ROMANIAN JOURNAL OF INFORMATION SCIENCE AND TECHNOLOGY
Volume **20**, Number 3, 2017, 198–209

Applying Communication Sciences in Artificial Societies

Monica DASCĂLU[1, 2] and Silvia BRANEA[3]

[1]Politehnica University of Bucharest, Romania
[2]Romanian Academy, Center for New Electronic Architectures, Bucharest, Romania
[3]Faculty of Journalism and Communication Studies, University of Bucharest, Romania
Email: monica.dascalu@upb.ro, silvia.branea@fjsc.ro

Abstract. In the last two decades, prominent researchers argued that it is important to develop models of 'artificial societies' in connection to theoretical assumptions and methodological constraints of social sciences. Recently several attempts were done to give a scientific basis to artificial societies from the social sciences perspective, but no definitive connection with sociology's scientific approaches to social reality was succeeded yet. Although some researchers put a particular emphasis on the importance of communication in human societies – an importance that should be reflected in artificial societies – communication is one of the dimensions that is less developed from a theoretical perspective in social simulations. This paper analyses the way communication was represented in artificial societies so far and emphasizes the lack of theoretical foundation from the communication theories perspective. We analyze several theories from communication sciences, in order to discover which theories can be applied in artificial societies, for the improvement of the modeling and simulation done with this paradigm.

Key-words: Artificial societies, social simulations, multi agent based modeling and simulation, multi step flow communication theory.

1. Introduction

Artificial societies are considered to be a new and important tool for social simulations that could contribute substantially to the methodological and theoretical development of social sciences. Two conditions are considered essential in this direction: (1) to build models that are based on solid theoretical background, and (2) the systematical use of real-life data in order to validate the models. This paper analyses the theoretical foundation of artificial societies and identifies a particular and fundamental area where the theoretical approach has to be consolidated: the communication. Several theories of communication are discussed from this perspective in order to identify which of them is compatible with the artificial societies computing paradigm.

Social sciences (including sociology), are still subject to fundamental theoretical and methodological debates, and most of them come from the contrast with natural sciences (if such comparison is justified is also a subject of debate). As the domain of social studies has specificities not applicable to natural systems, differences are inherent and are not necessary a deficit of social sciences, but rather a challenge. Experiments, for instance, are often impossible in social sciences like sociology and here is where the artificial societies came into play, with their large-scale computer simulations.

In social sciences – sociology included – there are a lot of difficulties in using the experiment as a method of research. In addition to all the practical difficulties, experiments are not much appreciated in this scientific field because of the many ethical issues and controversies around them. For instance, the fact that the subjects of such experiments were not correctly informed regarding the objectives of the research is considered to be ethically unacceptable (but on the other hand, if the subjects of such an experiment would have been informed about the research objectives, they wouldn't act naturally, and the scientific results of the experiment are compromised). Among other advantages, the experimental model of artificial societies can contribute to the scientific progress without trespassing deontological norms of sociology.

The model of artificial societies is conceptually simple and can be easily developed to embed complex features. It basically consists of a "landscape" in which a population of agents can move and evolve [1]. The "landscape" is the environment of the agents' evolution, establishing the geometry and the networking of the artificial system and offering supplies for the agents' activity. Depending on the particular model implemented, these supplies can be "food", "economical resources", and so on, allowing simulation of features like survival and growing, or "wealth". In other cases, instead of the spatial landscape, agents are interconnected in "networks" according to specific social links. The "agents" are the individuals that perform several functions in the "landscape". They can move around, gather resources, interact with each other, form groups etc. The agents interact with the agents around them, they are influenced by the landscape/network and act upon it, and therefore several phenomenon belonging to social and economic life can be modeled.

Some of the experiments undertaken so far with the artificial societies model construct a world of its own, with no necessary direct correspondence in the social reality (although analogies are often claimed), starting from different assumptions and analyzing the outcome of the population's evolution. Other aapplications reported in scientific literature model various aspects of the socio-economic realm, aiming to better understanding and prediction of real world phenomena. Some of them, according to Moss and Edmonds (2005), are intended to justify social policies [2].

According to Edmonds et at. (2013), "some simulation models are not intended to represent anything but rather created for another purpose, such as a tool for demonstrating an approach or an intervention in a decision-making process" [3]. But putting aside this kind of approaches that are hopefully the exception and not the general rule of this field, there is a scientific interest in social simulations. According to Salgado and Gilbert (2013),

"Computational sociology (or social simulation) is an outstanding method for modelling and building explanations of social processes, based on ideas about the emergence of complex behaviour from simple activities. With this technique we can study properties of emergent orders that arise from local interactions among a multitude of independent components. And we can understand the ways in which such emergent orders can influence or constrain the individual actions of those components. This process is known as 'self-organization' and is characterized by the concepts of 'bottom-up' and 'downward causation' "[4].

The artificial societies computing model is interesting in itself from the computer science perspective (the computing model is expressive and flexible, agent-based programming offer a direct implementation solution, there are significant artificial intelligence applications), but its most important advantage comes from the perspective of social sciences: it offers the possibility to make experiments in domains where experiments are almost impossible. Artificial societies are not yet accepted by "mainstream" sociology, but there is a significant interest in the scientific community in order to adjust the model not only to the specificity of the subject of study (the social realm), but also to the theoretical and methodological requests of social sciences.

In an article published in 2002 [5], Lansing puts the artificial societies computing model in the perspective of social sciences positivist dispute (quantitative research methods in sociology have advantages but also drawbacks) and of Popper's distinction between social theories based on differential equations and statistics. In Lansing's opinion, artificial societies can offer a "genuine methodological innovation". One particular application of this methodology, according to Lansing, could be "to explore such fundamental issues as the relationship between structure and function" [5].

Other researchers also consider the contribution of artificial societies in social sciences. Silverman and Bryden (2007) wrote that social simulations should play an essential role in developing a "new social science" [6]. Moss and Edmunds (2005) argued that "good social science can be facilitated by agent-based social simulation because of the wider possibilities for validation it facilitates" [2].

Epstein (2007) wrote that:

"Agent-based modeling offers powerful new forms of hybrid theoretical-computational work; these are particularly relevant to the study of non-equilibrium systems. The agent-based approach invites the interpretation of society as a distributed computational device, and in turn the interpretation of social dynamics as a type of computation." [7]

The enthusiasm of computer programmers around artificial societies (and the claims that their simulations are so similar to human societies) inevitably attracted criticism from the field of social sciences. The multi agent simulations approach was, in its first years, both praised and harshly critiqued as "simplistic scientism". The development of the field, however, came with more mature insights in the model construction and much more prudent interpretation of simulation results, and it is no surprise that the criticism of artificial societies, although still present, diminished. There are still unresolved and questionable issues within artificial societies, and some of them are related to fundamental debates in sociology, like for instance the methodological issue of building explanations (Sawyer, 2013) [8].

In the last two decades, prominent researchers argued that it is important to develop artificial societies' research in connection to theoretical assumptions and methodological constraints of social sciences. However, there are still few reported results of this kind (most significant are reviewed in section 2, Artificial Societies: Generative Social Science vs. Computational Sociology). Recently several attempts were done to give a scientific basis to artificial societies from the social science perspective, but no definitive connection with scientific approaches to social reality was succeeded yet. Section 3 (Embedding Social Sciences' Theory and Methodology in Artificial Societies) presents the state of the art in this direction. As we will see, although some researchers put a particular emphasis on the importance of communication, it is one of the dimensions that is less developed from a theoretical perspective in artificial societies.

Section 4 focuses on communication: how it is represented in artificial societies so far and emphasizes the lack of theoretical foundation – from the communication sciences' perspective. Subsection 4.2 discusses some theories of communication to be applied in an artificial society model. We analyze several theories from communication sciences, in order to discover which theories can be applied in artificial societies, for improvement of the modeling and simulation done with this paradigm.

2. Artificial Societies: Generative Social Science vs. Computational Sociology

There are two main trends in scientific literature about artificial societies, according to their objective: to understand social phenomena or to predict the evolution of a specific social subsystem. Sometimes understanding and prediction go hand in hand, but in terms of computer simulation there is a significant distinction. In the first trend we can include the work of scientist who 'grow' artificial societies and explore the effect of several modeling assumptions. The second type of research starts with observation of specific phenomena or subsystems in order to model particular aspects of the social realm.

2.1. Generating Societies in Artificial Lifes Style (Generative Social Science)

Epstein and Axtell (1996), the scientists who first coined the term "artificial societies" [1], used it to describe a model consisting of a population of individuals evolving in a specific environment that they had named "sugarscape". The "sugarscape" provide "sugar" for the individuals to eat. The simulations performed by Epstein and Axtell started with migration toward sources of food and survival, and were further developed gradually to include features like reproduction, group interactions, basic economic actions, cultural aspects etc.

The "artificial society" paradigm is closely related to the so-called "artificial life", of which the most prominent exponent is the famous Game of Life invented by John Conway in the 1970s. Sawyer (2013) considers that the artificial societies' idea of growing societies *in silico* is due to the influence of artificial life development [8]. As in artificial life, where the term 'life' resumes a supposedly basic feature of life (survival and reproduction of 'cells'), in artificial societies the focus is mainly on the interactions of 'individuals' with each other, forming groups with complex interactions that can be considered the basis of a 'society'.

Epstein introduced the concept of 'generative social sciences' as distinctive from inductive and deductive research methodologies in social sciences. Based on previous research, Epstein (2007) argues that 'generative social sciences' can contribute to the development of social sciences, and particularly to systems sociology, in many ways, mainly by the experimental dimension [7]. One of Epstein's simulations is particularly famous, the so-called Anasazi simulation: a model of a community that was designed, simulated and validated in order to fit to the historical data regarding the evolution of the population. Based on such simulations, specific hypothesis were tested regarding of the reasons and mechanisms that caused the historical phenomenon that was modeled.

Not all models in artificial societies community are so substantial and related to reality. There are a lot of examples in this field that implement some particular individual mechanisms considered to be an abstraction or simplification of real social mechanisms, with no legitimate association.

This kind of research is subject to critical observations, as somehow it is done just as a computer game, with no real connection with the reality they claim to model. According to Sawyer (2013):

"Researchers who develop multi-agent simulations often proceed without thinking about what the results will mean or how the results of the simulation might be used. After the simulation is completed, it is too late to begin to think about interpretation and understanding, because poorly designed simulations often turn out to be uninterpretable. An analysis of interpretation and understanding has to precede and inform the design" [8] (p.273).

2.2. Modeling and Simulation with Artificial Societies (Computational Sociology)

Particular applications of artificial societies in modeling of different social phenomena and subsystems have been reported in scientific literature of the last two decades. There are plenty of examples that justify the name of 'computational sociology' that has been associated with this type of simulations. Some examples (but not the complete list) of domains where computational sociology was applied included economy, ecology, politics, urbanism, demography, and epidemiology.

In spite of the apparently direct correlation of artificial society to the methodology of statistic quantitative research, it would be very difficult to build models of populations and treat their evolution the same way as the results of sociologic investigation are processed and interpreted.

Some examples of computational sociology will be briefly overviewed. Before the introduction of 'artificial societies' concept, Schelling (1971) used a simple artificial life-style model with a very specific application: segregation in residential areas [9]. Until now, his model is still considered an excellent example for the power of a simple local model to explain a complicated real word phenomenon and also one of the best examples for connecting the agents in a network of 'social relations'.

Computational sociology applications in economy cover a large span of mechanisms, processes and phenomena. In most artificial societies researchers are interested in the macro-level effects of micro-level causes. Following Epstein and Axtell's experiments in 'sugarscape', Dascălu *et al.* (1998) published the results of modeling production with artificial societies [10]. Basic economic mechanisms assimilated to production of goods led to a so-called 'social structure' based on wealth and influence.

Modeling complex real world economic situations and phenomena requires a much more complicated computing model. Axtell (2000) explored the influences in a social network with simulations that intended to replicate the evolution of retirement patterns in the US, after the retirement age was legally modified from 65 to 62 [11]. Wen *et al.* (2013) present their computational approach for complex socio-economical systems and the experimental platform they created, illustrated with a model of inflation [12].

Cederman (2001) is one of the authors that developed applications of agent-based modeling in political science [13]. A particular type of application refer to simulation related to social norms, trends, influences and reputation ([11], [14], [15], 16]).

Demography is another domain were artificial societies with their multi agent based simulations were largely explored. In order to improve the artificial societies models, many of the recent articles follow the so-called data driven approach, where real life data are systematically used in construction and validation of the model. For instance, Sajjad *et al.* (2016) modeled the pattern of family formation in Korea, using data from the national census in 1990 and official statistical information regarding the education and income [17].

Apart from these applications, artificial societies are a field of interest in Complexity studies. Such approaches can contribute to the fundamental debate over emergence in artificial societies' evolution: the outcome of simple local interactions can ever be something fundamentally different from the causes? Can something really complex emerge at the global level if only simple mechanisms are in action at the micro level? In order to make a theoretical distinction, Malita and Stefan (2013) defined the apparent complexity as opposed to real complexity [18].

2.3. Theoretical Outcome of Artificial Societies Research

As presented in the introduction, the main attraction for researchers in artificial societies is the exploratory potential of the multi agent based models in order to validate the theoretical knowledge and to understand social processes. Lansing (2002), for example, considers that artificial societies' value lies precisely in the possibility of understanding the connection between structure and function, explaining the emergence of social institutions [5].

Most optimistic researchers are suggesting that artificial societies can and should play a role in developing new social sciences theories, including general theories – see, for instance, Silverman and Bryden (2007). One of their argument is that:

"Being human beings, and therefore part of the system being modelled, we are not able to look at our society from the outside in the way we may look at nature. We propose that we require the input from grown artificial societies to give us new perspectives on our own society" [6].

Epstein (2007), already mentioned in section 2.1 considers that the main contribution of artificial societies is methodological, as offering a new approach, that could complement the induction and deduction-based methodology of social sciences [7]. However, the final outcome of this new methodology should be, again, validating hypothesis and construction of theories.

In spite of the interest of scientists in this direction, so far the artificial societies' explorations and the so-called computational sociology did not have a consistent theoretical outcome, meaning it did not produce a theory that is now widely accepted and promoted in the prominent social sciences communities. There are indeed interesting discussions on the topic, the wide potential of computational sociology is apparently accepted, but the manuals of sociology ignore it.

3. Embedding Social Sciences' Theory and Methodology in Artificial Societies

The relation of artificial societies with social sciences was for two decades a subject of high interest in the field. Many researches argued that the theoretical support is necessary in order to build realistic and useful models. Combining theoretical support in the construction of a model and real data in validation of the model and in running simulations seems to be the best approach ([2], [19], [20], [21]).

The models should be based on solid assumptions. Moss and Edmonds (2005) consider that "The design of the agents must not be constrained by any prior invalidated theory. The essential feature of software agents devised for purposes of social simulation is that they should be validated as good descriptions of the behaviour and social interaction of real individuals or collections of individuals" [2]. These authors have an interesting approach of model validation and consolidation based on qualitative data.

Because of the computational model they are based on, artificial societies seem to be limited from the very beginning to interactionist social sciences theories (because they focus on the micro-level mechanisms). However, macroscopic processes, as their reality cannot be denied, should be included in the models, as suggested by Sawyer (2013) [8]. Edmonds *et al.* (2013) explain that the correspondence theory-model is often present as the idea behind specific aspects of the model [3].

One way to capture different types of mechanisms from micro to macro level is the construction of structures of progressive complexity (like groups and organizations). An example is given in Moss and Edmonds (2005) [2]. Jonker and Treur (2013) suggest a formal approach to design multi agent based systems, in which they detail the possible significance of agents as social actors belonging to the public sphere (and not necessarily an individual) [22]. Either for including such organization /structure or social networks and spatial space, artificial societies can be defined as multilevel systems and simulated as such (Dascalu *et al.*, 2009) [23].

In order to give a strong theoretical foundation to the artificial societies models, some researchers considers that systems sociology is the most adequate theory. The computational model of artificial societies from the perspective of principles of sociology can be founded on the theme of self-reference in the autopoietic systems theory belonging to Niklas Luhmann. Luhmann can be considered a pioneer of the association of cybernetics and sociology. According to him, the social systems can be divided in three categories: societies, organizations and interactions.

According to Luhmann, apud Seidl (2004, pp. 14-15), the social systems that are self-reproducing on the basis of communication have the following properties [24]:

- all communications taking part in the reproduction of a particular functional subsystem 'carry' a specific code;
- each communication of a functional system relates to other communications of the same function system on the basis of the function-specific coding;
- only communications carrying the function-specific code can take part in the reproduction of the functional system;
- functional systems constitute environment for each other;
- the systems cannot 'exchange' their communications (an economic communication cannot take part in the scientific system);
- organizations are social systems which reproduce themselves on the basis of decisions;
- the standard definitions of decision are not very helpful; mostly decision is defined as 'choice'.

In organizations, the communication depends on the hierarchical structure, according to Luhmann, but the hierarchical communication is not the only type of communication. Several other channels of communication, like for instance matrix-organization, are available.

We are aware of the controversies and criticism of different philosophers and sociologists regarding Luhmann's general vision on society, but we agree with those who find his theories useful from the perspective of the computational sociology. The ideas mentioned above are useful to make the connection between artificial societies and social sciences. Luhmann's merit is the attempt to build an audacious theory of society (and that's why it was criticized) in which the communication plays an essential role in the reproduction of social world. Although Luhmann sees the communication as indispensable for the self-reproduction of social systems, and the communication is usually seen as an open system, Luhmann introduced the idea of 'closure'. In his view, in order to keeps its specificity, a social subsystem (an organization) has no contact to its environment.

The work of Di Prodi (2012) is an example that applies Luhmann's vision in order to construct a theoretical framework for developing artificial societies [25]. Particularly, the author is interested in the so-called 'reproduction' of social subsystems based on communication and learning mechanisms. The theoretical framework is applied in a simplified sugarscape-type model with two sub-systems: producers of food and stealers of food. Each individual belonging to a class learns and improve performances with communication-based mechanisms, as in Luhmann's systems sociology.

There are many directions in which this theory-based approach can contribute to further development of artificial societies, and one of them is that of communication and, particularly, media influences and mass communication, a domain where there is indeed a gap in present knowledge and reported research.

Salgado and Gilbert (2013) point that:

"Most research using social simulation ignores the importance of symbolic communication in the social realm, even though only this process can be called social in its own right. Because social communication is not an important issue within the mainstream of computational sociology, it is not hard to understand the reason why the most important advances in computational models about the emergence and the evolution of symbolic communication are just restricted to computational linguistics (cf. the review of Perfors, 2002)" [4].

4. Communication in Artificial Societies

The multi-agent based simulations imply, as an essential part of the computing models and algorithms, the communication as information exchange between agents. From a sociologic perspective, communication is the very essence of the human societies. (Luhmann's systems sociology is known also as a vision based on communication. In spite of this fundamental similitude of the artificial and human societies, communication itself is one of the aspects less explored by artificial societies researchers. We did not identify any significant attempt to include theories of communication and theories of mass communication in the artificial societies simulations.

4.1. From the Beginning to the State of the Art

Multi agent based computation (and computational sociology) developed rapidly starting with the 1990s and, as part of the development of the field, agent communication languages were developed, together with professional standards that cover the content, types of messages, operations and protocols. According to Sawyer (2003), agent communication languages have the theoretical foundation of speech-act theory [20].

However, the agent communication languages are mainly focused on the information exchange, cf. Finin et al (1995) [26]. There is an IEEE standard since 2002 regarding the agent communication language specifications and in this standard also the theoretical framework does not include other specific communication theories or sociologic theories of communication (www.fipa.org) [27].

The articles that address specifically the issue of communication in artificial societies consider it primarily in terms of computational communication, as protocols of information exchange. Toma (2003) explores the effects of different communication protocols in an artificial environment [28]. Eiben *et al.* (2005) discuss the relation between communication and cooperation in artificial societies. In their model, 'communication' is the exchange of information between agents according to a centralized or de-centralized message exchange protocol [29]. Shahidi and Nourafza (2015) experiment the 'effects of communication' in a sugarscape-type model, with no connection whatsoever with any real life phenomenon [30].

An example that was mentioned before as an effort to give a sociologic theoretical basis to artificial societies computing models, Di Prodi (2012), when it comes to communication itself, which is a main part of Luhmann's sociologic vision, applies Shannon's information theory [25].

Between computational sociology applications in scientific literature, very few are connected with mass communication, mass-media and other communication-related field of investigation. Pulick *et al.* (2016) conceived a simulation of the way various types of influences affect face-to-face group discussion in town meetings, based on agent-based modeling [31]. Their research is theoretically framed by psychologic principles belonging to behavioral psychology, mainly the reinforcement theory. Regarding media, they start with the assumption that individuals choose the sources closest to their existing views. The conclusion of the research is that face-to-face group discussions in town meetings do not reach a moderate central consensus, but opinions convergence at one of the extremes defined by polarized media. The approach of the research is impressive as design and effort, but it misses the perspective of communication theory, and therefore the results cannot be extrapolated or applied in order to conceive a media computational model.

As one can see from these examples, applying theories of communications in artificial societies is still an open field of research.

4.2. Theory of Communication Applied in Artificial Societies

Can one find any common elements between the model of artificial societies and the communication theories? Is it possible to construct a model based on some algorithms found in the paradigms in this field in a way that can lead to better understanding of how is manifested the influence of old and particularly new media and social networks? If the answers to such questions will be affirmative at the end of the survey, it would also be possible to develop a new vocabulary for the artificial society that is focused on communication issues. A first term in this new vocabulary could be 'infoscape', corresponding to the 'sugarscap'-type environment which Epstein is speaking about. In such 'infoscape' individuals would feed with news but such news is not exhausted in a similar way to the 'sugar' that individuals consume in 'infoscape'. Once in possession of the news, infoscape agents often come to develop it following examination thereof. By this developing feature of the "raw material" within the 'infoscape'-type environment, as information reaches several agents, it differentiates itself from the resources in other artificial environments where resources are exhausted.

One of the most useful theories for our approach is the theory of media effects. Neuman and Guggenheim (p. 188) considered that the "effects theory evolves from a starting point of a simple model of persuasion and transmission (persuasion theories)" [32]. The explanatory model based on persuasion issues deals to a rather limited extent with the manner in which the media persuasion recipients are involved in analyzing and developing the content of news and of other media products, and as such can hardly associate with the model of artificial societies. Other two paradigms within the effects theories (the active audience theories and the interpretive media effects theories) are more in line with the needs of 'infoscape' modeling, but the paradigm best suited to tracking how people integrated into various online communication networks are using 'infoscape' is, at the present moment, the "multistep flow of communication".

Ognyanova considers that the "multistep flow of communication" theory has to be classified into two categories [33]. The first of them "investigates social structure as a conduit for the spread of ideas and information. The focus in that context is on individuals and the connections among them (including, among others, ties of friendship, kinship, collaboration, discussion, advice - as well as their online equivalents). Media outlets are not seen as part of this network, though they do produce the content that propagates through it" (Ognyanova, 2017, p. 2). The approach to the social structure that benefits from the information transmitted by the online media through the perspective of individuals rather than through the leaders of opinion who had a higher status in the infoscape, according to the authors of the two-step flow of communication theory, makes it possible to analyze the social network as a group of agents within an artificial society. These agents are no longer divided into first-rank agents because they have the capacity, as leaders of opinion, to interpret media information, and regular agents who take over those interpretations. As a result, a sort of democratization is achieved in infoscape as well as a change of emphasis from the quality of interpretation of the information transmitted by the media, onto the quantity of individual interpretations and appreciations which such interpretations get within a network of friends from the online environment.

Ognyanova (2017, p. 3) also speaks of a second category of studies in the multistep flow of communication field: "Many works in this second category allow for the possibility that individuals as well as media outlets can generate, selectively filter, and disseminate messages" [33]. This second category of studies dealing with the multistep flow of communication represent the most useful approach to making simulations of infoscape as an artificial society type . So we are dealing with an infoscape type including both media outlets and individuals who communicate with their friends on Facebook, Twitter, etc.

Translation into an algorithm that can be simulated is possible, such as a Facebook page of a certain group specialized or not on a particular topic (for example, fans of a TV series). Besides the aspects above highlighted, the development potential of a particular group is also important, both by joining of other members as well as by increasing the information resources, namely integration of information received by other types of media outlets. It is also relevant to analyze a possible stratification of the group of agents according to the information resources they have and the roles they play in that respective group.

5. Conclusions

Communication is one of the fundamental components of human societies. In artificial societies, a computing model based essentially on multi agent based modeling, communication is inherent and is also a fundamental part of the model. In this computing model, communication appears as information exchange and is analyzed, discussed and optimized from the perspective of information theory and computational communication. We consider that, in order to ensure the theoretical foundation needed for social simulations (meaning, a theoretical foundation based on social sciences), communication also needs to be modeled from the perspective of social sciences and particularly communication sciences. This paper reviews the scientific literature and identified the way communication was modeled so far, concluding that there are few connections with communication sciences. Several communication theories are analyzed, in order to build this theoretical foundation. The paper introduces the concept of 'infoscape' for the 'information landscape' of artificial societies and suggests the way multi-step flow of communication theory could be used in order to model communication in this 'infoscape'.

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