The Outline of the Strategy for Solving Knowledge Inconsistencies in a Process of Agents' Opinions Integration

Radosław Katarzyniak and Agnieszka Pieczyńska

Institute of Information Science and Engineering, Wrocław University of Technology,
Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
{radoslaw.katarzyniak, agnieszka.pieczynska}@pwr.wroc.pl

Abstract. In this paper a strategy for integration of agents' propositional attitudes is proposed in order to solve the semantic inconsistency between opinions of members of agents' population. In proposed algorithm all the agents' answers are transformed into fuzzy set equivalents and then final formula representing the agreement of all opinions is obtained.

1 Introduction

Lack of central mechanisms of control in multiagent systems caused that the states of some objects from external world might be for some agents not known. In such cases the agents must be equipped with mechanisms that let them cope with incomplete knowledge. In our approach this mechanism is called the algorithm of messages generation [4],[5]. As an input of this algorithm the overall agent's knowledge base is given and as an output the propositional attitudes (opinions) in which the content is related to the current states of objects. The agents' opinions are in the form of logic formulas [4],[9]. Each formula is consisted of the modal operator and two indices to the properties that are observed by the agent $a \in A$ in the object $o_z \in O$ at the time point $t_n \in T$ or are estimated on the basis of agent's previous experiences applying the algorithm for the messages generation. The co-existence of these properties in objects from the set O is reflected by logic connectives such as: conjunction, exclusive alternative or alternative. The language is given as: $\Omega = \{OP^a(P_i(o_z) \wedge P_j(o_z)), OP^a(P_i(o_z) \wedge \neg P_j(o_z)), OP^a(\neg P_i(o_z) \wedge P_j(o_z)), OP^a(\neg P_i(o_z) \wedge \neg P_j(o_z)), Bel^a(P_i(o_z) \vee P_j(o_z)), Bel^a(P_i(o_z) \vee \neg P_j(o_z))\}$, where $OP = \{Bel, Pos, Know\}$. If the states of the objects are estimated on the basis of stored experiences then the modal operator of belief (Bel) or possibility (Pos) is used otherwise - the modal operator of knowledge (Know). For example for the formula $Pos^a(P_i(o_z) \wedge P_j(o_z))$ the spoken language interpretation is: In my (agent's a) opinion it is possible that the object o_z has the property P_i and the property P_j . Each modal operator has its numerical equivalent respectively: γ_{Know} , γ_{Bel} and γ_{Pos} that represents the level of agent's confidence. Additionally with each formula coefficient support α_p is correlated (see section 3). If an agent at the particular time point cannot perceive the current state of particular object from external world and the results of the algorithm for the message generation are

unsatisfied it asks other agents about their opinions. The agents send the answers that are the results of direct observation or applying the algorithm for messages generation. Due to the natural inconsistencies between prepositional attitudes carried out by different members of agents' population the incoming language responses can be different as regards to the used logic connectives in formulas and modal operators. Therefore, the agent interested in integration all these opinions, needs to apply certain strategies for semantic conflict resolution [5]. Proposed strategy is based on the idea of language grounding that states that each language formula needs to be related to a certain meaning embodied in private empirical experiences [1],[2],[3],[7].

2 A Strategy for the Integration of Conflicting Opinions

2.1 Basic Postulates

Postulates in relation to the states of objects:

1. If at the time point t_k the object o_z possesses both the property P_i and P_j then it belongs to the class of objects $O_1(t_k) \subseteq O$.
2. If at the time point t_k the object o_z possesses the property P_i and doesn't possess the property P_j then it belongs to the class of objects $O_2(t_k) \subseteq O$.
3. If at the time point t_k the object o_z doesn't possess the property P_i and possesses the property P_j then it belongs to the class of objects $O_3(t_k) \subseteq O$.
4. If at the time point t_k the object o_z doesn't possess neither the property P_i and P_j then it belongs to the class of objects $O_4(t_k) \subseteq O$.
5. If at the time point t_k the object o_z possesses either the property P_i or P_j then it belongs to the class of objects $O_5(t_k) \subseteq O$.
6. If at the time point t_k the object o_z possesses the property P_i or P_j then it belongs to the class of objects $O_6(t_k) \subseteq O$.

Postulates in relation to the messages:

1. With each message a support coefficient α_p , $p \in \{1, 2, \dots, 6\}$ is associated.
2. If an agent sends a message with conjunction as a logic connective then the support coefficient α_1 , $1=1, 2, 3, 4$ is equal 1. The state of an object o_z is unequivocally specified.
3. If an agent sends a message with exclusive alternative as a logic connective then the support coefficient α_5 is equal 0.5. The state of an object o_z is not unequivocally specified. Two states of affairs are considered: 1) an object o_z possesses the property P_i and doesn't possess the property P_j either 2) object o_z doesn't possess the property P_i and possesses the property P_j .
4. If an agent sends a message with alternative as a logic connective then the support coefficient α_6 is equal 0.3. The state of an object o_z is not unequivocally specified and three states of affairs are considered: 1) an object o_z possesses the property P_i and possesses the property P_j either 2) o_z possesses the property P_i and doesn't possess the property P_j either 3) o_z doesn't possess the property P_i and possesses the property P_j .

5. Each message φ_a about the state of an object o_z can be transformed into its first-level $fs^1_a(o_z)$ and second-level $fs^2_a(o_z)$, $a=\{1,2,\dots,\text{card}(A')\}$ semantically equivalent fuzzy set representation. First-level fuzzy set representation $fs^1_a(o_z)$ represents only the state of an object in relation to the co-existence of the properties P_i and P_j in the object o_z , but in the second-level representation $fs^2_a(o_z)$ also the power of agent's beliefs is taken into consideration.
6. If two first-level fuzzy set representations $fs^1_a(o_z)$ and $fs^1_b(o_z)$ consist a support coefficient α_i , $i \in \{1,2,3,4\}$ then the support levels for the correlated formulas φ_a and φ_b as a consensus opinion about the state of an object o_z are mutually equal.
7. If there is a support coefficient α_i , $i \in \{1,2,3,4\}$ in the first-level fuzzy set representation $fs^1_a(o_z)$ and α_5 (or α_6) in the first-level fuzzy set representation $fs^1_b(o_z)$, then the support level for the formula φ_a as a consensus opinion about the state of an object o_z is higher than the one for the formula φ_b .
8. If there is a support coefficient α_5 in the first-level fuzzy set representation $fs^1_a(o_z)$ and α_6 in the first-level fuzzy set representation $fs^1_b(o_z)$, then the support level for the formula φ_a as a consensus opinion about the state of an object o_z is higher than the one for the formula φ_b .

2.2 The Idea of the Algorithm for the Integration Propositional Attitudes

Input: The set of answers $Y=\{\varphi_1, \varphi_2, \dots, \varphi_{\text{card}(A')}\}$ sent by the agents from $A' \subseteq A$.

Output: The opinion φ_C about the state of an object o_z in relation to the properties P_i and P_j with the confidence coefficient γ_C .

Parameters: $\gamma_{\text{Know}}=1$, $\gamma_{\text{Bel}}=0.7$, $\gamma_{\text{Pos}}=0.4$, δ - the accepted value of tolerance in relation to the support function's value.

Step 1. Transform each formula φ_a into its first-level fuzzy set equivalent fs^1_a as follows:

$$\begin{aligned}
 &\text{if } \varphi_a = \text{OP}^a(P_i(o_z) \wedge P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 1), (k_2, 0), (k_3, 0), (k_4, 0)\}^\gamma \\
 &\text{if } \varphi_a = \text{OP}^a(P_i(o_z) \wedge \neg P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 0), (k_2, 1), (k_3, 0), (k_4, 0)\}^\gamma \\
 &\text{if } \varphi_a = \text{OP}^a(\neg P_i(o_z) \wedge P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, 1), (k_4, 0)\}^\gamma \\
 &\text{if } \varphi_a = \text{OP}^a(\neg P_i(o_z) \wedge \neg P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, 0), (k_4, 1)\}^\gamma \\
 &\text{if } \varphi_a = \text{OP}^a(P_i(o_z) \vee P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0.5), (k_3, 0.5), (k_4, 0)\}^\gamma \\
 &\text{if } \varphi_a = \text{OP}^a(P_i(o_z) \vee \neg P_j(o_z)) \text{ then } fs^1_a(o_z) = \{(k_1, 0.3), (k_2, 0.3), (k_3, 0.3), (k_4, 0)\}^\gamma
 \end{aligned}$$

where $\text{OP} \in \{\text{Know}, \text{Bel}, \text{Pos}\}$, γ represents the level of agent's confidence and is correlated with modal operators as follows: if $\text{OP}=\text{Know}$ then $\gamma=\gamma_{\text{Know}}=1$, if $\text{OP}=\text{Bel}$ then $\gamma=\gamma_{\text{Bel}}=0.7$, if $\text{OP}=\text{Pos}$ then $\gamma=\gamma_{\text{Pos}}=0.4$

Step 2. Transform each first-level fuzzy set representation $fs^1_a(o_z)$ into second-level fuzzy set representation $fs^2_a(o_z)$ as follows:

$$\begin{aligned}
 &\text{if } fs^1_a(o_z) = \{(k_1, 1), (k_2, 0), (k_3, 0), (k_4, 0)\}^\gamma \text{ then } fs^2_a(o_z) = \{(k_1, f_1(1, \gamma)), (k_2, 0), (k_3, 0), (k_4, 0)\} \\
 &\text{if } fs^1_a(o_z) = \{(k_1, 0), (k_2, 1), (k_3, 0), (k_4, 0)\}^\gamma \text{ then } fs^2_a(o_z) = \{(k_1, 0), (k_2, f_2(1, \gamma)), (k_3, 0), (k_4, 0)\} \\
 &\text{if } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, 1), (k_4, 0)\}^\gamma \text{ then } fs^2_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, f_3(1, \gamma)), (k_4, 0)\} \\
 &\text{if } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, 0), (k_4, 1)\}^\gamma \text{ then } fs^2_a(o_z) = \{(k_1, 0), (k_2, 0), (k_3, 0), (k_4, f_4(1, \gamma))\} \\
 &\text{if } fs^1_a(o_z) = \{(k_1, 0), (k_2, 0.5), (k_3, 0.5), (k_4, 0)\}^\gamma \text{ then } \\
 &fs^2_a = \{(k_1, 0), (k_2, f_5(0.5, \gamma)), (k_3, f_5(0.5, \gamma)), (k_4, 0)\}
 \end{aligned}$$

if $fs_a^1(o_z) = \{(k_1, 0.3), (k_2, 0.3), (k_3, 0.3), (k_4, 0)\}^\gamma$ then $fs_a^2(o_z) = \{(k_1, f_6(0.3, \gamma)), (k_2, f_6(0.3, \gamma)), (k_3, f_6(0.3, \gamma)), (k_4, 0)\}$, where f_p is the membership function of the object $o_z \in O$ to the class of objects $O_p(t_k)$, $p \in \{1, 2, \dots, 6\}$ and is defined as: $f_p: \{1, 0.5, 0.3\} \times \{1, 0.7, 0.4\} \rightarrow (0, 1]$

Remark: For each $fs_a^1(o_z)$ only one value δ_p of the membership function f_p , $p \in \{1, 2, \dots, 6\}$ is computed; $f_p(\alpha_p, \gamma) = \alpha_p \cdot \gamma$

Step 3. Compute fuzzy set representative $fsr^2(o_z)$ of all second-level fuzzy set representations $fs_a^2(o_z)$, $a=1, 2, \dots$, $card(A'): fsr^2(o_z) = \{(k_1, \Theta_1), (k_2, \Theta_2), (k_3, \Theta_3), (k_4, \Theta_4)\}$,

$$\Theta_1 = \frac{1}{card(A')} \sum_{\substack{fs_a^2(o_z) \in Fs^2(o_z) \\ p \in \{1, 6\}}} f_p(\alpha_p, \gamma) \quad \Theta_2 = \frac{1}{card(A')} \sum_{\substack{fs_a^2(o_z) \in Fs^2(o_z) \\ p \in \{2, 5, 6\}}} f_p(\alpha_p, \gamma)$$

$$\Theta_3 = \frac{1}{card(A')} \sum_{\substack{fs_a^2(o_z) \in Fs^2(o_z) \\ p \in \{3, 5, 6\}}} f_p(\alpha_p, \gamma) \quad \Theta_4 = \frac{1}{card(A')} \sum_{fs_a^2(o_z) \in Fs^2(o_z)} f_4(\alpha_p, \gamma)$$

$Fs^2(o_z)$ is the set of all second-level fuzzy set representations.

Step 4. Apply the procedure of the choice of consensus description of the state of object o_z [see 5].

Stop.

3 Final Remarks

In this paper a strategy of integration of agents' propositional attitudes was proposed in order to solve the semantic inconsistency between agents' opinions. The receiver of the messages applies the algorithm for the propositional attitudes integration. In this algorithm all the agents' answers are transformed into fuzzy set equivalents and then the formula representing the agreement of all opinions is obtained.

References

1. Coradeschi S., Saffiotti A., An Introduction to the Anchoring Problem, Robotics and Autonomous Systems 43, (2003), 85-96
2. Harnad, S.: The Symbol Grounding Problem. Physica, 42, 335-236
3. Katarzyniak, R., Pieczyńska-Kuchtiak, A.: A Consensus Based Algorithm for Grounding Belief formulas in Internally Stored Perceptions. Neural Network World, 5, (2002) 671-682
4. Katarzyniak, R., Pieczyńska-Kuchtiak, A.: Grounding and extracting modal responses in cognitive agents: AND query and states of incomplete knowledge. International Journal of Applied Mathematics and Computer Science, 14(2), (2004), 249-263.
5. Katarzyniak, R., Pieczyńska-Kuchtiak, A.: An Approach to resolving semantic inconsistency of multiple propositional attitudes. Journal of Intelligent & Fuzzy Systems 17(3), (2006), (to appear).
6. Pieczyńska-Kuchtiak, A., Towards measure of semantic correlation between messages in multiagent system, ICCS 2005, Lecture Notes on Computer Science, Kraków, (2004) pp. 567-574.
7. Vogt P., Anchoring of semiotics symbols, Robotics and Autonomous Systems, 43, (2003) 109-120.