# Defense Technical Information Center Compilation Part Notice

## ADP012345

TITLE: Influence in MultiAgents Systems - Application to Coalitions

DISTRIBUTION: Approved for public release, distribution unlimited
Availability: Hard copy only.

This paper is part of the following report:

TITLE: KSCO 2002: Second International Conference on Knowledge
Systems for Coalition Operations

To order the complete compilation report, use: ADA402533

The component part is provided here to allow users access to individually authored sections
of proceedings, annals, symposia, etc. However, the component should be considered within
the context of the overall compilation report and not as a stand-alone technical report.

The following component part numbers comprise the compilation report:
ADP012330 thru ADP012354

# Influence in MultiAgent Systems – Application to Coalitions

## Zakaria Maamar
Software Agents Research Group@ZU
College of Information Systems
Zayed University
PO Box 19282, Dubai, U.A.E
zakaria.maamar@zu.ac.ae

## Paul Labbé
System of Systems Section
Defence Research Establishment Valcartier
2459 Pie-XI Blvd. North Val-Bélair
(Québec), Canada, G3J 1X5
paul.labbe@drev.dnd.ca

## Wathiq Mansoor
Software Agents Research Group@ZU
College of Information Systems
Zayed University
PO Box 19282, Dubai, U.A.E
wathiq.mansoor@zu.ac.ae

## Emad Bataineh
College of Information Systems
Zayed University
PO Box 19282, Dubai, U.A.E
emad.bataineh@zu.ac.ae

**Abstract.** This paper presents a framework to deal with influence in multiagent systems. Influence is defined as the impact that a participant could have on another participant, known as target. Influence could be either positive or negative, according to how this target assesses the outcomes of the operations this participant has carried out. The presented framework could be viewed from two different perspectives: knowledge perspective with goal and belief as main components and organization perspective with task and resource as main components.

## 0. Paper structure

This paper is structured as follows. Section 1 presents an overview of influence and why it is relevant to study it in multiagent systems. Section 2 suggests definitions related to influence. Section 3 analyses influence at four levels, namely goal, belief, task, and resource. Section 4 illustrates the use of influence in the military domain. Finally, Section 5 consists of concluding remarks.

## 1. Overview

The purpose of this paper is to discuss the role that influence could play in understanding and predicting software-agents' behavior. Influence investigates the causes of human modification – whether that modification is a behavior, an attitude, or a belief [1]. Usually, influence is employed by a participant upon a target and relies on the social interactions that exist between them [3]. The participant is the one who influences whereas the target is the one who is influenced. Considering influence in MultiAgent Systems (MASs) has driven us to work at four levels, namely goal, belief, task, and resource. Goal and belief levels are seen from a knowledge perspective while task and resource levels are seen from an organization perspective. These four levels could be part of the agents' mental-model; this model is subject to modifications by the agent that is influenced (cf. Figure 1). These modifications depend on the outcomes of the operations undertaken by the agent that influences. We recall that goal, belief, task, and resource are connected to each other. An agent exhibits a goal-oriented behavior. Often, plans implement such a behavior. To achieve a goal, the agent selects the appropriate tasks on the basis of the beliefs it has in its mental model. Finally, tasks require resources in order to be completed. In this paper, **G**oal, **B**elief, **T**ask, and **R**esource constitute the GBTR framework.

In real life, the environment in which we live influences our behaviors in different ways. For example, we adapt our attitudes, reactions, and expectations. Influence could be either positive, i.e. "good", or negative, i.e. "bad". In the rest of this paper, we discuss how Software Agents (SAs) could be used for simulating influence. SAs are autonomous entities having the abilities to collaborate with other SAs to jointly solve different problems [2]. Usually, these problems are inherently distributed and heterogeneous. We intend to apply SAs as well as influence to military scenarios, where for instance several combat units have to cooperate regardless of the fact they are spread across a battlefield. These units influence each other, particularly if they are committed to the same operation. If a combat unit is defeated, a friendly unit should assess the consequences of this defeat. In fact, this friendly unit should assess how it will be influenced. For instance, this unit could expect attacks from the hostile troops. Interesting are situations in which a combat unit does not communicate with other units to avoid messages interception, i.e. "intelligence" surveillance. Therefore, such units are not able to assess how they will be influenced. Decisions, regarding the following operations to undertake, should be made under uncertainty. Uncertainty is defined as the difference between the knowledge that is required to accomplish a mission and the decision a decision-maker has at that time. Hence, uncertainty is inversely proportional to the decision-maker's belief of understanding of the current situation [[5].
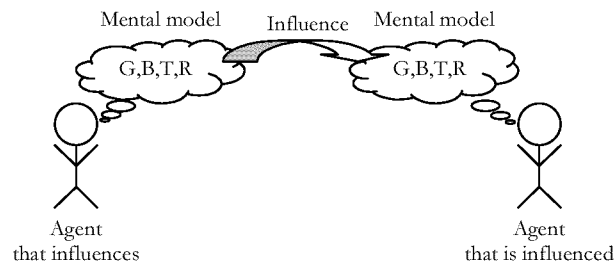


**Figure 1 Influence impact on the mental model**

[4] views influence as a cognitive process by which an agent acquires new knowledge. This process, known as social learning, takes place between an agent that is exposed to another. Both agents are located in a common environment; this means that they are aware of each other, for instance via observation. According to the same author, social learning could happen either by facilitation or by imitation. In the first situation, a learning agent updates its knowledge by perceiving the relationship between another agent and the physical or social environment that interests this learning agent. In the second situation, imitation is defined as a process in which a learning agent is ruled by the knowledge it has on the agent it is currently observing.

## 2. Definitions

In the GBTR framework, influence occurs at goal, belief, task, and resource levels. In what follows, a short definition is proposed for each level.

- **What does goal influence stand for?** Here, the agent's goal-hierarchy is adapted, after the insertion of a new goal in this hierarchy. Insertion involves dealing with this new goal, by identifying who is going to achieve it? How to achieve it in term of planning? When to achieve it? And what does it require in term of resources?

- **What does belief influence stand for?** Here, the agent's belief-repository is updated, after the insertion of a new belief in this repository. Consistency between the different beliefs should be ensured; an agent cannot manipulate contradictory beliefs.

- **What does task influence stand for?** Here, the agent's task-repository is updated, after either the insertion of a new task in this repository or the modification of the characteristics of a specific task of this repository. In the insertion situation, the agent should find who is going to perform this new task? How to perform it? When to perform it? And what does it need in term of resources? In addition, the execution chronology of tasks should be dealt with since a new task has been introduced. In the modification situation, a task could be changed regarding for example who is going to perform it or when it is going to be performed.

- **What does resource influence stand for?** Here, the agent's resource repository is updated. This agent could either receive additional resources or lose some of its resources momentarily. In the first situation, the agent uses the resources it gets in order to carry out its goals. In the second

118

situation, the agent outsources its resources.

These four types of influence require from the agent that is influenced to possess two modules, known as awareness and assessment. The awareness module is a means to identify the agents that are part of the agent's environment and that could influence this agent. The assessment module is a means to identify how the agent is influenced either positively or negatively and at which level, i.e. goal, belief, task, or resource. The assessment module relies on the awareness module. In what follows, we describe how both modules should work from the perspective of the agent that is influenced (cf. Figure 2).

– The awareness module has the following working cycle:
a. The agent identifies who is located within its environment.
b. After knowing its acquaintances, the agent establishes what kind of relationships it has with these acquaintances. Examples of relationships could be friendly and hostile.
c. Finally, the agent makes out the operations its acquaintances have performed.

– The assessment has the following working cycle:
a. The agent needs to know if the agents it has identified in Step a. of the awareness cycle are either new or it has already encountered them.
b. Then, the agent investigates if the relationships it established in Step b. of the awareness cycle are valid.
c. Finally, the agent analyses the outcomes of the operations these agents have undertaken. This analysis permits this agent to adapt its behavior on the basis of how it is influenced, either positively or negatively.

We recall that the awareness and assessment modules work in an interleaved arrangement. In fact, each step of the awareness cycle is followed by a step of the assessment cycle and *vice-versa*.
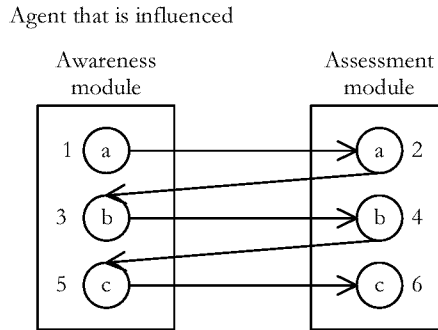


**Figure 2 Awareness and assessment interleaving arrangement**

We view the GBTR framework as a means to represent the agent adaptability in an open environment. As this environment changes, agents are affected and consequently must be ready to act. For illustration purposes, assigning a new goal to an agent requires either designing new plans or repairing the previous plans. In an open environment, classical long plans are not always successfully executed due to unpredictable changes in the world. A change in the world can make plans invalid.
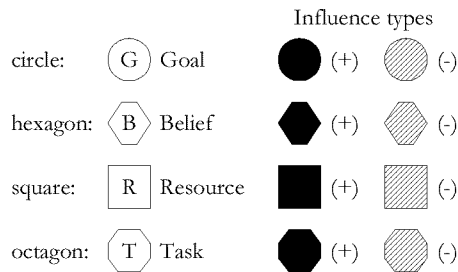
## 3. Analysis

Influence depends on the relationships that exist between agents. Such relationships could be of type "supervise", "supervised-by", or "peer-to-peer". Both "supervise" and "supervised-by" define who reports to whom? "Who does what" question is also important when dealing with influence. This question defines the origin of influence, i.e. the operations that are the cause of this influence.

In the GBTR framework, an agent could influence another agent at goal, belief, task, and resource levels. Since influence could be either positive or negative, the following combinations are obtained (cf. Table 1). We assume that $agent_1$ influences $agent_2$. In a negative influence, the agent that is influenced should proceed as follows: suspend its operations that are in progress, carry out the operations of the agent that influences, and finally resume its operations.

**Table 1 Types of influences between agents**

| Influence | Type | | Description |
|---|---|---|---|
| Goal | Positive | (+) | Agent₁ generates a new goal that will support agent₂ in achieving its goals. Agent₁ will be in charge of satisfying this new goal for the benefit of agent₂.<br>*Facilitate relationship between goals.* |
| | Negative | (-) | Agent₁ generates a new goal that will delay agent₂ in achieving its goals. In fact, agent₂ will be in charge of satisfying this goal for the benefit of agent₁.<br>*Hinder relationship between goals.* |
| Belief | Positive | (+) | Agent₁ produces a new belief that will affirm some of agent₂'s beliefs<br>*Affirm relationship between beliefs.* |
| | Negative | (-) | Agent₁ produces a new belief that will contradict some of agent₂'s beliefs. Agent₂ should amend its beliefs.<br>*Contradict relationship between beliefs.* |
| Task | Positive | (+) | Agent₁ carries out some of agent₂'s tasks on its behalf.<br>*Conduct relationship between agents and tasks.* |
| | Negative | (-) | Agent₁ entrusts some of its tasks to agent₂, in addition to the tasks agent₂ is already in charge.<br>*Work for relationship between agents and tasks.* |
| Resource | Positive | (+) | Agent₁ offers some of its resources to agent₂. This helps agent₂ to carry out its tasks and in the same time to achieve its goals.<br>*Offer relationship between agents and resources.* |
| | Negative | (-) | Agent₁ takes over some of agent₂'s resources. Agent₂ could lack resources to carry out its tasks and thus, to achieve its goals.<br>*Take over relationship between agents and resources.* |

The symbols representing the different types of influences are in Figure 3. Filled symbols correspond to positive influence whereas dashed symbols correspond to negative influence. In what follows, T stands for time.



**Figure 3 Symbols for influence representation**

Goal influence

| T | Agent₂ works towards achieving G₂ goal. | |
|---|---|---|
| T+1 | Agent₁ influences agent₂ | (+)<br><br>Agent₁       Agent₂<br>*Facilitate*<br>●————→(G₂)<br>Agent₂       Agent₂<br><br>Facilitate(new_goal,G₂)<br>Agent₁ generates a new goal, filled circle, for the benefit of agent₂. |

120

| | | |
|---|---|---|
| | | **(-)** <br><br> Agent$_2$       Agent$_2$ <br> ⊘  *Hinder*  (G$_2$) <br> Agent$_1$       Agent$_2$ <br><br> Hinder(new_goal,G$_2$) <br> Agent$_2$ carries out the new goal, dashed circle, for the benefit of agent$_1$. |

## Belief influence

| T | Agent$_2$ has B$_2$ belief. | |
|---|---|---|
| T+1 | Agent$_1$ influences agent$_2$ | **(+)** <br><br> Agent$_1$       Agent$_2$ <br> ⬢  *Affirm*  ⬡B$_2$ <br> Agent$_2$       Agent$_2$ <br><br> Affirm(new_belief,B$_2$) <br> Agent$_1$ generates a new belief, filled hexagon, for the benefit of agent$_2$. |
| | | **(-)** <br><br> Agent$_1$       Agent$_2$ <br> ⬡  *Contradict*  ⬡B$_2$ <br> Agent$_2$       Agent$_2$ <br><br> Contradict(new_belief,B$_2$) <br> Agent$_1$ generates a new belief, dashed hexagon, contradicting agent$_2$'s belief. |

## Task influence

| T | Agent$_2$ carries out T$_2$ and T$_3$ tasks. | |
|---|---|---|
| T+1 | Agent$_1$ influences agent$_2$ | **(+)** <br><br>            Agent$_2$    Agent$_2$ <br> Agent$_1$ —*Conduct*— ⬢ → ⬣T$_3$ <br>             T$_2$ <br><br> Conduct(Agent$_1$,T$_2$,Agent$_2$) <br> Agent$_1$ conducts T$_2$ task, filled octagon, for the benefit of agent$_2$. |
| | | **(-)** <br><br>            Agent$_1$    Agent$_2$ <br> Agent$_2$ —*Work for*— ⬣ → ⬣T$_2$ <br>             T$_1$ <br><br> Work-for(Agent$_2$,T$_1$,Agent$_1$) <br> Agent$_2$ works for agent$_1$ regarding T$_1$ task, dashed octagon. T$_1$ task will precede T$_2$ and T$_3$ tasks. |

## Resource influence

| T: | Agent$_2$ manages R$_2$ and R$_3$ resources. | |
|---|---|---|

| T+1 | Agent$_1$ influences agent$_2$ | (+) |
|-----|-------------------------------|-----|
|  |  |  Offer(Agent$_1$,R$_1$,Agent$_2$)<br>Agent$_1$ offers R$_1$ resource, filled square, to agent$_2$. |
|  |  | (-) |
|  |  |  Take-over(Agent$_1$,R$_2$,Agent$_2$)<br>Agent$_1$ takes over R$_2$ resource, dashed square, of agent$_2$. |
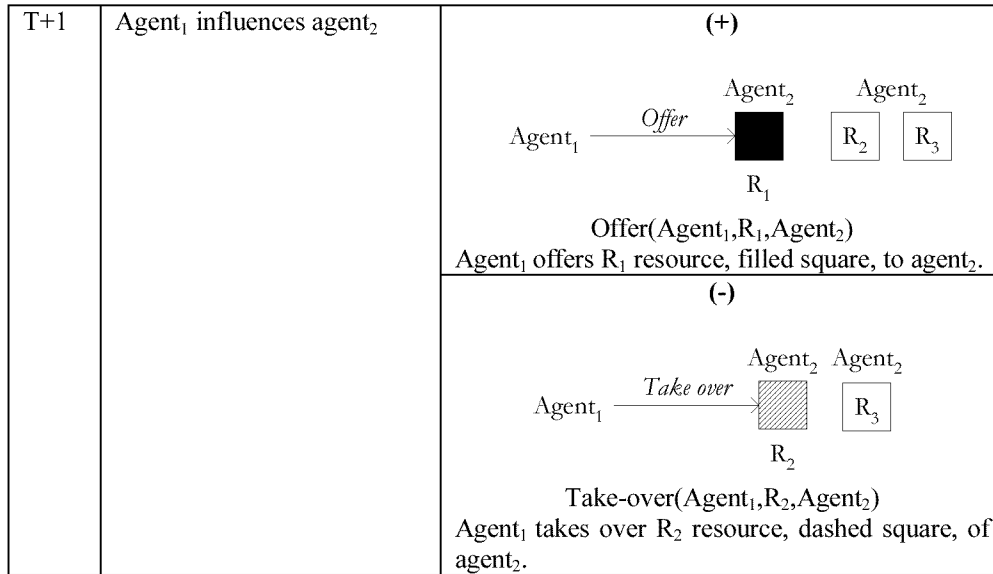
According to the type of influence, either positive or negative, the flow of work between the influencing agent and the influenced agent represents a delegation. For instance, in a positive-goal influence, the influenced agent is supported by a new goal that the influencing agent will be in charge. In a negative-goal influence, the influencing agent assigns a new goal to the influenced agent.

## 4. Running scenarios

In this section, we discuss how we are applying the influence concept and the GBTR framework as well to military scenarios. These situations could be decomposed into four types: maritime-oriented, land-oriented, air-oriented, and mix-oriented. According to the situation type, we expect that influence should take a different form. In fact, each situation has its structural and functional requirements in terms of doctrines, combat strategies, means, and missions. Therefore, influence should be dealt with differently. Let us recall that the equipments that will be committed to military scenarios should be associated with SAs that will act on their behalf. Simulations that implement proper national doctrines and operational procedures are more likely to be accepted and fostered by computer literate military users and decision-makers.

Each oriented-situation, i.e. maritime, air, and land, requires unique staff skills and training tune to their environment and type of operations, and requires specific infrastructures and equipments. Maritime-oriented situations involve for example vessels and submarines. The nature of the environment, namely sea, has an impact on the operations these vessels will undertake and the interactions these vessels will have together. Air-oriented situations involve for example airports, aircrafts, and helicopters. Land-oriented situations involve for example tanks, armored personnel carriers, and assault vehicles. Finally, mix-oriented situations are a combination of different operations, environments, and equipments[1], e.g. planes and vessels in support of land forces in a littoral area. As with Maritime-oriented situations, each oriented-situation, either air, land, or mix has its requirements that can be very complex and difficult to manage and satisfy.

Figure 4 is an example of the participants that could take part to a maritime-oriented situation. Two vessels and a submarine are used. In military situations, influence between participants is usually bi-directional. For understanding purposes, we assume that influence is unidirectional: vessel$_1$ influences vessel$_2$ and both vessels influence submarine$_1$. Regarding submarine$_1$, receiving contradicting information from vessel$_1$ and vessel$_2$ would occur.

---

[1] Interesting to consider the equipments that could be simultaneously used in different situations, for example from maritime to land and *vice-versa*. Amphibious vehicles are among these equipments.

Vessel₁ → Vessel₂

Submarine₁
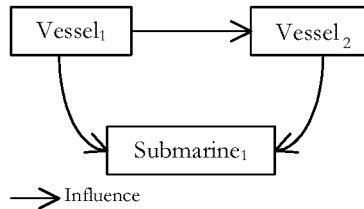
→ Influence

**Figure 4 Example of a maritime-oriented situation**

In what follows, we provide examples on how influence could occur according to the GBTR framework.

1. Goal influence:
   - Positive influence between vessel$_1$ and vessel$_2$: vessel$_1$ will transport a part of the troops that vessel$_2$ has been tasked to perform. Therefore, vessel$_1$ will pursue a new goal, e.g. carry_troops_for_vessel$_2$.
   - Negative influence between vessel$_1$ and submarine$_1$: because vessel$_1$ could lose a battle in progress, submarine$_1$ has been asked to join the combat as a support to vessel$_1$. Despite that submarine$_1$ is already in charge of securing a specific region, it has to pursue a new goal, e.g. provide_support_to_vessel$_1$.

2. Belief influence:
   - Positive influence between vessel$_1$ and submarine$_1$: submarine$_1$ believes that vessel$_2$ is friendly. Vessel$_1$ confirms to submarine$_1$ that vessel$_2$ is friendly. This permits to reinforce submarine$_1$'s beliefs.
   - Negative influence between vessel$_1$ and vessel$_2$: vessel$_2$ believes that submarine$_1$ is committed to a surveillance operation. However, vessel$_1$ informs vessel$_2$ that submarine$_1$ has been withdrawn from this operation. This new statement contradicts what vessel$_2$ assumed about submarine$_1$'s responsibilities.

3. Task influence: it is a consequence of goal influence.
   - Positive influence between vessel$_1$ and vessel$_2$: according to the positive goal-influence case (see above), vessel$_1$ has been ordered to transport equipments on behalf of vessel$_2$. Therefore, vessel$_1$ needs to perform as tasks: load equipments from the original destination, convey these equipments, and finally unload these equipments at the final destination.
   - Negative influence between vessel$_1$ and submarine$_1$: according to the negative goal-influence case (see above), submarine$_1$ will fulfill new tasks for vessel$_1$, such as attacking the enemy float. In fact, these tasks have not been planned in submarine$_1$'s initial schedule.

4. Resource influence: it is a consequence of goal influence
   - Positive influence between vessel$_1$ and vessel$_2$: according to the positive goal-influence case (see above), vessel$_1$ has to transport equipments on behalf of vessel$_2$. The new tasks that vessel$_1$ will carry out requires the use of its resources, such as a crane.
   - Negative influence between vessel$_1$ and submarine$_1$: according to the negative goal-influence case (see above), submarine$_1$ will fulfill new tasks for vessel$_1$. To this end, submarine$_1$ will use its resources.

## 5. Conclusion

In this paper, we discussed influence role in modeling and understanding software agents' behavior. To this end, we suggested the GBTR framework that views influence from two inter-related perspectives: knowledge and organization. The knowledge perspective consists of goal and belief components while the organization perspective consists of task and resource components. Influence could be either positive or negative. This requires enhancing the agent that will be influenced with appropriate mechanisms, such as assessment. Finally, we illustrated the use of the GBTR framework on different situations from the military domain. More work is needed. For instance, how to define the origin of influence is among our concerns. We just started considering Bayesian Networks to deal with this concern.

## References

[1] http://www.influenceatwork.com/. Visited December 2000.

[2] N. Jennings, K. Sycara, and M. Wooldridge. A roadmap of agent research and development. *Autonomous Agents and Multi-Agent Systems*, 1(1) pp. 7-38, 1998.

[3] D. Foryth. *Group Dynamics*. Brooks/Cole, Pacific Grove, CA 2$^{nd}$ edition, 1990.

[4] R. Conte Intelligent social learning. in *the symposium on starting from society – the application of social analogies to computational systems –* held as part of AISB'2000, April 2000.

[5] L. Falzon, L. Zhang, and M. Davies. A Policy Analysis Approach to Operational Level Course of Action Analysis. in *The 5$^{th}$ International Command and Control Research and Technology Symposium, Modeling & Simulation Track.* http://www.dodccrp.org/ visited January 2001.