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Modelling structured societies: A multi-relational approach to context permeability

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ABSTRACT

The structure of social relations is fundamental for the construction of plausible simulation scenarios. It shapes the way actors interact and create their identity within overlapping social contexts. Each actor interacts in multiple contexts within different types of social relations that constitute their social space. In this article, we present an approach to model structured agent societies with multiple coexisting social networks. We study the notion of *context permeability*, using a game in which agents try to achieve global consensus. We design and analyse two different models of permeability. In the first model, agents interact concurrently in multiple social networks. In the second, we introduce a *context switching* mechanism which adds a dynamic temporal component to agent interaction in the model. Agents switch between the different networks spending more or less time in each one. We compare these models and analyse the influence of different social networks regarding the speed of convergence to consensus. We conduct a series of experiments that show the impact of different configurations for coexisting social networks. This approach unveils both the limitations of the current modelling approaches and possible research directions for complex social space simulations.

1. Introduction

In most simulations of complex social phenomena, agents are considered to inhabit a space in which structure is very simple. This space has little resemblance with the social world it is supposed to depict and for which conclusions are supposed to be extrapolated. This simplicity does not come by chance, rather, it is necessary and desired by the researchers: the problems to be approached are themselves so complex that whichever factors of complexity can be reduced (or at least postponed), the reduction is always welcome. So, it is common practice that geographical space is reduced to a two-dimensional grid, and all social relations between agents are condensed into one more or less structured abstract relation. Most social simulation and modelling approaches disregard the fact that we engage in multiple social relations. Moreover, each kind of social relation can possess distinctive characteristics that include: rich information such as degree of connectivity, centrality, trust, interactions frequency, asymmetry, and so on.

To explore the addition of multiple relations and its consequences for the dissemination of phenomena in social simulations, we put forward to *reduce* the emphasis given on agent individual interactions. We accomplished this by choosing a simple – and especially neutral – game to model those interactions. Our main concern was that the game itself would

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not provide biases or trends in the collective phenomenon being studied, so we chose the *consensus formation game*, with a straightforward majority rule to decide the outcome of each individual move.

While most models are simplified descriptions – reductions – of real-world phenomena, many constitute complex systems themselves and thus, we need techniques such as simulation to explore their properties. We can make a distinction between two types of complexity: the complexity of real systems (*ontological complexity*) and the complexity of models (*descriptive complexity*) [1]. The levels of abstraction in a simulation model can then range from data-driven paradigms to more abstract descriptions that allow us to create *what-if-scenarios*. The study of this abstract *descriptive complexity* in simulation models is as valuable as its *data-driven* counterpart. We may not be able to make predictions based on the direct application of such models; but, their study can inspire the engineering of artificial complex systems and reveal properties with applications beyond the explanation of observable phenomena. Studying consensus formation can thus advance our understanding of related real-world social phenomena.

Examples of thematic real-world phenomena in social simulation models include for instance the joint assessments of policies or, in the context of economics and politics, *the voting problem*. Herbert Simon's investigations on this problem were one of the first stepping stones to the field of social simulation [2]; which then inspired models (like the one we present in this article) related to evolution and dissemination of opinions, which we call *opinion dynamics*. In agent-based *opinion dynamics*, agent interactions are guided by *social space* abstractions. In some models, the dimensionality and structure of this space is irrelevant (any agent can interact with any other agent). Other models use an underlying artefact that structures agent neighbourhoods. Axelrod for instance, represents agent neighbourhoods as a bi-dimensional grid in its model of *dissemination of culture* [3]. In an attempt to mimic real social systems, one can also make use of *complex network models* to create the infrastructure that guides agent interaction (see [4] for an example).

In real-world scenarios, actors engage in a multitude of social relations different in kind and quality. Most simulation models don't explore *social space* designs that take into account the differentiation between coexisting social networks. Modelling multiple coexisting relations was an idea pioneered by Peter Albin in [5] but without further development. The process of interacting in these different complex social dimensions can be seen as the basis for the formation of our social identity [6,7].

In this article, we explore the modelling of opinion dynamics with multiple social networks. We look at how the properties of different network models influence the convergence to opinion consensus. We present a series of models that use these networks in different ways: which create distinct emergent dynamics. We want to study the consequences of using multiple social networks at the same time while maintaining the interaction model as simple and abstract as possible (following the methodology in most opinion dynamics literature). We present two models where agents can: interact at the same time in the multiple networks (choosing partners from any network); or switch between networks (choosing only partners from their current network).

1.1. Article structure

This article is organised as follows. In the next section, we present the work related to *opinion dynamics*, *social space* modelling and *complex network models*. In the following section, we describe our game of consensus and introduce our multiple model variations. These are designed to study the notion of *context permeability* and consensus formation in multiple social networks. Section 4 describes the experimental setup; the set of tool and methodologies followed to conduct our investigations. In Section 5, we present and discuss our results and compare the different simulation models. Finally, we summarise what we learned from our experiments and point out future research directions.

2. Related work

In this section, we present work related to *opinion dynamics*, *social space* modelling, and *complex network models*.

2.1. Opinion dynamics and consensus formation

Formal opinion dynamics models provide an understanding, if not an analysis, of opinion formation processes. An early formulation of such models was created as a way to understand complex phenomena found empirically in groups [8]. The work on consensus building (in the context of decision-making) was first studied by DeGroot [9] and Lehrer [10]. Empirical studies of opinion formation in large populations have methodological limitations. Computational sociology arises with a set of tools – simulation models in particular – to cope with such limitations. We use *multi-agent simulation (MAS)* as a methodological framework to study such social phenomena in a larger scale. Most opinion dynamics models make use of binary opinion values [11,12], or continuous values [13,14]. For a detailed analysis over some opinion dynamics models, refer to [15].

Opinion dynamics models allow us to discover under which circumstances a population of agents reaches consensus or polarisation. Agent-based models can have broader application outside social simulation though. In computational distributed systems, consensus is a means by which processes agree on some data value needed during computation. Typically, this agreement is the result of a negotiation process (often with the aid of a mediator). In human societies, social conventions emerge to deal with coordination and subsequently with cooperation problems [16]. These conventions are regularities