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A MULTI-AGENT MODEL FOR SIMULATING THE IMPACT OF NEW INFORMATION AND TELECOMMUNICATION TECHNOLOGIES ON THE ADOPTION OF TELE-WORK

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ABSTRACT
This paper reports the results of an application of a Multi-Agent System (MAS) approach to investigate new model capabilities for dealing with commuting, accessibility and telecommuting adoption.
As simulation by agents is gaining increasing importance in social sciences and geography, new potentials are disclosed for modelling urban phenomena, and a wide set of simulation platforms, such as SWARM, REPAST, STARLOGO, etc., are made available. This innovative trend is also affecting the very core of modelling activity in geography, although so far the full range of possible advancements is still unforeseen. In presenting the modelling experience an effort is made to address this issue and discuss a few implications of adopting a MAS perspective for coping with the complexities of urban phenomena.

Key words: physical versus virtual accessibility, social simulation, cognitive modelling, multi-agent approach

1. INTRODUCTION
Multi-Agent System (MAS) approach is widely diffusing in many domains of social sciences (see, Axtell, 2000, Ballot and Weisbuch eds., 2000; Conte, Hegselmann, and Terna, eds., 1997; Gilbert and Troitzsch, 1999; Kohler and Gumerman eds., 2000; Marney and Talbert, 2000). In geography, in particular, its introduction raises a number of questions about the

future advancement of the field, in an era in which new information and communication technologies not only affect the spatial deployment of phenomena but also modify the ways we learn about them (see for example the Project Varenius).

This paper presents some results of an ongoing research activity carried out at Ires, in which a Multi-Agent System (MAS) approach is used to explore new model capabilities for dealing with commuting, accessibility and telecommuting[1] adoption.

Underlying this model development are two lines of reasoning (Occelli, 2000):

- that accessibility implies a notion of *performance* associated with an agent's action space (the better the performance the greater is the agent's accessibility);
- that there exits a further notion of accessibility which results from the interaction of individual behaviours. Accessibility at a system (macro) level, therefore, *emerges* from the interaction of individual action spaces at the micro-level. This statement of emergency is based on a few presumptions: a) that there exist a number of recognised and collectively shared representations of accessibility, b) that some of these are likely to forge the *cultural fingerprints* of accessibility and become part of the prior information available to individuals, and c) that new views can result from a negotiation of already existing representations. These may affect policy norms and planning and ultimately modify individual action spaces.

The present discussion is subdivided into three main sections.

In the first we introduce the modelling application and point out a few major potentials of a MAS approach compared with those used by other types of models. Then, we outline the conceptual and methodological structure of the multi-agent model which has been built, the SimAC (Simulating ACcessibility) model, using the SWARM simulation platform (Bellomo and Occelli, 2000, 2003, Occelli and Bellomo, 2003).

Finally, the last section discusses some simulation results. Some general remarks about this experience with a MAS model conclude the paper.

2. THE SIMAC MODEL: A COMPARISON WITH OTHER MODEL TYPES

Developing the SimAC model reveals a number of fundamental advantages for dealing with urban accessibility issues:

- First, it makes it possible to revise the very concept of accessibility, i.e. to question the commonly held view that accessibility is a kind of entity derived from transportation demand (Couclelis, 2000, Occelli, 2000). A MAS approach allows us to view accessibility as: a) a resource for human settlements depending on the action spaces of individuals, and b) a collective outcome resulting from the interaction of individuals' behaviours. Re-interpreting urban accessibility in terms of agents' behavioural profiles, i.e. considering

[1] Although tele-work and tele-commuting does not exactly indicate the same phenomenon, in this paper the distinction is not relevant.

their goals, cognitive abilities, and their rules of interaction is a challenging task, but one we cannot avoid if we want to harness the complexities of a sustainable urban development.

- Second, it allows us to explicitly treat the time dimension and recognise the different temporal scales on which urban dynamics unfold. Many critical situations we observe in urban areas today are caused by this intertwined deployment of events in certain places and times.
- Third, a MAS model provides an exploratory context in which experimentation with a model can yield substantial contributions for policy making, i.e. reasoning about how to cope with the novel features of accessibility.

In developing SimAC, two major aspects underpin the modelling experience, although both will deserve further attention in future applications. They are related to:

a. the type of city considered by the model, i.e. the kind of view of city we are adopting in designing the model;
b. the kind of model approach we aim to implement.

As far as the former is concerned, the well established idea of self-organizing city is at the base of the SimAC's world. Whilst substantially sharing several features of the IRN (Inter Representation Network) cities posited by Portugali (2000, p.15), the city dealt with by SimAC is the city of everyday life, where ordinary people live and operate. It is therefore characterized by the daily routines people follow in partaking to urban activities. In the SimAC's world, in addition, people are not blind avatars, but possess a kind of cognitive ability, i.e. they have certain perceptions of their urban environment and these guide their spatial behaviour.

As far the kind of model approach is used in SimAC, this can be better appreciated mentioning the typology of model approaches elaborated elsewhere in a more general reflection about modelling, the modelling activity multi-agent model and the role of simulation (Occelli, 2002, 2003). In defining that typology two main views were considered:

a. a *structural perspective* which sees modelling as an activity through which an understanding of the organizational structure of an urban system is obtained. The model is a (simplified) representation of certain urban phenomena and of their changes to exogenous or controlled induced perturbations (Occelli, 2001);
b. a cognitive perspective, which considers modelling as an activity for testing, exploring, creating and communicating knowledge about certain urban phenomena. Models therefore are means for representing the working of our knowledge hypotheses (and of their outcome).

The resulting types of models can be briefly outlined as follows, see Tab.1 .

- Intelligent packages: they address specific well-defined urban questions. They exploit consolidated modelling methodologies, which thank to the advances in information and

communication technologies are being incorporated in user friendly packages, and diffused to a large public. The structural perspective to modelling largely predominates. Simulation is mainly restricted to the internal loop. It plays a major role as an analytic dimension supporting algorithmic procedures and making it possible the operational implementation of the model.

	Main features of the model	Role of simulation
Intelligent Package	A model is an analytic device to duplicate in a simplified way an urban phenomenon	It allows the functioning of the computer object
Decision Support System	A model is an analytic device by which a (simplified) duplication of urban phenomena permits replications of our knowledge hypotheses about them	It links the functioning of the computer object with the external world
Cognitive model	A model is an artefact allowing us to duplicate how we replicate the learning process of urban phenomena	The external world is made functioning within a computer program

Table 1. Types of models and role of simulation

- Decision support systems: they are primarily aimed at assisting analysts for policy making. Both the structural and cognitive modelling perspectives are involved although to a various extent. In particular, a 'what if' perspective is adopted, where attention is turned not just on the 'what' but on the 'if'. They typically are hybrid systems integrating three kinds of components: a core system describing the urban structure, an information component for data retrieval and output evaluation and a graphical interface for output visualization. In these system models the role of simulation is not limited to the internal functioning of a component but, because of the 'what if perspective', a set of links with the model external domain are established, although mainly associated with the kind of technological backcloth characterizing the information system architecture.
- Cognitive models. The knowledge of human decision making and action in an uncertain and changing environment is the main purpose of these models. The role of cognitive mediation which underlies a modelling activity is particularly relevant. It acts both as an activator of simulation potentials and as a recipient of these latter. Simulation is an intrinsic dimension of for this type of models. Its novel features are co-determined by the cognitive mediation role.

SimAC belongs to this latter type of models.

3. AN OUTLINE OF THE SIMAC MODEL

The building of SimAC started a few years ago within a Ires research project on accessibility and time use in the Turin metropolitan Area (Occelli,1999, 2000). Over time, the model underwent a number of developments which owe as much to the upsurge of interest in simulation and multi-agent approach as to the refinements in the computer program. This was implemented using the SWARM simulation platform (see Terna, 2002).

Although maintaining the original structure, the current version of the model considerably expands the earlier version (Bellomo and Occelli, 2000, Occelli and Bellomo, 2000).

SimAC does not aim to give a complete description of an urban structure. An artificial world is set up which is populated by a number of agents whose behaviour in mandatory mobility obeys certain rules, and is constrained by the features of the urban environment (i.e. the transport and telecommunication networks, the kind of access demand to work, the types of job accommodation).

The following presentation of the model is taken from Bellomo and Occelli (2003). A detailed description is discussed in Occelli and Bellomo (2003).

3.1. A description of the structure of the model

3.1.1 Types of agents

Three types of agents populate the artificial world simulated by the model, see Fig.1 and Tab. 2.

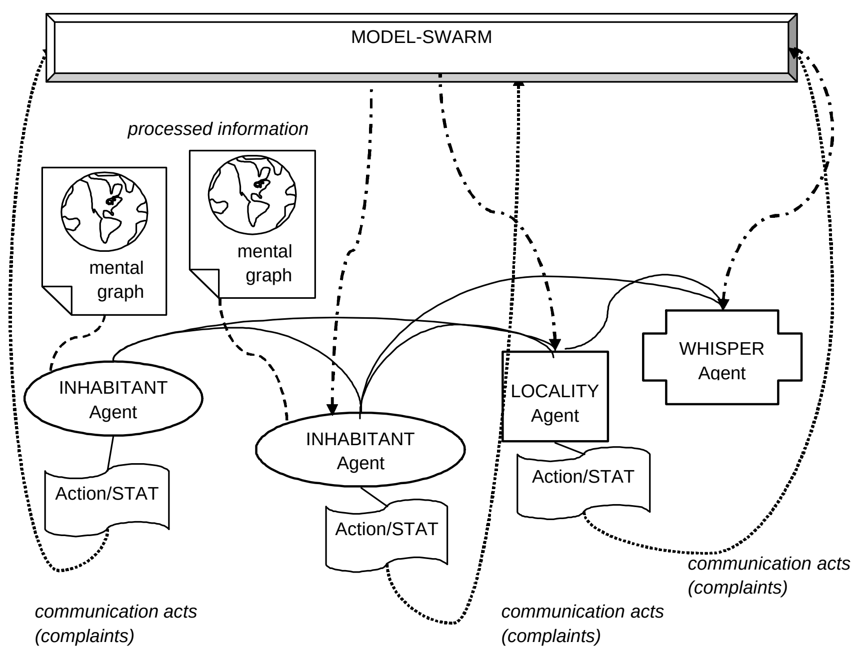

Figure 1. The overall architecture of the SimAC model

INHABITANTS: These agents mimic certain features of mandatory mobility behaviour of individuals in an urban setting. Inhabitants daily commute in order to get to their workplace. This shapes their action space and determines their accessibility. Inhabitants are able to make an evaluation of their accessibility and to modify their travel path accordingly. They also have the possibility to telecommute. This decision depends on both drives and constraints, acting at individual and system levels (Mokhtarian and Salomon, 1994). The drives depend on the individuals' action spaces. The constraints are both external, i.e. the availability of telecommunication networks and labour regulations, and internal, i.e. the psychological factors related to the need of face-to-face contacts. Inhabitants' overall dynamics unfolds on two different time scales. Accessibility changes occur on a relatively short time span, while the decision to telecommute is made on a relatively longer one.

	Inhabitant agents	**Locality agents**	**Whisper**
Main goal within the artificial world	They have to work. To reach their workplace they have to travel, but can substitute physical movement with virtual contacts	They have to provide employment to INHABITANTS and job accommodations for their employees	He gives prescriptions and recommendations for action to INHABITANTS and LOCALITIES
Role in the artificial world	As they value time, have a time budget and are sensitive to time constraints, they are motivated to reach their workplace as soon and easily as possible.	They have to maintain (improve) a certain performance level in their production activity	He monitors the behaviours of both INHABITANTS and LOCALITIES at a system level
Drives to action	Changes in the commuting time and in the factors underlying their drive to telecommute	Changes in the environmental and socioeconomic factors	Variations in the system diagnostic indicators
Communication	They send complaints to the Swarm Manager and receive information from LOCALITIES and WHISPER	They send complaints to the Swarm Manager and receive information from IHABITANTS and WHISPER	He collects complaints (signals) from the Swarm Manager and give information to INHABITANTS and LOCALITIES

Table 2. General features of the profiles of agent types

LOCALITIES: These agents embody features related to work activity and urban places. In the current version of SimAC, localities refer to workplaces which are spatially 'fixed'. Besides

providing jobs to inhabitants, localities have to supply a bundle of job accommodations, i.e. car parking availability, office floor space, telecommunication infrastructure, etc[2]. Localities are able to monitor the behaviours of their own employees as they access their workplace, i.e. they can measure the traffic congestion produced in the surrounding areas. Consequently, they can introduce more flexibility into working times to contrast the negative externality effects. In evaluating their performance, localities take into account their overall revenues and costs. We suppose that these latter depend on a relatively slow changing set of structural determinants, i.e. costs of labour, rents and facilities and a relatively faster changing set of factors, i.e. congestion, road price, adoption of new information technologies, which are more sensitive to the dynamics of the SimAC world.

WHISPER: This agent does not represent any given physical entity. Broadly speaking, he can be understood as a kind of repository of the tangible and intangible *information pool* existing in a city. On a more practical ground, he may represent an external observer, who is able to observe certain outcome of the behaviours of both Inhabitants and Localities. As he collects and processes, information for policy purposes, he also computes a set of diagnostic indicators of the overall performance of the system. Some of these are used by the Whisper to undertake certain actions, i.e. increase capacity of certain roads, introduce traffic calming and road price, and favour the diffusion of new information technologies.

Others may be used to give prescriptions or recommendations.

3.1.2 The interactions among agents

Agents' interactions are based on two main types of relationships:

- The so-called *structural relationships*. These are the social, functional and physical relationships pertaining to the different activity spaces of a city, i.e. those associated with the participation of individuals to urban activities (work, school, leisure, retailing, etc.) and their movements in the urban environment (see Bertuglia, Bianchi and Mela eds., 1998; Golledge and Stimson, 1997; Janelle and Hodge, eds., 2000). This kind of relationships, which underpins the majority of current urban models, also underlies the overall structure of relationships in the SimAC world.
- The so-called *informational relationships*. These are associated with the communications established in the artificial world (i.e. among the agents and between agents and the environment). Communication is a fundamental feature of a multi-agent world and can deploy itself in many forms (see, Ferber, 1999; Nilsson, 1998). In this model application a communication act is broadly understood as a kind of speech act associated with agents' conative functions. As the architecture of the agents' internal models is not fully developed, the major role of communication acts is simply to accompany agents'

[2] In developing this part of the SimAC model we took advantage of previous studies we carried out about the introduction of new information and communication technologies in urban systems, see Bertuglia, Lombardo., Occelli and Rabino (1995); Bertuglia, Lombardo. and Occelli (1998); Bertuglia. and Occelli (2000).

evaluative activities, i.e. reinforcing, constraining or inhibiting certain determinants of agents' actions, and thus affecting their final outcome[3].

3.2. Features of the model design and implementation

In developing SimAC the possibilities of the standard SWARM simulation platform have been exploited. A few aspects in the model implementation are worth being mentioned, and namely a) the drives in the agent's cognitive abilities, b) the management of the informational relationships and c) the treatment of time dynamics in the agents' behaviour.

3.2.1 Agents' drives

Two main drives underlie agent's cognitive abilities:

- Self-evaluation. Urban agents regularly make an assessment of their current situation within the urban environment and may change their behaviour accordingly. This evaluative activity can be considered as a kind of internal goal, associated with the intrinsic nature of urban agents. We hold in fact that this is an intrinsic characteristic of any living systems that have a capability to derive measures from the external environment and making sense from them (i.e. the so called operational closure in Pattee, 1986)[4].
- Communication. Besides the various signals produced by agents' interactions and mediating role of the environment, communication between agents has a role in stirring agents' behaviours. It, therefore, influences their decision-making, providing additional information about choice alternatives, reinforcing certain determinants of choice, making it possible to anticipate or postpone an action. A corollary assumption is that a communication is likely to be related to an evaluation activity.

Although SimAC does not design a complete architecture of agents' cognitive abilities, it however maintains the idea that agents' actions are *deliberative* in the sense that they are based on a kind of *agents' internal (or mental) models* of the urban environment. As mentioned above, these depend on the evaluation activities (and communication acts) undertaken by agents. In addition, these internal models possess a kind of memory, making it possible for agents to recall past experiences in their evaluation activity[5].

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[3] We realize that in developing this architecture we should give the possibility to agents to establish links among their internal model, and namely to enable them to reason about other agents' behaviours (goals, resources, actions and plans), see Sichman, Demezeau, Conte and Castelfranchi (1994).

[4] In particular, we would need to understand how (Golledge and Stimson, 1997; Mark et al., 1999):
1) humans process spatial information;
2) spatial information is collected, memorized and retrieved;
3) spatial decisions are undertaken.
To fully address these aspects would require a model architecture capable to explicitly deal with the cognitive attitudes and decision-making processes of distributed agents (see Rao and Georgeff, 1995, Broersen et al., 2001). Given the limited scope of this study, we can only make a few assumptions about the general principles.

[5] Besides memory, also the ability to anticipate future events is a major characteristic in agents' internal models (see Rosen, 1985; Ferber, 1999). This aspect, however, is not dealt with in the present version of the model.

To implement the evaluation activities undertaken by agents a kind of behavioural agenda has been defined which uses an IF THEN format. Its general expression is as follows:

'IF the temporal variation in a component and /or variable of in the evaluation is greater or less than a certain threshold value

THEN makes an action, i.e. update certain variables and/or their relative weights, and/or send a message (a complaint) to Inhabitants and/or Localities and/or Whisper'.

3.2.2 The informational relationships

As shown in Fig.1, at the upper layer of the SimAC architecture there is the model general manager, Model Swarm. Besides ruling the structural relationships and their implementation, i.e. input-output operations, time schedules, Model Swarm also manages the informational relationships. It collects all the messages sent by the agents, through their communication acts, processes them and make their result available to the agents. Whereas agents of different type can exchange information, communication among agents of the same type has to be managed by Model Swarm. This latter, therefore, acts as an intermediary of the informational flows among the agents. Although this intermediary role may limit the range of communication possibilities in the system it proved the only way to deal with communicating agents with scarce cognitive abilities[6].

3.2.3 The treatment of time dynamics

In SimAC an effort is made to account for the co-existence of different dynamics in agents' behaviours. Agents are able to put into perspective the changes occurring in their surrounding environment. This means that they have certain 'windows of observation' of these changes, i.e. their decision-making and decision to act therefore may refer to different time horizons; these can also vary by agent types or across a certain population of agents. To address this aspect, in SimAC we introduce the possibility that each type of agent can undertake their evaluation activities considering different time intervals. As a result, the decisions to act, by agent type, does not necessarily occur simultaneously, but may be shifted in time. Although the implemented approach is still a group centred view, it nonetheless allows us to investigate how different time scales in agents' decision-making can affect their outcome in the urban evolution.

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[6] At the lower layer are the Inhabitant, Locality and Whisper agent types. For each of them there is a module describing their cognitive abilities, actions and their outcome (action/STAT module in Fig.1). In addition, Inhabitant agents have a module accounting for their mental representations of the spatial network, i.e. the mental graph, which is daily updated as agents travel on the network .

4. SIMAC IN ACTION : SOME RESULTS OF SIMULATION EXPERIMENTS

4.1 Configuration of the experiments

A number of simulation experiments have recently been run and allowed us carry out some preliminary testing of the model capability (Bellomo and Occelli, 2003. Occelli and Bellomo, 2003).

Unlikely earlier experiments which referred to an undifferentiated urban environment consisting of uniformly spaced residential zones, the current ones also consider an artificial world where the spatial network, although still grid shaped, consists of links having different (time) length, see Fig.2.

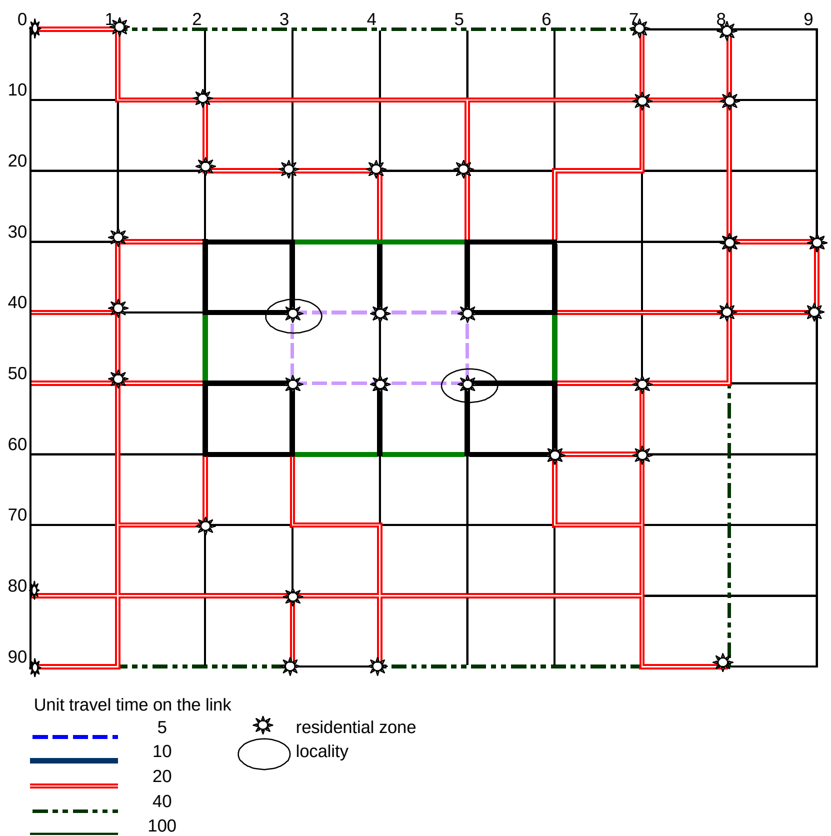


Figure 2. Configuration of the urban environment with an irregular spatial network

The artificial environment, therefore, looks like a kind of a metropolitan area, where the spatial pattern is characterized by:

a. a central urban core, consisting of six very close residential zones (i.e. the travel times of their transportation network are the lowest).This is surrounded by a transport ring connecting the core area it to the outer ones;
b. a set of suburban residential areas on the fringe of the urban core;

c.   a set of sparsely distributed residential areas located in the outer parts of the area.

Inhabitant agents are almost uniformly distributed over 35 residential zones. There are 2 Locality agents located in the core of the area which employ the same number of Inhabitants.

Each experiment simulation has a fixed time period consisting of 100 time units (days).

All the results of simulations are referred to periods of 10 time units. To facilitate the discussion, experiments are labelled with a W followed by numbers indicating the width of the observation window taken into account by the Inhabitant, Locality and Whisper agents.

Two set of experiments have been carried out:

- the first compares the results of the adoption of tele-work resulting from different widths of observation windows, for an urban environment with a regular and an irregular spatial network;
- the second focuses on the non homogenous urban environment and investigates the effect on the adoption of tele-work and travel times for different sensitivities to tele-work adoption.

4.2. Tele-work adoption for different widths of observation windows in urban environments with regular and irregular spatial network

As already observed in previous experiments, the number of adopting agents increases more significantly in those experiments in which the width of the observation window for the WHISPER agent is relatively smaller, see Fig.3.

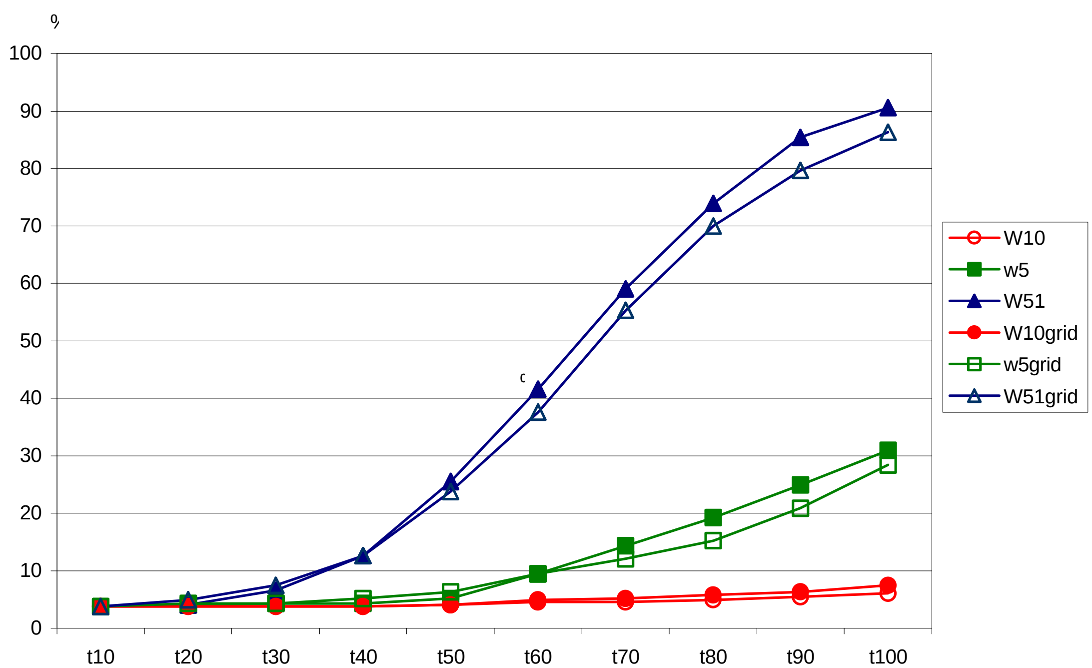


Figure 3. Tele-work adoption in an urban environment with regular (grid) and irregular spatial network for different widths of the observation window

In these cases, in fact, the constraining factors to adoption tend to be weaker as a result of a greater availability of telecommunication services in residential zones. The Whisper agent is able to make telecommunication investments a greater numbers of zones.

This happens in both a urban environments with a regular and irregular spatial network.. Figure 3 also shows that the less performing results are observed in the experiment, W101010, in which the width of the observation window, for all types of agents is the largest, i.e. the agents' awareness to the changes of the urban area is relatively lower.

A major aspect worth being emphasized is that the increases in tele-work adoption are higher for the urban environment with an irregular spatial network. Although this result may depend on the particular configuration of these simulation experiments, a plausible explanation is that, in a more highly constrained spatial environment, agents' drive to improve their accessibility is likely to be higher.

The variations in the average travel times as observed at the end (T100) and beginning (T10) of the simulation period seems to support this explanation, see Fig. 4.

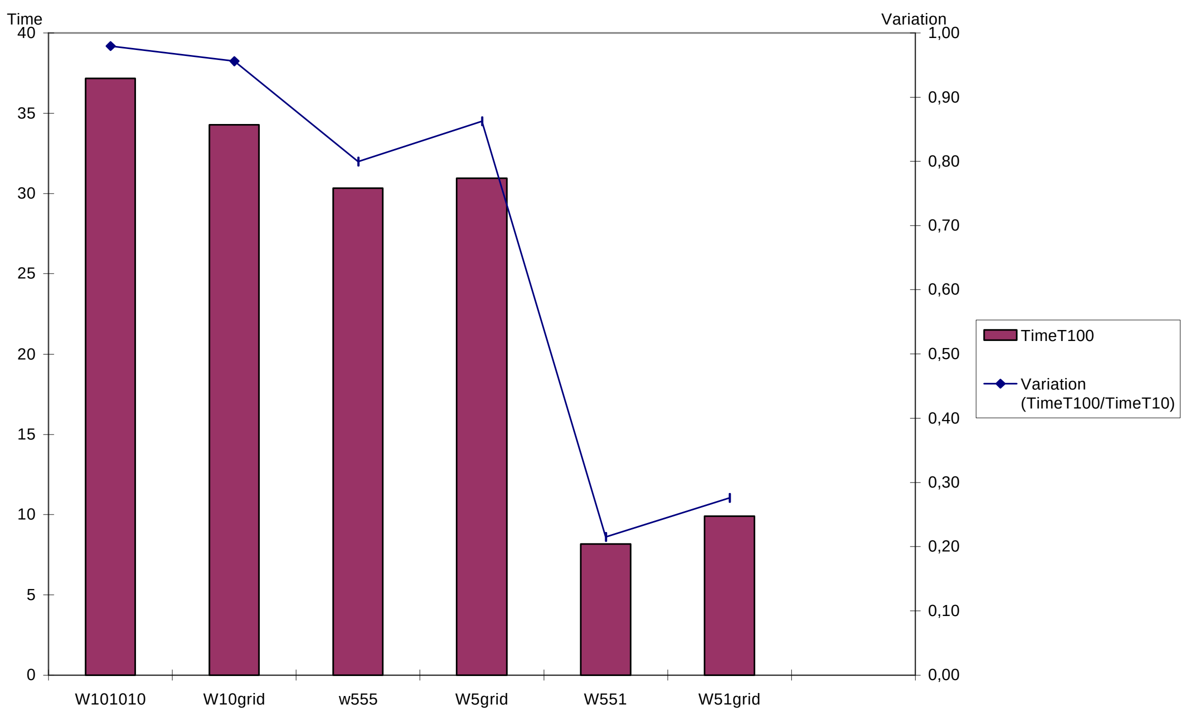


Figure 4. Average travel time at the end of the simulation period and time variation in an urban environment with regular (grid) and irregular spatial network for different widths of the observation window

This result also provides further evidence to what has already been pointed out in earlier experiments (see Occelli and Bellomo, 2000) about the fact that the higher is agents'

sensitivity to travel time, the greater their propensity to explore alternative travel paths, in order to improve their accessibility to jobs.

4.3. Impact on the tele-work adoption and travel times for different sensitivities to tele-working

In this second set of experiments attention is turned to the non homogenous urban environment and the effects of varying the sensitivity to tele-work adoption in certain zones of the system are analysed.

Although not explicitly mentioned in 2, it is worth recalling that in SimAC there are two kinds of parameters modulating this sensitivity (Occelli and Bellomo, 2003):

- a parameter, which applies to the system as a whole and reflects the general propensity of the urban system to the introduction of innovation. This is kept constant in this set of experiments;
- a parameter, s, acting at the individual level, influencing the internal drives of the Inhabitant agents to tele-work. In particular, this modulates the information received from the Locality agents to tele-work.

Attention is limited to the W555 experiment which was run a number of times assuming that the s parameter has an higher value for the inhabitants living in certain areas of the urban system.

More precisely, three sets of experiments have been carried out. In the first, s is raised only in the six zones of the residential core (W5core). In the second, we assume that the increase involves six zones at the outskirts of the area (W5periphery). Finally, in the last we investigate the case in which s is increased in zones situated in an intermediate area between core and periphery (W5core-periphery). In all the experiments a total of six zones (about 60 Inhabitant agents) are affected interested by changes in the s parameter..

As could be expected, raising s has a positive impact on the adoption of tele-work and we observe an increase, though moderate, in the total number of tele-work adopters in the system, see Fig.5. This increase, however, and this was not entirely expected, is slightly more significant when the changes in the s parameter involve the core area (W5core). This latter is also the part of the urban environment most significantly affected.

This can be best appreciated in Fig. 6 which illustrates the variations which are produced in the residential zones at the end of the simulation period. For comparison, the results of the W101010 and W551 experiments are also shown.

Adopters' increase is the lowest when the changes in s involve the Inhabitant agents living in the periphery of the area (W5periphery). It is even lower than that resulting in the W555 experiment where no variation in the sensitivity parameter is introduced.

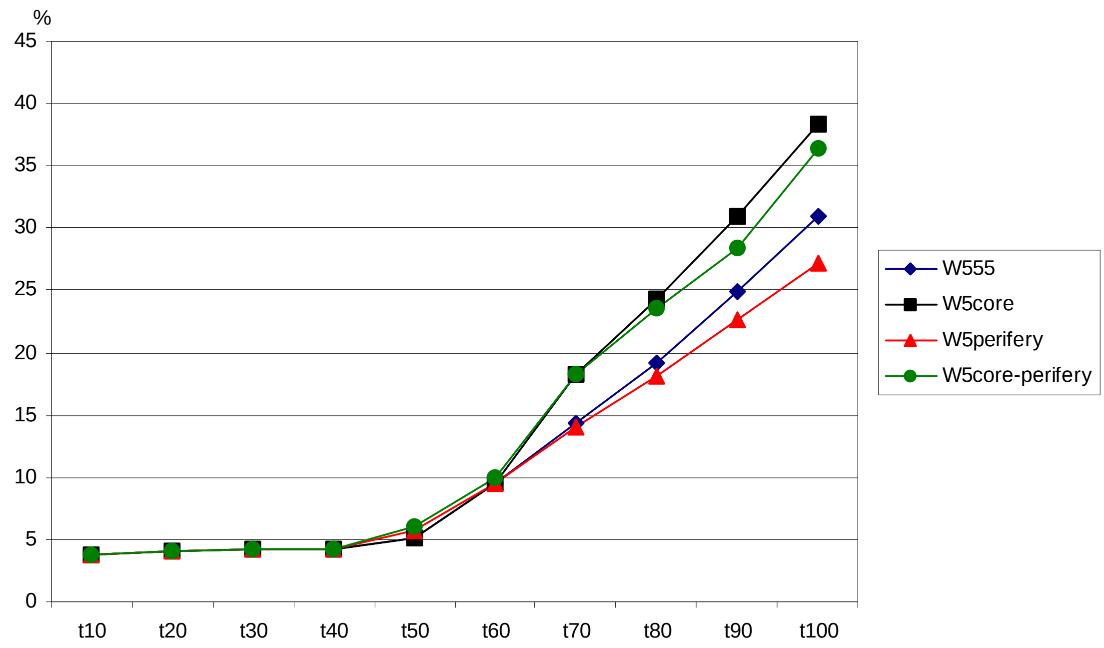


Figure 5. Tele-work adoption for different values of the sensitivity parameter s in the core, periphery and core-periphery residential zones

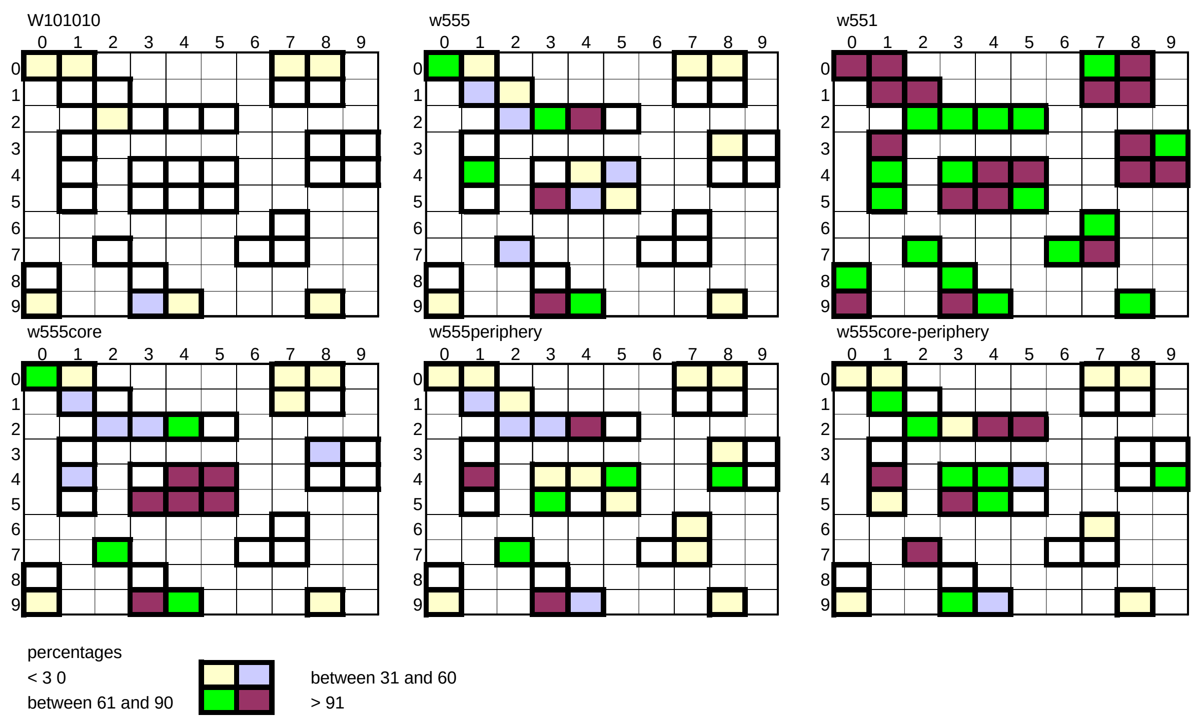


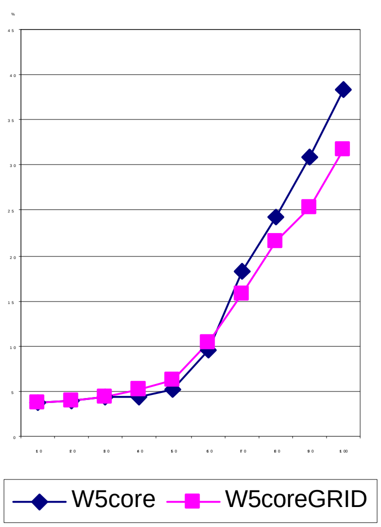
Figure 6. Percentage adopters in the residential zones at the end of the simulation period in the different experiments

In the W5periphery experiment, in addition, the spatial distribution at the end of the simulation period is also more scattered than in the W5core (see Fig.6). An intermediate result is obtained when increases in s are applied the agents located in semi-central areas (W5core-periphery experiment).

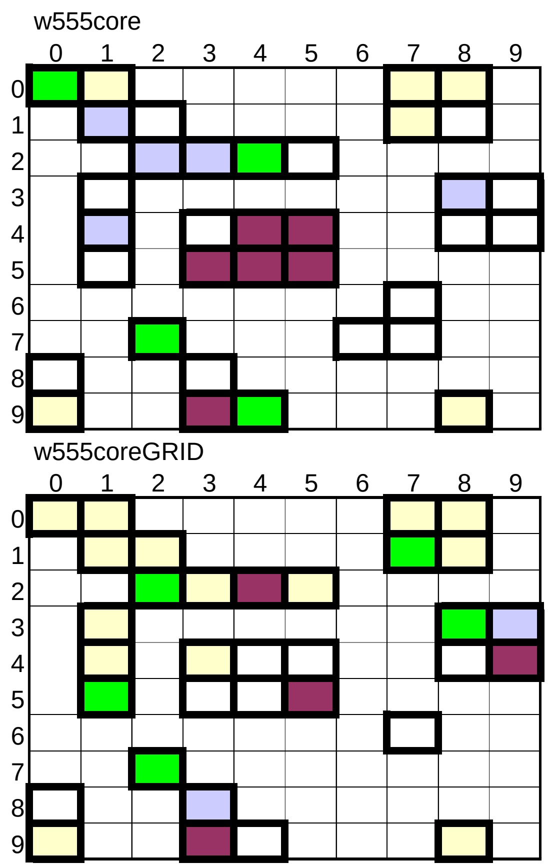
What these experiments show is that a different pattern of variations in the sensitivity to adoptions, can produce different spatial effects. Both the process of adoption, i.e. the formation of both a critical mass and level of information, and the spatial structure of the urban environment play a role in determining the spatial diffusion of tele-work adopters.

To better appreciate the influence of the spatial structure on the final outcome the W5core experiment was run again for an urban environment with a regular spatial pattern (W5coreGRID).

In this case, we can observe that the kind of increase which was significantly concentrated in the core area for the irregular spatial network, tends to disappear, see Fig.7.



7a. Percentages adopters during the simulation period



7b.Percentage adopters in the zones at the end of the simulation period (see Fig.6)

Figure 7. Tele-work adoption for higher values of the sensitivity parameter in the core, in an urban environment with regular(grid) and irregular spatial network

5. CONCLUDING REMARKS

In this paper we reported some further results of an application of a multi-agent model, the SimAC model which is being developed at Ires. SimAC is aimed to investigate new model capabilities for dealing with commuting, accessibility and the adoption of tele-work.

The SimAC model in particular:

- makes an effort to account for features of urban interactions which depend on the communication between agents,
- points out the need to explicitly address agent's cognitive abilities to deal with their decision-making in an urban environment;
- explores novel ways to treat the coexistence of different time dynamics and the relationships between micro-macro system levels.

Although further experiments are necessary to fully test the overall capabilities of the model, the experience we gained so far suggests that this type of model throws interesting challenges for the modelling of urban phenomena.

This, in particular, calls for a deeper attention to the kind of arguments we introduced in the first part of this paper about the development of the cognitive type of models and, more generally, the use of models for policy oriented spatial analysis.

It has already been noted that because they enhance our capacity of perceiving, understanding and managing phenomena, MAS models are likely to play an increasingly relevant role also in spatial analysis. A number of reasons can be mentioned to support this thesis, i.e. the greater capacity of cognitive mediation underlying the modelling activity and the enhanced possibilities offered by the computer artefact (see Occelli, 2003). The many ways in which this enhancement is expected to benefit the current practice of policy making and application are further aspect to probe

In this respect, we can mention a twofold kind of questions which have both theoretical and operational implications and may be worth to be given prior consideration:

- Which kind of knowledge we want to model, and namely, which kind of cognitive abilities do our agents have? Which type of operational architecture is tractable enough for their implementation (see, Rao and Georgeff, 1995)?
- What are the ranges of advantages we get when applying a MAS approach in a practical situation?.

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RIASSUNTO

La simulazione multi-agente rappresenta oggi uno degli approcci più promettenti per lo studio teorico e per l'analisi empirica dell'evoluzione dei sistemi territoriali. Essa nasce dalla convergenza di diversi campi di ricerca, quali quelli dell' intelligenza artificiale distribuita, delle scienze cognitive, e delle teorie della decisione, resa possibile dai recenti sviluppi dei computer e delle capacità computazionali. Grazie anche alla crescente disponibilità di piattaforme standardizzate per la simulazione multi-agente, SWARM, REPAST, STARLOGO, l'uso dei MAS (Multi-Agent System) si sta diffondendo rapidamente in tutta la comunità delle scienze sociali anche se le applicazioni in campo territoriale sono, per ora, ancora limitate.

Questo lavoro presenta l'applicazione di un MAS, il modello SimAC; finalizzato allo studio di fenomeni connessi all'accessibilità, alla pendolarità ed all'adozione del tele-lavoro in un sistema urbano.

Originariamente costruito nell'ambito di uno studio sull'accessibilità per l'area metropolitana di Torino condotto dall'Ires alla fine degli anni '90, SimAC è stato progressivamente ampliato ed ora consente di simulare l'introduzione delle Nuove Tecnologie di Informazione di Comunicazione in un sistema urbano (l'adozione delle NTIC da parte delle imprese, l'introduzione delle iniziative ad esse collegate da parte del decisore nelle zone del sistema) ed il processo di decisione di tele-lavorare da parte dei residenti interessati dalla mobilità sistematica per lavoro.

Gli aspetti maggiormente innovativi che contraddistinguono SimAC rispetto ad altre sperimentazioni modellistiche inerenti l'introduzione delle NTIC nei sistemi territoriali riguardano:

- l'introduzione della comunicazione nelle interazioni fra agenti (le informazioni scambiate, pertanto, possono abilitare e/o condizionare le decisioni di azione da parte degli agenti);
- il riconoscimento dell'importanza delle relazioni fra funzione rappresentativa e funzione conativa nel processo decisionale da parte degli agenti;
- la possibilità di ammettere l'esistenza di finestre di osservazione delle dinamiche del sistema di 'ampiezza diversa' da parte dei diversi tipi di agenti.

La relazione è articolata in tre parti principali.

La prima descrive i presupposti concettuali che stanno alla base del modello e richiama il contesto epistemologico nel quale si colloca la presente sperimentazione di SimAC

La seconda illustra la struttura generale del modello ed il profilo generale dei diversi tipi di agenti che sono stati implementati (cosa fanno gli agenti, come interagiscono).

L’ultima parte infine presenta alcuni risultati delle simulazioni che sono state condotte per un sistema urbano fittizio.

Alcune considerazioni generali sulle potenzialità di uso di questo tipo di modelli relativamente ad altri approcci modellistici correntemente utilizzati nelle scienze regionali concludono il lavoro.