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## Social Features, Spatial Features and Temporal Features: An Urban Archaeological Data Model

*Abstract:* The use of GIS to study the spatial evolution of pre-industrial cities over the “longue durée” requires rigorous formalisation of heterogeneous data from different sources into robust entities. An initial model using the HBDS (Hypergraph Based Data Structure) method enabled us to distinguish social and spatial features. In this paper, we develop a specific model for the temporal dimension. The definition of urban objects using social, spatial and temporal features enhances the study of urban dynamics and of change over the “longue durée”.

### Introduction

The spatial study of a city over the “longue durée” (large time spans) is based on knowledge of urban objects and their relationships with each other from the beginning of human settlement to the present day.

In GIS, time is always linked to movement or change of state (usually for short periods) in order to manage the history of observed features in order to reconstruct successive states. As archaeologists, our aim is to work on heritage, entropy, and dynamics over the “longue durée”.

This observation raises three issues with regard to urban objects:

- The social use – function;
- The duration and chronology – time;
- The location and surface area – space.

The proposed conceptual modelling of archaeological information breaks the data down into social use, space and time. The method used is the HBDS (Hypergraph Based Data Structure) based on the theory of graphs and the theory of sets (BOUILLÉ 1977). It refers to two concepts: simple objects, and complex objects formed from simple objects.

As a general rule, archaeological objects, at whatever level of analysis, are described by typologies organised according to hierarchical thesauri.

Social use is thus organised according to a tree-structure model. Space is the most formalised set of the three; in GIS, it is structured on the model of a planar topological graph without isthmuses.

Time, always considered as linear and continuous, has not received any specific modelling in information systems. Our proposed model is based on an analogy with space. The procedure involves

defining a specific model for each of the three sets before putting forward a global model.

### The Urban Object

#### The Association of three Sets: Social Use, Space and Time

To study the fabric of a town over the “longue durée” (GALINIÉ 2000), the urban object (OH Objet Historique) constitutes the analytical unit of the former urban space: a church, a cemetery, a market, etc. Its definition is formed from three sets: social use, space and time. This is known as Peuquet’s triad (PEUQUET 1994, 447–451) and is frequently used (EGENHOFER / GOLLEDGE 1998; LARDON / LIBOUREL / CHEYLAN 1999; THÉRIAULT / CLARAMUNT 1999; OTT / SWIACZNY 2001; PANOPOULOS / STAMATOPOULOS / KAVOURAS 2003). Each of these sets can be represented by a circle overlapping with the other two (Fig. 1).

Inside each circle there is a reiteration process linked to the inductive and hypothetical-deductive interpretation of the archaeological data. Each of the three processes follows the intrinsic reasoning of the model of the circle to which it belongs. Nevertheless, the continuous overlapping of the three sets is such that each process is conditioned by the other two. Donna Peuquet (PEUQUET 1994, 448) expressed this by: when + where → what ; when + what → where ; where + what → when.

- The functional interpretation of an urban object is carried out by choosing a social use in a thesaurus. Dating, i.e. the time frame of the urban object, and its location, i.e. how it occupies the space, have a direct influence on this choice. Certain social

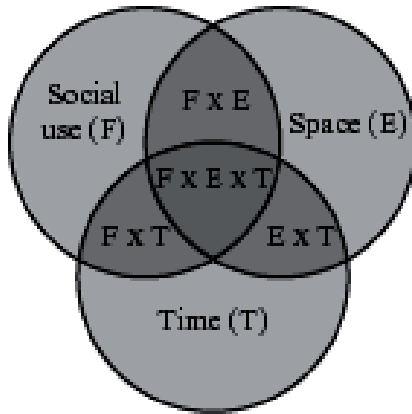


Fig. 1. The three sets: social use, space and time.

uses in the thesaurus are determined by a specific space (canonical cloisters, burial area, etc.) and others by their chronology (domus, parish churches, etc.).

- The temporal nature of an urban object is characterised by the date of its appearance and disappearance. A change in place (relocation), a significant morphological change or a social use change constitutes a temporal break and entails one urban object becoming another.
- The location and form of an urban object are determined by the social use (necropolis, a building for entertainment) and chronology (necropolis, defence systems). Moreover, the division of the space is determined by the temporal and social use definition of the urban object.

Thus defined, the urban object is similar to the geographical object “in relation to the scale, time frame and materiality of the data” brought together in “the idea of spatio-temporal granularity” (LANGLOIS 2005). As archaeologists, we use the same criteria to define the historical object univocally as one unit distinct from others.

**Transformations**

The association of the three sets are each characterised by an interaction (function/space, function/time, space/time or function/space/time) to which are linked one or more themes from the study of urban dynamics over the “longue durée”.

The study of urban dynamics is situated at the association of these three sets (F, S, T). A break in at least one of these dimensions involves one urban object changing to another.

Association	Study dimension
F X S	Specialised space determined by use: canonical cloisters, burial area, production area, port, etc.
F X T	Social use specific to a given time frame: domus, parish church, etc. Change of social use: re-use
S X T	Location specific to a given time frame: necropolis, defence system, etc. Movement: relocation of a social use (baptistry, minting workshop, etc.); morphology: change of form (from chapel to funeral basilica, etc.); spatial redistribution (reorganisation of convent buildings, etc.).
F X S X T	Trajectories of urban objects, study of former urbanised space and urban dynamics over the “longue durée”.

The reasoning is based on the type of modifications of a place over time (Fig. 2) grouped into three categories: thematic, spatial and temporal (LARDON / LIBOUREL / CHEYLAN 1999, 51–52).

**Objectives**

Starting from the urban object as defined above, the aim is to draw up a data model to constitute a geo-historical data base with the following objectives: 1) to provide a vertical and horizontal view of the phenomena (events at a particular period of time, changes that have occurred in a particular place); 2) to preserve the intrinsic nature of each place, namely its functional, temporal and spatial changes; 3) to avoid information redundancy, to facilitate data analysis and management.

Time	Attribute	Shape	Time
	no change	no change	continuity
	no change	no change	discontinuity
	change	no change	continuity
	change	no change	discontinuity
	no change	change	continuity
	no change	change	discontinuity
	change	change	continuity
	change	change	discontinuity

Fig. 2. Types of modification (GALINIÉ / RODIER / SALIGNY 2004).

## Modelling

Urban functions and spatial features are based on different concepts. While spatial dynamics constitute the objective of the study, chronology should also be included. However, each set will be described with its own data model.

The first stage consists in differentiating social use from geometry. This requires formalising data from multiple and heterogeneous sources into a robust univocal entity. It entails dissociating historically pertinent social features from the corresponding geographically pertinent spatial features in order to observe the dynamics. To analyse these dynamics, the chronology must then be converted into temporal features.

### The HBDS Method

Modelling consists in deconstructing information, even if this means going against our overall perception of a phenomenon. To achieve this, our work uses the HBDS method (BOUILLÉ 1977; SAINT-GÉRAND 2005) based on the theory of graphs and sets. This method groups together five fundamental elements:

Class	a set of objects which have the same characteristics. These objects are said to be "simple". Each class is represented by an ellipse.
Hyper-class	a set of one or several classes. These objects are said to be "complex". They are also represented by an ellipse.
Attributes	they define the class or set of objects (e.g. dating). They are represented by squares linked to the class.
Links	these involve the relationships between the object classes and are represented by arrows. They can be bearer of attributes.
Hyper-links	a set of links from same nature.

The simple object has its own geometry, while the complex object does not since it comprises several simple objects. Modelling in this way can thus cre-

ate an interlocking system: one group of complex objects can form another complex object.

### Social Features

In the field of urban topography studied over the "longue durée", information with documentary potential comes from three types of sources (GALINIÉ 2000, 18–24; GALINIÉ / RODIER 2002): material elements (underground or standing); written records; iconographic representations.

Numerous examples of functional groups exist in archaeological and contemporary historical bibliographies stemming from urban geography (HEIGHWAY 1972; VAN ES / POLDERMANS / SARFATIJ 1982; LEPETIT 1988). We have used the one drawn up and tested by the Centre National d'Archéologie Urbaine of the French Ministry of Culture and which has been used successfully since 1990 to process topographical data from pre-industrial towns<sup>1</sup>. The functional interpretation is established according to the use value and the urban value (Fig. 3). For example, a building is interpreted as a workshop (use value); from this it can be assumed that there was an artisan sector and a production- or transformation-activity sector (urban value).

The recording unit chosen for analysing urban organisation and its transformations over the "longue durée" is the social features (EF entité fonctionelle), defined as a topographical, anthropogenic or natural element with a single dated and localised social use.

Social use (Fig. 6) is thus organised according to the tree-structure model. The resolution of the thesaurus using a three-level hierarchy (urban value, use value and description) is based on the anticipated scale of perception. The items in the thesaurus are limited to the chrono-cultural period studied. It is, however, drawn up to cover this period as broadly as possible. Not all the items listed are necessarily required.

### Spatial Features

The spatial modelling proposed (GALINIÉ / RODIER / SALIGNY 2004) is based on the principle of non-redundancy of features. On the one hand, it consists in identifying the social features (EF) as complex

<sup>1</sup> See the directory of urban field operations 2005 on-line on the CNAU site: <http://www.culture.gouv.fr/culture/cnau/fr/index.html>.

- |   |   |   |
|---|---|---|
| <p><b>1. Roads, development</b></p> <ul style="list-style-type: none"> <li>11. thoroughfares, streets</li> <li>12. unoccupied spaces</li> <li>13. riverbank works</li> <li>14. landscape works</li> <li>15. crossing points</li> <li>16. water supply systems</li> <li>17. sewers/ drains</li> <li>18. monuments, vestiges</li> <li>19. unspecified monuments</li> </ul> <p><b>2. Defence and military structures</b></p> <ul style="list-style-type: none"> <li>21. urban defence systems</li> <li>22. fortified structures</li> <li>23. garrisons, barrack buildings</li> </ul> | <p><b>3. Civil constructions</b></p> <ul style="list-style-type: none"> <li>31. public spaces</li> <li>32. civil authorities, justice</li> <li>33. education, culture</li> <li>34. health</li> <li>35. entertainment, sports</li> <li>36. baths, thermal baths</li> <li>37. private homes</li> </ul> <p><b>4. Religious buildings</b></p> <ul style="list-style-type: none"> <li>41. pagan worship</li> <li>42. buildings for Catholic worship</li> <li>43. convent or monastery buildings</li> <li>44. ecclesiastical buildings</li> <li>45. worship other than Catholic</li> <li>46. parish churches</li> </ul> <p><b>5. Burial places</b></p> <ul style="list-style-type: none"> <li>51. burial area</li> <li>52. parish cemetery</li> <li>53. special burial place</li> </ul> | <p><b>6. Trade, crafts, production places</b></p> <ul style="list-style-type: none"> <li>61. trade, markets, shops</li> <li>62. crafts, workshops</li> <li>63. agriculture, livestock farms</li> <li>64. manufacture, industrial premises</li> <li>65. extraction, quarries</li> </ul> <p><b>7. Natural formations</b></p> <ul style="list-style-type: none"> <li>71. coast lines</li> <li>72. rivers (alluvions)</li> <li>73. marshes</li> <li>74. colluvial events</li> </ul> <p><b>8. Other</b></p> <ul style="list-style-type: none"> <li>81. unspecified</li> <li>82. no confirmed occupation</li> <li>83. abandoned</li> </ul> <p><b>9. Non-urban</b></p> <ul style="list-style-type: none"> <li>91. complex settlement of a non-urban character</li> <li>92. peripheral structure</li> </ul> |
|---|---|---|

Fig. 3. Urban values (1 to 9) and use values (11 to 92) according to the CNAU thesaurus.

objects interpreted archaeologically, and on the other hand, the spatial features (ES entité spatiale) as simple objects with localised geometry. In this model, space is continuous; it can in some places be unoccupied. In a given place, there can be one and only one ES, but this can play a role in as many EFs as necessary. The aim is to create spatial features according to the way they develop morphologically, and not according to their functional definition. This requires cutting up or breaking down the place into different or multiple objects (ESs) which are not defined by dating and/or social use.

One ES or a group of ESs define an EF at a given moment (chronological range, dating, etc.) for one or more specific functionalities. In an initial model, the dating and/or social use attributes have consequently become the attributes of the relationship between the place and its constituent objects, this relationship being invalid without at least one attribute. An EF can consist of one or more ESs. An ES can belong to one or more EFs. This proposal is being applied in a PhD thesis on the formation and transformation of the urban fabric of a district in Tours from the fifth to the eighteenth century (LEFEBVRE 2006).

Fig. 4 shows a succession of transformations that can be found in numerous towns in various forms.

In GIS, space is structured according to a planar topological graph model without isthmuses in

which the ESs are included. The ESs are created according to the definition of urban objects. Space (Fig. 6) is continuous, circumscribed by the definition of a study area. It contains gaps or unoccupied spaces which are the result of removing the ESs from the study area.

In our example, the ESs created correspond to spatial realities, clearly defined and localised forms, which take on detailed historical meaning due to their successive spatio-temporal connections in the EF.

### Temporal Features

The procedure that we have followed has taken us from a functional to a spatial approach. Although this construction frees us from spatial redundancy, it generates temporal redundancy and means that time and social use remain subject to space.

Our intention is to consider time as a specific feature in the same way as space and social use. We propose constructing a time-specific model which, by linking it with those used for space and functional interpretation will allow the phenomena we are studying to be dealt with from both a spatio-temporal and a temporal-spatial point of view. This change in perspective, distinguishing time from space, seems to be a necessary step for basing the study of dynamics on an analysis in which time and

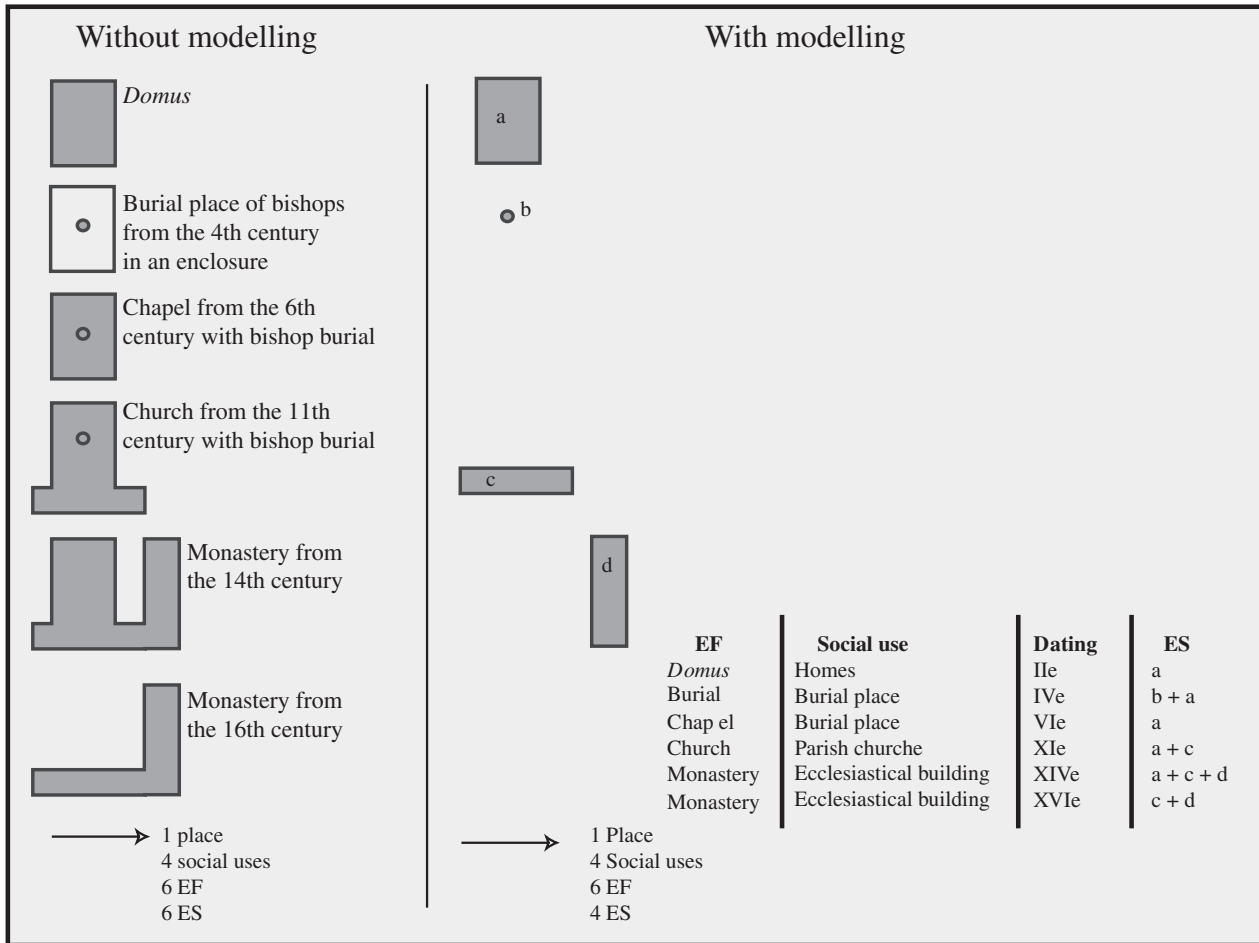


Fig. 4. Example of an FE becoming an SE (GALINIÉ / RODIER / SALIGNY 2004).

space have equal value. The starting point is thus the study object and not one of its characteristics: social use, time or space.

Since our aim is to work on heritage, entropy, trajectories and dynamics over the “longue durée”, time must be considered in its own right and no longer as belonging to spatial objects.

Whatever the objective of the modelling or the scale of analysis, once historical data is involved, time becomes the essential parameter. However, as long as it is confined to the role of an attribute, it cannot be applied globally, but only specifically to each class of features and repeated for each of them. Time must therefore be considered as a class of features in its own right. We propose to model time by analogy with space. To this end, a neutral, a temporal feature (ET entité temporelle) needs to be defined using the smallest time unit of value for dating the phenomenon studied. In its simplest form, ET can be assimilated with the notion of “date”.

In this case, no time redundancy should be observed; like space, time is continuous. There may be moments when it is not used. At a given moment, there can only be one ET, but it can be relevant for as many urban objects as necessary. The temporal resolution chosen for the ETs defines the dating of urban objects. Continuous time is circumscribed by the time markers of the studied object. ETs thus belong to a set with a known number of elements. The ETs concerned with the urban objects make up a sub-set whose removal from the total ETs reveals time gaps.

The time model is linear and topological as for space. Here, time is assimilated to a space and a dimension. In line with HBDS modelling, we have defined a “time” hyper-class. It consists of time features, simple objects represented by dates and intervals. This time formalisation in instants and intervals is based on Allen’s algebra (ALLEN 1984), extensively used in the field of artificial intelligence (PEUQUET 1994, 454–455; LARDON / LIBOUREL / CHEY-



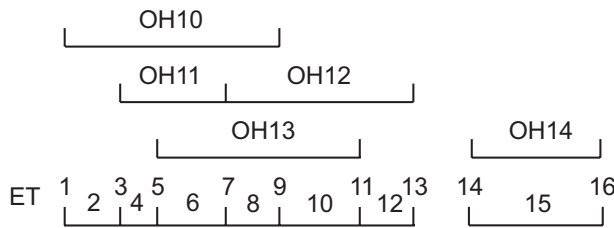


Fig. 5. Deconstruction of time into ETs.

LAN 1999, 48–49; MULER / DUGAT 2007, 39). However, we propose deconstructing time into as many ETs as necessary to constitute urban objects (Fig. 5).

Thus there is no longer time redundancy, and consequently all ideas of duration, century and period can be reconstructed from this model (Fig. 6). The duration and number of ETs for a time period determines a frequency. By observing this distribution it should be possible to analyse rhythms.

### Global Model

The organisation of these three features around the urban object constitutes the global model of former urbanised space for studying the town over the “longue durée”.

The way social use, space and time hyperclasses relate to the urban object determine how it is interpreted, localised and dated respectively. The attributes of these relationships enable them to be qualified: reliable interpretation, precise localisation and the origin and precision of dating.

Using this organisation, on the one hand, the urban object can be placed at the centre of the model interacting with its three components, and on the other hand, social use, space and time can be independent.

This is of course a theoretical proposal which will be implemented in a second phase.

### Conclusion: from the Model to Analysis

The aim of conceptual formalisation is to enable models and analyses of data to advance the understanding of observed phenomena. Constructing temporal modelling by analogy with spatial modelling implies that temporal analysis is based on concepts similar to those of spatial analysis with the following equivalences:

Concepts of spatial analysis	Concepts of temporal analysis
Location	Dating
Distance	Duration
Relative position	Relative dating
Spatial interaction	Temporal interaction

However, the models used to analyse temporal interactions remain to be written. The analysis of temporal interactions will enable rhythms to be observed and highlight the accelerations and decelerations, contractions and expansions of time observed empirically by archaeologists. Identifying these rhythms will probably highlight the state of knowledge by underlining the source effects. However, it will also offer the possibility of focusing observations on the transition from one state to another, i.e. concentrating more on changes in state than on the states themselves.

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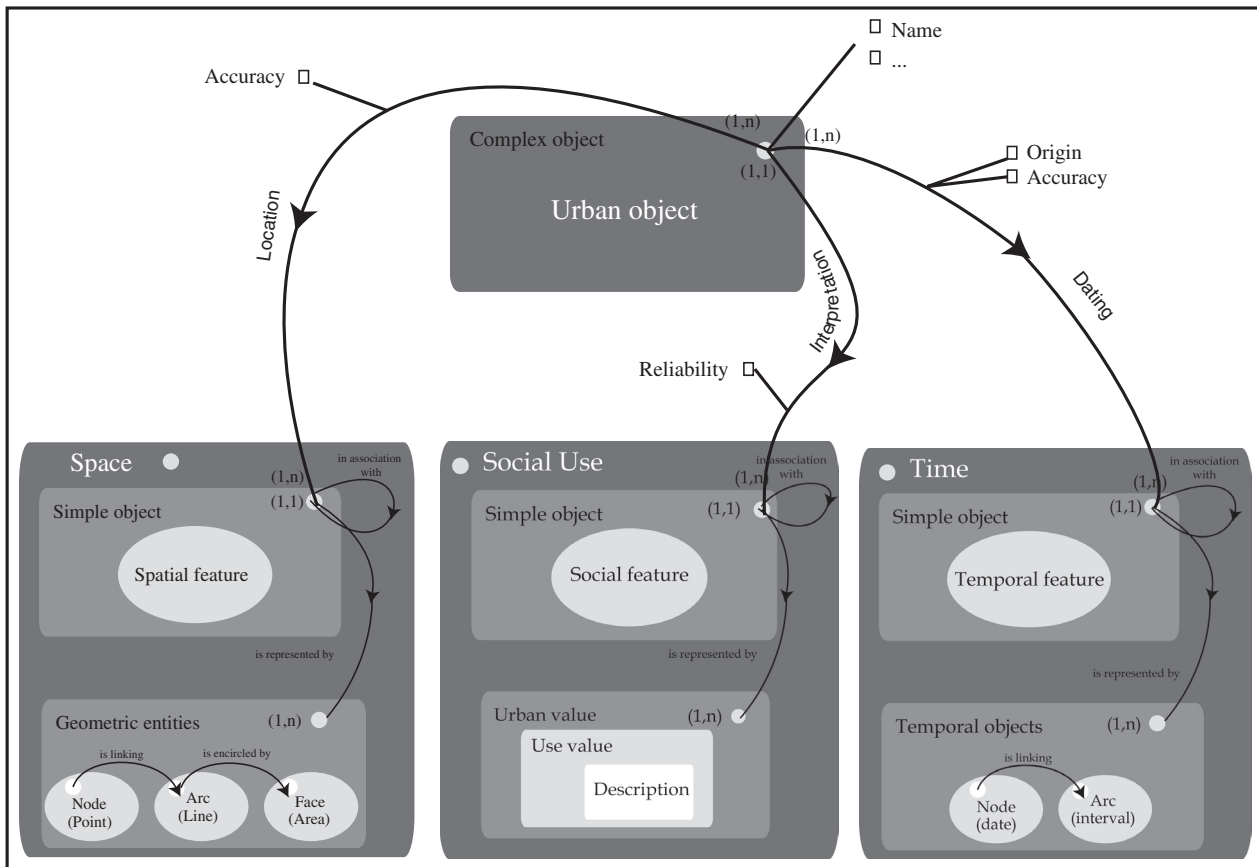


Fig. 6. Global model.

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