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Simulating retail locations using GIS and an agents decision model for urban planning

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Abstract
This paper focuses on a methodological approach which intends to simulate subsequent transformations of urban patterns within a GIS. We describe conceptual models of data and process dedicated to a problem interfacing actors and territory: location strategy of retail outlets.

This research project tackles the following question: which area will be chosen if some retail outlets arrive or change their location in a town ? The aim of the model is first, identification of potential problems in the system's functioning (for example, lack of proximity stores may penalize non moving population), secondly, evaluation of retail structures' fragility towards planning realizations.
The theme of retail location covers two interdependent aspects which are supply and demand (Merenne-schoumaker, 1987). Our model concerns especially supply's settlement dynamics. It does not take directly into account neither retail potential rentability (for example: calculation of potential sales purchased at one store, according to household incomes), nor consumer behaviour (evolution in course of time of consumers preferences). However, because of interdependence

between supply and demand, the latter appears implicitly, through evaluation of urban areas attractiveness for each type of store. For example, one criterion for measuring attractiveness is the number of people frequently visiting each area.
The scale considered for the modelling is intraurban, which enables us to analyze competition phenomena between areas in the location process. According to a general point of view, a town is made of heterogeneous areas interacting. One form of this interaction is competition for attracting, on one side retails, on the other side consumers. Concerning location strategies, competition depends on the type of urban areas. It may be:

– strong and introduce equilibrium position when attractiveness measures complement each other, or desequilibrium position when attractiveness measures are unequal;
– weak or tends to complementarity when areas show different retail structures and attraction for consumers.

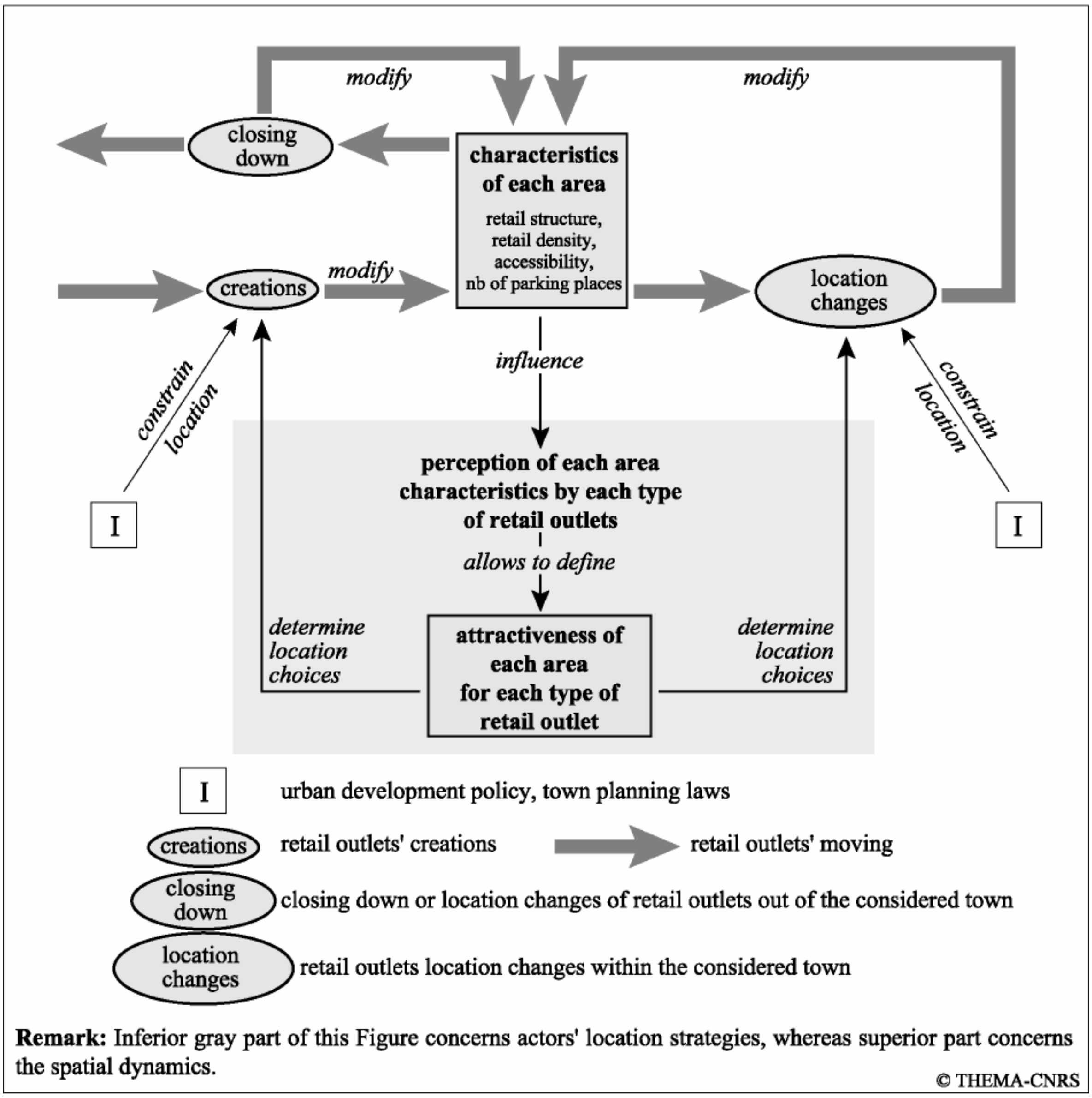
This illustrates that successive location choices are at once sources and results of spatial differentiation.
An important remark must be made here. The model differs from the mainly used for retail choice location problems. We do not search for an optimization of a location network for a retail chain (eg: location-allocation models), or for the selection of an optimal site for a new store. Our aim is to provide a better understanding of interactions between actors and their territory, and to improve knowledge about existing links between retail and urban structures.

The first part of this paper deals especially with the representation of influence of space characteristics upon actors' location decision and subsequent spatial transformations. In the second part, we explain how we formalize retail location process, in a way compatible with an information system. We chose to implement the model in a GIS based on Object Oriented programming (Cheylan et al., 1997) and a relational database, both available on SmallWorld GIS. Indeed this tool permits to express relationships and dynamic behaviours using dynamical methods linking two different objects ("triggers"). Due to the object orientation programming, we can easily model retroaction between actors and space. The third part is dedicated to the presentation of two conceptual models, one concerning information processing, and the other data structure.

1• Representation of the interactions between actors and their territory

The general architecture of the model is based on a representation of interactions between socio-economic actors (such as small fashion shops, hypermarkets, bookshops, etc.), public actors (politicians, urban planners) and territory. Socio-economic and public actors modify the urban pattern (building of new stores, new roads…), but the territory influences actors' behaviour, too. The form and structure of urban pattern are a constraint for actors' action. The territory represents not only an inertia force, but an action force, too. This feedback between actors and space, in case of retail location, can be represented as shown in Figure 1.

Figure 1: Interactions between socio-economic actors and their territory concerning retail settlement dynamics



2• Formalization of the location decision process

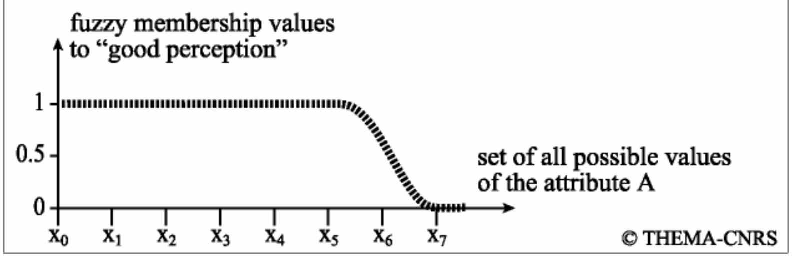
The location decision process is divided into two phases. The first one consists in the evaluation of competitive areas’ attractiveness measures. It can be considered as a location choice phase. The second one consists in the choice of the most attractive area, the verification of the vacancy of the chosen sites, the verification of the conformity towards planning laws. It represents a settlement phase.

1• Location choice phase

Each area is characterized by a set of attributes like accessibility, land prices, retail structure, image of the zone, etc. These attributes can be interpreted as an "objective" qualification of the area. They correspond to the element *"characteristics of each area"* mentioned in Figure 1.

When some retail outlets want to set up in a town, they evaluate the attributes of the areas according to the qualities they need for setting up. The use of fuzzy values permits to take into account imprecise decision process of actors and to formalize semantic attributes (like "rather good accessibility") (Dubois, Prad, 1980). That's why their requirements are represented by the way of fuzzy membership functions (see Figure 2) and importance values. Each group of retail outlets also appreciates each attribute and assigns an importance to it, independently of urban areas. So, there exists a set of membership functions and a set of importance values for each attribute and type of retail outlets.

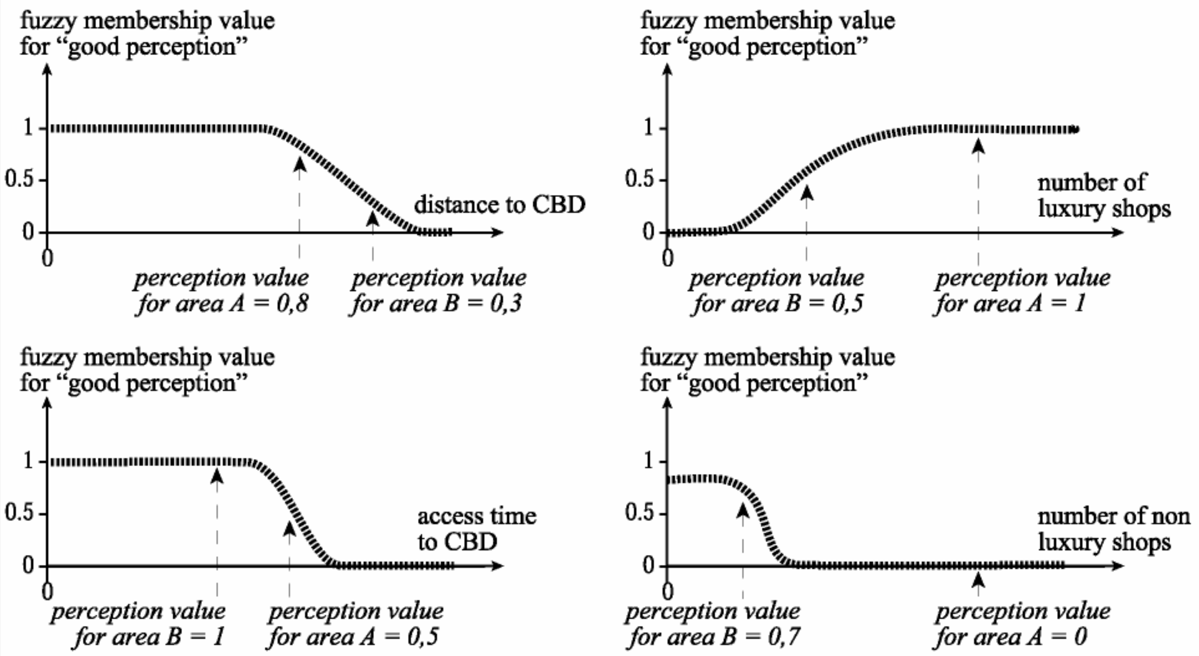
Figure 2: A membership function for an attribute A



In course of simulation, "real" values of each areas' attributes are compared with perception values defined by membership functions. Thus, we obtain a fuzzy perception value for each area's attributes according to each type of actors. Evaluation of attractiveness of each area by each type of retail outlet is based on the combination of perceived attributes values and their respective importance (Zimmermann, 1987). This combination is made by fuzzy operators, which may be different depending on the attributes' types (for further explanations, see (Frankhauser et al., 1998)). Some attributes, such as accessibility, retail structure or image of a zone, are intrinsically synthetic. That is why they are decomposed into some "elementary attributes". For example, the attribute "accessibility" is decomposed into "distance" and "time". Elementary attributes could be considered as being more "objective", because easier to valuate.

Let us recapitulate our purpose by an example. Some luxury shops are looking for a setting up area. Only two location criteria are taken into account, accessibility and retail structure. The first step consists in the evaluation of these two criteria (see Figure 3). The second step is the calculation of attractiveness values for each area according to each shop, combining importance and perception values of accessibility and retail structure.

Figure 3: How to evaluate the perception of areas' characteristics by luxury shops?



Importance for elementary attributes

distance to CBD	*access time to CBD*	*number of luxury shops*	*number of non luxury shops*
0,7	*1,3*	*1,1*	*0,9*

Example of evaluation of each perceived characteristic, according to a chosen operator

– *accessibility: combination between perception and importance values of access time to CBD and distance to CBD to obtain the perception of the accessibility for area A and B*

Perception of accessibility for area A, P_{ac}(A)

$P_{ac}(A) = MIN\ (P_{access\ time}(A)^{1,3} ; P_{distance}(A)^{0,7})$

$= MIN\ (0,5^{1,3} ; 0,8^{0,7}) = 0,4$

Perception of accessibility for area B, P_{ac}(B)

$P_{ac}(B) = MIN\ (P_{access\ time}(B)^{1,3} ; P_{distance}(B)^{0,7})$

$= MIN\ (1^{1,3} ; 0,3^{0,7}) = 1$

– *retail structure: combination between perception and importance values of number of luxury shops and number of non luxury shops to obtain the perception of the retail structure for area A and B.*

Perception of retail structure for area A, P_{ret}(A)

$P_{ret}(A) = DIFF*MIN\ (P_{luxury}(A)^{1,1} ; P_{non\ luxury}(A)^{0,9}) + (1-DIFF)*MAX\ (P_{luxury}(A)^{1,1} ; P_{non\ luxury}(A)^{0,9})$

$DIFF = MAX\ (P_{luxury}(A)^{1,1} ; P_{non\ luxury}(A)^{0,9}) - MIN\ (P_{luxury}(A)^{1,1} ; P_{non\ luxury}(A)^{0,9}) = 1$

$P_{ret}(A) = 1*0 + 0*1 = 0$

Perception of retail structure for area B, P_{ret}(B)

$P_{ret}(B) = DIFF*MIN\ (P_{luxury}(A)^{1,1} ; P_{non\ luxury}(B)^{0,9}) + (1-DIFF)*MAX\ (P_{luxury}(B)^{1,1} ; P_{non\ luxury}(B)^{0,9})$

$DIFF = MAX\ (P_{luxury}(B)^{1,1} ; P_{non\ luxury}(B)^{0,9}) - MIN\ (P_{luxury}(B)^{1,1} ; P_{non\ luxury}(B)^{0,9}) = 0,23$

$P_{ret}(B) = 0,23*0,47 + 0,77*0,7 = 0,65$

2• Settlement phase

The attractiveness measures are used to determine potentials for the choice of the different areas and govern the dynamics of retail spatial arrangements. Here takes place retroaction between actors and territory. Indeed, attributes may be affected by subsequent changes of retail structure, and attractiveness of areas may decline or increase.

3• Realization of conceptual data and processing models using the MERISE formalism

1• Why use MERISE as method of Information System development?

The MERISE method (Nanci, Espinasse, 1996) comes from research tasks about systemic studies (Lemoigne, 1990) applied to companies Information Systems. It integrates various components within a same system, namely the subsystem of piloting (which reflects, decides and controls), the operative subsystem (which transforms and produces) and, between these two, the information subsystem (which memorizes, computes and diffuses). These three subsystems communicate through various flows of information.

In addition, the MERISE method proposes two levels of modelling for information systems.

1– An organisation level, broken up into two other levels:

* a conceptual level, which corresponds to a high level representation of the information system; typically, one takes care here of processes and data significance without any technical or economical constraints ;

* an organisational level, integrating organisational and economic constraints; here intervenes the filter due, for example, to the given structure of a firm.

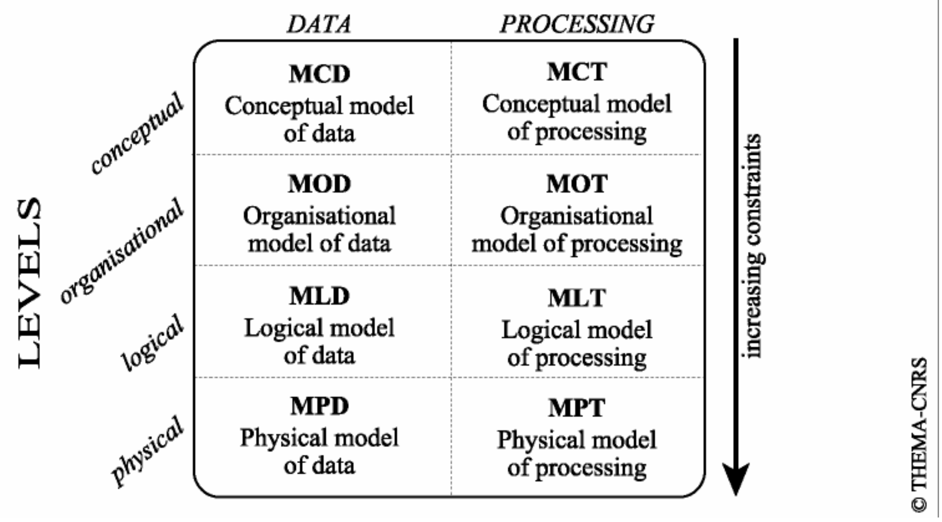
2– A computerized level involving:

* a logical level, taking into account various constraints affecting the operating domain and the data ; at this level, one must take into account the computer system available;

* a physical level, corresponding to technical architecture and physical implementation within the selected DBMS (DataBase Management System).

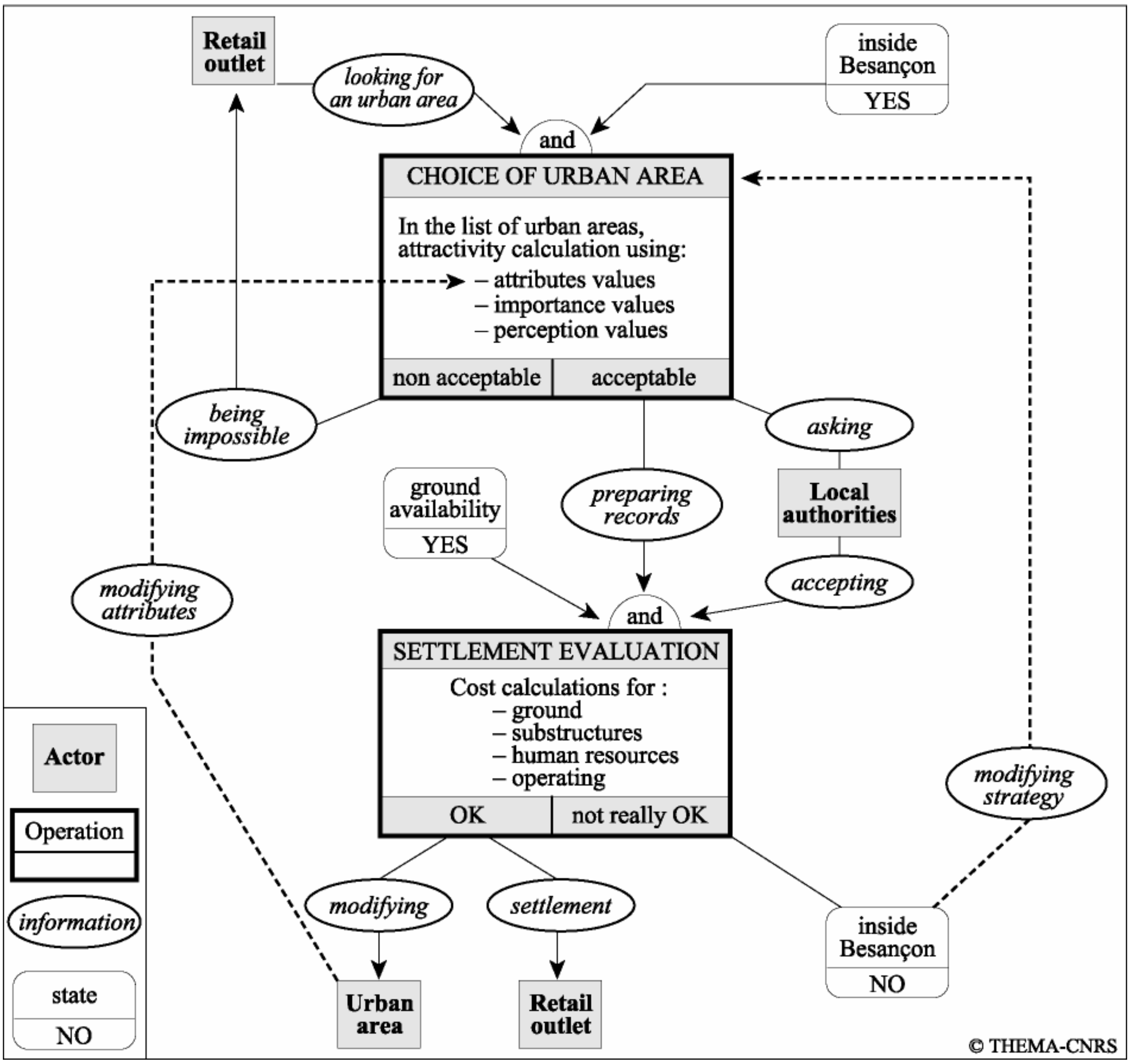
These four levels (conceptual, organisational, logical and physical) relate to both data modelling and processing. Thus, one defines 8 levels, out of which four for data (MCD, MOD, MLD, MPD) and four for processing (MCT, WORD, MLT, MPT). See Figure 4.

Figure 4: The different types of processing and data models in MERISE



As we have explained above, the problem tackled can be apprehended in a systemic way. Therefore the MERISE method can be adapted relatively easily to geographical applications. In fact, it has been applied to design software of cartography and spatial phenomena modelling especially within DBMS of GIS (Thomson, Laurini, 1992). In our problem, we essentially use methods belonging to conceptual and technical levels (MCD, MCT, MPD, MPT). Indeed, in a research context, logical and organisational constraints seem to be much weaker than in a professionnal private context. The MERISE method appeared to us as a good way to formalize location decision process for retail outlets in urban areas. Actually, we work on building processing and data model at the conceptual level.

Figure 5: Conceptual model of processing (MCT) in MERISE, application on retail location



2• MCT: conceptual model of processing

The conceptual model of the processing allows a fine representation of actors' behaviour in the system. Three types of components are identified in this model:

* the operations, which correspond to a sequence of procedures to solve part of actors activity ;
* the actors, defined only by the fact, that they act by receiving information and emitting some in return ;
* the states, which are binary variables taking positive or negative values;
* the events, which support information flows between operations and/or actors.

The example enhanced in the preceding paragraph is shown in a simple way by Figure 5 using MCT formalism. The operations are those presented in the second part of this article: the choice of an urban area and the settlement feasibility according to the selected area. The actors are the retail outlets, the local authorities and the urban area. The choice of the area requires the wish to settle in Besançon (this is a state). This starts up the searching process of an adequate area. However, it is necessary that the area chosen own grounds available and that local authorities accept the retail outlet to settle. Grounds are evaluated by retail. If one of those is appropriate, settlement process can begin in the town of Besançon. If not, it has to look for another geographical sector in another city. This will redefine the characteristics of urban areas and will thereafter influence retail outlets location strategies.

3• MCD: conceptual model of the data

The conceptual model of the data is built on specifications of Entities-Relationship model. From a formal point of view, information can be either in classes of entities, or in relations. Thus, the value of attractiveness is associated to the relation between the "retail outlet" and the "urban area", the characteristics of the retail outlets to the class of entities "retail outlets" (Figure 5). In MCD we can find the main characteristics of the MCT but for two significant differences.

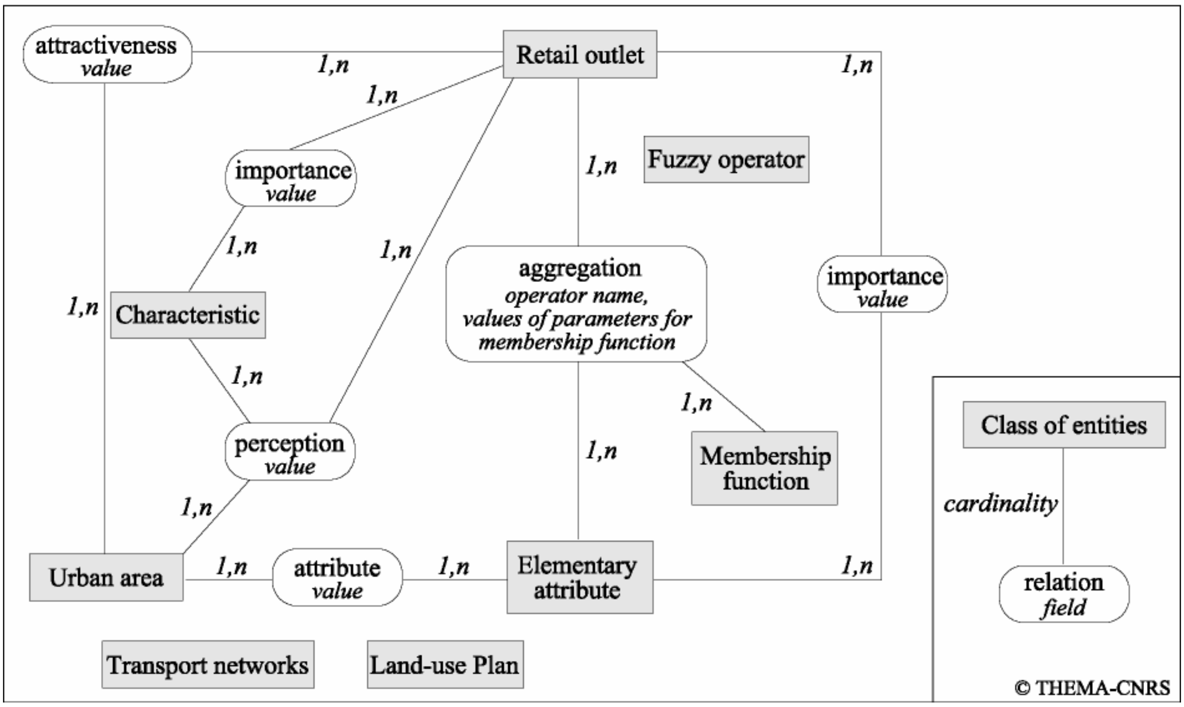
First, the model focuses on structure. This structure is made up of entities classes and relations associated with some cardinalities (Thomson, Laurini, 1992). Retails and urban areas are thus represented. Secondly, other classes of entities and relations appear. They mainly correspond to the criteria taken into account during the process of location: choice of urban area and setting up (Figure 6). These criteria can be the results of an analysis of experts' statements and can be part of the information available when the system initialises. There are:

* importance that any retail outlet attaches to each descriptive attribute,
* values of the attributes of urban areas,
* parameters defining the shape of the membership functions.

Decision criteria can also be calculated or evaluated during the simulation of the decision-making process. That occurs in some cases:

* choice of fuzzy operator to apply,
* perception evaluation of each characteristic of a given urban area,
* attractiveness calculation.

Figure 6: Conceptual model of data (MCD) in MERISE, application on retail location



4• Dynamic aspects

On Figure 6, we added to the model some behavioural links between the entities involved. These links are data-processing methods which start automatically when they are requested (they are called “triggers”). Their outputs can act on other entities, via some fields which describe them (physical or logical fields, and even geometrical ones). These methods are to be implemented in SmallWorld GIS. They are related to the conceptual model of the processing. They correspond to sequences of calculations (using fuzzy operators, for example) activated when a retail outlet wants to settle in a town (choice of the urban area, settlement, and feedback on territory characteristics). The principal stages of calculation and required information are shown in figure 6. In a simplified way, they correspond to both steps of the location decision process: location choice phase and settlement phase.

Conclusion

The first results of this research program are encouraging, in spite of some difficulties encountered. In addition to the topic complexity (very difficult to apprehend), principal methodological difficulties encountered come from the fuzzy operators formation (this work is in progress) and from the representations of relations between the various classes of entities. It was sometimes necessary to reformulate the problem to make it more adapted to the Entity-Relationship model.

The methods (“triggers”, for example) are developed in an Object Oriented Environment and applied to a relational data base. This raises the delicate problem of how to deal with representation and implementation, supported by two different modelling paradigms. However, mixing a fuzzy formalism, high level methods for data and process modelling (MCT, MCD) and a powerful GIS with spatial functionalities is a very positive point. Indeed, this set of tools and methods is very open. It ensures a good management of all parameters identified in the system. It provides useful access to all classes of entities, geographical or not. It integrates, in addition and if necessary, some dynamic aspects, via the “triggers”. It makes it possible to the thematician to structure expert knowledge in terms of information and associated processes. It avoids the “black box” effect, for which models investigating the relation between actor and territory are often reproached.

In our case, this approach already allows a better comprehension of the complexity of location strategies for retail outlets. We start the implementation in order to carry out “realistic” simulations, in partnership with experts working in the town of Besançon.

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