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Abstract Agent-based simulation has long been used to study the dynamics of innovation adoption and diffusion. However, the vast majority of these works are limited to an abstract and simplified representation of this process, which does not make it possible to explain the reasons for an agent's change of opinion, an element that is nonetheless fundamental to understanding the dynamics of innovation diffusion. In order to overcome this limitation, we propose an agent-based model of innovation adoption and diffusion based on a classical theory of psychology, the theory of planned behaviour, and on formal argumentation. Each agent thus has the opportunity to exchange arguments with another agent and to build his/her opinion on an innovation from the set of arguments he/she knows. An application of this model is proposed to study the diffusion of communicating water meters by farmers on the Louts River (southwestern France).

Keywords Innovation diffusion · Agent-based simulation · Formal argumentation · Theory of planned behavior

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1 Introduction

Human societies are strongly characterized by their ability to innovate. Understanding how an innovation will succeed in imposing itself in a society is in this context of primary importance to better understand its past and future evolution. Nevertheless, understanding these dynamics is complicated because it requires taking into account complex interactions between individuals.

Many studies have already focused on modeling the process of innovation diffusion. The issues are essentially to better understand the adoption process in a population and to anticipate the dynamics of adoption at a micro or macroscopic level. Most existing models are based on the work of Rogers [8]. He defines the diffusion of innovations as the process by which a new practice, idea or product spreads in a society and proposes to represent the adoption process through five stages (information, persuasion, decision, implementation, confirmation).

A very classical model using part of Rogers' work is the Bass model [1]. This model aims to predict the peak of new adoptions. Its descriptive power is weak because this model does not attempt to represent the decisions of each individual but only the evolution of the number of adopters at a given moment; the different stages of adoption proposed by Rogers, the heterogeneity of the population and the interactions between individuals are not taken into account, nor is the impact of the means of dissemination set up by the institution.

To go further in the description of the processes of diffusion of innovation, many works such as those of [5] have proposed the use of agent-based modeling to represent this process: each agent representing an individual is capable of influencing the others on their adoption of the innovation. Most of these models represent the opinion of each agent on an innovation by a numerical variable that evolves directly during their interactions with other agents. This type of representation provides little information on the change of opinion of the agent because the reasons why he/she changed his/her mind are not known.

To overcome this limitation, a relevant framework is that of formal argumentation [2]. Argumentation deals with situations where information contains contradictions because it comes from several sources or corresponds to several points of view that may have different priorities. If several agent-based models already integrate argument exchanges to represent opinion dynamics processes [7,10,9], to our knowledge, no model proposes to explicitly integrate arguments to simulate the innovation diffusion process.

2 Proposition

We therefore propose in this work a generic model in which the knowledge of each agent is explicitly represented in the form of arguments, which carry information about the innovation. These arguments are the objects that the agents will exchange during their interactions. The advantage of this approach is that it allows to trace the state of knowledge of an agent in order to understand the evolution of its behavior in front of an innovation. We also propose to represent the decisional model of the agents with the Theory of Planned Behaviour (TPB). This theory, very classical in psychology, offers an integrative framework to formalize the behavior of agents [6,3]. In TPB, the intention to behave is derived from three variables: the attitude, the subjective social norm and the perceived control of the behavior (PBC). The attitude represents the knowledge and opinion that an individual has about a behavior - in our case the adoption of the innovation. The subjective social norm is the individual's perception of the adoption intention of his/her social network. Finally, the PBC is the capacity felt by the individual to adopt the innovation (in terms of cost, time, skills, technical aids, ...). In our model, we use the equation proposed by [6] to calculate the intention from these three variables.

Our proposal is to compute the attitude of the agents from their knowledge about the innovation, modeled as an argument graph, using the same approach as the one proposed by [10]. Concerning the social norm, we propose to be inspired by the work of [4], who suggests that during an interaction between two individuals the influence of one on the other depends on the opinions and the certainties that they have on the subject.

At last, concerning PBC, which is specific to the type of innovation studied and to the individual concerned, we propose to transcribe it in the form of a variable specific to each individual, which may or may not be constant depending on the case of application.

3 Application

In the Louts region (southwestern France), mechanical meters, which are owned by farmers, fail to estimate water consumption correctly because of their low accuracy. This is an advantage for the farmers, as there is less risk of being overcharged if the allocated quota is exceeded. For this reason, the Ministry of the Environment has required a periodic refurbishment of the metering system every nine years. The "Compagnie d'Aménagement des Coteaux de Gascogne" (CACG), which is in charge of managing water distribution in this area, is counting on this regulation to install its new communicating meters. These new meters are more precise and allow to follow in real time the consumption of each farmer and thus to better manage the use of water.

However, CACG is having difficulty convincing farmers to install this device because they perceive it negatively. This obstacle is closely linked to the distrust that farmers have of the institution. A large part of the farmers believe that the new meter does not benefit them and that it is only useful for the institution. However, a minority, more inclined to new technologies, finds arguments in favor of these meters, such as the management of material leaks, the automatic calculation of consumptions to regulate at best the withdrawals in order not to exceed the allocated quota and to limit the losses.

The analysis of various scientific documents and websites has allowed us to identify forty arguments (16 (40%) against and 24 (60%) in favour) divided according to five criteria: confidence (in the institution), ecology, social, productivity, financial.

The model was used to show that, as with mechanical meters, it was possible to observe a trend towards acceptance of this technology by farmers. We were also interested in fake news. Indeed, these last years have been strongly marked by the massive emergence of fake news in the public debate, generally coming from unreliable websites or social networks. For example, in the case of the Linky electricity meters, a lot of false information linking the meters to cancer risks has emerged. We have thus shown, using the model, that if they were numerous enough, these fake news could totally saturate the public space and thus totally alter the acceptance of the communicating water meters by farmers.

These first experiments illustrate the type of study that can be conducted with our models. To go further in this study, an important work will concern the collection of data. Indeed, some of the parameters of the model used for the experiments were estimated or drawn at random. A future objective is to set up field surveys to obtain these parameters. Similarly, we would like to obtain data on the evolution of farmers' opinions on communicating water meters in the Louts region through questionnaires, which would allow us to validate the results obtained by simulation.

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