GIS, were not successful.

This workshop concentrates on geographic objects and their behavior in time and space. It singles out socio-economic units as the object of study to reduce the field further and excludes therefore other kinds of geographic spatio-temporal behavior (movement of persons or other physical bodies in space, temporal changes of fields of attribute values as they are often used to describe natural phenomena).

It is proposed that a careful analysis with formal methods of different kinds of spatial changes is undertaken. Differentiation between the life cycle, the beginning and ending of objects, and the movements of objects is made. Socio-economic units like communes are created by legal act and can disappear by merging with other units, again by legal act. Movement of physical bodies in space is the prototypical case for change, but movement of geographic objects, especially objects which are not physical bodies like glaciers, pose challenging questions.

Socio-economic units, from the political subdivision to census tracks, from regions with dominant ethnicity or religion, to urban zoning, appear to have a life and to move in space. Concentrating on this specific case, it is expected that meaningful research results can be achieved.

1. INTRODUCTION

Current Geographic Information Systems (GIS) are modeling static spatial situations. Using Sinton's terminology, they hold time constant and then either vary theme or location - depending if they are vector (object) or raster (field) oriented [ref. sinton, refs. leicester goodchild, AF]. The world in which we are interested is in constant change; nothing is ever stable. This has been observed by the Greek philosophers and identified as one of the chief difficulties to understand the world. We need to identify objects which we can see as (relatively) stable and against which we can compare others.

This is particularly important for socio-economic objects in geographic space, which are typically non-physical. By socio-economic object we understand areal units which are delimited to describe social or economical phenomena. They encompass census tracks for statistical data collection, political subdivisions (boroughs, town, county, nation etc.), urban and rural zones, areas delimited for demographic descriptions (ethnicity, religion, language etc.) . These socio-economic units are conceptual constructions [see position paper by raper] and are not corresponding directly to a physical reality. Change and movement does therefore not have exactly the same meaning as with physical bodies.

Our conceptualization of change is influenced by the perception of change of physical objects, mainly the moment of physical rigid objects. The experience with physical objects, primarily rigid bodies, but also with liquid, melting ice etc. determine the cognitive categories we use to describe other objects and their movements, using metaphorical transformation [johnson-lakoff]. It is thus recommended that the modes of change of the relevant physical objects are studied and formalized in order to transform the results to the socio-economic units and the special properties identified.

Socio-economic units appear often with an ontology similar to ‘shadows’ [varzi]. They are non-physical properties of an area which can be moved without any movement of material. Shadows and holes are ontological categories which have only recently been systematically studied. The socio-economic units, as abstract objects, are perceived and understood in terms of such ontologies. Clarifying these will be a enormous first step.

1.1 IMPORTANCE OF CHANGE FOR GIS

There are very few applications where only the current situation is important. Most uses of GIS technology are interested in change. This is true for scientific and administrative use of GIS.

Sciences in general, and geography can serve here as an example, are interested in processes, which transform things. Processes are the general rules, the descriptive data is the particular, and thus of lesser standing. Scientists collect data in order to understand general rules, which are mostly seen as processes. The collection of data, the descriptive part of scientific activities, is necessary to have the foundation on which deductive work is building on. The need for support for time related data was voiced by anthropologists, architects, atmosphere scientists, marine biologist, planners, urbanists, wild life specialist, etc. The topic has become of even more interest lately with the global change efforts [NASA ref.], where the object of the study is change itself, as it occurs on a global scale.

Administrative uses of GIS sometimes work properly with the current status only: tax mapping, facilities management for public utilities, forest management can do. But wherever legal aspects of liability, due process or the use of proper administrative procedures is felt, previous states are stored to assure that changes can be reconstructed.

1.2 REPRESENTATION OF CHANGE

Support for temporal data in GIS software, so called temporal GIS, has been asked for a long time [zubrow book, NASA project report boyle,smith].The lack of support for time related data in GIS may be one of the reasons why GIS is often seen only as a tool to help with the descriptive part of scientific work [goodchild Zurich]. A tool for geographers, helping with the descriptive part of science, but not helping with the hart of science, where processes are in the focus.

It is indeed surprising to see how poorly a current commercial GIS deals with data which represents objects which change in time. The best we can currently do is to show a snapshot of the data and even this may represent data collected over a period of time [see cheylan's position paper which deals with data collection]. Data quality standards demand that this is properly documented - but again, most data collections are lacking in this respect. Neither the software nor the data help with understanding changes.

To simulate change, snapshots of the situation at a specific time are accumulated. What would be required is a representation of change and the events that limit gradual change with the time they occur. To deduce the same information from the differences between snapshots is difficult and limited by the temporal resolution of the snapshots. This is a similar phenomenon as the one discussed in [burrough/frank IJGIS], where the difference between the capabilities of current GIS software and the requirements were compared. The social sciences need tools to represent and analyze change.

1.3 LIFE AND MOTION AS TWO TYPES OF CHANGES

Change comes in two forms: change of the objects of interest and change in the position or geometric form of these objects. For the first we use the heading ‘life’ of objects, objects may appear and disappear (e.g. a forest, or a residential zone), two object may merge (e.g. two parcels or two towns), an object may split (e.g. a ..). For the second we use the heading ‘motions’ , objects may move or may appear to move, with or without changing their form at the same time.

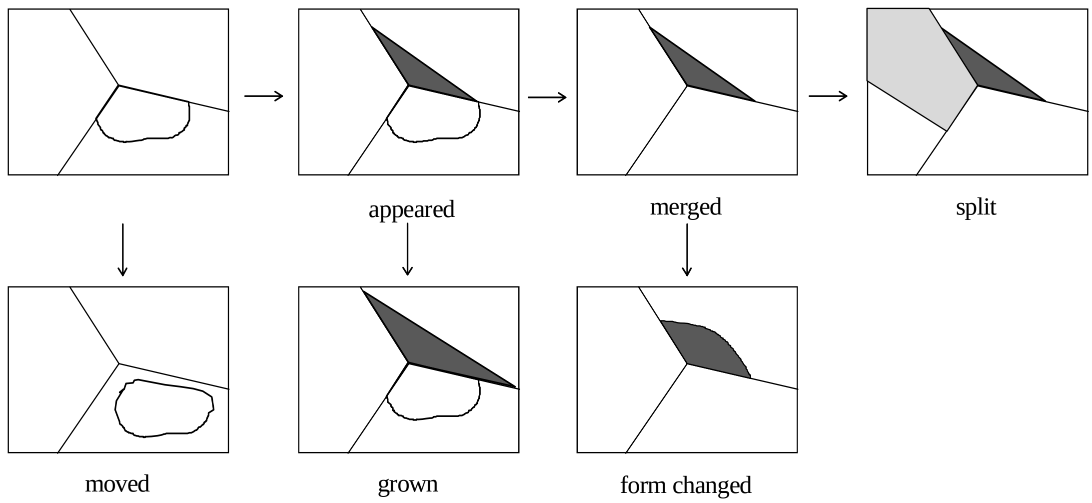


Fig. 1.1. Objects life and motion

The life and motion of physical bodies, especially of human beings in space, are the prototypical notions dominating our experience. The motions of physical bodies in the natural sciences is sometimes complex but the direct experience with the phenomena and the possibility to analyze the physical movements of particles constituting the bodies gives an approach to their understanding.

More unusual are the ‘life and motions’ of spatial units of economic or social sciences or administration. Administrative units are moving in space (e.g. Poland is here the best known [centennia]) or are merging or splitting - causing enormous difficulty with the analysis of statistical data collected for these (changing) units [openshaw lit]. The central business districts are changing size, form and location over time - even without having clear cut boundaries [burrough/frank book].

1.4 APPROACH

The past discussion of time in GIS can be classified in several groups:

- snapshots and differences between states [langrain etc.]
- discussion of work time, data flow and database time [Langrain on nautical chart updates]
- formalists discussion of space time as a multi dimensional continuum [worboys etc.]

These approaches were comprehensive (or generalizing) but do not allow to go beyond the obvious because too many dissimilar phenomena were treated at once. What is advocated here is an approach where different aspects of changes are analyzed and formally described, starting from the dominant human experiences with motion of rigid bodies (but also liquids) and following the cognitive metaphorical transformation of these cognitive categories to describe abstract objects like socio-economic units. It is asked for which real world situation their are applicable and which application areas use models for ‘life’ or ‘motions’ of objects of this type.

One can differentiate different types of ‘life and motion’ of objects:

- motions of physical bodies in small scale space, or in geographic space, along a predetermined path or in a field,
- motion of large physical bodies in geographic space, where the objects follow the rules of rigid body motion or the rules of liquids,
- motion of collectives in geographic space, where the motion of the collective is the sum total of the motion of the individuals [cheyland - sheep - pisa],
- motion of non-physical objects, e.g. administrative units, which glide shadow-like over the landscape.

It is assumed here, that each of these kinds of motion follows its own set of rules - its own ontology [frank bolzano]. Understanding what is similar and dissimilar for these types of changes will be useful, in particular to model the more abstract changes in socio-economic objects. It becomes clear from this analysis that the kinds of ‘lives’ and ‘motions’ objects may have are bound in a set of logical schemata, best described as algebras (or categories in the sense of mathematical category theory) [af - sdh time].

Different applications not only differ regarding the models for changes they use but also regarding the scale of time or space they employ. Geological time and space scales are very different from the temporal and spatial scale to describe urban changes. The classification attempted here is then to be combined with these scale differences.

2. STATE OF THE ART

The difficulties to include model data with respect to change in time are multiple, some generic and some specific for spatial databases:

2.1 TEMPORAL DATABASES

Database theory for temporal data exists (for a review see [Snodgrass, 1992 #108]) but none of the current commercial DBMS do include extensive support for time varying data. Lotus Notes and other systems support replicated databases with time stamps for any change [Lotus book - German]. This can be used to model the flow of information within the organization (database time) and thus contributes to supported collaborative work [reef to conference series], it does not apply to data describing an exterior, changing world (real world time).

Temporal database theory covers mostly a static or snapshot view of time and changes cannot be analyzed at the level of user semantics. It can be used to reconstruct a database after data loss but reasoning about motion and change is limited.

2.2 TEMPORAL GIS

Geometric models are static. In particular Euclidean geometry models static situations. Newtonian physics provides a sort of 'dynamic geometry' but it is appropriate only for the table top object space [Montello, 1993 #164]. GIS need support for temporal change in environmental and geographic space. For raster data the operations of map algebra can be used to compare images from two different points in time (epochs) and to identify cells which have changed. This is not an appropriate model to describe the movement of an object in space in general, but can be used in certain application areas . Chrisman and Langrain have investigated land use changes [Langran, 1988 #106; Langra n, 1988 #276; Langran, 1989 #275] following a snapshot approach related to the database viewpoint.

A number of workshop discussed support for temporal data in GIS (published reports are available for [Barrera, 1991 #359; Barrera, 1991 #358 ; Egenhofer, 1995 #109]). Generally, these meetings reaffirmed the importance of support for temporal data in a GIS - known at least since [Abler, 1987 #22; NCGIA, 1989 #21].The discussion invariably also shows a wide variety of application areas and possible solutions. Frank has concluded - in analogy to the discussion of the spatial domain - that there are many different types of time, which must be handled differently in a GIS[Frank, 1994 #133]. Different situations lead to different experiences of time - walking over a hill is a different experience than observing a city sprawl - which lead to different formalizations.

2.3 CHANGE IN PHILOSOPHY AND COGNITIVE SCIENCE

Philosophy looks back over two thousand years of discussion of the notion time. The duality between duration and event which has occupied the best minds since Zenon [ref. fraser - chapter 3] has been very fruitful [gartner goedel escher bach]. It attempted to find a uniform and all encompassing explanation of time - to correspond to the human belief that there is a single notion of time as there is assumed to be a single type of space. Time is crucial to science because time is intricately linked with causation. *Post hoc, ergo propter hoc* is not a permissible deduction rule, but temporal -precedence implies so often causality, that the inverse conclusion has become a common mistake. For scientific analysis, but also for many administrative applications, an ordered time is sufficient, because causation implies precedence lack of precedence rules out causation

Experientialism [Lakoff, 1988 #165; Lakoff, 1987 #43] takes human direct experience and perception as fundamental. Other domains of human endeavor, which cannot be directly experienced, are conceptually organized in analogy to the domains which can be directly experienced [Lakoff, 1980 #85]. There are at least two different base experiences of time and motion: the observation of motion of objects in figural space [Montello, 1993 #164], e.g. moving an apple from the left side to the center of the table, and bodily experience of walking in open space, e.g. over a hill.

The perception of time is dependent on the situation. Resolution of time is according to the task: only differences which can be of importance are observed and recorded. Human perception limits the resolution of two events to few tenths of a second, but in most situations, much larger concepts of instantaneous are used: start points for meetings are understoo d as 5 minutes more or less; in business, most durations are measured in days. This is similar to space, where resolution depends on the task at hand.

3. RESEARCH PROGRAM: DEFINE DIFFERENT TYPES OF CHANGES RELEVANT TO GIS

3.1 ABSTRACT FROM SCALE OF RESOLUTION

I start with the assumption that for each description of a process, which links causes and effects a specific resolution for space and time is appropriate: a scale on which necessary differentiations can be made and irrelevant detail disappear. These scales vary over several orders of magnitude [power of 10 book - on staudingers bookshelf], from the time/space scales for galactic or planetary movement, to those used to describe the daily migration of humans in a city. Frazer assumes that reality is divided in several clusters of interaction, which all have similar time/space scales [frazer, the voices of time, intro]. Such clusters form the subject matter of scientific disciplines.

Certainly there are a number of combinations of time and space scales relevant to geography [Frank, 1994 #133]. The effort here should abstract from these, as they are trivial to characterize, it is sufficient to indicate the resolution in time and space for a process.

3.2 ABSTRACT FROM THE PARTICULAR TYPE OFSPACE AND TIME

From a perceptual perspective, there are different types of time as there are different types of space. Perception of space is different for small scale space (tabletop) and geographic space [Montello, 1993 #164]. This is the same for time, where time in administrative processes is discrete and structured as containers, whereas time for other social and natural processes has a continuous aspect and can even be cyclic [Frank, 1994 #133].

For the effort here, we do not focus on these differences as they have been dealt with previously. We assume:

- geographic space, defined as too large to be perceived at once from a single vantage point;
- a discrete, linear time,

For both, time and space, we assume a resolution fine enough for the process of interest.

3.3 SEPARATE CHANGE IN LIFE AND MOTION ASPECTS

A possible hypothesis to structure change in geographic objects is that the aspects of ‘life’ and ‘motion’ can be separated.

By *life* we understand all aspects of the existence of an object in time. It is created, and lives on till it is destroyed. It may be ‘killed’ and later ‘reincarnated’. Objects may fuse, aggregate etc. Also the non-spatial properties of the object may change in time [Al-Taha, 1994 #201].

Motion covers all aspects of the movement of the object or change in the form, i.e. all geometric changes. A change in the form can be seen as a movement of the boundary of the object.

3.4 START WITH PROTOTYPICAL SITUATIONS

The prototypical situation for motion is the movement of human or animal bodies in space, but also the motion of liquids in small scale space. The best formalization is for movement of rigid bodies, as taught in every high school physics class. For life the prototypical situation is the life cycle of a person (or animal), but also the life cycle of a rigid body or of liquids.

We assume that the abstract objects of geographical space - in particular the socio-economic spatial units - are perceived and represented in terms very similar to these prototypical situations. Metaphorical transformation allow for the change from small scale experience to large scale space and from the physical experience to the general abstract [Lakoff, 1980 #85; Johnson, 1987 #152].

4. PROTOTYPICAL SITUATIONS

4.1 LIFE STYLES

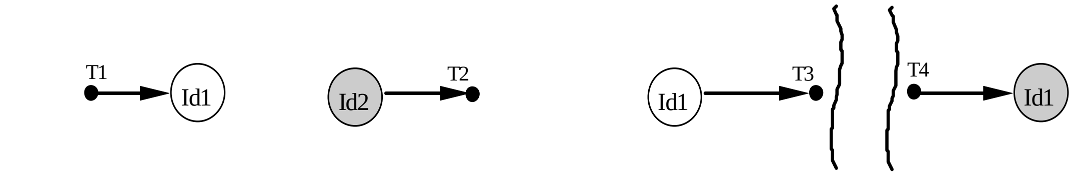
The notion of *life* is closely related to persons. A person is identical with itself from birth to death. This requires a notion of identity for an entity, where two things can be tested if they are identical, even if they differ in some descriptive values: a person at age 10 and at age 30 is the same legal person, despite the apparent change and the likely complete change of all the substance (molecules) it consists of. It is proposed to use the operations *create* and *destroy* to start and end an entity with identity [ref.].

Further, one may allow that entities get *killed* and *reincarnated* [ref.] - customary for gods and heroes of the ancient sagas.

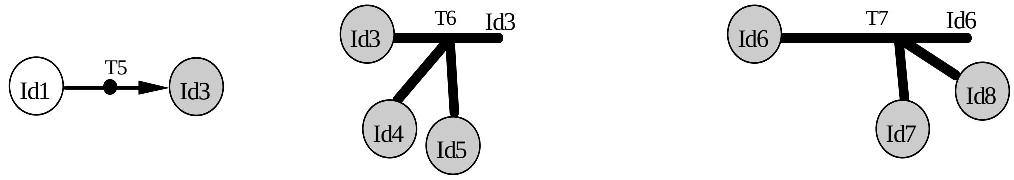
Objects can *evolve*, where one object disappears and a new one appears at a specify time.

An objects may be *identified* as being the same as another one, or two objects may *aggregate* where the identity of the second object is preserved within the first one. Two objects can be *fused* to form a new one.

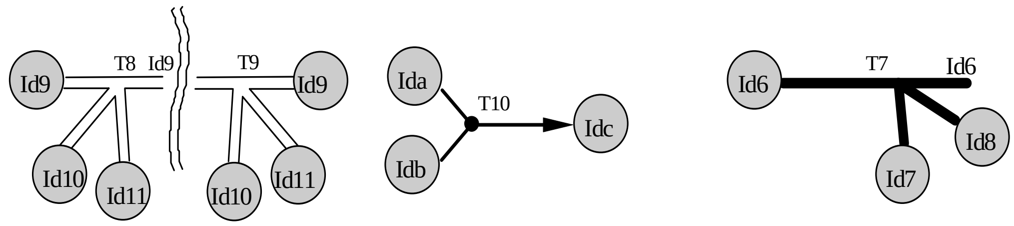
An object may *spawn* a new one or two previously aggregated objects may become *disaggregated* again. *Fission* breaks an object into parts, which form new objects.



a) Id1 *Created* at T1 **b)** Id2 *Destroyed* at T2 **c)** Id1 *Killed* at T3 and *Reincarnated* at T4



d) Id1 *Evolved* into Id3 at T5 **e)** Id4, Id5 *Identify* to Id3 at T6 **f)** Id6 *Spawns* Id7, Id8 at T7



g) Id10, Id11 *Aggregate to* Id9 at T8 Id9 *Disaggregates* at T9 **h)** Ida, Idb *Fuse into* Idc at T10 **f)** Id6 *Spawns* Id7, Id8 at T7

Not all these changes can occur to all objects, they form logical clusters and depend on each other. Formal methods can be used to analyze these dependencies and to document them. By life style we understand coherent sets of life operations: cars and similarly manufactured objects are created, parts are aggregated and disaggregated from them and they are destroyed. It is very unusual for cars to be killed and reincarnated, or to evolve, to spawn new objects. Thus the operations create, aggregate, disaggregate and destroy form the life style 'manufactured goods'.

4.2 MOVEMENT OF (RIGID) BODIES IN SPACE

4.2.1 MOVEMENT OF SMALL OBJECTS IN SMALL SCALE SPACE

The prototypical case is the observation of a physical body in space. This is one of, if not the primary experience of change as motion. A physical object is found at position a1 at time t1 and position a2 at t2, and at any time ti at a position ai between a1 and a2. It is implied that the size of the object is relatively small compared to the movement and the temporal resolution of the movement. Galton has formalized an ontology of movement of physical objects, which reconciles the event and the duration position [Galton, 1995 #401][storck's book 96].

It appears that movement of small objects is typically perceived as instantaneous change of position; the path of the change is usually not described nor noticed, probably because it is not consciously planned, but an appropriate path for the movement is left to the non-conscious motoric planning.

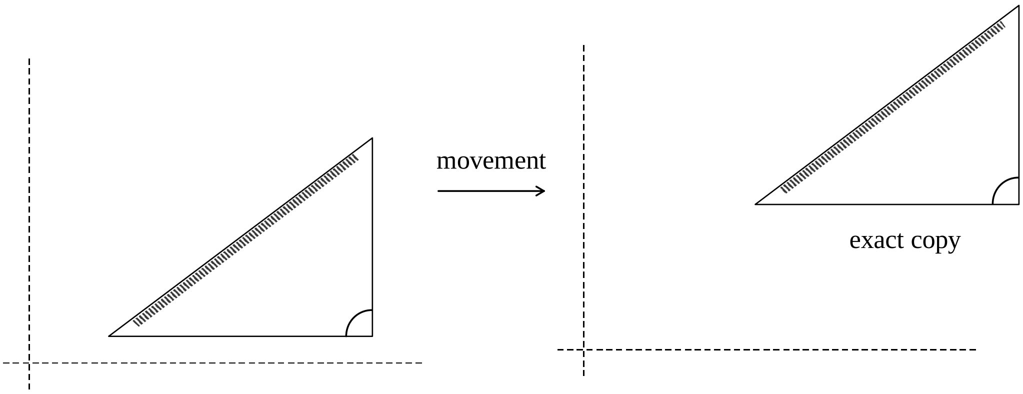


Fig. 4.1. Movement of a small object

4.2.2 MOVEMENT OF A PERSON

Generally, movement in large scale space (or spaces larger than small scale) of a self moving body, too large to be moved.

The movement can be across a field in the landscape, visible from a distance. The standard situation is on a surface in a gravity field, which influences the effort necessary for movement along the path; gives a component of resistance/acceleration along the path and one orthogonal to it. Related is the movement of a liquid in space: it follows the vector field. The movement of water in the landscape is of outmost importance to human economy.

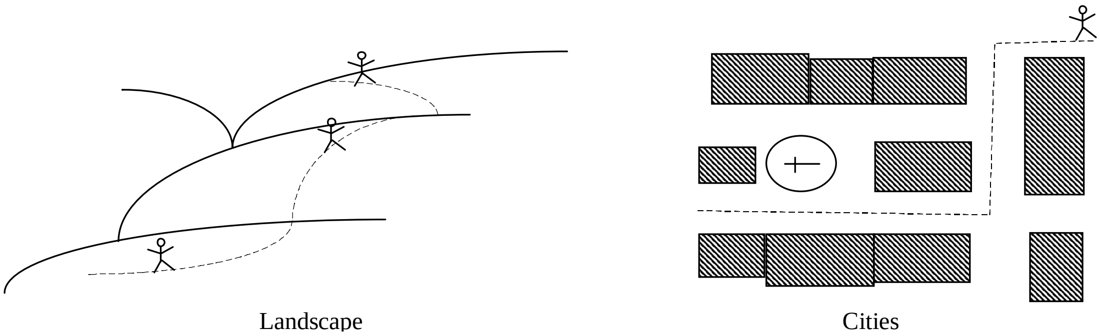


Fig. 4.2. Movement of a person

The movement of a person along a path is a fundamental experience. It is experienced by every human when it walks, but also perceived when other humans or animals move in space. It is perceived as movement along a path with a duration.

4.2.3 CHANGE OF GEOMETRIC FORM: MOVEMENT OF A BOUNDARY

The change can result in a change in the boundary, which is often seen as a movement of the boundary. One says the forest advances, meaning that the forest boundary changes (the only forest actually moving is the Birnam wood in Macbeth). It appears as if the boundary was moving - but mind: boundaries are not physical objects, their are limits between physical objects and as such have a complex ontology [Casati, 1994 #403].

Change in the geometric form can have multiple origins. They can occur through accretion of the small pieces the object consists of or the loss of components, which lead to erosion. To this the lifestyle of kill/reincarnation fits: a lake (e.g. the shallow Neusiedlersee in Austria) can disappear trough draught and reappear.

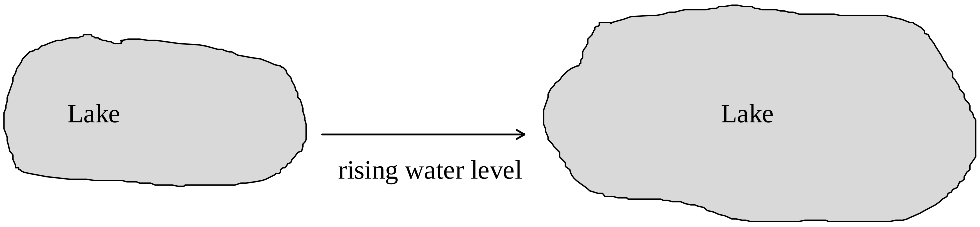


Fig. .4.3. Change of geometric form

4.3 CHANGES WHICH ARE UNDERSTOOD AS MOVEMENTS

Many changes are understood as movements **-** e.g. the movement of a forest **-** even if in reality the forest as an object does not move, and even if no physical objects moves at all.

4.3.1 COLLECTIVE BODIES

By collective bodies we understand objects which are composed of individuals which are at the next level of resolutions separated [Cheylan, 1993 #218; Talmy, 1983 #154]. Compare with collective nouns in language [Langacker, 1991 #425; Langacker, 1991 #424].

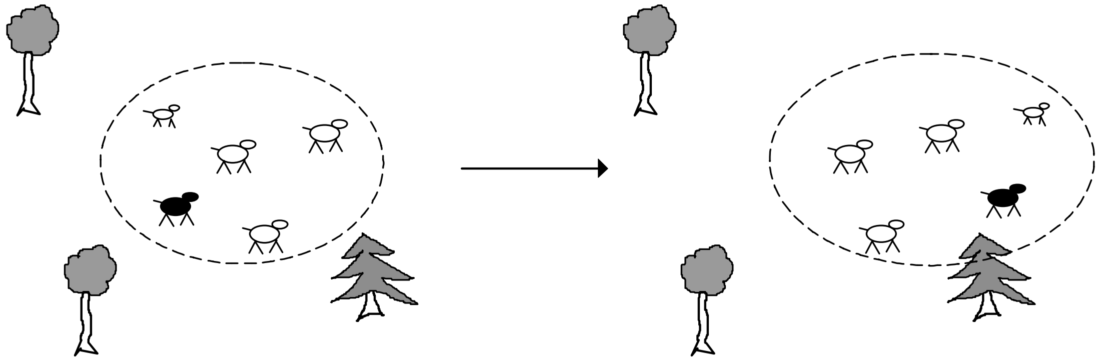


Fig. 4.4. Movement of a flock of sheep

The movement of the individuals in a collective body can be ordered, i.e. the same individuals remain in the advancing boundary (military formation), or the ones most back advance to the top (flocks of sheep).

4.3.2 LIQUID LIKE THINGS

The movement is similar to an ordered collective movement, but the form of the entity follows always the limits of other objects. In geography, cities seem to flow around ‘forbidden areas’ (like lakes, forest, if legally protected, etc.).

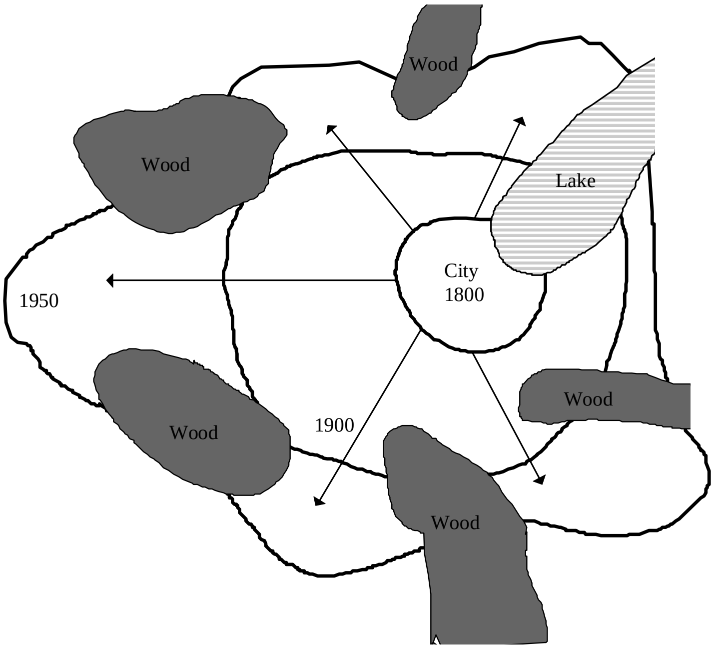


Fig. 4.5. Growing of a city (e.g. Zurich)

The movement may includes evaporation (e.g. glacier - where movement is mass movement plus the movement of mass through the boundary (df/dt + integral v x P/dl) or accretion from diffuse distributed material which is collected at a location and thus increases the object.

4.3.3 APPARENT MOVEMENT RESULTING FROM INDIVIDUAL CHANGES OF PROPERTIES

If individual areas of space change their property individually then a movement of the area with he same property may appear. A tree in a forest does not move, but trees on one boundary of the forest may be cut consistently and on the other boundary preserved. Thus the forest recedes on the one side and advances on the other, without any physical movement. If the change of an individual cell is strongly correlated to the properties of the neighbors, individual change may appear as a movement. All habitat seem to belong to this group.

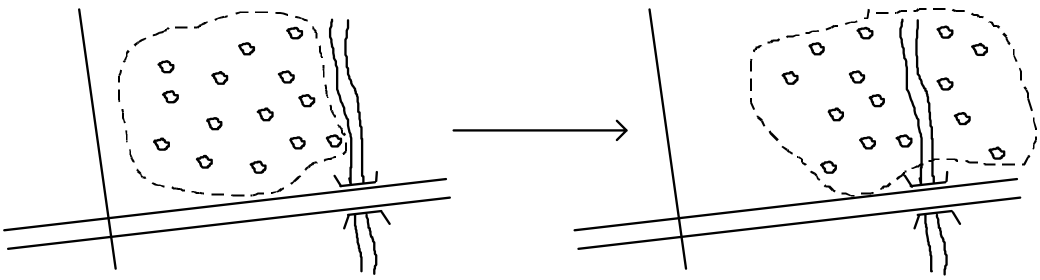
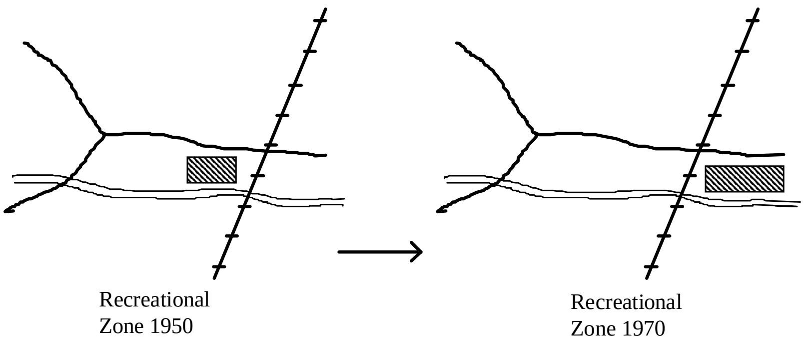


Fig. 4.6. Movement of a forest

4.3.4 MOVEMETN OF SHADOWS

By shadows we understand areas of uniform, non-essential properties of the objects which make up space [Casati, 1994 #403]. Shadows are cast on the object and can move without affecting the object. This is ontologically similar to legal assignments of areas to urban zones, to protected areas etc. Ownership rights are similar cases or the assignment of a country to an area; in this sense, Poland (or any other nation) is a shadow, and as such can move (this is to be differentiated from the area populated by people speaking the polish language, which move as collective bodies).



5. REPRESENTATION OF CHANGES

In a current GIS we cannot describe the changes directly, but indirectly: Change is the difference between two snapshots, representing states. A direct representation of movement of physical bodies is a vector of their speed (defined as difference in position divided by difference in time). With a startpoint one can compute the points this object will be at in future. Other forms of change are very different to describe and no such simple and general method is known (e.g. differential equations).

In a GIS we must be able to represent directly the different kinds of change. Each of the lifestyles and kinds of motions lead to its own representation scheme. Therefore the classification effort described in the previous point is crucial to identify appropriate representations. One may follow the example set by natural sciences: differential equations are a powerful method for wide variety of kinds of changes in attribute values, which can be described as fields a = f (x) [Goodchild, 1992 #323], and thus applicable for natural science objects in a GIS. Kuipers [Kuipers, 1994 #322] shows how do translate differential equations to the qualitative domain and how to use them in cases where no exact measurements, but only qualitative (i.e. more, less etc.) descriptions are available. These methods could be extended to spatial objects.

Representations are not only necessary for the internal storage in a GIS, but are required over a whole spectrum of methods of communication. Graphical and natural language methods are necessary to communicate effectively with humans, whereas the formal and internal storage methods support the design and implementation of GIS software.

The traditional methods for communication of change used by humans must be studied to understand the cognitive categories humans use to discuss change. Especially natural language expression for change can be analyzed to understand the image schemata [Lakoff, 1987 #43]. The cartographic tradition contains a series of examples to represent change on maps [vassilou].

6. TOPICS TO WORK ON:

From this ‘program’ a series of specific topics to work on can be identified. These topics appear relevant for today’s GIS industry and ready to work on, and small enough that there is a good chance of success within a year of effort.

The research topics can be seen as a set of theoretical questions:

- formalizing the prototypical cases listed (section 4);
- description of the prototypical cases for natural language expression or graphical expression of change, life or motion;
- formal representation methods and effective storage methods, including particular data structures;
- connection between change, life and motion and general description of data quality.

In each case, a specific subset of the total question should be tried first and justified by a particular real case. For example the description of sheep movements on a mountain (alp) could serve as an interesting test case, many different methods could be applied to. The paper by cheylan [Cheylan, 1993 #218] could serve as the base description of the case.

In general , work in the area of change of socio-economic units should be motivated by specific and realistic cases. It is far too easy to construct complex cases which cannot be solved in general, but each specific case of which the complex one is an amalgamate, could be solved.

REFERENCES

Note: Formal references will be completed for the next version of this paper. Details for incomplete references are available by email, if needed.

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