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Modelling the impact of beliefs and communication on attitude dynamics: a cognitive agent-based approach

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***Abstract*—In the context of military training for stabilization operation of a crisis zone with civilian population, understanding the formation of attitude and its dynamics is a key issue. This paper presents a multi-agent model for simulating attitude formation and change based on individual's perception of information and its diffusion through communication. We represent the attitude as object-evaluation associations of varying strength proposed by Fazio [1]. Individuals observe military operations. They exchange and revise beliefs about social objects depending on multiple criteria deriving from social psychology theories. They compute their attitude value based on analytic assessment of these beliefs. We illustrate, through several simulation experiments, the role of communication on attitude dynamics.**

***Index Terms*—multi-agent system, social simulation, social psychology, attitude dynamics, information diffusion.**

I. Introduction

Industrial Context

The new paradigm of war: During the last two decades, stabilization operations in Former Yugoslavia, Somalia, Timor, Western Africa, Iraq and Afghanistan have brought to light a deep shift that occurred in the military affairs from industrial war to a paradigm identified as *"war amidst the people"*[2]. Today, most of the military operations involving western Forces face irregular opponents. These new types of opponent (insurgents such as guerrillas, rebels or terrorists) use asymmetrical tactics (Improvised Explosive Device, ambush, hostage taking, night letters) and blend themselves into their "human environment", where they find some support based on ethnic, political or religious affinities. In order to counter them and stabilize the crisis zone, one must restore security and governance and provide grounds for economical development. In this context, stabilization does not consist only in tactical success in combat operations, but also relies on what is known as "non-kinetic" actions (*i.e.* that do not rely on effective usage of force). The so called "civil-military" actions and specific communication actions[1] aim at altering the perception, attitudes and behaviours within the population and at hindering pro-insurgent dynamics. Several recent military doctrines in US [3], UK[4] and France [5] have emphasized these new capabilities in support of stabilization and counter-insurgency operations. The understanding of the human terrain and its dynamics is the key for answering those new operational needs and obviously calls for a modelling effort.

Needs for new systems: The command and control systems and the training simulation systems currently in use by the military Forces have all been designed for conventional warfare. They show little relevance to capture or simulate population-centric phenomena and human dynamics. More specifically units specialized in non-kinetic actions do not appear to have any digital tools to plan or evaluate their operations and no computer aided training is available to them. Moreover, conventional combat unit and command staff lack training for human terrain awareness when attempting to plan and run "full spectrum operations"[6]. Several industrial research projects based on multi-agent simulations modelling social phenomenon in an insurgency situation were realized in order to address these new needs. They tackle various issues such as forecasting irregular warfare, training soldiers to befriend the population or modelling impacts of stabilization operations on populace beliefs [7],[8],[9]. Although the major need that is to model the perception-attitude-behaviour dynamics toward Forces actions and peculiarly communication actions remains unsolved. The first part of this problem which corresponds to the building and adaptation of population attitudes according to their perceptions and communications call on a well known topic by academics: the research field of attitude dynamics.

[1]Also known as Psychological Operations [NATO], Military Information Support Operation [US], Military Community Outreach [UN]

Scientific Context

The concept of *attitude* derived from social psychology could be defined as "a mental and neural state of readiness organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" [10]. Therefore attitudes have been at the heart of models that anticipate behaviour as in the military approach we have showed in the previous section. The latent characteristic of the attitude implies that at least two levels exist: the genotypic level (*i.e.* its formation and transformation level) and the phenotypic level (*i.e.* where it is expressed). The opinion is located at the latter level by enabling the inference of its underlying attitude: it represents one of the behavioural expression form of the attitude. In other words, the quantification of the opinion concerns epistemologically only the verbal expression of the subject and is under no circumstance a transparent reflection of the attitude [11]. In some scientific research on the topic of "opinion" dynamics, the words attitude and opinion are often confused, despite their clear distinction in social psychology. In our model we will avoid such confusion and focus on attitude dynamics only. By attitude dynamics we refer to the propagation and evolution of attitudes in a population of individuals. This field interests various disciplines such as social simulation, social psychology, social physics or complexity science. The process of attitude dynamics can be modelled as the result of communications and influences between members within a group. Thus, agent-based modelling constitutes an appropriate approach to study complex social phenomenon as it is funded on micro modelling of individuals and their interactions to analyse emergent macro trends [12].

Objectives

In this context, our aim is to propose a multi-agent based simulation model that will help the Forces to understand populations' attitudes dynamics by considering three aspects :

1) People construct and adapt their attitude according to their perception, evaluation of the social object. In order to account for such a mechanism, our model will take inspiration from social psychology theories, following the methodology of psychomimetism [13]. In particular we will follow the Fazio's approach of attitude as object-evaluation associations [1] as a basis for our modelling framework.
2) Facts are witnessed by only a small part of the population, while some of them are known by the majority. This could be due to the spreading of the information among some social networks. Therefore it would be crucial to account for these communication factors if we aim to understand the attitude dynamics.
3) Social tensions (*e.g.* ethnic or religious conflicts) that can fracture the human terrain alter the information interpretation of individuals depending on their affiliation. The model will integrate such tensions by including attitudes between potentially conflicting social groups.

In summary, our model will address the problem of attitude construction and adaptation toward Forces based on the perceptions that have individuals on their actions, inter-personal factual communication and populations' social preferences. The present paper is organized as follows. After presenting the related works in social simulation of attitude dynamics, we will detail our model of attitude dynamics. The conceptual objects will be described in the Static Model section, and the Model Dynamics section will detail how we manipulate the concepts to enable our population construct, revise and then communicate their beliefs and attitudes. Finally, we will show experiments through some scenarios using the model and their results before concluding.

II. Related Works

Attitude dynamics studies diverse complex social phenomenon such as the vote [14], the expansion of extremism [15] or the diffusion of information and its effects [16]. Despite this variety of subjects studied, it is generally possible to classify the literature along three different axes [17]: the model of attitude itself, the diffusion/communication mechanism and the impact of the network topology constituting the social environment. However, in our work, as discussed in the previous section, we propose to focus on two aspects of attitude dynamics: the model of attitude and the communication mechanism. The following paragraph shows some contribution in these domains and pinpoints some limits. Subsequently, we will propose a model that could fulfil these shortages.

A. Attitude model

Attitude dynamics first depends on the representation model of attitude. In the first known models of attitudes (*e.g.* [18]), attitude was represented as a binary or real value. During the last decade, several works proposed more complex representations of attitudes. For instance, in their study on political attitudes and behaviours dynamics, Kottonau *et al.* [14] construct attitudes based on multiple social psychology theories encompassing the ten dimensions of attitude strength such as its extremity, intensity, certainty, importance *etc.* [19]. However, as was pointed out by [20], most of these models choose to represent information as attractive or repulsive forces. The reason is that they focus only on the individuals' interactions and the resulting changes in attitude (through diffusion): they do not consider the construction mechanism of the attitude itself. Other research in social psychology study the formation of attitudes at an individual level: in these models, an attitude is based on information concerning the social object, acquired through experience [10], [21], [22], [**?**]. Based on this, Urbig and Malitz [15] propose to represent attitude as the sum of the evaluations of the aimed object's features. This approach is derived from the attitude theory of Fishbein and Ajzen [22], [23]. While Urbig and Malitz' model constitute an interesting view on attitude formation, it has two limits with respect to our objectives. First, the attitude revision is based on the bounded confidence model [24], [25]: when two individuals (selected randomly) have attitude values close to each other (with a fixed threshold), each one modifies its attitude so that it gets closer to its peer's. As a consequence, the attitude value after the initialization phase is no longer connected to the beliefs of each agent regarding the social object (it is mainly influenced by the peers' values). d Second, this model does not consider the limited rationality specific to a human being [?], all the evaluations are equally accessible within the memory whether these information are recent or old, important or not from the individual's point of view. As a result, individuals could retain not pertinent information forever instead of forgetting it (*i.e.* exclude it from the attitude construction).

However, the model proposed by Fazio, based on object-evaluation associations with varying strength, seems a promising approach to overcome these two weaknesses [1]. The main idea of this model is to represent an attitude as a set of evaluations of the social object. Each evaluation is based on information about the object, called memory association, and is weighted by an accessibility value determining the evaluation's degree of reminiscence. By essence, this model maintains the connection between cognitive representation of object's and the corresponding attitude, following Heider's recommendation [26]. Moreover, it takes into account the reminiscence capability of individuals, *i.e.* the limited rationality [?].

To our knowledge, Fazio's model has not been implemented and evaluated in multi-agent simulation. In this paper, we propose to implement this concept of attitude. More precisely, the model will base the attitudes on the evaluation of individuals' beliefs about actions done by the object of attitude. For modelling purposes and for the sake of simplicity, beliefs refer to informations held by individuals and do not encompass incorrect beliefs, intentional deception *etc.* The accessibility value will be computed using the impact of the action and the credibility of the source.

B. Communication mechanism

The second dimension we consider in our research for attitude dynamics is the diffusion mechanism of attitude through which simulation's actors influence each other. This mechanism is characterized by three basic settings [17]: the definition of the information type, the definition of the participants required to the interaction and the definition of the influence process.

Regarding the information type, in most works, the message content is the attitude itself [17], [20] or parts of the attitude [15], [27]. While it is true that daily communication is heavily based on attitudinal information (*e.g.* assessment without arguments, commercials *etc.*), conversational narratives (reporting facts) also represent a significant part of communication, maybe up to 40% according to Eggins [28]. Moreover, to our knowledge, there is no psychological theory describing in detail the impact of a communication about attitude itself. For this reason, we propose to base our attitude dynamics and communication mechanism on beliefs exchange and updates, rather than direct attitudinal influence.

Little work seem to have been done in this view in the domain of attitude dynamics. However, research in the domain of innovation diffusion, such as the COBAN system [29], propose models for beliefs exchange. In the model proposed by Thiriot and Kant [29], knowledge representation relies on associative networks and the communication protocol is based on social objects. More precisely, communications consist in exchanging part of the emitter's belief network to his addressee. Then, the receiver of the message may revise his own network depending on some criteria such as the source's credibility or the compatibility of the new information with his/her own knowledge. This model was proposed for innovation diffusion and evaluated on a word-to-mouth problem. However, since the whole knowledge network is an evaluation of a social object, it is very similar to an attitude, hence, we can assume this model can be used to compute attitude diffusion (and dynamics). For this reason, we propose to reuse this communication mechanism in our model, by replacing the knowledge network by agent's beliefs about actions proceeded by the Forces.

C. Attitude Dynamics Based on Beliefs Dynamic

In the next sections we will present our model of attitude dynamics implementing Fazio's concept of attitude, with a belief diffusion model based on Thiriot's model. Basically, the idea of a simulation's proceeding consists in execution of actions (patrol, medical support, bombing) by the Forces (UN, terrorist or others) over time that are perceived by the individuals. Those individuals' perceptions, once evaluated respectively to their subjectivity characterized by their former attitudes and affiliations, will bring them information on Forces' benefits which will be memorized into their beliefs. Based on these personal beliefs' evaluations, people will adapt their attitudes and may communicate their knowledge to spread information into their social network. Every agent will compute attitudes toward the Forces based on the evaluation of their belief base.

We will first present the static model (section III) which describes the key concepts needed to construct the simulation: the different actors (the population represented by individuals grouped into different factions, and the Forces), the actions, their corresponding beliefs, the attitudes and finally the messages. We will show, in section IV, how the model manipulates these concepts by exchanging beliefs and dynamically computing attitudes.

III. Static Model

This section defines the representation of the key concepts in our multi-agent model of attitude dynamics. In our model, we consider a set of *Forces*, representing the belligerents as abstract entities (the UN, the terrorists, *etc*) and a set of agents, representing the members of the population, each one building and updating an attitude toward the Forces.

A. Individuals

The individuals of the population are represented by computational agents and are characterized by a unique social group defined as "a set of individuals sharing similar characteristics or goals" (in our application case, these social groups are ethnic groups). Let us denote $SG = \{SG_1, SG_2, ..., SG_n\}$

the set of social groups and Ind the set of all individuals. Each individual $i \in Ind$ is defined by a tuple

$$i = \langle socialGroup(i), Blf(i), Cnt(i) \rangle$$

with:

- $socialGroup(i) \in SG$ the social group of the individual
- $Blf(i)$ the set of all the beliefs on actions present in the individual's memory (belief description is detailed in section III-F)
- $Cnt(i) \subset Ind - \{i\}$ the set of all the contacts of the individual in the interaction network (see section IV)

B. Forces

The Forces represent objects that can act in the simulation and for which we want to analyse the attitudes evolution among the population. Each of them correspond to an computational automaton executing its actions list given by the user (for instance, in the context of military interventions, the UN can secure a zone, the terrorists can perform a bombing attack ...). For each Force $f \in F$, we denote $actionList(f)$ the ordered list of actions (defined in III-D) to be executed during the simulation.

C. Social Objects

We call social object an abstract or concrete, human or artificial entity on which people (at least two) exert a social behaviour (attitude formation, opinion exchange, formation of social representation, *etc.*). Here, the social objects are the objects that are the focus of the attitudes: the Forces and social groups. We denote ***SO*** $\in SG \cup F$ the set of all social objects.

D. Actions

An action represents an accomplished task by a *Force* that affects *SO* through *impacts*. We denote *Act* the set of all actions. An action $a \in Act$ is defined by:

$$a = \langle name(a), force(a), date(a), impactList(a) \rangle$$

with:

- $name(a)$ the unique name of the action
- $force(a) \in F$ the *Force* which performed the action
- $date(a)$ the occurrence date of the action
- $impactList(a) = \{impact(a)_1, \cdots, impact(a)_k\}$ a list of impacts' information due to the action (defined in the section below).

In the following sections, i and j will always be used to denote an individuals (*i.e.* agents) and a will always represent an action.

E. Impact

An *impact* defines the objective effect's payoff of an action on a specific *social object*. Impacts are always defined w.r.t. a specific actions. Besides this information is associated to a certain *credibility* accorded to its source. Thus, we define an impact $ip(a)$ as a tuple:

$$ip(a) = \langle subject(ip(a)), payoff(ip(a)), credibility(ip(a)) \rangle$$

with:

- $subject(ip(a)) \in SO$ the social object associated to the subject impacted by the action
- $payoff(ip(a)) \in [-1, 1]$ the payoff acquired by the subject which is negative when harmful and positive when beneficial
- $credibility(ip(a))$ noted also $\sigma(ip(a))$, the credibility of this impact's information's source with $\sigma(ip(a)) \in \Sigma = \{\sigma_1, \sigma_2, ..., \sigma_s\}, s \in \mathcal{N}, \sigma_1 \succ \sigma_2 \succ ... \succ \sigma_s$

It is important to note that we have a finite ordered set of possible credibility values, with a minimum (σ_1) and a maximum (σ_s). They will be used in the action perception mechanism in section IV.

F. Beliefs

The computation of attitudes by the individuals of the population is done by manipulating a set of *beliefs* about *actions* that they have either directly witnessed or indirectly heard of. The set of all the *beliefs* of an *individual i* is defined as a set of actions:

$$Blf(i) = \{action_1^{(i)} \dots action_n^{(i)}\}$$

with: $action_k^{(i)} \in Act$ the action concerned by the belief stored in the agent's memory.

Actually, actions will only exist in our model as beliefs, should they be witnessed actions, believed actions or communicated actions. For this reason, we shall always indicate the point of view of an action. We denote $a(i)$ the action as it is believed and interpreted by agent i and, by extension, we denote $impactList(a, i)$ the impact list of action a interpreted by i and for each $ip(a, i) \in impactList(a, i)$:

- $subject(ip(a, i))$ the impacted social object;
- $payoff(ip(a, i))$ the payoff estimated by i for the social object;
- $\sigma(ip(a, i))$ the credibility of this impact's for i.

G. Attitudes

For a given individual, each *social object* is associated to an *attitude*. We build a function $att : Ind \times SO \rightarrow [-1, 1]$ a function that computes the attitude $att(i, o)$ value of the individual i toward the social object so, negative when bad and positive when favourable (see IV-G).

We must distinguish between two sorts of social objects:

a) Attitudes on Social Groups: People have attitudes toward the different social groups that emanate from social tensions present within the population. We define a table $aTable_{|SG|,|SG|}$ with values in $[-1, 1]$, parameter of the simulation, which contains the inter social groups attitudes, that are considered fixed in our model. The attitude of an agent toward an social group follows this table:

$$\forall i \in Ind, \forall sg(j) \in SG, att(i, sg(j)) = aTable(sg(i), sg(j))$$

Below, an example of attitudes configuration:

By extension, we will define $att(i, j)$ the attitude of agent i toward agent j as:

$$\forall (i, j) \in I^2, att(i, j) = att(i, sg(j))$$

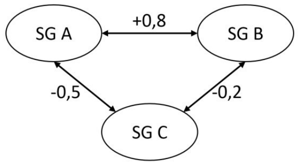

Fig. 1. Example of inter-social group attitudes configuration

b) Attitudes on Forces: The heart of this model consists to simulate the dynamics of the attitudes of the population toward the Forces. We conceptualize this dynamic as the result of individual's perceptions of the Forces' actions. The dynamic model of attitudes' revision is described in section IV. The value of $att(i, f)$ will be defined in this section.

H. Messages

During the simulation, Forces communicate on their actions to the population in which the information is propagated. These communications are done through messages defined by:

$$m = \langle emitter(m), date(m), act(m), Adr(m) \rangle$$

where:

- $emitter(m) \in SO$ the social object associated to the emitter of the message
- $date(m) \in \mathcal{N}$ the emission/reception date of the message
- $act(m) \in Blf_{emitter(m)}$ the action belief reported by the message
- $Adr(m) \subset Agt$ the addresses of the message

IV. Model Dynamics

This section describes the different cognitive mechanisms that will allow the agents to revise their beliefs and compute attitudes. In the course of the simulation, Forces proceed to actions that impacts the population. Individuals that perceive these actions acquire new information and revise the associated impacts. This modification of their beliefs will allow them to compute new values for the attitudes toward the Forces.

A. Action perception

In our model, action perception can be done in three ways:

1) **Direct perception**: the agent either is subject to the action or directly witnesses it (*e.g.* the UN Force brings food to the village and the agent is a member of the village or was around when the action was done);
2) **Force communication**: the Force communicates about an action toward the population and the agent is one of the addressees;
3) **Intra-population communication**: the agent is given information about a previously perceived action by another agent, through a *message*.

Cases 1 and 2 are scripted in our model: they are defined in each $actionList(f), \forall f \in F$. In that case, the credibility value of the impact for this action is fixed: all direct perceptions have a credibility value set to the maximum (σ_1) and all Force communication actions have a credibility value set to the minimum ($\sigma_m in$). For the intra-population communication (case 3), the value of the impact credibility of the communicated information ($action(m)$) is exactly the value in the sender's belief base ($action(emitter(m))$): the agent communicates the action as it is in its belief base. As will be shown in subsection IV-C, it is the addressee that might modify this value when adding this new information to its own impact list.

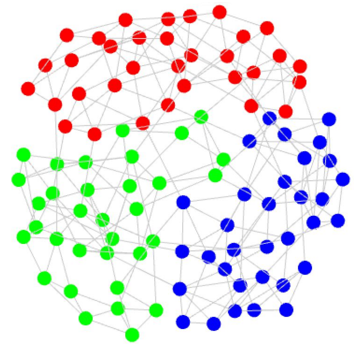

Fig. 2. Small-world network for 3 social groups used in our simulation model

B. Intra-population communication

The intra-population communication relies on the list of individual contacts ($Cnt(i)$): agent can communicate information from their belief base (*i.e.* actions) to their contacts. We will first explain how this contact list is built in our model. We will then show how agents select which belief they want to communicate and when.

1) Network topology: The contact list of agents is defined by the network topology of the social environment in which the information spread through interactions. In most work on attitude dynamics, research use a network to define the interaction between agents, their frequency and intensity (*e.g.* based on affinity between individuals). In our model, we simply consider the links as possible communications between two individuals, regardless of their social group or any other possible affinity. However, unlike what is done in some work [18], [30] where the agent do not really consider any network topology, it seems important in our model to have a network topology that captures in some sense the context of the simulation with different social groups: agents communicate more inside their social group. The recent trend in this domain is to explore the model dynamics in the context of complex social networks such as small-world [31] or scale free networks [32]. Some rare works use advanced networks build with synthetic population generators which take into account qualitative and/or quantitative social demographic data (*i.e.* social statistics, social structure, economic data *etc.*) [33], [34]. In our case, due to the lack of data on the human environment of our interest (crisis zones), we build our social environment based on small-world networks. Figure 2 gives an example of such a small-world network for 3 social groups. For simplicity purpose, the topology of the network is given as a parameter and remains static during the whole simulation.

2) Belief communication : The purpose of intra-population messages is to report actions made by the Forces to let people know their impacts. Whenever an agent receives a message (knowledge acquisition), it will not only update its belief base (as presented in subsection IV-C): it will also evaluate its level of interest for re-transmission to the agents in its contacts $Cnt(i)$.

The value of re-transmission interest is based on two criterion from the simplicity theory by Dessalles [35]:

- The credibility of information: credible information is more likely to be communicated.
- The recency of the information: recent information is more interesting to communicate.

Given an action a that an agent i has just received and interpreted (see section IV-C below), the interest for the agent i to re-transmit a toward all the agents $j \in Cnt(i)$ using a message is given by the linear combination of the average credibility of a and its recency, defined as:

$$\overline{cred}(a,i) = \frac{\sum\limits_{ip \in impactList(a,i)} \sigma(ip)}{|impactList(a,i)|} \quad (1)$$

and:

$$recency(a,i) = 1 + max\left(0, \frac{date(a,i) - cdate}{m}\right) \quad (2)$$

where $cdate$ is the current date and m is a fixed parameter, equal to the size of the working memory. We define two parameters α and β that balance the importance of recency and credibility. Let $interest(a)$ be the re-transmission interest value of a:

$$interest(a,i) = \alpha \times \overline{cred}(a,i) + \beta \times recency(a,i) \quad (3)$$

The action a will be re-transmitted if and only if $interest(a,i) > T_{com}$, with T_{com} being a fixed threshold in the simulation.

When the belief a has to be re-transmitted, the agent does not retransmit it to all its contacts in $Cnt(i)$: the selection of contacts is based on a uniform random basis, depending on the action's interest. The agent builds a list of recipients R for the message $m = \{i, cdate, a(i), R(m)\}$. Let $j \in Cnt(i)$ be a contact agent: the probability that $j \in R(m)$ is defined by choosing a random value $r \in [0, interest(a,i).T_{com}]$.

Note that the transmitted action only contains the impacts of the initial communication. For instance, if a Force does an action with given impacts several times, agents will only communicate about the impacts of the last occurrence. Also, as it will be presented in the next subsection, agent interprets action a prior to computing its interest and re-transmitting it. Hence, the credibility value of the impacts related to the transmitted action might differ from those of the initial information. The idea is that an information coming from the uncle of the wife of a friend is less credible than if it came directly from the friend. Thus, the reach of messages' dissemination is limited by this decreasing credibility process.

C. Belief revision

Whenever an agent i receives a new information $a(j)$, either as a direct observation, through Force communication or via intra-population message exchange, it updates its beliefs $Blf(i)$ as follows:

1) If the action comes from a Force communication or intra-population communication, each credibility $\sigma(ip(a,i))$ associated to the impact $ip \in impactList(a,i)$ is decremented of one unit with respect to its initial value $\sigma(ip(a,j))$. For instance, if a friend tells us that he saw an action, we won't believe it at the same level as he would.
2) If the action a does not already exists in $Blf(i)$ (*i.e.* there is no action with the same $name(a)$ and $force(a)$), the agent adds this action as a new belief. The date of the newly added action is the current date and the impacts is set to $impactList(a,j)$.
3) If the action already exists, its date and impact list is updated depending on the impacts list of the received information. $date(a,i)$ is set to $date(a,j)$. For each impact $ip \in impactList(a,j)$, three situations can occur:
   a) If ip does not appear in the impacts list of $a(i)$, *i.e.* if there is no $ip' \in impactList(a,i)$ such that $subject(ip') = subject(ip)$, then ip is added to the impact list $impactList(a,i)$. This corresponds to the acquisition of new information: in this action that the agent already heard of, someone was rewarded/punished and he did not know this.
   b) If ip appears in the impacts list of $a(i)$ and is compatible in terms of impact value, *i.e.* if there exists $ip' \in impactList(a,i)$ such that $subject(ip') = subject(ip)$, and $|payoff(ip') - payoff(ip)| \leq \varepsilon$, with ε a fixed threshold, then ip is not added to the belief base but instead, $\sigma(ip')$ has a probability to be modified to the immediate next value in Σ if and only if $\sigma(ip') < \sigma(ip)$. This corresponds to the situation in which the agent already knows about someone being rewarded or punished through an action, but it learns this information again from a higher-confidence source.
   c) If ip appears in the impacts list of $a(i)$ and is not compatible in terms of impact value, the agent has to revise both the impact and credibility value. There is a probability that the new impact ip replaces the impact ip' in $impactList(a,i)$.

For impact revision in case of compatible or incompatible informations (case 3.b and 3.c above), we implement a process derived from the probabilistic revision proposed by Thiriot and Kant [29]. Their mechanisms are based on a probability table that compares the credibility of the new information's source to the belief's one stored in memory. The information supported by the highest credibility gets a higher probability to be retained. This method offers several descriptive properties compliant with real-world observation : the temporality of information (*i.e.* more information is old, more it risks being replaced), the impact of multiple sources (*i.e.* more it has sources, more it increases the likelihood of revision) and information inertia (*i.e.* recent information is unlikely to be replaced). In our precise case, the information is the impacts of actions related by beliefs. The revision probability value for $|\Sigma| = 3$ is given by Figure 3. If a low credibility is given to an impact and a new information accounts for an impact with high credibility, the impact value and corresponding credibility will very probably be updated. On the contrary, if a high credibility impact is in contradiction with a low credibility one, there is only a 10% chance that the agent revises this impact.

$\sigma_{mem}/\sigma_{new}$	σ_1	σ_2	σ_3
σ_1	0.5	0.25	0.1
σ_2	0.75	0.5	0.25
σ_3	1	0.75	0.5

Fig. 3. Example of revision probability table depending on credibility confrontation

D. Attitude construction: general principle

Whenever the reception of a new information about an action a done by a Force f resulted in a belief revision in $Blf(i)$, individual i will adapt its attitude toward f based on its new mental state.

As presented in the previous sections, our model for attitude construction is based on action beliefs' evaluations associated to the object, as proposed by Fazio [1]. Figure 4 illustrates the representation of an attitude according to the model proposed by Fazio.

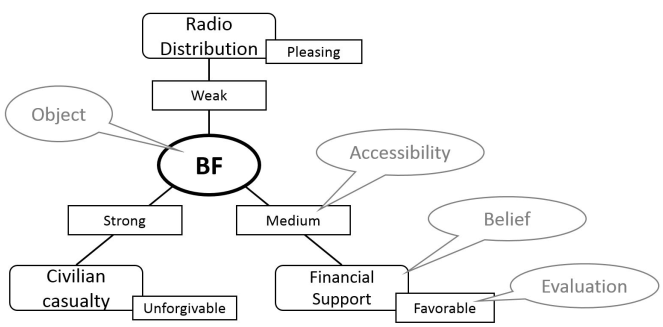

Fig. 4. Example of attitude in Fazio, 2007.

Our implementation first evaluates a subjective benefit of the actions' impacts (see section IV-E). Second, we determine the accessibility of these different impacts. This accessibility value allows us to select a subset of impacts (the most accessible ones) for the building of the attitude. This selection corresponds to the notion of limited rationality of human being [**?**]: one does not use its entire knowledge when evaluating a fact, but only a subset. In our model, the selection of impacts follows the peak-end theory [36] which stipulates that people recalls facts that are either the most impressive (peak) or the most recent (end). This will be detailed in subsection IV-F. The final computation of attitudes based on the selected impacts is a simple aggregation of the selected evaluations weighted by their accessibilities, as will be presented in section IV-G.

E. Interest and benefit evaluation

The benefit of an action $a(i)$ are determined subjectively, *i.e.* in respect to agent i's attitude and beliefs, using the evaluation model proposed by Fishbein and Ajzen [37]. This model combines the impact of the action for a subject with the attitude of the individual toward this impacted subject. In this way, an individual judging an action which is beneficial for him or for some of his "friends" (positive attitude), the overall benefit would be positive. Conversely, if the action is beneficial for his "enemy" (negative attitude), the action would have be evaluated with a negative value.

The *benefit* of the action is defined as the aggregation of the impacts weighted by the attitude. We use a classical multi-criteria aggregation operator OWA [38] instead of the mean value:

$$evaluation(a,i) = OWA_{ip \in impactList(a,i)}(payoff(ip) \times att(i, subject(ip))) \quad (4)$$

F. Accessibility estimation

The selection of the "most accessible" impacts in memory, which will serve to compute the attitude, we rely on the peak-end theory [36]. To implement this model, we need to determine some selection criterion for "peaks" information and "ends" one.

a) Peaks: The evaluation of peaks is similar to the interest value that was defined for the intra-population communication in section IV-B2, except that we consider three criteria instead of one: the source credibility, the sum of impacts and the unexpectedness. This choice is supported by some elements of Dessalles' simplicity theory [35]: 1) the higher the credibility, the more is the information interesting; 2) very positive or very negative impacting actions are more compelling; 3) unexpected event are more easily retained.

The source credibility follows formula 1 defined previously:

$$\overline{cred}(a,i) = \frac{\sum\limits_{ip \in impactList(a,i)} \sigma(ip)}{|impactList(a,i)|} \quad (5)$$

The sum of the impacts' intensity of a function is weighted by the attitude toward each subject (both as absolute values): the more consequences an action has on each individual it concerns, and the more the individual is important (positively or negatively) for the agent, the higher the interest of this action:

$$sumImpact(a,i) = \frac{\sum\limits_{ip \in impactList(a,i)} |payoff(ip) \times att(i, subject(ip))|}{|impactList(a,i)|} \quad (6)$$

The unexpectedness is computed as the difference between the previous evaluation of the action and the new one (once the new information has been integrated in the belief base):

$$evalDiff(a,i) = \frac{|evaluation_{old}(a,i) - evaluation_{new}(a,i)|}{evaluation_{old}(a,i)} \quad (7)$$

b) Ends: Since the end criteria corresponds to the most recent information selection, we will simply use the recency of the information as described in section IV-B2 and its corresponding function 2:

$$recency(a,i) = 1 + max\left(0, \frac{date(a,i) - cdate}{m}\right) \quad (8)$$

c) Accessibility: Based on the previous values, the accessibility of an action belief is obtained by:

$$\begin{aligned} acc(a,i) \quad = \quad & \alpha \times \overline{cred}(a,i) \quad + \quad \beta \times recency(a,i) \\ + \quad & \delta \times sumImpact(a,i) \quad + \quad \delta \times evalDiff(a,i) \end{aligned} \quad (9)$$

with α, β, γ and δ that represent the weights for each criteria, taking their values in $[0, 1]$

G. Attitude construction

Once each actions' benefits and accessibilities were computed, the individual can finally compute his attitudes. To account for subjects' bounded rationality we assume that this computation could not occur on all the actions he/she observed. There is a limitation – we denote $maxMemory$ – to the size of the working memory used by the subject to store the list of actions – denoted $aList(i)$ – that will impact the current attitude. Following Fazio's theory, each action a in $aList(i)$ will impact this attitude with a factor $evaluation(a,i) \times acc(a)$. Then, the global attitude impact will be an aggregation of these factors using a classical multi-criteria aggregation operator OWA [38]: $OWA_{a(i) \in aList(i)}(evaluation(a,i) \times acc(a,i))$. Finally, we add a non-linear response factor to this aggregated impact using a sigmoid-like function. Hence the final attitude $a(i,f) \in [-1,1]$ of agent i toward a Force f is given by:

$$att(i,f) = \\ tanh\left(\rho.OWA_{a(i) \in aList(i)}\left(evaluation(a,i) \times acc(a,i)\right)\right) \quad (10)$$

Observations

This overall process of cognition revision is compliant with some real-world/psychological observations:

- Attitude inertia: the intrinsic nature of the attitude makes it fluctuate very little. By conserving the last evaluations for computing the new attitude that derives from a new information acquisition, the model transcribes this feature.
- Consistency between attitudes and beliefs: being directly based on beliefs, attitudes preserve an harmony amid the cognition as proposed by Heider [39].
- Compatibility with other attitudinal theories: while not being fully exploited, the structure of attitude formation is compatible with other models of attitudes like the tripartite view [40].
- A limited memory: by implementing the peak-end rule based on the evaluations accessibility, the agent is able to limit the amount of used information for revising attitudes.
- Subjective perception: impacts are evaluated by considering the individual's attitude toward the subject of the action which makes the information subjective to his point of view.

V. Model Evaluation

This section presents several preliminary experiments results of our model and analyses the impact of some key parameters on the attitude dynamics. We first describe the shared basic settings of the simulations such as their initialization and other cognitive parameters (V-A) before presenting the actual simulation runs. Then, we show some experiments to understand the basic behaviour of the model mechanisms through a simple scenario in which the Force affects a specific social group with beneficial and harmful actions (V-B). This allow us to study the resulting attitudes dynamics of the different social groups based on their relationships. In a second stage, we analyze the evolution of attitudes in a more complex scenario that involves Force's communication (*e.g.* radio broadcasting) to show the effect of a messages which are discordant with the actual perception of the population (V-C).

A. Shared settings

All the experiments are based on a set of shared parameters settings:

- Initialization: The population is split into three social groups (A, B and C) each composed of 33 individuals connected by an interaction network described in IV-B1. The inter-social group attitudes are defined as shown in Figure 1, social groups A and B are allied against a third group C. People are confronted to a series of actions performed by one Force determined by a scenario. Since the population have no information on the Force at the beginning of a simulation, their corresponding attitude is "set" to zero.
- Belief related parameters: We map the highest credibility σ_1 to the subject itself, σ_2 to an individual in the subject's direct contact and the lowest credibility σ_3 to the Force and others. Accordingly, we use the revision probability table described in Figure 3.
- Attitude related parameters: α, β, γ and δ used in the computation of the accessibility (IV-F) are fixed to be equal: 0.25. Also, for these preliminary experimentations, the parameter for the OWA function is set to $\frac{1}{n}$, thus, corresponding to a simple mean.

B. Basic behaviour

In order to understand the basic behaviour of the model, we propose to run simulations through a simple scenario in which the Force targets the social group A and proceeds to actions in three phases:

- Phase 1: six repetitions of beneficial (+0.2) actions visible by 15% of the group
- Phase 2: six repetitions of harmful actions (-0.8) visible by 5% of the group
- Phase 3: six repetitions of beneficial actions (+0.3) by 30% of the group

Actions are separated by an interval of 5 time steps.

Inter-individuals communication's impact on social groups' attitude means dynamics: We propose to vary the communication interest threshold T_{com} to study its impact on the attitude dynamics. Note that decreasing the value of T_{com} increases the communication activity within the population. In the first experiments presented below, we show the general evolution of attitudes means per social group by setting $T_{com} = 1$ (*i.e* no communication) through the simple scenario that impacts the social group A. The curves as coloured as follows: A-red ; B-blue ; C-green.

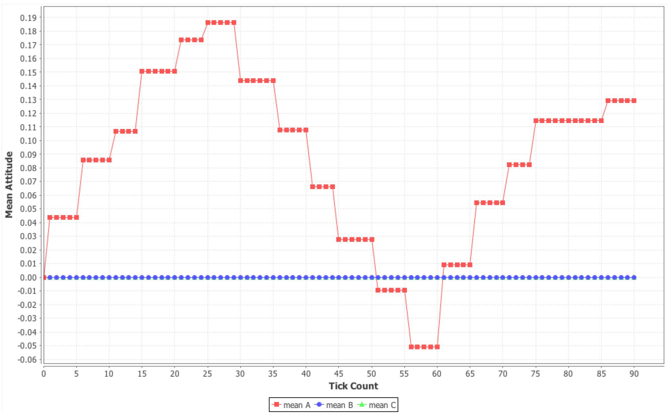

Fig. 5. Attitude means per social group with $T_{com} = 1$ (no communication)

Figure 5: Since there is no communication between the agents, only the witnesses are able to acquire information. Thus, only a part of the group A is informed of the action as we can see, therefore only A's mean is altered. At each action, the number of informed individuals increases. This is confirmed by the shape of A's curve evolving every 5 time steps that corresponds to action interval.

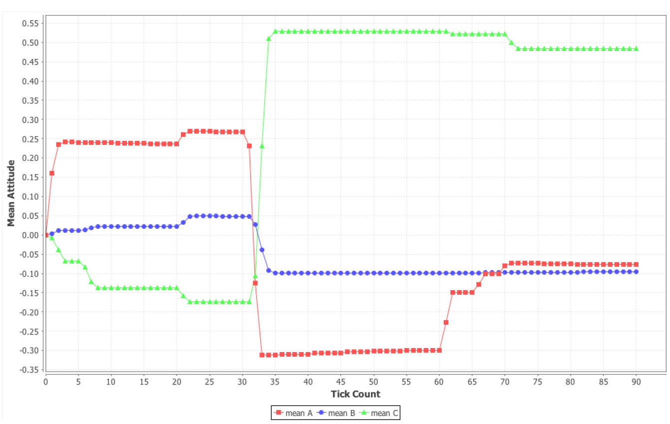

Fig. 6. Attitude means per social group with $T_{com} = 0.22$

Figure 6: Adding communication enables other individuals, including other group's, to get informed of the action. We found that there is an interesting bifurcation effect depending on a certain T_{com} threshold value that affect the inter-individual communication impact. With $T_{com} < 0.22$ there is almost no communication effect on the overall attitude dynamics. Here, with $T_{com} = 0.22$, we can notice that the evolution of the social group B (in blue) is following the curve of the social group A (in red). Since these two social groups are tied with a positive attitude, these groups evaluate the actions in the same way. However, the communicated information's impacts intensity on B's curve is weaker than A's variation. This is due to the fact that the actions do not concern directly B, their accessibility in the memory of B's individuals is lower than in A's memories. Conversely, the curve of the social group C (in green) is virtually symmetrical to A's with which it is connected by a very negative attitude. Also, some information are not well relayed in the network. For instance, we can see that group B is not aware of the third phase's actions since its mean is not evolving after $t = 60$. This is due to the low amount of communications. In the next simulation, we decrease the threshold to $T_{com} = 0.1$ in order to increase the amount of exchanges.

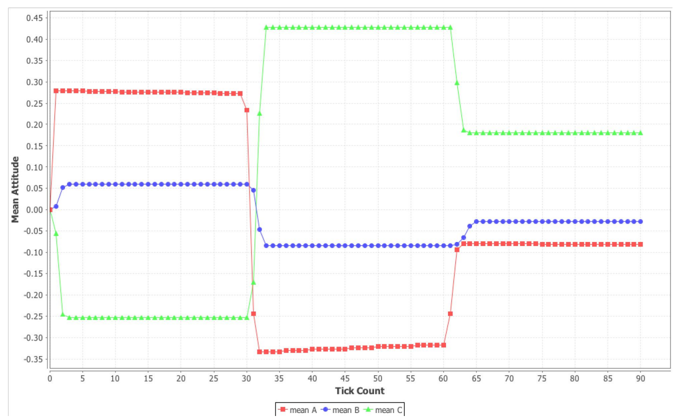

Fig. 7. Attitude means per social group with $T_{com} = 0$

Figure 7: By removing the boundary for messages' interests we let the agents communicate each beliefs they acquire, therefore the amplitude of groups' reactions is increased compared to the previous simulation. Here, a very large proportion of the individuals are aware of Force's actions, but some individuals remains unaffected due to the probability of revision or to the network topology. We can also notice that the mean of the social group A is almost instantly raised to its stabilized value in each phase. This phenomenon is due the quick spreading of information: individuals are informed of the first occurrence of the phase's action before it is repeated, whether by directly witnessing it or during a communication with his neighbours.

C. Discordant communication broadcast

One of the role of military communications consists in providing information in favor of them, as well as done by civilian's (e.g. publicity), in order to facilitate their operations in the area. For instance, they can relate embellished impacts of their actions in messages broadcast through radio. In the next simulation, we show the reaction of the population to a series of actions along with messages broadcast from the Force relating their proceeded actions with embellished impacts. The scenario is based on the latter simple scenario except each action is followed by a message broadcast reaching 30% of total population that relates the action with a doubled impact. First, we run the simulation without inter-individual communication:

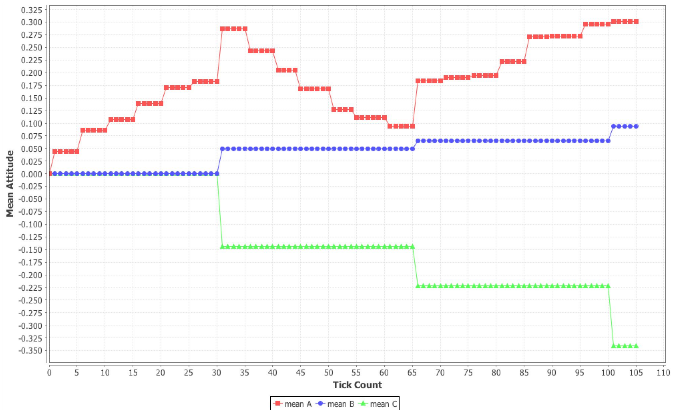

Fig. 8. Discordant message: Attitude means per social group with $T_{com} = 1$

Figure 8: As in the previous simulation 5, only the impacted social group A is aware of the action since we can notice that B and C's means remain steady during the first phase. They are informed of the action after the Force's message broadcast at $t = 30$. All the broadcasts impact the attitude means, this is due to the fact that the majority of the receivers are not direct witnesses of the actions, therefore they believe the message as it is and integrate the related information into their belief base. However, if the receiver has previously witnessed the action by his own-self, the probability that he will trust the message is very low (10% as shown in Figure 3) since the credibility of the Force is very low (σ_3) toward subject's own credibility (highest credibility σ_1). Thus, it would be interesting to see the effect of inter-individual communication on the acceptance of the broadcast message. In the next simulation, we let the agents interact so that the witnesses can inform the action's true impact.

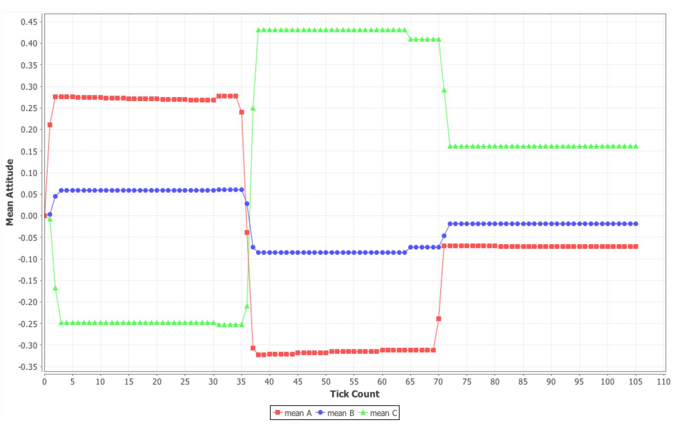

Fig. 9. Discordant message: Attitude means per social group with $T_{com} = 0.1$

Figure 9: The graph shows that the communications broadcast have a very weak impact on the attitude means. This situation demonstrates that the majority of the individuals do not take into account the Force's messages. With a high communication activity within the population, each time an action is witnessed by an individual, its information is diffused within the population. Since the credibility of a message coming from a neighbour is higher than the Force's credibility – *i.e* the neighbour directly witnessed the action – or at least equal – *i.e* the neighbour relayed a message from another source –, the probability to revise their knowledge base using the broadcast message is very low.

D. Dispersion of individuals attitudes

Finally, we study the dispersion of individual attitudes. To do so, we analyze the aggregated standard variation value $agStdDev$ as the mean of the three averages standard variation within each social group. This value corresponds to the average dispersion within each group and is different from the overall standard deviation. We show below, the graph for the simple scenario with $t_{com} = 0.22$:

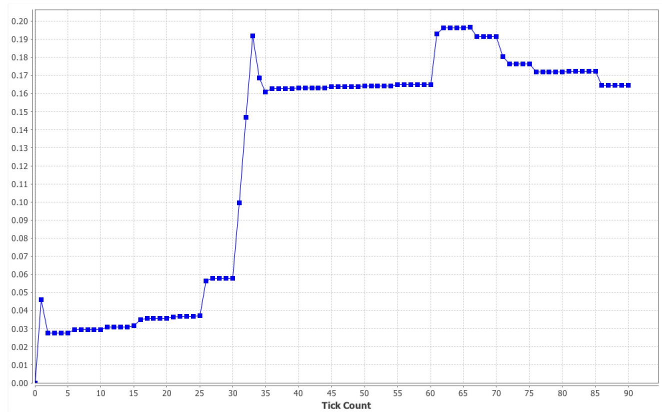

Fig. 10. Aggregated standard deviations of social groups with $T_{com} = 0.22$

Figure 10: We can see that each phase correspond to a plateau with a tendency of an increasing $agStdDev$ over time. This increase is due to the fact that at each new injection of new information, we raise the probability that an individual is aware of the information, thus widening the dispersion with the others who are not informed. Moreover, we can see some transient boosts in these increases that can be explain by the inter-individual communication: at the beginning of a phase, an action is perceived by some agents. This situation creates a disparity within groups between the individuals who are aware and those who are not. But the corresponding information is then diffused into the network via interactions between agents. Thus, this process reduces the disparity by allowing more individuals acquiring the fact. Besides this, the second transient boost in the figure is larger than the others. As we can see in Figure 7, this phase reverses the attitude means for all the groups, as a result it generates a big gap between agents attitudes which explains this peak. Moreover, we found again that the communication intensity has an impact on this $agStdDev$ variation. We show below the variation of $agStdDev$ along with t_{com}:

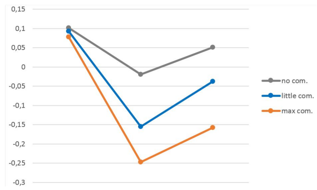

Fig. 11. Aggregated standard deviations at each phase with $T_{com} = \{1, 0.22, 0\}$

Figure 11: We can notice that increasing the communication activity within the population decreases the standard deviations within groups. This is due to a form of agreement within groups catalyzed by the exchange of information.

VI. Conclusion

We proposed a simulation model of attitude dynamics based on socio-psychological theories. This model relies on belief revision for attitude construction, based on communication information. Our communication mechanism considers intra-population relations and influence. The credibility of the information and its importance impacts the computation of the attitude over time. We studied the dynamics of this model on several simple examples that illustrate the impact of the communication on the attitudes.

One goal of our model is to help western countries to rely on communication strategy in stabilization operation and to reduce the use of conventional kinetic actions *i.e.* based on the use of military force. However, this model is not limited to military applications and can be easily adapted to civilian usage: the Forces can represent any kind of active social object such as political parties, institutions, companies, brands *etc.*

The model presented here can be extended in several ways. Our first perspective is to further analyse the sensibility of our model to the various parameters used in the dynamics and also to the simulation initialization. Besides this, it will be interesting to calibrate the model using real-life data collected on the terrain to study both its expressiveness and simulation power. Our second perspectives aim at extending the population model. We want to include the notion of population behaviour (actions) influenced by their attitudes, so that our model can be used for anticipating the actual actions of the studied individuals.

April 15, 2014

References

[1] R. H. Fazio, "Attitudes as object-evaluation associations of varying strength," *Social Cognition*, vol. 25, no. 5, p. 603, 2007. [Online]. Available: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2677817/

[2] R. Smith, *The utility of force: the art of war in the modern world*. New York: Knopf, 2007.

[3] D. O. T. A. HEADQUARTERS, *FM 3-05.301 (FM 33-1-1) MCRP 3-40.6A Psychological Operations Tactics, Techniques, and Procedures DECEMBER 2003*. HEADQUARTERS, DEPARTMENT OF THE ARMY 2007.

[4] B. Army, *British Army Field Manual. Volume 1 Part 10: Countering Insurgency*. Army Code, 2009.

[5] M. de la Defense, "Contre insurection - doctrine interarmees DIA(A)." [Online]. Available: http://www.cicde.defense.gouv.fr/spip.php?article264

[6] M. D. L. DEFENSE, "LES OPRATIONS D'INFORMATION DANS LE CADRE D'OPRATIONS DE SOUTIEN DE LA PAIX."

[7] A. Geller and S. J. Alam, "A socio-political and cultural model of the war in Afghanistan," *International Studies Review*, vol. 12, no. 1, p. 830, 2010. [Online]. Available: http://onlinelibrary.wiley.com/doi/10.1111/j.1468-2486.2009.00910.x/full

[8] B. G. Silverman, D. Pietrocola, N. Weyer, R. Weaver, N. Esomar, R. Might, and D. Chandrasekaran, "Nonkin village: An embeddable training game generator for learning cultural terrain and sustainable counter-insurgent operations," in *Agents for Games and Simulations*. Springer, 2009, p. 135154.

[9] J. K. Alt, A. Leroy, D. Hudak, and S. Lieberman, "The cultural geography model: Evaluating the impact of tactical operational outcomes on a civilian population in an irregular warfare environment," *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology*, vol. 6, no. 4, p. 185199, 2009. [Online]. Available: http://dms.sagepub.com/content/6/4/185.short

[10] G. W. Allport, "Attitudes." 1935. [Online]. Available: http://psycnet.apa.org/psycinfo/1935-19907-010

[11] J.-L. Beauvois and J.-C. Deschamps, *La psychologie sociale 2. 2.* Grenoble: Presses Univ. de Grenoble, 1996.

[12] A. Drogoul and J. Ferber, "Multi-agent simulation as a tool for modeling societies: Application to social differentiation in ant colonies," in *Artificial Social Systems*. Springer, 1994, p. 223.

[13] J.-D. Kant, "Modeling human cognition with artificial systems : some methodological considerations," in *Proceedings of HCP 99 (Human Centered Processes)*, Brest, September 1999, pp. 501–508.

[14] J. K. Pahl-Wostl and Claudia, "Simulating political attitudes and voting behavior," Oct. 2004. [Online]. Available: http://jasss.soc.surrey.ac.uk/7/4/6.html

[15] D. Urbig and R. Malitz, "Drifting to more extreme but balanced attitudes: Multidimensional attitudes and selective exposure," *ESSA, Toulouse*, 2007. [Online]. Available: http://www.diemo.de/documents/UrbigMalitz-ESSA2007.pdf

[16] G. Deffuant and S. Huet, "Differential equation models derived from an individual-based model can help to understand emergent effects," Mar. 2008. [Online]. Available: http://jasss.soc.surrey.ac.uk/11/2/10.html

[17] H. Xia, H. Wang, and Z. Xuan, "Opinion dynamics: Disciplinary origins, recent developments, and a view on future trends," 2010. [Online]. Available: http://www.iskss.org/KSS2010/kss/10.pdf

[18] A. Nowak, J. Szamrej, and B. Latane, "From private attitude to public opinion: A dynamic theory of social impact." *Psychological Review*, vol. 97, no. 3, p. 362, 1990. [Online]. Available: http://psycnet.apa.org/journals/rev/97/3/362/

[19] J. A. Krosnick, D. S. Boninger, Y. C. Chuang, M. K. Berent, and C. G. Carnot, "Attitude strength: One construct or many related constructs?" *Journal of Personality and Social Psychology*, vol. 65, no. 6, pp. 1132–1151, 1993.

[20] C. Castellano, S. Fortunato, and V. Loreto, "Statistical physics of social dynamics," *Reviews of modern physics*, vol. 81, no. 2, p. 591, 2009.

[21] A. H. Eagly and S. Chaiken, *The psychology of attitudes.* Harcourt Brace Jovanovich College Publishers, 1993. [Online]. Available: http://psycnet.apa.org/psycinfo/1992-98849-000

[22] M. Fishbein and I. Ajzen, *Belief, Attitude, Intention and Behavior: An Introduction to Theory and Research*. Addison-Wesley Pub (Sd), Jun. 1975.

[23] ——, "The influence of attitudes on behavior," *The handbook of attitudes*, pp. 173–222, 2005.

[24] G. Deffuant, D. Neau, F. Amblard, and G. Weisbuch, "Mixing beliefs among interacting agents," *Advances in Complex Systems*, vol. 3, no. 01n04, p. 8798, 2000. [Online]. Available: http://www.worldscientific.com/doi/abs/10.1142/S0219525900000078

[25] R. Hegselmann and U. Krause, "Opinion dynamics and bounded confidence models, analysis, and simulation," *Journal of Artificial Societies and Social Simulation*, vol. 5, no. 3, 2002.

[26] F. Heider, "Attitudes et organisation cognitive," *Faucheux, Psychologie sociale theorique et experimentale, Journal of Psychology*, vol. 21, 1971.

[27] S. Thiriot and J.-D. Kant, "Reprsenter les croyances par des rseaux associatifs pour simuler la diffusion dinnovations," *ESSA*, vol. 7, p. 2, 2007.

[28] S. Eggins and D. Slade, *Analysing casual conversation*. Equinox Publishing Ltd., 1997.

[29] S. Thiriot and J.-D. Kant, "Reproducing stylized facts of word-of-mouth with a naturalistic multi-agent model," in *Second World Congress on Social Simulation*, vol. 240, 2008.

[30] G. Deffuant, F. Amblard, G. Weisbuch, and T. Faure, "How can extremism prevail? a study based on the relative agreement interaction

model," *Journal of Artificial Societies and Social Simulation*, vol. 5, no. 4, 2002. [Online]. Available: http://jasss.soc.surrey.ac.uk/5/4/1.html

[31] S. Milgram, "The small world problem," *Psychology today*, vol. 2, no. 1, pp. 60–67, 1967.

[32] X. F. Wang and G. Chen, "Complex networks: small-world, scale-free and beyond," *Circuits and Systems Magazine, IEEE*, vol. 3, no. 1, p. 620, 2003.

[33] F. Gargiulo, S. Ternes, S. Huet, and G. Deffuant, "An iterative approach for generating statistically realistic populations of households," *PloS one*, vol. 5, no. 1, p. e8828, 2010. [Online]. Available: http://dx.plos.org/10.1371/journal.pone.0008828

[34] S. Thiriot and J.-D. Kant, "Generate country-scale networks of interaction from scattered statistics," in *The fifth conference of the European social simulation association, Brescia, Italy*, vol. 240, 2008.

[35] A. Dimulescu and J.-L. Dessalles, "Understanding narrative interest: Some evidence on the role of unexpectedness," in *Proceedings of the 31st Annual Conference of the Cognitive Science Society*, 2009, pp. 1734–1739. [Online]. Available: http://csjarchive.cogsci.rpi.edu/proceedings/2009/papers/367/paper367.pdf

[36] D. Kahneman, D. Kahneman, and A. Tversky, "Experienced utility and objective happiness: A moment-based approach," *The psychology of economic decisions*, vol. 1, pp. 187–208, 2003.

[37] I. Ajzen and M. Fishbein, "The influence of attitudes on behavior," in *The handbook of attitudes*, D. Albarrac, B. T. Johnson, and M. P. Zanna, Eds. Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers, 2005, pp. 173–221.

[38] R. R. Yager, "On ordered weighted averaging aggregation operators in multicriteria decisionmaking," *Systems, Man and Cybernetics, IEEE Transactions on*, vol. 18, no. 1, pp. 183–190, 1988.

[39] F. Heider, *The psychology of interpersonal relations*. Lawrence Erlbaum, 1982.

[40] M. J. Rosenberg and C. I. Hovland, "Cognitive, affective, and behavioral components of attitudes," *Attitude organization and change: An analysis of consistency among attitude components*, vol. 3, p. 114, 1960.