MODELLING AND MANAGING KNOWLEDGE THROUGH DIALOGUE: A MODEL OF COMMUNICATION-BASED KNOWLEDGE MANAGEMENT

Violaine Prince
University of Montpellier and LIRMM-CNRS
161 Ada Street 34392 Montpellier cedex 5 France

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Abstract: In this paper, we describe a model that relies on the following assumption; ontology negotiation and creation is necessary to make knowledge sharing and KM successful through communication. We mostly focus on the modifying process, i.e. dialogue, and we show a dynamic modification of agents knowledge bases could occur through messages exchanges, messages being knowledge chunks to be mapped with agents KB. Dialogue takes account of both success and failure in mapping. We show that the same process helps repair its own anomalies. We describe an architecture for agents knowledge exchange through dialogue. Last we conclude about the benefits of introducing dialogue features in knowledge management.

1 INTRODUCTION

Knowledge has muted from a personal expertise towards a collective lore. Thus, knowledge management (KM) and modelling contains social features and deals with society of agents. As a society, agents interact, and interaction conventional aspects have attracted the attention of the KM community, with different points of view : (i) The deep relationship between knowledge and knowledge communication (Ravenscroft and Pilkington 2000); (ii)The power of the communicative process as a knowledge modifier (Parson et al. 1998), (Zhang et al. 2004).
Although communication is an active component in KM, most studies have dealt with cases where agents were sufficiently close in type and knowledge in order to share common ontologies. In extensive KM systems, knowledge sharing is hampered by the lack of common ontologies between artificial agents. Integrating different designations for the same concepts has been tackled by (Williams 2004) in a shared environment named DOGGIE (Distributed Ontology Gathering Group Integration Environment) allowing negotiation of terminology among different ontologies. The author's approach is that of a 'peer-to-peer' situation that allows agents to share knowledge and learn. His aims was more to demonstrate how heterogeneity in representations could be overcome, than to focus on the dynamic process that underlies it, that is, dialogue.
Our approach is in the same main line of thought, but the added value is that we focus on the properties of dialogue as **a process of incremental knowledge adjustment**. Human dialogue occurs between interlocutors distinct in state, knowledge and intents. It happens when a need for knowledge occurs. It is used when discrepancies in representations appear.
Applying dialogue requirements to KM is an issue we will address in section 2. Although difference is a mandatory component for dialogue existence, too great a distance between agents might not even let the chance for a dialogue to occur. Section 2 states the likely requirements for dialogue success and consequently those for an adequate KM through interaction. Section 3 presents an architecture implementing the process between artificial agents, an instantiation of which, dedicated to agent teaching, has been presented in (Yousfi and Prince, 2005). Teaching is one of the tasks in which knowledge sharing is tracked at best (Williams 2000). This architecture has been evaluated through its applications: the teaching application, dedicated to conceptual knowledge revision, presently runs as a prototype. Another application about risk management ontologies acquisition (Makki et al. 2006) is developed according to both model and architecture described in this paper.

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2 DIALOGUE AS A MEAN FOR SHARING KNOWLEDGE

Agents are considered heterogeneous when they differ in *nature* or in a major attribute. In this paper we will restrain the definition of heterogeneity to cognitive artificial agents with the following properties :(i)Different ontologies and knowledge bases (i.e different world representations); (ii) Different tasks within the system; (iii) Possibly belonging to different applications that need to share knowledge, Web services or activity. Heretogeneity produces variations in building, sharing and communicating knowledge.

Theoretical Framework in Agents Knowledge Sharing

Human beings favour dialogue as a major mean for knowledge acquisition: Each agent considers any fellow agent as a knowledge source 'triggered' through questioning. Information is acquired, from the answer, as an external possible hypothesis. This is the starting point of both an acquisition and a revision-based process, where the external fact, the *message*, is subject to confrontation with the inner knowledge source of the requiring agent. It drives the latter to proceed to derivation by reasoning.The feedback observed in natural dialogue is that the knowledge source could be addressed for understanding confirmation. Along with other researchers,(Finin et al. 1997), (Zhang et al. 2004), we consider this process as translatable into the software world and interesting as an economical mean to acquire, mediate and share knowledge.

The cognitive agents we are representing can be seen as entities foregoing the following cycle (Prince 1996): (i)*Capture,* and symmetrically, edit data. *Data* is every trace on a media; (ii)*Transform* the captured data into *information*, as the output of an interpretative process on data. This result will be either stored as knowledge or discarded. (iii)*Keep and increase knowledge*, which, in turn, is of various types: (a) Stored information seen as useful; (b) Operating 'manuals' to interpret data; (c) Deriving modes to produce knowledge out of knowledge (reasoning modes); (d) Strategies to organise and optimise data capture, information storage, and knowledge derivation. Knowledge is by essence defined as *explicitable knowledge*, the only variety that could be implementable. (iii) *Acquire bypasses* to data interpretation and action on the information environment through time-saving procedures: e.g. developping know-how in the information field. The four parts model is called DIKH (for Data, Information, Knowledge and know-How). KM relies mostly in the two last components : "know-How", and "Know" are distinguished according to their properties involving explicitness vs implicitness, transferabilty vs non transmissibility. Since it is representable and conceptualisable, "Know" or "Knowledge" (K) has been mostly investigated by KM. "Know-how" has been claimed as embedded in expert systems, but since it is implicit it cannot be easily described. Therefore, know-how has to be assumed as an important skill of cognitive agents, but not as to be further investigated, unless in very restricted areas. Since KM is at stake, we are focusing on the K fourth of the model. DIKH assumes a recursive modelling: Part of knowledge derives from data, part of it derives from present knowledge, and part of it is an economical optimisation of its organisation. The K part puts in a nutshell several known elements of KM. (i) *Lexical Knowledge* represents tontological contents, relations, organisation. (ii)*Produced knowledge* is the kept part of information (interpreted data). It might rejoin either lexical knowledge (new concepts to integrate in the ontology), or production knowledge (rules, general laws). (iii)*Production knowledge* has been mostly investigated by research in AI: rules, reasoning, going further to meta-rules, and to strategies in organising KM is an important issue in cognitive agent modelling. (iv) The*"know-how"* part of knowledge, an originality of the DIKH model, strengthens upon profiling, preferences, and presentation, as the agent signature key. In single-application architectures, all agents tend to share the same "know-how" since the latter belongs to the architecture designer. In heterogeneous systems, many architectures might be confronted with each other. Web semantics and services have integrated this aspect: Languages such as XML have been devoted to emphasize the know-how about knowledge presentation. The DIKH recursive modelling might easily represent the KM part of a rational natural agent (a person), as an extension from artificial agents environment, to Human-System environments. Since "information" is a temporary status for knowledge, the model reduces to the representation given in figure 1. A rational cognitive agent might be designed, from the static point of view, as: (i)*A set of lexical skills*: ontological knowledge, relationships between names and concepts, variables and their domains; (ii) The core of a *reasoning engine*: Local axioms, strong beliefs that help deriving other rules and rules having a lesser status; (iii) Last, elements of belief and knowledge that help optimising the engine, those are the *adaptive modes* derived from experience.

A Message/Knowledge Chunk Exchange Theory:

A **message** (Jacobson and Halle 1956) can be defined as a formated data set which: (i) is emited as a sender's intention concerning his recipients ; (ii)follows a protocol (conventions in format and exchanges) ; (iii) has a content ; such that the whole (form, intention, protocol, contents) is supposed to

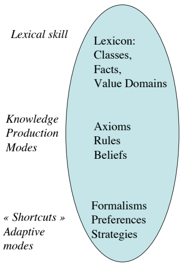

Figure 1: the K-model: A static representation of the rational cognitive agent.

modify the internal state of the recipient agent(s).
Related to artificial agents communication, the message *properties* are the following: (i) *presentation* : Formatting properties of the message as a meta-format. (ii) *content* : it is in itself a complex system that can be decomposed into: 1. how content is formalised; i.e.: (i) The selected elements in the chosen language to designate different items ; (ii) composition rules used for the message.

2. The **semantic content** of the message: lexical data meaning and formal compositions.

3. The **informational content**: What the recipient agent has been able to understand from the received message.

4. The **Intentional content**: what the sender agent has wanted to transmit.

Definition : The **formal structure of a message** can be described as a ternary structure composed of:(i) *Data*: The lexical and syntaxic items composing the message strata, equivalent to the **rheme** in the Speech Act Theory (SAT)(Searle 1969).

(ii) *Knowledge*: which is itself decomposed into: 1. the necessary knowledge to encode/decode data (1). 2. the message semantic content is knowledge (2), equivalent to the **topic** in SAT. 3. the knowledge to embed / derive the semantic content (intentional / informational content) (3)

(iii) *Formulation* (the adapted terminology for ”presentation” in the formal structure) : Style and formalism are qualitative indicators.

The preceding definition has a striking resemblance with agents K-models. Hence, the formal structure of a message and the K-model of the agent could be seen as related by a strong morphism. (i) Data in message definition is provided by the *lexical skills* of both sender and recipient agents. (ii) The semantic content is the *knowledge chunk* exchanged between agents: It is used to enhance the recipient lexical skills in ontological knowledge building or updating (iii)the intentional versus informational contents of the message, tackles the issue of confronting the *knowledge production modes* or engine of both locutors. (iv) Last, message formulation is the result of applying the sender's preferences about message exchanges, and triggers the recipient's adaptive modes to accept the message or reject it if it is not properly designed. This explains why *the exchange of messages is a natural mode of knowledge enhancement*. If the message is structurally compatible with the K-model of an agent, then:

Let A_μ be the K-model of agent μ. Let m be the formal structure of an incoming message. The question is: is $A_\mu \bigcup m$ a new possible state of μ's K-model ?
For this, we need an interpreted form of the message.

Definition : An **interpreted form of a message** is obtained through the following process: (i) Applying decoding knowledge: unification algorithms and abductive rules are used to initiate this phase; (ii) Semantic interpretation of the decoded form *(informational content)*: Deductive and inductive reasoning is used. (iii)If formulation is not a liability for interpretation, the informational content should be equal or close to semantic content of the message.

Given the preceding results, a message, seen from its formal structure point of view, could be designed as a *knowledge bridge* between agents. Its purpose is to: (i)Allow agents to update their knowledge through other agents knowledge; (ii)Fix knowledge discrepancies between agents. Let m be the formal structure of the message to be exchanged between two agents μ and ν. The three components of m , `data`, `knowledge` and `formulation`, could be designed as following; (i) The data of m belongs to the lexicon of μ as a sender, and should also belong to the lexicon of ν. (ii) The knowledge in m needs the corresponding items of μ's and ν's knowledge engines. However, if the message is supposed to increase the recipient's knowledge, this part also comprises knowledge that is either new or which extensions are new to the recipient. (iii) Last, the formulation is the formalism used for the bridge (language, or protocol). It requires adaptation from the sender to the recipient, and vice-versa.Figure 2 shows a representation of the formal structure of a message as bridge between cognitive agents.

Dialogue as Knowledge Adjustment Seeking :
A theory of messages suggests dealing with the following cases: (i) Wether the message has been misinterpreted, or not decoded at all, which is a failure in communication (an issue we will not tackle here); (ii) Or if the message, being correctly interpreted has roused contradictions and thus, has failed to reach its goal; (iii) A combination of both cases, a common situation in natural dialogues. We will focus here on contradiction in knowledge or belief revision.

Belief revision appears as a compulsory process when: (i) The recipient finds its knowledge contradicted by

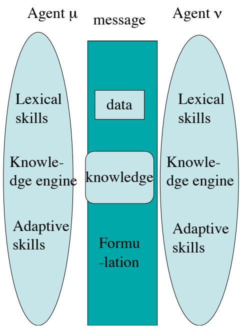

Figure 2: Modelling the message as a bridge between two K-models.

what the others know (this happens when launching the primitive DetectConflict described in next section) ; (ii)The informational content the recipient has derived from the message seems irrelevant with the dialogue situation. The first case is a pure KM problem. An agent needs to receive a message, i.e., a future knowledge chunk of its own K-model, and this leeds to a major revision of its beliefs and its lexical skills. Therefore a ”why” -type of dialogue is initiated on the recipient's behalf, and revision could be undertaken as soon as the recipient is convinced of the quality of the received knowledge. This has been mostly investigated in (Parson et al. 1998) and (Zhang et al. 2004). They have shown that not only the contradicted agent is likely to change, but also its contradictor, since the latter needs to restructure its own KB in order to convince the other. Our theory reaches the same results since the ”why-questions”, seen as messages from the former recipient, force the sender to use its skills in formulation and in knowledge derivation. In (Yousfi and Prince, 2005), we have shown how an artificial ”teacher” agent modifies its KB during the process, at least at the student model level, but furthermore, while teaching, it might spot its own defaults in knowledge.
The other case is the knowledgeable problem of *misunderstanding*. Wether misunderstanding bursts out from decoding errors or mistaken reasoning, the fact is that the following equation : *informational content (INFC) = semantic content(SC) = intentional content (INTC)* is sometimes not achieved between formal agents. Until now, the latter tended to abort interaction whenever it failed. However, since artificial agents need to be more robust, they have to be provided with fonctionalities helping them to pursue dialogue further. Our theory provides some heuristics for approximating this double equality: (i) *Reformulation dialogues* tend to achieve the first equality : INFC= SC; by using other knowledge items or other laws maybe closer its present K-model, the recipient agent might reach a state where it finally understands the message ; (ii) Every careful choice of formulation, on the sender's behalf might help providing the second equality SC = INTC. *Argumentation*/explanation dialogues play an important role in trying to reach a good approximation.
In conclusion, whenever agents need to interact, it is not a problem if interaction is not a successful one shot process. Dialogue is an incremental process acting as a mutual adjustment mechanism, that repairs both its own failures and agents mutual discrepancies. However time consuming, dialogue is less costly than a wrong action based on false beliefs. It is thus very important in decision-making tasks where crucial stakes are involved.

3 A GENERAL ARCHITECTURE FOR KM THROUGH DIALOGUE

The general sofware architecture modelling a knowledge sharing and revision activity between two rational artificial agents is presented in figure 3. Components that have to be implemented are the agents K-models comprizing the other agent model, communication primitive allowing messages exchanges, and dialogue strategies underlying the communication protocol. World and activity models are provided either from each agent environment or activity, or from applications and services they need to address or from which they are issued.
Implementing Agents:
Implementing the K-model is an easy task since it involves : (i) The local agent ontology and lexical skills; (ii) A set of Reasoning Primitives, and an access to Dialogue Strategies (sharable between rational agents) and a set of local rules for knowledge and message construction; (iii) One or many representation formalisms with which the agent processes (e.g.XML for structure, KQML for communication acts ((Finin et al. 1997) etc...).
Sharable Reasoning Primitives are the following:
1.Add(K) ; adds knowledge to the K-Model
2. Revise (K,O); triggers an algorithm trying to attach parts of K to the Ontology. Described in (Yousfi and Prince, 2005). Provides a flag REVISEF indicating success (or not) in attachment, and where it happens.
3. DetectConflict (K) ; if REVISEF = false detects conflictual attachments. Its result is issuing a CreateMessage(M,OtherAgent) (see next subsection);
Two other modal primitives are necessary for a situation where knowledge has to be shared: (i) Wanted

; applied on knowledge (from O or A parts), is the situation that launches dialogue; (ii) `Believed` : applied on knowledge from O, A or P parts, is what the agent assumes as true without have checked it.

By default, all knowledge in the K-model that is neither `wanted` nor `believed` is considered 'known' until contradicted. Accessible Dialogue Strategies are common and shared rules about dialogue protocol (cf Dialogue Strategies component). Whenever an agent is in a situation to communicate, it launches the creation of the 'Other Agent Model'. The latter is a subcomponent of the K-model created and updated with a procedure inspired from the following (we have chosen here an application where agents accept several programming languages):

```
  Create OtherAgentModel(Ag) ;
Proc main
  New O; New A; New P;
  Add (wanted (K), O);
  Believed (A) : <-Add; Revise;
DetectConflict;
  Believed (P) : <- KQML; XML; Java
endproc
```

Comment: The agent creates a new K-model of its interlocutor agent with its three parts : Ontology (O), Axioms (A) and P (presentation). It bootstraps the ontology with the knowledge it wants (it assumes that the other has it). By default, the `OtherAgentModel` A part gets the sharable Reasoning Primitives, and the P part gets the languages the agent itself understands. Message sending and especially message reply will make it know if its assumptions are right or wrong. An agent creates such a model to trigger communication. The next logical step is to create a message asking the interlocutor about the wanted knowledge.

Communication Primitives

Three basic communication primitives are necessary: One is `CreateMessage` the second is `AcceptMessage`, and the last is`RejectMessage`. All deal with three variables: `D` standing for Data, `K` standing for knowledge and `F` for formulation. The first receives receives the lexical choice after the K part has been expressed in a logical form the INTC (intentional content) and translated in the language instantiating the F part. As an example, we present `CreateMessage` below. The other primitives follow a similar description. `RejectMessage` returns the value of the part responsible for rejection (language, or unknown data). Whereas `AcceptMessage` triggers a matching and revision procedure within the recipient agent K-model, that might in turn end up with another `CreateMessage` primitive. These primitives use also basic functions `Sendto` and `Ack` (for acknowledge) that deal directly in interfacing with the other agent.

```
  CreateMessage(M,Ag, L) ; arguments are the Message, to the Agent, in a Language
Proc main New D; New K; New F;
Set F to L; sets the formulation in a given language. Helps adjusting to the other agent language if L value is not accepted
INTC <- Wanted (Kn) ; The intentional content of the message is the wanted knowledge
F <- TranslateIn (L, INTC)
D <- D(F) ; Message Data is the data part of the translated message
K <- INTC ; Message knowledge is the wanted knowledge
Sendto (M,Ag, R); sends the message to the agent typing it with a 'role' (to be explained in next subsection)
Endproc;
```

Dialogue Strategies : Message-level and Scripts: *Messages Roles*: The exchange of communication primitives follow dialogue strategies available to every artificial agent. A strategy is related to the agent goal and satisfaction of its needs. It can be typed in order to extract information from the other agent or to make it perform an action or a task.Thus, every message plays a 'role' in a dialogue instantiation, according to a strategy. Roles have been labelled after the Speech Act Theory illocutionary functions (Searle 1969) or according to the functional roles theory (as in (Yousfi and Prince, 2005)) and depend on the task or activity type.At the message level, roles are the materialisation of Dialogue Strategies. For instance, the most used speech acts in agents modelling and communication are **performative** (i.e the message runs an applet) or **directive** (the message is a command to the other agent). The functional roles we have used atmost in agents learning are *askfor-knowkedge*, *askfor-explanation*, *give-knowledge*, *give-explanation*, *assert-satisfaction* or *assert-unsatisfaction*. Those were modals applied to the CreateMessage primitive and transmited with the message. In this paper, we present a generalisation of the architecture and components, and one can notice that the role R is sent as an argument of the `Sendto` command. **Dialogue Strategies from expectations**: When an agent issues a message with a given role, then it expects in turn a reply with a compatible role. The adjustment script available to agents follows these guidelines:

```
  CreateMessage(M,Ag,L);
Expect(AcceptMessage(M',OtherAgent, L),
R); the agents expects an understandable reply with a given role
If no (AcceptMessage(M',OtherAgent, L))
or RejectMessage(M',Reason) then when no answer is or an answer with decoding problems is provided
Call RepairCommunication else the strategy
```

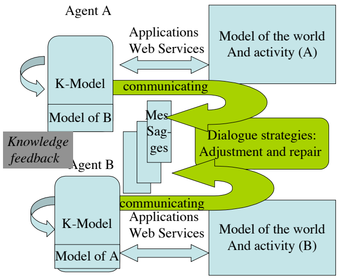

Figure 3: Architecture of Communicating Agents Sharing Dialogue Strategies, but Addressing Different Applications and Activities.

```
shifts to the other script
TransformIn (M, O, A) , the message is transformed into its parts and matched with ontology and axioms
Revise (O, A) reasoning is applied on the added elements
if Wanted(Kn) then R<- 'ok'
CreateMessage (M, OtherAgent, L) the
agent has found the wanted knowledge and asserts its satisfaction
else R <- need else the agent sets the role to its need
Call Adjusment and calls recursively the strategy
```

Let us note that their is a timeout associated to recursive calls ie if no replies are given or if the dialogue enters an endless loop, then the dialogue strategy component stops communication.
Unfortunately we have no room here to present the FailureCommunication script but let us say that it deals with reformulation (shifting languages) and explanation roles and strategies in messages exchanges.

4 CONCLUSION

The model presented here and some elements of its architecture have instantiated in a learning environment for cognitive artificial agents. It is sufficiently general to be implemented within different applications and activities, as long as they need an advanced communication framework for knowledge sharing, revision and for communication. The originality of the model relies in modelling the dynamic process in KM, ie, dialogue, as the crucial component in knowledge revision, and not only considering the static dimension of KM. What has not been explicitely detailed here is that the same theory applies to Human-Computer interaction and to Collective vs Individual agents KM. The issue that is dealt with goes much further than artificial agents programming. But what we have shown here is that even restricted to a formal and decidable framework, the theroy takes into account knowledge conflict and provides it with solutions inspired from natural agents' behaviour.

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