A Classification of Paradigmatic Models for Agent-Based Social Simulation

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Abstract. Given the strong interdisciplinary character of Agent-Based Social Simulation (ABSS), and the difficulties related to ambiguous terminological and methodological assumptions, there is an increasing need to make more explicit the modelling paradigm underlying each research paper or project. In this paper we propose a classification of paradigmatic models in ABSS, which characterise different ontological assumptions and pragmatic criteria with respect to their targets. The classification is composed by different classes of models at different levels of abstraction, in a layered architecture that enables switching among levels. Each class is based on different kinds of assumptions, which possibly call for different logics of scientific research. The taxonomy was well validated with researchers in the field. It seems a good analytical tool for characterising or comparing models according to various criteria, such as methodological, philosophical, or simply pragmatic and usability criteria.

1 Introduction

After the consolidation of the multiagent paradigm in artificial intelligence, the role of Agent-Based Social Simulation (ABSS) has been acquiring importance in a large range of scientific fields, such as the social and natural sciences. Some indicators are the profusion of conferences, workshops and journals in the area, like the series of ICMAS/AAMAS workshops on Multi-Agent-Based Simulation and the Journal of Artificial Societies and Social Simulation. The sources of analogy between agent-

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based technologies and models of actual social systems have been creating an intense interdisciplinary meeting and cross-fertilisation between researchers from different fields, and very often with somehow different scientific backgrounds.

If there is no doubt about the appeal of interdisciplinary research in ABSS, there is not yet a clear picture of its current organisational structure. Under a dialectical perspective, one factor that delays a general description of ABSS seems to be its interdisciplinary character itself, which demands a difficult interlacement of different methodologies, terminologies and points of view. Some efforts are being attempted to disambiguate methodological puzzles in ABSS. The Socionics project [20], for instance, works out the advantages of integrated relationships between Distributed Artificial Intelligence (DAI) and Sociology. Another example is the First International Workshop on Collective Robotics [10], which attempts to explore the relationships between researchers of DAI, Artificial Life and Robotics, dedicated to Collective Robotics. These and other efforts represent a difficult but necessary challenge in the discipline.

One important aspect that should deserve attention is identifying which paradigmatic models are being currently used in the discipline, as well as clarifying its methodological roles. There are presently a considerable number of models in ABSS, which seem to be founded on different ontological assumptions, such as those based on "socio-cognitive" or "rule-based" agents. Given the strong interdisciplinary character of ABSS, and the difficulties related to various terminological and methodological assumptions, there is an increasing need to make more explicit the modelling paradigm underlying each project. The analysis of model use in ABSS can guide us at various levels:

- To disambiguate concepts and assumptions, and to help distinguish or conciliate different interdisciplinary perspectives and research goals, which in ABSS involve researchers from several scientific areas. This will possibly contribute to improve synergies or/and resolve methodological barriers or incompatibilities;
- To promote a deeper discussion of several research topics, such as the problem of observation of emergent phenomena, verification and validation of different types of models, which may possibly call for different logics of scientific research.

With the aim of helping define a more precise description of ABSS, this work puts forward a classification of models. The proposal results from ongoing activities developed in the context of the SimCog project [24]. One of the goals of the project is assessing methodological questions in the intersection of multi-agent-based simulation, computer science and the social and natural sciences[1]. To this purpose we have done the following steps. We firstly identified in the literature four types of models that seem to be based on different ontological assumptions in regard to the nature of the modelled target, as well as different kinds of formalisms that are used to model it. Such models are explained in section 2. Secondly, an exploratory survey based on an on-line questionnaire was designed. The questionnaire included, among

[1] Another goal of the survey was to gather information about the needs of the community with respect to a multi-agent based simulation platform for socio-cognitive agents.

other questions, a multiple-choice question that invited the respondents to choose the models that could best represent their intended use of simulation. The survey involved the contribution of one hundred and ninety six (196) researchers in ABSS[2]. Later, the survey statistical results allowed us to investigate the organisational structure of those researchers according to different combinations of models. This will be presented in section 3. Finally, we have designed a classification of models in line with such organisational structure, which we will put forward in section 4.

This classification defines a better picture of the use of models in ABSS. It can be used, for instance, as a schema to conceptualise ABSS according to various philosophical foundations or methodological procedures associated with different kinds of models, such as the kind of research goals that we are after or the set of technological requirements to achieve those goals. We will give an example in section 4, by characterising the models according to three dimensions: (i) abstraction level for modelling the target system, (ii) type of evidence in the validation process, and (iii) application context (social scientific, technological, etc.).

2 Types of Models in ABSS

The hypothesis that we put forward is that different research and development objectives interfere in the modelling process, since they call for different types of models specified at different levels of abstraction and based on different kinds of assumptions, which possibly call for different logics of scientific research. In order to identify relevant types of models, one can adopt various criteria. Meanwhile, it is possible to observe certain prominent patterns in the literature. We have distinguished four different types of models that vary in relation to different ontological assumptions and formalisms for modelling one or more targets. We will designate these classes of models in the following way: *Artificial Social*, *Socio-Cognitive*, *Socio-Concrete* and *Prototyping for Resolution*.

A. Artificial Social Models. The level of abstraction within this trend is often purely theoretic, where the researcher is free to abstract *a priori* any relationships of mathematical, physical, social or psychological nature. If this trend is radically adopted, with no connection at all to what we conceive actual or objective in the "real world", then there is a single empirical reference to the model put forward in the simulation: the behaviour of the simulation. The emphasis of research is therefore devoted to the verification between models: to what extent is the model of the observed behaviour of the simulation determined by the conceptual mechanisms specified in the original model? It is more usual, however, to have these models and their outcomes confronted with meaningful traits in the real world other than the simulation itself, even if at a very suggestive level. The more meaningful the model outside the simulation is, the less it is likely to be classified as a pure artificial social model. The following models vary with respect to the level of its relationship to the real world at different levels, even if very minimally and subjectively. The

[2] 17 respondents in Asia and Oceania; 54 in Canada and USA; 116 in Europe and Russia; and 9 in Central/South America.

Daisyworld model of an imaginary planet for which its temperature is an emergent property of growing flowers [19]; the models investigating the implications of meta-belief spread [17]; or the Sugascape model [13] that attempts to model human-being behaviour through very simple rules, such as rules of sexual reproduction or cultural transmission. At any rate, the intention is not to base the model and its results on strong empirical relationships to any target system, but to establish relationships at a more or less suggestive level.

B. Socio-Scientific Models. In this type of model, researchers use the theoretic framework of social, natural and/or environmental sciences to represent social phenomena. The target systems are already known or there is evidence about their existence. Two main directions can be detected: *socio-cognitive* and *socio-concrete* models.

B.1. Socio-Cognitive Models. This type of model is usually founded on computational animation of logic formalisms, which represent agents and social structures according to a specific theory. The animation serves a purpose of theory consistency checking and refinement. It has been considerable influenced by the experimental tradition of Artificial Intelligence and Cognitive Science, characterised by the use of cognitive agent architectures that represent explicit knowledge, such as those based on SOAR [25]. A characteristic example is the DEPNET [4] system, based on the Theory of Dependence and Social Power [2]. The authors explore a social reasoning mechanism, where the agents can represent social dependence relations not only in accord with their goals and plans, but also with what they believe to be the other agents' goals and plans. The specification of the model is based on first-order and modal logics [23]. The use of cognitive architectures of this kind is motivated by the idea of exploring how society is implemented within the minds of its members, the exploration of the "*footprints that a multi-agent system leave not only on the behaviour of its component members, but also in their minds*" [3].

The translation of formal logic-based specifications to computational algorithms, however, seems to be a problem to scalability. As a consequence, most simulations tend to relax the semantics of their original models, where the agents' internal architectures become more rudimentary, and where mental objects become segments of algorithms "*in which logistic and social information are conditions for the application of given routines*" [3]. While the theoretic role of logic-based models is certainly appealing, it does not necessarily imply the ontological conception of socio-cognitive human activity in terms of logic-based formalisms and reasoning. For example, in contrast with the modal logic-based specification of Dignum and Conte [5], the work of Stalles and Petta [26] simulates a cognitive model of social norms based on the functional appraisal theory of emotions. Caldas and Coelho [1], for instance, simulate the aggregated performance of various institutional and normative systems by using very simple evolutionary rules.

At any rate, it is incontestable that socio-cognitive and sociological models represent a considerable part of current work in ABSS, regardless of being specified or not with the aid of logical formalisms.

B.2. Socio-Concrete Models. This type of model should desirably represent direct observations of social and institutional concrete processes. The goal is the use of social simulation "*to describe observed social systems or aspects thereof and to* *capture the sometimes conflicting perceptions of the social system by stakeholders and other domain experts*" (see, for example, Moss' claim in [6]), such as the modelling of socio-economic and environmental systems. The intention is to establish substantive relationships between the simulation and the target, which typically calls for data-driven empirical research in the target.

In principle, the empirical data gathered in the target should guide the specification of the model, and should be compatible with the outcomes of the simulation as well. For instance, Hemelrijk et. al [18] report a model of female dominance in group-living primates during the period of sexual attraction, in which both the specification and the outcomes of the simulation are, to a certain extent, confronted with empirical evidence. Unfortunately, even though this confrontation is desirable, it is not always possible to close the circle. Most modelled systems are complex, difficult to specify and/or produce outcomes that are very sensitive to initial conditions. As a result, most models simplify the validation process and concentrate their validation efforts either in the specification or exclusively in the outcomes. For instance, the model of Dean et al. [9] simulate historical conditions that could in *theory* explain empirical knowledge about the patterns of extinction of the Annazi population in the U.S.A. over the period 800 to 1300 A.D. The resulting explanations are thus purely theoretic. Other alternatives have proposed a weaker form of empirical validation, suggesting the use of participatory-based simulation, whereby a set of stakeholders, such as domain experts or the system end-users, contribute to discuss and negotiate the validity of the specification and the simulation results (see e.g. the work in the context of the CORMAS project [7]).

C. Prototyping for Resolution Models. The purpose of these models is to explore and test technical or end-users' requirements for given multiagent-based computer applications. The modelling of the environment should be the most realistic as possible in order to "train" the agents in similar conditions. In some cases agents in the simulation may interact with humans or other real systems. A characteristic example is the ARCHISIM project, which aims at both simulating a realistic traffic evolution and making the behaviour of the simulated drivers credible for human-drivers placed in a driving simulator [12]. Other projects involve: train new users in a system, predict behaviours of agent-oriented software end-users' actions and construct intelligent buildings [8], or assess modelled systems to subsequent application in the real world (e.g. [21]). The modelling is thus somehow normative, insofar as the model is validated according to the end-users' approval of the simulation behaviours.

3 The SimCog Survey

The SimCog survey [24] is an exploratory statistical survey that involved the contribution of a hundred and ninety-six (196) researchers. The survey adopted a non-random selection, based on a judgment sample (see [15]). This kind of sample does not allow us to generalise the survey results to the target population, but can give us good qualitative indicators. The sample frame is a list of email addresses obtained through the following sources: articles in some of the most prestigious scientific publications in the area, key researchers and email discussion lists. Data were gathered through an on-line questionnaire with thirty-four closed questions and two open questions. Responses were received between September and December 2002.

The four types of models previously described were presented as a closed multiple-choice question, and an open question was available to allow the respondents to state other types of models. For sake of brevity, we presented in the questionnaire a short description of each type of model. Figure 1 illustrates the distribution of models among the respondents. It can be observed that the vast majority of researchers chose at least one available option, and only a minority (11.7%) did not feel represented by the four options. Moreover, among the minority of respondents that completed the open question, none of them proposed alternative models. This is an encouraging result, suggesting that the proposed types of models were significantly accepted and appropriately interpreted. These results suggest that the meaning of the models was well understood.

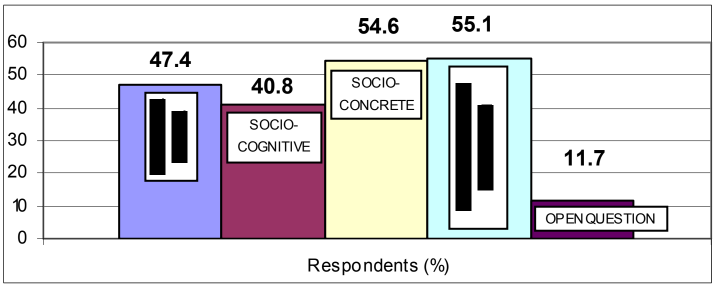

Figure 1: Distribution of responses according to the four models.

The fact that there is a fair distribution among the four types of model does not necessarily mean that the organisation or researchers around this variable is trivial. Indeed, we observed a high level of spreaded choices: 28.6% of respondents chose a single option, whereas 48.5% chose two options, 13.3% chose three and 8.2% chose all options. Also, the use of artificial social models alone is negligible (<1%), since the vast majority of the respondents chose it in conjunction with other models. These results lead us to the following remarks: (i) most researchers work with more than a single type of model; (ii) socio-scientific models, including both socio-cognitive and socio-concrete approaches, seem to be more common than prototyping for resolution and artificial social models; (iii) the use of artificial social models is no more than an inspiring or complementary activity to other models. These observations are useful to hypothesise a classification of respondents according to specific sets of models, instead of just one model.

In Figure 2 we illustrate the pattern of responses organised around a tree-based classification of multiples choices, and the corresponding number of respondents for each branch and leaf. The resulting organisation was structured according to three branches, namely:

- Socio-Scientific (SS): includes respondents that chose socio-scientific models (i.e., socio-cognitive or socio-concrete), with or without the artificial social model, and did not choose prototyping for resolution;
- Prototyping for Resolution (PR): includes respondents that chose the prototyping for resolution, with or without the artificial social model, and did not choose socio-scientific models;
- Dual (D): includes respondents that chose both socio-scientific and the prototyping for resolution models, with or without the artificial social model.

All leafs are a specialisation of branches SS, PR and D. For instance, the leaf D.socio-cognitive/concrete encompasses respondents whose options were socio-cognitive *and* socio-concrete *and* prototyping for resolution models, including or not the artificial social model. Statistical results indicate that there is a significant difference between the frequencies observed in these leafs (Chi Square Goodness of Fit=58.73, DF=7, $p<0.05$).

Branch SS (85) – Researches with a Socio-Scientific approach:
SS.artificial social (3): artificial social
SS.socio-cognitive (22): socio-cognitive *or* (artificial social *and* socio-cognitive)
SS.socio-concrete (35): socio-concrete *or* (artificial social *and* socio-concrete)
SS.socio-cognitive/concrete (25): (socio-concrete *and* socio-cognitive) *or*
(artificial social *and* socio-concrete *and* socio-cognitive)
Branch D (58) – Researchers with a Dual approach, including both prototyping for resolution and socio-scientific approaches:
D.socio-cognitive (11): socio-cognitive *or* (artificial social *and* socio-cognitive)
D.socio-concrete (25): socio-concrete *or* (artificial social *and* socio-concrete)
D.socio-cognitive/concrete (22): (socio-concrete *and* socio-cognitive) *or*
(artificial social *and* socio-concrete *and* socio-cognitive)
Branch PR (50) – Researchers with a Prototyping for Resolution approach:
PR.prototyping-resolution (50): with *or* without artificial social

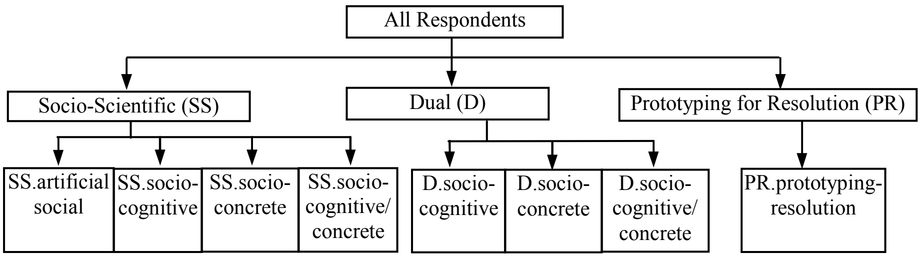

Figure 2. Hierarchical organisation of respondents according to the four models.

4 Classification of Models

The previous results offer evidence for an overview of paradigmatic models classified according to figure 3. The classification is based on the hierarchical organisation of responses illustrated in figure 2. Table 1 associates the patterns of figure 2 with the classification in figure 3.

The classification is organised under a multi-model approach. A multi-model is a model composed by other models at several abstraction levels (see [14]). By using abstraction levels we can switch between models and use the most appropriate abstraction for a specific situation. The classification is related to other efforts to analyse the modelling process in ABSS (e.g. [11]). However, it goes a step further since: (i) it is more detailed and based on a formal framework to characterise ABSS models, (ii) it is based on a significant portion of the ABSS community.

At the top level the classification converges in the junction of two general classes: socio-analytic and techno-analytic. The meeting of socio-scientific models with the exploratory and abstract character of artificial social models converges in the class of socio-analytic models. The meeting of prototyping for resolution with artificial social models gives rise to techno-analytic models. These classes encompass general characteristics and properties. Subsequently, specific model types are defined, associated with more specific approaches. At the top level, the meeting of socio-analytical with techno-analytic models converges in the class of socio-technical models.

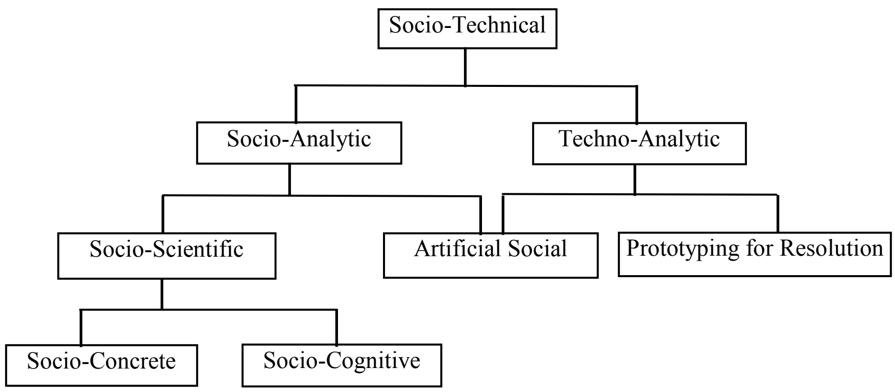

Figure 3: Classification of models in ABSS.

Table 1: Classification of models *versus* the patterns of responses in figure 2.

Classification of ABSS models	Patterns of Responses
socio-technical	branch D
socio-analytic	socio-scientific (branch SS), including or not artificial social models
techno-analytic	prototyping-resolution (branch PR), including or not artificial social models
prototyping for resolution	branch PR without artificial social models
socio-scientific	branch SS without artificial social models
socio-cognitive	leaf SS.socio-cognitive without artificial social models
socio-concrete	leaf SS.socio-concrete, without artificial social models

Socio-technical models are probably where the interdisciplinary effort between the computational sciences and the social sciences is more intense, and where agent-based theories are more often transferred between these two domains. The goal is twofold: (i) to apply theories of complex social systems to real information technologies, which should become more adaptive in response to the increasing intractability of large and decentralised software environments; (ii) to test and explore inferential consequences of those same theories, and interpret those consequences back to the social scientific domain. Examples of ongoing projects working on this basis are the Socionics [20].

4.1 Characterising the Models

One can use this classification for analysing certain features, for instance, to investigate philosophical foundations or methodological procedures for different types of models or for ABSS as a whole, as well as other practical considerations, such as the set of software requirements appropriate to certain models. After defining general requirements for top-level classes, we can walk through the multi-model and detect other relevant requirements for each specific class.

Since each modeler may have different assumptions about the world, different models can be designed based on a same target system, depending on his/her perspectives about the nature of the target or simply due to pragmatic constraints with respect to the model (e.g. computational scalability). We will use the term *dimension* to indicate any kind of perspective that may be adopted with respect to the modelling of target systems. In the rest of this paper, we will characterise the models according to three dimensions: (i) abstraction level for modelling the target system, (ii) type of evidence in the validation process, and (iii) application context.

The dimension *Abstraction Level of the Target System* (ALTS) considers that the modeller may deliberately assign different levels of hypothetical existence to the target. Three levels will be considered: *low*, *intermediate* and *high*. If the level of abstraction is high, then the simulated target is a pure "would be world" with no intentional relationship at all to a real world target. Conversely, if the level of abstraction is low, then there is a real intention in representing a real world target.

The dimension *Type of Evidence in the Validation Process* (TEVP) considers that the validation process seeks to assure that the specification and the simulation represent the target with an acceptable degree of adherence. We will consider two broad kinds of validation in ABSS. Validation through structural similarity, which seeks for qualitative elements of realism, striving for structural similarity between theories and the target as we know it, making it "plausible" or "credible" [16]. In addition, empirical validation considers that the main source of knowledge comes from successive experimentation, valorising perception, trial-and-error and control. We will use the following levels:

- structural-weak, when the structural similarity with the target is merely pictorial and evocative, such as the suggestive effect of colour clusters in a grid interpreted according to the real social world (e.g. the domain of ethnic segregation in the Shelling model [22]);

- structural-strong, when the structural similarity is evocated through a richer domain of descriptive representations such as mathematical-based expressions of social networks, modal-logics for mental states or organisational constraints among different actors;
- empirical-weak, when such descriptive representations are actively negotiated by stakeholders and domain experts such as in participatory-based simulations;
- empirical-strong, relying on strong empirical overt procedures and real world quantitative data.

The dimension *Application Context* (AC) considers two broad types of contexts, where simulations can be applied. The *social scientific* context, where ABSS uses the basis of social and/or natural sciences to model social phenomena; and the *technological context*, where multi-agent simulations are used to test and prototype software applications.

4.2 Investigating the Scope of ABSS

In this section we will characterise each class of models according to the three previous dimensions. By integrating all classes, we will be able to characterise the scope of ABSS in line with such dimensions. The characterisation of a subset of these classes will be our assumptions or given axioms. For purposes of illustration we will depict each class in Cartesian chart according to the aforesaid dimensions. This does not mean that the dimensions are (orthogonally) independent from each other, as we will demonstrate later on.

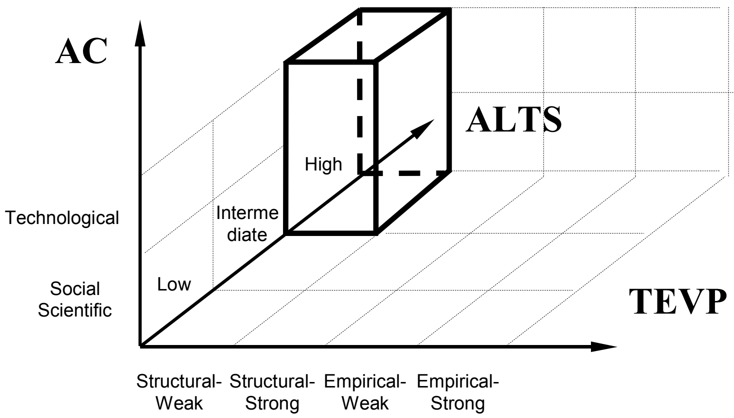

Figure 4: Characterisation of artificial social models.

Artificial Social Models. This class involves simulations with a deliberate non-existent or weak relation to a real world target, involving simulations where:

- the application context, given by the dimension AC, can assume a technological or a social scientific context;
- the abstraction level, given by the dimension ALTS, can assume the high value;
- the validation process, defined in the dimension TEVP, can assume a structural-weak form.

Figure 4 characterises this class. For instance, in the Daisyworld model [19] we have: (i) the application context is social scientific, since it simulates the self-regulating behaviour of a population of flowers called 'daisies'; (ii) the abstraction level is high, since the Daisyworld is an imaginary planet; (iii) the type of validation is structural-weak, because the output of the simulation is compared against an idealised structure of some hypothetical world.

Socio-Cognitive Models. Simulations in this class serve the purpose of checking the consistency or refining cognitive-based and/or sociological theories. Figure 5 characterises these models. Most of the (hypothetical) objects to which the theories refer are usually non-directly observable. The validation process is eminently qualitative and does not rely on empirical overt procedures. This class involves simulations where:

- the application context, given by the dimension AC, can assume the social scientific context;
- the abstraction level, given by the dimension ALTS, can assume the intermediate value;
- the validation process, defined in the dimension TEVP, can assume the structural-weak and structural-strong forms.

For instance, in the DEPNET model [4] we have: (i) the application context is social scientific, since the purpose of the model is to test and refine the theory of dependence and social power; (ii) the abstraction level is intermediate, since the intention is to model socio-cognitive phenomena according to a theory that is abstract and considerably analytic, not directly tied to a very specific real world situation; (iii) the validation process is structural-strong since the interpretation of the theory and the simulation results are based on a well-defined formal-logic framework, but does not rely on strong empirical overt procedures.

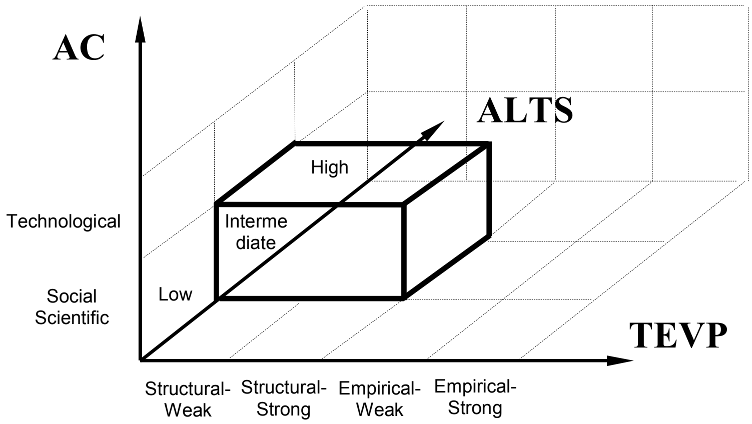

Figure 5: Characterisation of socio-cognitive models.

Socio-Concrete Models. These models should establish substantial relationships between the simulation and the target, which typically calls for participatory based modelling and data-driven empirical research in the target. Figure 6 characterises this model. The class involves simulations where:

- the application context can assume the social scientific context;
- the abstraction level can assume the low value;
- the validation process can assume the structural-strong, empirical-weak and empirical-strong forms.

For instance, the simulation of the Kayenta Anasazi population [9] has the following characteristics: (i) the application context is social scientific, since the target of modelling is a pre-historic civilisation; (ii) the abstraction level is low, since the intention is to confront computational data with historical and archaeological aggregated data; (iii) the validation process is structural-strong, empirical-weak and empirical-strong. While the simulation outcomes are tested against empirical aggregated data and knowledge of experts, the underlying model specification is a highly hypothetical structure. In effect, this means that this model could as well be classified as a socio-analytical model (see below).

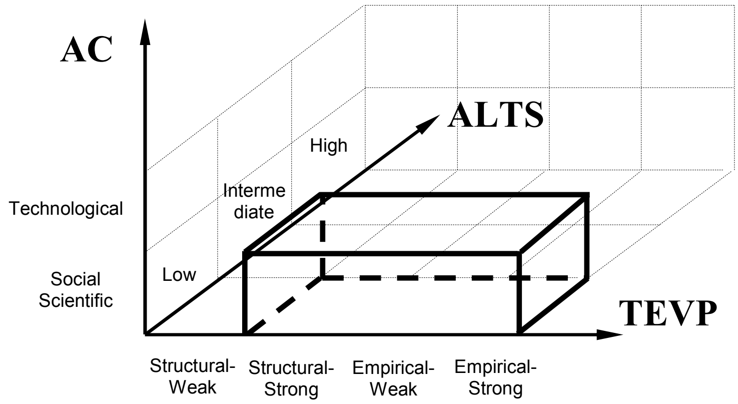

Figure 6: Characterisation of socio-concrete models.

Socio-Scientific Models. The scope of socio-scientific models is characterised in figure 7. It is a linear integration of socio-cognitive and socio-concrete models.

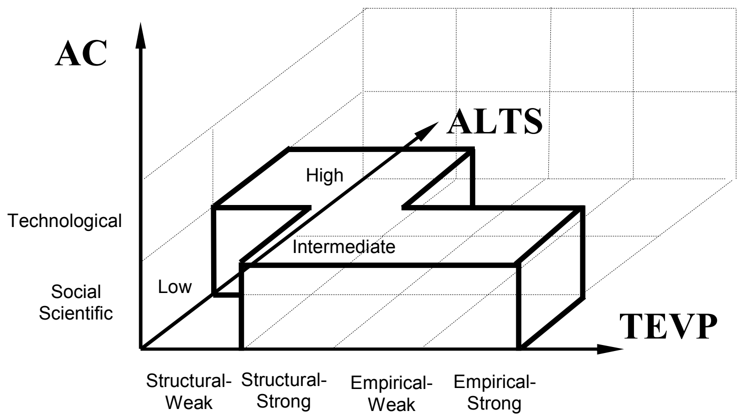

Figure 7: Characterisation of socio-scientific models.

Socio-Analytic Models. Figure 8 characterises socio-analytic models. The class combines socio-scientific models with the exploratory character of artificial social models.

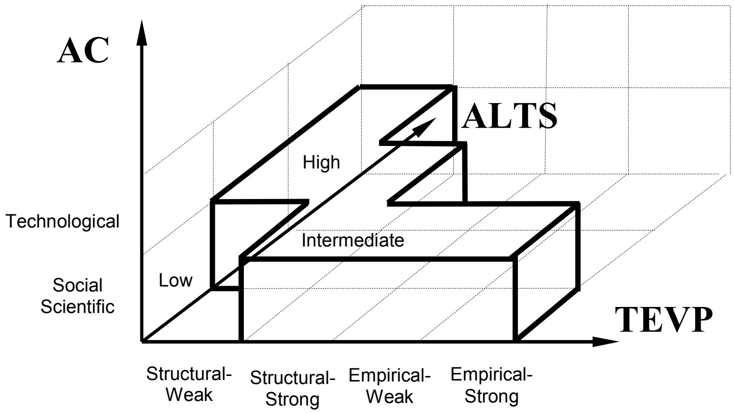

Figure 8: Characterisation of socio-analytic models.

Prototyping for Resolution. The goal is to test intended behaviours according to technical or end-user requirements for given multi-agent systems. The validation involves tests according to technical figures (e.g. efficiency, response delay) and, quite like participatory-based modelling, the end-users' approval of the simulation behaviour. Figure 9 characterizes this model. The class involves simulations where:

- the application context can assume a technological context;
- the abstraction level can assume the low value;
- the validation process assumes the structural-strong, empirical-weak and empirical-strong forms.

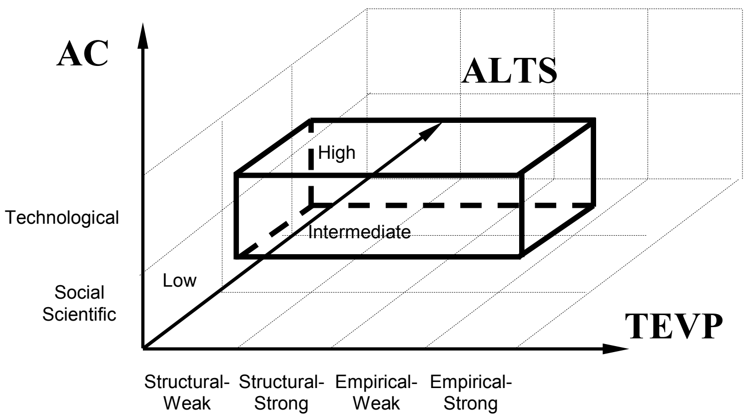

Figure 9: Characterisation of prototyping for resolution.

For instance, the ARCHISIM [12] model, which simulates a realistic road traffic evolution, presents the following characteristics: (i) the application context is a technical one, since the ultimate goal is to make the computer behaviour credible for a human driver placed in the driving simulator; (ii) the abstraction level is low, since there is a commitment to reproduce a realistic traffic system; (iii) the validation process is empirical-weak and strong, since the output data is contrasted against real technical figures and the end-users' approvals.

Techno-Analytic. In figure 10, this class enlarges the scope of prototyping for resolution models with the exploratory influence of artificial social models. The high abstract character and structural-weak validation of artificial societies gives place to intermediate abstract levels with structural-strong validation.

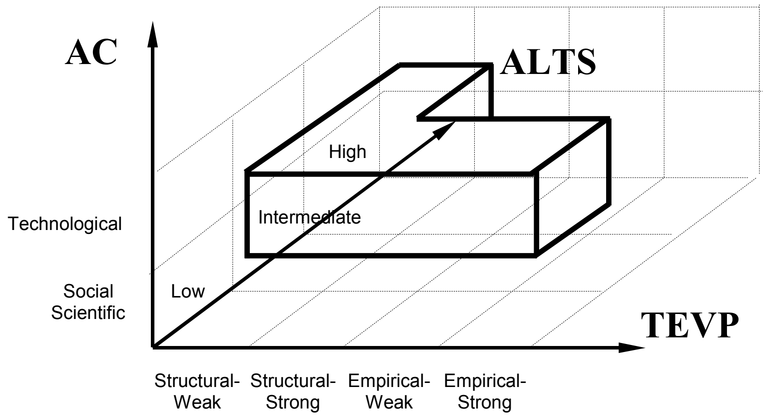

Figure 10: Characterisation of techno-analytic models.

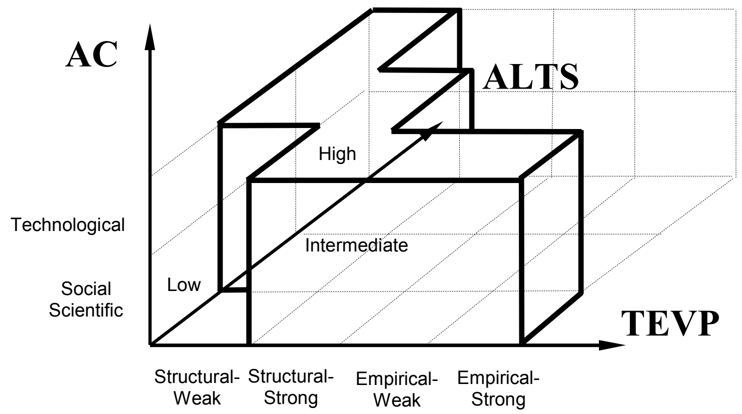

Figure 11: Characterisation of socio-technical models.

Socio-Technical. In figure 11 we characterise simulations involving socio-technical models according to the three dimensions. These simulations should add the characteristics of prototyping with the stronger exploratory character of social analytic simulations. Socio-technical models should be the ones with the largest scope, giving us the conditions to characterise the scope of ABSS according to these three dimensions. Apparently, ABSS does *not* involve the co-ordinates:

- (structural-weak, abstraction low, {social scientific and technological contexts})
- (structural-strong, abstraction high, {social scientific and technological contexts})
- ({empirical-weak, empirical-strong}, {abstraction intermediate and high}, {social scientific and technological contexts})

Unsurprisingly, there is an incompatibility between high levels of model abstraction and strong levels of model validation. Of course, depending on the set of considered axioms, one can depict different characterisations of models, possibly by using different or additional dimensions. But although there are certainly different kinds of epistemic conceptions to validate theories, all these models are useful in their own right, provided their goals and assumptions are clearly stated.

In principle, two different simulations should only be compared if their underlying paradigmatic models and dimensions are explicitly stated. In many well-established scientific areas it is normal practice to have a specific section at the beginning of a paper describing the underlying methodological assumptions and tools. Given the strong interdisciplinary character of agent-based simulation, and the difficulties related to ambiguous terminological and methodological assumptions, there is an increasing need to make more explicit the modelling paradigm underlying each project. The present proposal is interesting, since the taxonomy was well validated with researchers in the field. It is also a useful analytical tool for assessing or comparing different paradigmatic models in terms of arbitrary dimensions, such as philosophical, methodological or simply pragmatic. In the future, we plan to use it in order to identify different sets of software requirements for simulation platforms, which must be consistent with its intended modelling paradigm (which in our specific case is to prototype socio-cognitive models). The set of appropriate software requirements will be investigated based on the SimCog survey statistical results.

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