Coupling Agent-Based Models and Argumentation Framework to Simulate Opinion Dynamics: Application to Vegetarian Diet Diffusion

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Abstract. Agent-based simulation has been extensively used to study opinion dynamics. However, the vast majority of the existing models have been limited to extremely abstract and simplified representations of the diffusion process, which impairs the realism of the simulations and disables the understanding of the reasons for the shift of an actor's opinion. This paper presents a generic framework implemented in the GAMA platform allowing to explicitly represent exchanges of arguments between actors in a context of an opinion dynamic model. More precisely, we propose to formalize the inner attitude towards an opinion of each agent as an argumentation graph and give them the possibility to share arguments with other agents. We present an application of the framework to study the evolution of the vegetarian diet at a city level.

Keywords: Opinion dynamics · Agent-based simulation · Argumentation framework · GAMA platform · Vegetarian diets

1 Introduction

Agent-based modeling is a classical approach to study opinion dynamics, as it allows to take into account the heterogeneity of actors and the impact of local interactions between them. Among existing approaches, the most popular uses a numerical value to represent the opinion towards an option [8,14]. The opinion of each agent is updated by averaging a set of agent opinions. These last fifteen years, many studies have proposed to enrich this generic model, for example by taking into account fixed uncertainties and by studying the model behaviour when adding extremists [17] or contrasting effects [15].

These models are very relevant to study social influence, however, most of them remain theoretical as very few of them have been applied to real case-studies using data and validated [12]. Another drawback is the difficulty to understand the inner motivation concerning the modification of opinion of an agent.

Indeed, as the opinion is usually summarized by a single numerical value, it is not possible to know precisely why the agent has changed his/her opinion.

In order to better represent the inner deliberation of agents towards an opinion, we propose to follow an opposite approach by adopting a KIDS [10] approach rather than a KISS [1] one. Doing so, we assume that explicitly representing how people deal with arguments and diffuse them to other people to try to convince them to change their opinion (or reinforce their opinion) can lead to the development of more grounded opinion dynamic models.

Another relevant framework is the argumentation model [3]. Argumentation deals with situations where information contains contradictions because it comes from several sources or corresponds to several points of view that possibly have different priorities. It is a reasoning model based on the construction and evaluation of interacting arguments. It has been formalized both in philosophy and in computer science [23] and applied to various domains including non-monotonic reasoning [9], decision making [28] or negotiation [16]. The system introduced in [9] consists of a set of arguments and a binary relation on that set, expressing conflicts among arguments. An argument gives a reason for believing a claim, or for doing an action. Historically, the typical field of application of argumentation in computer science was the legal domain [22]. More recently, several studies proved its relevance in social-related concerns, medicine, food systems, chains, policies and controversies, especially for decision-making purposes [28].

We thus propose to integrate these studies, and in particular the system introduced by [9], in a generic framework implemented in the GAMA platform [27], dedicated to the development of opinion dynamic models. Doing so, the model presented adds an important innovation to the literature in social influence models [30,12], by implementing interactions between arguments. Compared to [9], our argument descriptions are not abstract but detailed by a rich set of attributes, including criteria, the latter being in line with the conclusions of [30].

Section 2 presents the generic framework that we propose. Section 3 presents an application of this framework in a model to study the evolution of the vegetarian diet at a city level. Finally, Section 4 concludes and presents some perspectives of this work.

2 Generic framework proposed

The main goal of this study is to enable modelers to easily define agent-based models using argumentation. Modelers, especially those who are not computer scientists, tend to use modeling platforms such as Netlogo [29], GAMA [27] or CORMAS [5] to develop their models. We made the choice to directly integrate an argumentation framework inside the GAMA platform.

GAMA, like Netlogo, provides modelers with a dedicated modeling language which is easy to use and learn. It also allows them to naturally integrate GIS data and includes an extension dedicated to generating a spatialized and structured synthetic population [7], which is particularly interesting for building KIDS models. Finally, GAMA integrates an optional BDI architecture, called BEN [26,4], that provides agents with cognition, emotions, emotional contagion, social relations, personality and norms.

The framework proposed was implemented as a plug-in for the GAMA platform and was designed to be usable with the BEN architecture. The idea behind this framework is to explicitly represents agents' own mental deliberation process from arguments towards an opinion, through the use of the argumentation framework of [9].

Definition 1. *(Dung's argumentation graph). An argumentation graph is a pair* $(\mathcal{A}, \mathcal{R})$ *where* $\mathcal{A}$ *is a set of arguments and* $\mathcal{R} \subseteq \mathcal{A} \times \mathcal{A}$ *is an attack relation. An argument* a *attacks an argument* a' *if and only if* $(a, a') \in \mathcal{R}$.

The framework is built on the concept of argument that is defined as a new type of variable in GAMA.

Definition 2. *(argument in GAMA). We describe an argument by a tuple* $a = (I; O; T; S; R; C; A; Ts)$*, with:*

- *I (mandatory): the identifier of the argument;*
- *O (mandatory): the option that is concerned by the argument;*
- *T (mandatory): the type of the argument (with values in favour of, denoted by '+', against, denoted by '-', or neutral, denoted by '0', towards the option);*
- *S (optional): the statement of the argument, i.e. its conclusion;*
- *R (optional): the rationale underlying the argument, i.e. its hypothesis;*
- *C (optional): the criteria which the argument relies on: defined as a map in GAMA, which associates a set of criteria with their corresponding numerical values that represent the importance of each criterion for the argument;*
- *A (optional): the agent who proposes the argument;*
- *Ts (optional): the type of source the argument comes from.*

Example 1. An example of argument for the vegetarian diet context is ("1", "adoption of the vegetarian diet", "-", "Vegan diet is deficient in B12 vitamin", "Vegetable proteins do not contain B12 vitamin", "Nutritional::1.0", "journalist of 'Canard Enchainé'", "Newspaper"). Except for the three first variables that are mandatory, the others are optional: according to the application context (and to the knowledge/data of the modeler), the modeler will not necessary have to fill all these variables.

The plug-in also defines a new skill for agents, called *argumenting*. A skill in GAMA is a built-in module that provides agents with a set of related built-in attributes and built-in actions. The *argumenting* skill provides agents with 2 new attributes and 7 new actions.

List of attributes:

- *criterion_importance*: for each criterion which arguments rely on, a score (numerical value between O and 1) representing the importance of this criterion for the agent;

- *argumentation_graph*: a directed graph that represents a Dung's argumentation system. Each node is an argument, and each edge represents an attack from an argument to another argument. The weight of an edge represents the strength of the attack for the agent.

List of actions:

- *add_ an_argument(new_argument, referenced_graph)*: add *new_argument* to the agent's argumentation graph and connect the argument to the other arguments according to the existing attacks in the *referenced_graph*. The interested reader can refer to [32] for different ways to define attacks.
- *evaluate_argument(an_argument)*: evaluate the strength of *an_argument* for the agent. More precisely, the strength of an argument arg for an agent ag is computed as follows:

$$strength(ag, arg) = \sum_{c \in CRIT} arg(c) \times ag(c) \tag{1}$$

  with $CRIT$, the set of criteria, $arg(c)$ the value associated with the criterion c in the map C of the argument arg (see Definition 2), and $ag(c)$ the importance of c for the agent ag.
- *preferred_extensions(an_argumentation_graph)*: compute the set of preferred extensions from *an_argumentation_graph* using $JArgSemSAT$ library [6].

  Definition 3. *(Preferred extension). Let an argumentation system* $(\mathcal{A}, \mathcal{R})$ *and* $B \subseteq \mathcal{A}$. *Then:*
  - *B is conflict-free if and only if* $\nexists a_i, a_j \in B$ *such that* $(a_i, a_j) \in \mathcal{R}$*;*
  - *B defends an argument* $a_i \in B$ *if and only if for each argument* $a_j \in \mathcal{A}$*, if* $(a_j, a_i) \in \mathcal{R}$*, then* $\exists a_k \in B$ *such that* $(a_k, a_j) \in \mathcal{R}$*;*
  - *a conflict-free set B of arguments is admissible if and only if B defends all its elements.*

  A preferred extension is a maximal (with respect to set inclusion) admissible set of arguments.

- *evaluate_conclusion(list_of_arguments)*: evaluate the conclusion that can be taken from *list_of_arguments*. More precisely, the value of a set of arguments $Args$ for an agent ag is computed as follows:

$$value(ag, Args) = \sum_{arg \in Args} strength(ag, arg) \times type(arg) \tag{2}$$

  with: $type(arg) = \begin{cases} -1 & \text{if arg.T = -} \\ 0 & \text{if arg.T} = 0 \\ 1 & \text{if arg.T = +} \end{cases}$
- *update_graph_weight*: update (recompute) the weights of the edges (attacks) of the argumentation graph according to the argument criteria and to the agent's criterion importance. We define the weight of an attack as the strength of the argument at the origin of the attack and evaluated by action *evaluate_argument*.

– *simplify_graph*: simplify the argumentation graph according to the weights of the edges. If an argument a attacks an argument a' and if a' attacks a, only the attack with the highest weight is kept in the simplified graph. If the attacks have the same weight, both attacks are kept. Formally:

  Definition 4. *(Simplified argumentation graph). Let* $(\mathcal{A}, \mathcal{R})$ *be an argumentation graph and* $(a, a') \in \mathcal{R}$*. The simplified argumentation graph* $(\mathcal{A}, \mathcal{R}')$ *obtained from* $(\mathcal{A}, \mathcal{R})$ *is defined by:* $(a, a') \in \mathcal{R}'$ *if and only if:*
  - $(a, a') \in \mathcal{R}$ *and*
  - *if* $(a', a) \in \mathcal{R}$ *then* $strength(ag, a) \geq strength(ag, a')$*.*

– *deliberate*: make a decision concerning an option from the argumentation graph. The deliberation action is composed of 4 steps:
  1. updating the weights of the attacks of the argumentation graph using the *update_graph_weight* action.
  2. simplifying the argumentation graph using the *simplify_graph* action.
  3. computing the set of preferred extensions from the simplified argumentation graph using the *preferred_extension* action.
  4. computing the opinion from the preferred extensions: for each extension compute its value using the *evaluate_conclusion* action, then return the value of the extension with the maximal absolute value. If this value is higher than 0, it means that the agent is in favour of the option, if the value is lower than 0, it means that the agent is against the option, and if the value is 0, the agent is neutral towards the option.

The plugin was designed to be as modular as possible. Indeed, several actions depend on other actions (for example, the *deliberate* action depends on the *evaluate_argument*, *update_graph_weight*, *simplify_graph*, *preferred_extension* and *evaluate_conclusion* actions) that can be easily tuned by the modeler. For example, a modeler who wants to take into account the type of source in the computation of the strength of an argument can just override the *evaluate_argument* action using the modeling language of the GAMA platform. All the other actions that depend on this action (e.g. *deliberate*) will take into account the action defined by the modeler instead of the built-in one.

The plug-in was developed under the GPL-3 licence, and is available on Github[4]. It can be directly downloaded and installed from GAMA 1.8 RC2 from the gama experimental p2 update site[5].

3 Application to vegetarian diets diffusion

3.1 Context

Vegetarian diets are gaining more attention as animal welfare concerns are raising and environmental impacts of animal productions are better assessed [13,19].

[4] https://github.com/gama-platform/gama.experimental
[5] http://updates.gama-platform.org/experimental

While higher income per capita is historically correlated with higher consumption of animal products [20], recent data suggest that this tendency might reach a turning point in the near future, where higher income per capita would correlate with lower consumption of animal products [31]. One hypothesis to explain such trend shift would be the diffusion and wider adoption of diverse vegetarian diets, from semi-vegetarian (or flexitarian) to strict vegetarianism (or vegan diet) [2]. Reasons for such diet choice range from ethical, environmental and health concern [24]. Our assumption is that the diffusion of ethical, health and environmental arguments in favour of such diets probably fuels the vegetarian diets adoption process. The relation between argument acquisition at the individual level and behavior diffusion has never been explored for vegetarian diets.

In order to get insights on arguments as well as external events at stake when a citizen decide whether to follow a vegetarian diet, we conducted individual interviews, a survey, and built an argument database. We conducted 20 life story individual interviews about vegetarian diets transitions. We collected detailed qualitative data about the process of diet change. We also conducted a survey among a panel of 1714 French citizens. They were asked their willingness to change, the type of argument they are sensitive to (economic, health, ethical or environmental), as well as expressing on a lickert-scale their degree of agreement with 16 key arguments. These 16 arguments were extracted from the participatory online platform Kialo which allows users to co-construct argument hierarchies about any topic. We considered the first level of arguments of the hierarchical network about "humans should stop eating meat" [6]. Finally, we also constructed a database of 114 arguments obtained from google search about vegetarian diets and established an argumentation network establishing attacks between them [25].

3.2 Generic model

To illustrate the use of the proposed framework to study opinion dynamic -and more specifically the diffusion of vegetarian diet- we built a simple model based on two types of entities:

- citizen: the main agent of the model, it owns the *argumenting* skill. In addition to the attributes provides by the *argumenting* skill, citizen agents have the following attributes:
  - social_attributes: all types of attributes that are necessary to characterize the agent.
  - social_network: list of other citizens they can exchange arguments with,
  - opinion: correspond to the opinion of the agent.
- event: an event will be the source of new arguments for a sub-set of citizens
  - new_arguments: new arguments brought to citizens,
  - citizen_aware: list of citizens that will directly receive the new arguments.

[6] https://www.kialo.com/the-ethics-of-eating-animals-is-eating-meat-wrong-1229?path=1229.0 1229.1

At each simulation step, three types of processes are activated:

1. an event can occur and bring new arguments to some of the citizen agents,
2. citizen agents can give one or several arguments to other citizen agents of its social_network,
3. based on their internal argument graph, citizen agents choose to keep their current opinion or to modify it.

The first process concerns the occurring of an event that will impact the base of arguments of some of the agents. For instance, for our application, a sanitary crisis can bring new arguments for some people to stop to eat animal products.

The second process deals with citizen agents who try to convince other citizen agents through the exchange of arguments. More precisely, each citizen agent can choose to give one or several arguments to one or several other citizen agents. The choice to exchange arguments and which arguments to exchange can depend on the personality of the citizen, but also on his/her opinion. Indeed, someone who is radicalized tends to be more proselyte than someone who is neutral.

The last process consists for the citizen agents who got new arguments to deliberate on their new argument graph and eventually change their opinion. To do so, we use the *deliberate* action provided by the *argumenting* skill.

3.3 Simulation of vegetarian diet diffusion

The generic model was instanced in the context of the vegetarian diet diffusion in the city of Rouen. Rouen is a middle size city of France with an estimated population of 110,754.

We use the data from the French National Institute of Statistics and Economic Studies (INSEE) and the Gen* plugin of GAMA [7] to generate and spatialize the population. Each citizen agent has 3 social attributes: age, occupational category and localization. These attributes were used to generated the social network: the closest are the agents (for these three attributes), the higher the the probability to be connected. For each citizen agents, we drew a number of citizen agents in its social network using a Gaussian distribution, with a mean of 10 and a standard deviation of 3.

Concerning the arguments, we use the 114 arguments collected. For the initial argumentation graph, for each citizen agent, we drew a number of initial arguments using a Gaussian distribution, with a mean of 20 and a standard deviation of 5. The arguments were selected randomly among the 114 arguments.

For the criterion importance values, we used the survey to determine the relative importance of the different criteria. More precisely, we use the data collected to define for each criterion a mean value, then we drew the importance of criteria by using a Gaussian distribution. In the future, we plan to use the survey to make a link between these values and the social attributes of the people (in particular, the occupational category and the age).

Finally, we used the survey to define 4 possible categories that correspond to possible diet choices: omnivorous, flexitarian, vegetarian and vegan. The choice

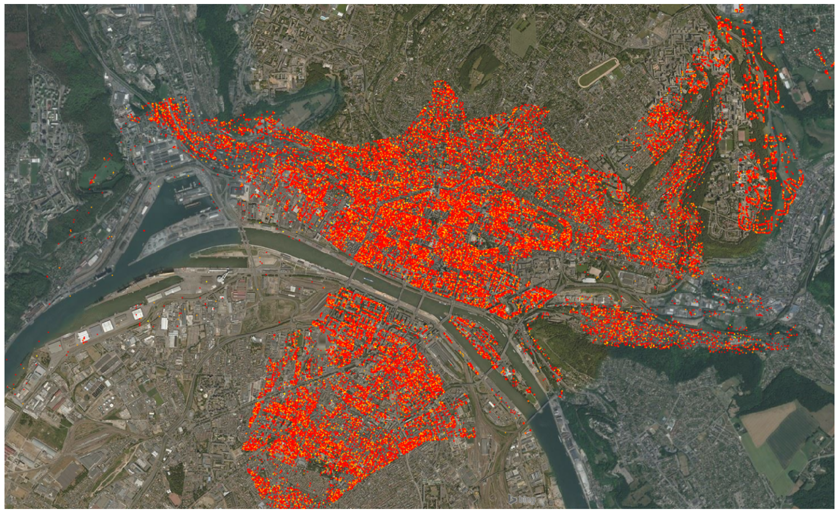

Fig. 1: Snapshot at the initialization of the simulation. red circle: omnivorous; orange circle: flexitarian; yellow: vegetarian; green: vegan

of a category depends of the value returned by the *deliberate* action. We defined for each category an interval of values:

- omnivorous: $]-\infty, 2.0]$
- flexitarian: $]2.0, 3.5]$
- vegetarian: $]3.5, 4.5]$
- vegan: $]4.5, \infty[$

The intervals were defined in order to approximately get the same proportion of people in each category than in the survey. Table 1 shows the proportion obtained at the initialization of the simulation (mean of 10 simulations) in comparison to the one of the survey.

Category	Model - Mean value (standard deviation)	Survey
omnivorous	74.25% (0.17%)	70.4%
flexitarian	22.48% (0.15%)	26.7%
vegetarian	2.82% (0.04%)	2.5%
vegan	0.45% (0.02%)	0.5%

Table 1: Proportion of omnivorous, flexitarian, vegetarian and vegan according to the survey and at the initialization of the model.

Figure 1 shows a snapshot of the simulation after the initialization and a deliberation stage from their initial argumentation graph.

In the simulation, a simulation step corresponds to 1 year. The number of arguments and the choice of argument exchanged each step depend on the agent opinion. Indeed, someone who is very convinced by his/her opinion and whose opinion is not standard for society, like a vegan, will be more proselyte than someone rather neutral. In addition, a vegan will try to give arguments that are in favour of not eating animal product, while an omnivorous will tend to give arguments against it. So we define the following rules according to the value returned by the *deliberate* action:

- $]-\infty, -2.0]$: gives 1 argument against veg. diets to 10% of its social_network
- $]-2.0, 2.0]$: gives 1 argument against veg. diets to 5% of its social_network
- $]2.0, 3.5]$: gives 1 argument in favour of veg. diets to 10% of its social_network
- $]3.5, 4.5]$: gives 1 argument in favour of veg. diets to 20% of its social_network
- $]4.5, \infty[$: gives 2 arguments in favour of veg.diets to 30% of its social_network

We use the model to test two scenarios. The first one is the business as usual scenario in which no specific event occurs during 20 years. In the second scenario, we integrate a sanitary crisis (like the mad cow disease crisis in the nineties in Europe) that occurs after 5 years. This event adds a new argument about the danger of eating meat (health criterion) to 2O% of the population.

Figure 2 shows the yearly evolution of the proportions of the different categories for the business as usual and the sanitary crisis scenarios (mean of 10 simulations). For both scenarios, the number of omnivorous tends to decrease over time with a constant speed as more people become convinced by vegetarian diets. We can see in the sanitary crisis scenario the impact of the integration of a new argument: when the event occurs, a significant part of the omnivorous population change their diet for a vegetarian one.

A last result to mention is the computation time: with an i7 computer (only 1 core used), the total time for the simulation of the 110,754 agents for 20 simulations step was less than 8 min (less than 25 seconds per simulation step), which is rather good considering the number of agents and the fact that there is a lot of room for optimization (first of all, the possibility to distribute the computation on several cores).

To conclude on this application, our generic framework, and its application for opinion dynamic simulation offers numerous possibilities. If the purpose of the simple model presented was above all to illustrate the type of use that could be made, we plan in the future, by using the collected data, to build a more credible and grounded model. The source code of the model is available on OpenABM[7].

4 Conclusion

The paper presented a generic framework integrated in the GAMA platform allowing to use formal argumentation in agent-based models, in particular in the context of opinion dynamics. The use of the framework was illustrated through an application concerning the diffusion of vegetarian diet. The experiment carried out shows the possibilities offered by our framework.

[7] https://www.comses.net/codebases/23ab03f4-4c8f-42f5-b5e8-351558b5aa33/releases/1.0.0/

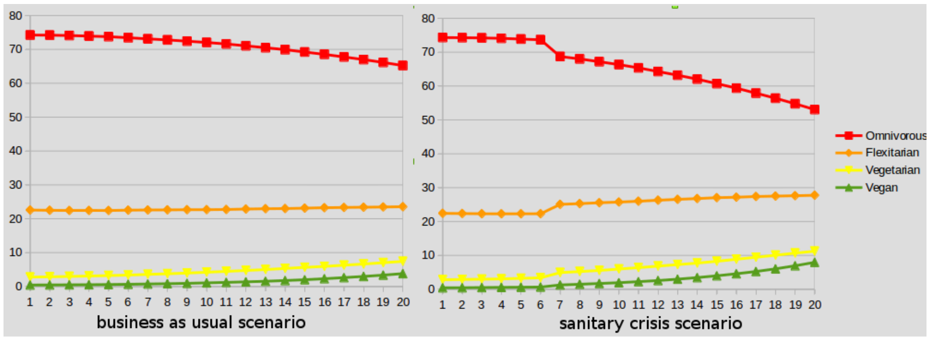

Fig. 2: Result for the two scenarios (mean of 10 simulations); x-axis: number of years; y-axis: percentage of the population.

This study is a first step towards the coupling between argumentation and agent-based modeling and its use for opinion dynamic models. In particular, we plan to enrich the generic framework implemented in the GAMA platform in order to offer complementary tools to the modelers in terms of management and analysis of an argumentation graph, such as computing various types of extensions (complete, stable, semi-stable, etc.).

We also plan to enrich the way arguments are evaluated. In the current version, the evaluation of arguments depends on the criteria concerned by the argument and on the importance for the agent of these criteria. Other factors can impact the perception of an argument, and among them, the source of the argument [21]. Indeed, for example, the profusion of fake news from dubious source can impact people differently. Our framework should soon be able to take this difference of perception into account.

A last perspective related to the generic framework concerns the link between this framework and the BEN architecture. Indeed, in addition to the BDI reasoning engine, the BEN architecture introduces numerous concepts that could be interesting for our work such as the personality of agents based on the classic OCEAN model [18] and the social relation between agents evaluated according to 5 dimensions (liking, dominance, solidarity, familiarity and trust).

Concerning the generic model, we plan to add new types of agents, in particular influencers (lobby, government, company, etc.), which will diffuse new arguments to citizen agents. We are considering as well to add a mechanism to enable en evolution of the criterion importance for the agents. Indeed, these values are not fixed for life but can evolve after a particular event and from the influence of other people. Finally, we plan to enrich the argument exchange protocol (which arguments citizen agents choose to exchange). In this regard, [11] describes how social norms are mainly questioned when individuals holding different views interact. Indeed, one of the utilities of social norms is that they save time and energy in decision making. As Josh Epstein puts it in [11] : "When I'd had my coffee this morning and went upstairs to get dressed for work, I never considered being a nudist for the day.". In that sense, we could first improve the argument exchange procedure by limiting it to interactions between agents holding differing norms, or else, by limiting such exchange in case they have in their social network another agent holding a differing perspective. Secondly, we could adapt the type of arguments exchanged depending on norms hold by both parties. For example, a flexitarian would exchange a pro-vegetarian argument to an omnivore, but would exchange a pro-omnivore argument to a vegetarian.

For the application case of the diffusion of the vegetarian diet, we plan to better take profit from the data collected to generate a more credible population of agents (criterion importance, social networks, initial arguments, etc.), validate the model, take profit of the model to test a wide range of scenarios.

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