Dialogue between non-task oriented agents

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abstract

We propose a model for dialogue between non task oriented agents, based on the dissonance theory. Non task oriented agents are studied as a model for non expert agents, as opposed to task oriented agents, in order to provide models for social science simulations. Dialogue between non task oriented agents can not be modelled like task oriented dialogue because no task is provided to define the beginning and the termination of a dialogue, with respect to a common goal. The dissonance theory has been proposed by cognitive researchers as a *drive* for acting. Therefore, dissonance is a seducing theory to model the *motivation* of an agent to open a dialogue. Pertinence is also introduced to model the development and termination phases of such dialogues. An implemented system, called OPDS, in then presented and evaluated.

Dissonance for NTO dialogue

NTO Agents

While task-oriented agents interact with other agents in view of the completion of their task [9], what drives non-task-oriented agents to open a dialogue? This question is of primary interest for social informatics [1] because multi-agent based simulation for social issues is an increasing application domain of multi-agents research. Social issues deal with what we call *ordinary people*, that is people that have no special expertise, and cannot be modelled by task oriented agents (TO agents). Therefore, ordinary people are rather modelled by what we call *non-task-oriented* (NTO) agents (contrary to Wooldridge, see [12]).

For NTO agents the question of the opening and of the termination can not be so solved with an external measure element, since no **common** task is provided. If we consider that NTO agents have a goal to drive their behavior, this goal can only be **private**. In fact, NTO agents do not form a CSCW-like systems but **collectives**, in the sense that they mostly *co-act* rather than *cooperate*, they can even sometimes have conflicting goals within a perfectly functioning collective.

NTO Agents in Dialogue

Dialogue is divided into three main phases that are the opening [9], the development and the termination. We propose a model for the *motivation* of a NTO agent to open a dialogue, based on the cognitive dissonance theory. Cognitive dissonance is a theory proposed by Festinger [3, 4] stating that dissonance is a painful state for a human agent that leads him to act in a way that will reduce the dissonance in order to reach the maximum possible of consonance. This dissonant state has therefore the status of a *drive*, we will call it the *dissonant drive*.

Dissonant Drive in Dialogue

In an attempt to apply the dissonance theory to information-based NTO agents, we will state that there is a *consonance* if a fact f_a is a *logical* consequence of a fact f_b (in the sense of the first order logics), and there is *dissonance* when the logical coherence of the knowledge base is contradicted by the reception of a new fact.

There are three categories of solutions to solve the dissonance:

- The first one of them, S_1, is to ignore the new fact, that is the most recently received, and decide that it is not compatible with its own knowledge system : that means that the agent decides not to "believe" the new fact.
- A second solution, S_2, is to declare that some piece of information already present in the agent's knowledge base and that participates to the incoherence of is wrong. This means that the agent decides that the new fact has **more confidence degree** than his current believes.
- Finally, the third solution, S_3, to solve the incoherence is to suppose that the new fact and the already existing one that participates to the incoherence are only *apparently* in contradiction, and that some further explanation (new fact or logical rule) would solve the puzzle and explain how those two could become compatible. That is then a good reason for an agent to open a dialog: in quest for this hypothetical extra information.

We propose that applying the solution S_3 to get out from a dissonant state, is a *drive* for a NTO agent to open a new dialog.

The OPDM model

In multi-agents systems, the agents are defined using an agent's definition formalism [12], the queries are written in an Agent Communication Language [6], and the dialogue is decomposed into exchange steps, according to conversation policies [10], [5].

Formal definition of a NTO agent

In a first step of modelling, we consider NTO agents as *information based* agents carrying a knowledge base (noted KB_i for an agent A_i) and acting with information oriented goals G_i. Each agent's knowledge base KB_i includes facts, noted f and rules, noted r. For the simplicity of the analysis, the formalism used to model the information in the knowledge base is a first order logic with a three values $(true, false, unknown)$ valuating function. The agents are defined in a description language implemented over the Mathematica programming language [11]. Each agent's base KB_i is defined according to the following structure:

- **Facts** are defined by: a *symbol* $f_{i,j}$ where i refers to the agent A_i and j is the numbering of the fact in A_i's list of facts; a *body* ${f_{i,j}}^\beta$ containing the fact's predicate in terms of first order logics; a *path* ${f_{i,j}}^\pi$ that is a *conversational chain* of agents through which the fact came to A_i; and also the *lists* of the agents that agreed ${f_{i,j}}^{\{agree\}}$, rejected ${f_{i,j}}^{\{reject\}}$ or knew ${f_{i,j}}^{\{know\}}$ already the fact $f_{i,j}$. The path ${f_{i,j}}^\pi$ and the lists ${f_{i,j}}^{\{\}}$ are build *sequentially* during conversations.
- **Rules**: they are implications in the sense of first order logics, and are noted $r_{i,j}$ where i refers to the agent A_i and j is the numbering of the rule in A_i's list of rules. Like the facts, they are also defined with a *path* and *agree*, *reject* and *know* lists.
- **Channels** are *unidirectional* structures, noted $ch_{i\to b}$, where i stands for the agent A_i and b stands for its locutor A_b. A new channel is opened each time a dialog is opened with a new locutor [1] and is never closed. $ch_{i\to b}$ is composed of a *symbol* b, referring to the agent to which it is connected, the *list* of the facts already told to A_b, $ch^{tolds}_{i\to b}$, the *list* of the facts to tell to A_b, $ch^{totell}_{i\to b}$, selected among the facts that participate into a

[1]We will see that channels are used to record contextual information, or trace chronicles, about the streams exchanged between two agents. The viewpoint of an agent on such an exchange stream is called a channel.

dissonance, and the integer cumulated counts of all the agrees $ch_{i \to b}^{agree}$, rejects $ch_{i \to b}^{reject}$, and knows $ch_{i \to b}^{know}$, obtained during the dialogues on this channel.

Formal dissonant state

As already stated, we will say that an agent A_1 is in a dissonant state if there is a logical *incoherence* between its own base KB_1, and a new information received by it and noted i_{new} (a new fact or a new rule). The logical incoherence being defined as:

$$\{KB_1 \cup i_{new}\} \Longrightarrow \perp$$

In order to track a dissonant state, each agent must check for the logical coherence of its possibly new base $\{KB_1 \cup i_{new}\}$ each time a new piece of information i_{new} is received. This checking is done by a deduction motor.

Solving dissonance: Confidence and Trust

To get out of its dissonance state, A_1 may apply one of the three solutions cited above: S_1, S_2 or S_3. To select which solution to apply, the agent calculates the degree of confidence he can put in each of the elements implied in the dissonance and compares these values. For that purpose, we formally define these confidence measures in $[0, 1]$ in the next subsection. Once the measures are calculated, the agent A_1 then selects a solution according to:

- If the the confidence degree in i_{new} is less than the confidence degree in internal facts and/or rules participating to the dissonance, then the solution S_1 is chosen.
- If the confidence degree in i_{new} higher than the confidence degree in internal facts and/or rules participating to the dissonance, then the solution S_2 is chosen.
- If the confidence degrees in i_{new} and in the internal facts and/or rules participating to the dissonance are "comparable" in value (this measure is further defined in the next section), then the solution S_3 is chosen.

Moreover, the agent A_1 calculates also the trust it puts in the source agent A_2 that send i_{new} to it, and may compare it with its own "self-confidence".

Measure of confidence in an internal information of KB_1

The measure of confidence in an information of KB_1 is the confidence degree C_{1,f_j}, respectively C_{1,r_j}, in any fact $f_{1,j}$, resp. any rule $r_{1,j}$, of its knowledge base KB_1. This measure is a function of the *history* of the acquisition of the information $f_{1,j}$, resp. $r_{1,j}$, by A_1: this history is stored in the path ${f_{1,j}}^{\pi}$, resp. ${r_{1,j}}^{\pi}$.

The path ${f_{1,j}}^{\pi}$ keeps track of the succession of agents through which ${f_{1,j}}^{\pi}$ was transmitted to A_1, each time, together with their own confidence in this information, for example:

$${f_{1,j}}^{\pi} = \{(A_3, C_{3,f}), (A_5, C_{5,f}), (A_9, C_{9,f}), ..., (A_k, C_{k,f})\}$$

where A_3 is the last agent that send $f_{1,j}$ to A_1, and A_k was the first one of the chain. Then, the measure C_{1,f_j} is given by:

$$C_{1,f_j} = ((0.6 \times C_{3,f}) + (0.3 \times C_{5,f}) + (0.1 \times C_{9,f}))$$

which means that only the three last agents of the chain are taken into account, with a weighted sum giving much more weight to the last agent in the chain, here A_3.

Measure of confidence in an outside information

For all practical purposes, the score will always be the one of the source agent. In the case where the receiver agent A_1 decides to integrate this new information (case of solution S_2), then a confidence degree is given to f_{new}, which now becomes part of KB_1 and is renamed $f_{1,j+1}$. This confidence degree is calculated with the following formula:

$$C_{1,f_{new}} = C_{1,f_{j+1}} = (C_{2,f_{new}} \times t_{1 \to 2})$$

where $t_{1 \to 2}$ is the trust that A_1 has for A_2, this parameter is defined below.

Measure of trust in another agent

The **trust** degree $t_{1\to 2}$ represents the trust that the agent A_1 has for the agent A_2. Each agent A_i measures and updates a trust degree $t_{i\to j}$ associated with each `other` agent A_j.

The trust degree $t_{i\to j}$ depends on the interaction *history* between the agent A_i and A_j, in a unidirectional $1 \to 1$ correspondence, this information is stored in the channel $ch_{i\to j}$.

The trust degree $t_{1\to 2}$ is then given by:

$$t_{1\to 2} = \frac{((ch_{i\to j}^{agree} + ch_{i\to j}^{know}) - ch_{i\to j}^{reject})}{3}$$

This formula is the simplest we can propose, but of course we could also consider different weights as long as the overall result is normalized by $N = w_{agree} + w_{know} + w_{reject}$.

Measure of self-trust

The **self-trust** degree $t_{1:1}$ [2] corresponds to self-confidence that the agent A_1 has. In our model, $t_{1:1}$ depends on the interaction *history* between the agent A_1 and all the other agents A_j ($j \neq 1$), in a $1 \to (n-1)$ correspondence.

The history of the interaction of A_1 with all the other agents is stored in all the channels $ch_{1\to j}$ of A_1. The general self-trust degree of an agent A_i is then given by:

$$t_{i:i} = \frac{1}{3\times(n-1)}[$$

$$(\sum_{j=1,j\neq i}^{n}(ch_{i\to j}^{agree}))+(\sum_{j=1,j\neq i}^{n}(ch_{i\to j}^{know}))-(\sum_{j=1,j\neq i}^{n}(ch_{i\to j}^{know}))]$$

Note that this value is different from the average of all the trusts $t_{i\to j}$ that A_i has for all the other agents A_j, $j \neq i$.

Pertinence and Semantical Focus

We define a measure of the pertinence p_f or p_r of a content information. The pertinence is modelled by the lexical semantical intersection defined in the Worldnet project [2]. This pertinence is calculated with respect to the current focus of the dialogue.

The *focus* of a dialogue is dependent on the content information exchanged, and may be different for each agent because they have their viewpoint on a dialogue.

In the OPDM model, the focus of a dialogue between A_i and A_j, from the point of view of A_i, is given by:

$$Focus(i \leftrightarrow j, A_i) = \cup\{ch_{i\to j}^{tolds'}, ch_{i\to j}^{totell'}\}$$

where $tolds'$ stands for the three most recent elements of the list $tolds$, and $totell'$ stands for the three most recent elements of the list $totell$.

This focus is used by A_i to test the lexical pertinence of each new content information f_{new} sent to it. The pertinence is then the boolean result from the intersection $\cap\{Focus(i \leftrightarrow j, A_i), f_{new}\}$.

[2]the : instead of the $\to$ symbol is merely a convention for the expressivity of the symbol.

The OPDS system

Communication language

An agent A_s, called the sender, sends a sentence σ_{sr} to an agent A_r, the receiver. The sentence σ_{sr} is called a sentence to differentiate it from a query, because σ_{sr} transports a piece of content information. The sentences are written in a very simple Communication Language, ACL [6], that is composed of three levels: The primitive dialog acts (defined according to speech acts [8] concerning information exchange, that is tell or ask information); The conversation policies; The script language.

Primitive dialogue acts

We define the following primitive dialog acts **for the sender** A_s:

- `INFORM`: A_s gives a content information. An answer can be returned to this act but not necessarily. The same information is not proposed more than once by A_s to the same receiver A_r.

- `ASK`: A_s asks A_r for a content information and waits until A_r sends it. During an ask, A_s does not send any content information to A_r.

- `END`: A_s has nothing more to say because there is no content information $i \in KB_s$ that is pertinent with respect to the focus of the dialogue and that has not been send via an INFORM to A_r.

And we define the following primitive dialog acts **for the receiver** A_r:

- `AGREE`: A_r agrees with the content information i_{new} received from A_s if and only if A_r did not have the information i_{new} in his knowledge base KB_r, and the information i_{new} is pertinent with respect to the focus of the dialogue. In this case, the information i_{new} is then integrated in the base KB_r.

- `REJECT`: A_r rejects the content information i_{new} received from A_s (contrary of an AGREE), if and only if the information i_{new} was not present in the knowledge base KB_r of A_r, and this information is not integrated to KB_r. The reasons for i not to be integrated in KB_r are either that i is not pertinent with respect to the focus of the dialogue, or that it cannot be integrated because of the application of a type S_1 solution to a dissonant state.

- `KNOWS`: the content information i received by A_r from A_s is already present in KB_r.

- `FAIL`: A_r received an ASK from A_s concerning a content information i that A_s wants to get from A_r, but A_r has no content information j that matches the query, either $j = i$ or j pertinent with i. Therefore, A_r has nothing to answer to the ASK.

A last dialog act `CHANGETOPIC` is provided to change the focus of a dialogue. Indeed, the termination of a dialogue as defined above would be immediately reached with the first non pertinence. Since not all the knowledge in a knowledge base is connected through common symbols, it may happen that two agents have still knowledge to share with pertinent exchanges but do not "know" it.

Scripting language

The OPDS system is an object-oriented program written with a scripting language that we defined over the Mathematica programming language [11]. We define the following classes: `AGENT, RELATION, FACT, INDIVIDUAL, CHANNEL`.

Where `INDIVIDUALS` are the constants and variables of the first order logic predicates corresponding to rules and facts. The other classes correspond to the concepts of agents, relations, facts and channels of the OPDM model.

Global lists keep record of the total existing agents, facts and rules in the world of the simulation. The sender and receiver of a particular exchange are noted `SENDER` and `RECEIVER`, while the focus in a dialogue is noted `FOCUS`.

Note that the symbols used for the facts $f_{i,n}$ and rules $r_{j,m}$ are universal in each simulation, in the sense that a same symbol designates a same content information for all the agents. That means that we are not concerned with semantical heterogeneity in a first step of our model, and that the pertinence, coherence, and presence of an information in a base are only *lexically* checked.

Evaluation

The evaluation of the OPDS system can not be an evaluation of the complexity of the algorithm because it was not designed for that purpose and basically all the functions have combinatorial complexity. In the case of small numbers of agents per simulation, this is not; however, a constraint. The evaluation that is more interesting is to measure the confidence and trust degrees evolving through time when several dialogues are run. An agent having only new facts with respect to the others will have a high self-confidence after a few runs because nobody will contradict it (by dissonances detected). An agent having conflicting facts with others might get a lower self-confidence also. Worlds with more or less intrinsic incoherence[3] are tested and the main consequence is to bring down

[3] In the sense that the facts and rules in the knowledge bases of all the agents carry much incoherence.

the self-confidence of agents when the incoherence grows up.

Conclusions

We proposed a model of dialogue between non task oriented agents based on dissonance theory and pertinence measure. The main hypothesis of this model is that a dialogue can be opened by an agent in the goal of solving an internal dissonant state, and that it may be developed by the agents as long as the exchange of information is pertinent with respect to the focus of the conversation.

Pasquier et al's [7] already proposed that the dissonance theory could bring interesting highlights to the problem of structuring dialogue between agents. The idea that it could be a model for the opening of such a dialogue between non task oriented agents that do not interact as a function of an external task, is however not further modelled or implemented. It could be interesting to introduce the difference between internal dissonance (within one KB) and external dissonance (between agents KBs), to follow one other interesting idea of their paper. This difference is however not clear from our model in its present state because all the dissonance are coming only from dialogues and not from perceptions.

To model the notion of dissonant state, and the application of solutions to it, we introduced the confidence and trust degrees, that are meta-knowledge of the agents over the information they posses. This *meta-knowledge* is calculated using the history of the dialogue that is recorded in the paths and channels.

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