Coordination Model Research Based on Command Decision Joint Intension

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Abstract. Command Decision Simulation (CDS) is not only an important and difficult issue in the field of simulation, but also a technique issue to be tackled in the course of collective Modeling and Simulation in Joint Operations Experiment Center. CDS can give support to all kinds of simulation. Using computer to realize the Blue side’s command decision automatic execution in the operation training simulation system can improve training effect. Using computer to realize the lower level command unit’s automatic command decision can help to reduce the number of controllers and liberate them from heavy work. It can also enlarge simulation scale and increase the freedom of the simulation entity especially the command entity, thus enhance the authenticity and credibility of the simulation. On the basis of the command decision structure and the Joint Intention Theory, the thesis puts forward the method of making use of Coordination Matrix (CM) to realize cooperation among the entities in CDS and constructs the calculation sketch of Task Execution, Task Monitoring and Task Replanning. At the same time, the thesis brings forward the CDS structure vision based on Partial Global Planning(PGP).As CM is an indispensable part of combat simulation, the theory and method of CDS will become an important part for the theory of Combat Simulation.

Keywords: Command Decision Simulation (CDS); The joint intention theory; Multi-agent System (MAS); Coordination Matrix (CM); CDSModel.

1. Introduction
The mutual coordination and mutual support of many agents to finish special task, and rich knowledge and powerful functions of each agent, make up the multi-agent system(MAS) The actions of each agent are autonomous and independent, and their actions and targets are not restrained by other agents; they finish the targets set by the system together via competition, negotiation and cooperation. The resources of the MAS are dispersive, while the calculation and the task execution are distributing. On the basis of applying with certain knowledge regulations and management strategies, the task partition, resources distribution and action cooperation are judged and decided via the mutual effect and environmental perception of each agent.

The characteristics of the MAS:None agent has enough information and capability to resolve the problems that should be resolved;Without system overall control; The figures are dispersive; The calculations are asynchronous.

When the actions of agent meet any of the following conditions, coordination will be happened: With a common target, the agents’ actions tend to realize this target;The actions executed by agent realize not only its own aim, but also the aims of other agents.

In the simulation system, each simulation entity agent can be looked as an individual with a certain “psychology” condition (for example, faith, wish and intension), which dominate the future actions of
these agents. “Intension” is the kind of “psychology” condition, which expresses the promise that agents will take actions in the coming future.

The individual actions dominated by “intension” include: When deciding to chase the target that it has promised, an agent will enter a special condition; “Intension” is used to organize the future actions: when promising a target, agent must decide to execute necessary actions within the appointed time in the future.

“Intension” owns scheme plan functions: in order to realize these functions, “intension” must possess the following characteristics: the “intensions” of an agent should not contradict each other; “Intension” should own the characteristics of stability and flexibility. For stability, it means that the “Intensions” should not change frequently; while, for the flexibility, it means that “Intensions” can be changed when special condition happens. In order to realize the balance between the two, several regulations should be made to explain that under what condition, “intensions” can be reconsidered. And this means that agents should supervise the execution of the “Intensions”, check at any time to see whether the agent contradicts the promise, and timely make an evaluation on the “Intensions”, in order that the “intensions” can be changed. And the regulations should consider about the accidents that may happen during the resolution of coordination question.

“The Joint Intention” is the common promise to execute a collective action. In order to adapt to the resolution of multi-agent cooperation problems, the model of “The Joint Intention” should possess the following characteristics: Multi-agent must share a common target; Multi-agent must agree to coordination in order to realize the common target; Multi-agent must agree to a common planning in order to realize the common target; All the actions by different agents rely on each other; Several regulations are needed by multi-agent to supervise the intension execution.

The basis of joint action is the common target, the birth of which is impelled by individual motive. If the unit of the coordination group is team, thus as soon as the common target and coordination expectation are confirmed, all the members of the whole team will make a promise to realize the common target. To take the meaning into consideration, the common target is just like a binder that combines the individual actions into a group action. And the common plannings provide the common target with a series of action schemes that are agreed by all the coordinators.

The establishment of the common planning is based on the individual planning, which explains the actions that are agreed to execute by the coordinators in the joint action, and still have not been executed; the individual planning also defines rules to supervise the execution of the common planning. The common planning also contains the instructions to deal with emergency. For example, when an entity can not fulfill the actions of the common planning, it must inform other entities, in order that the coordinator group can reevaluate the original planning or make a new planning.

For the convenience of the later discuss, several definitions are made as following: Weak Goal is made up by three exclusive conditions. Make p as to fulfill a task, be an intellect or have the aim to fulfill p, or to believe p has been finished, or believed that it is impossible to fulfill p now, and this fact should be known by other members. An entity should not only try its best to fulfill a target, but also make sure that its thoughts are known by its partner entities; Weak Mutual Goal is that all the members of the team mutually believe that all the members have the weak goal to realize the tasks; Joint Persistent Goal is that the members of the team believe mutually that the task p is false, and share a common target to make p right, until p is believed to be right, impossible to realize, or unconcerned by all of the members. Thus they mutually share a weak mutual goal to make p to be right; Persistent Weak Achievement Goal: before JPG is set up in a multi-agent system S, the promise made by member \( v_i \) to system task p, can be expressed by \( PWG(v_i, p, S) \).

2. The Joint Intension Foundation and Execution Process in the Course of Command Decision

The foundation course substance of the joint intension in the command decision is the establishment course of the combat action class. The foundation of the joint intension and execution process in the command decision can be divided into four steps: to analyze the coordination demand, formation of coordination action class during the course of task execution, to form a combat plan, and to execute tasks.
2.1. To Analyze the Coordination Demand during the Course of Task Execution
During this course, while analyzing the task, the Command Decision entity should analyze coordination questions among all the actions happened when subordinates fulfill this task, mainly the mutual rely relation, mutual impact relation, special demand during the execution course, and so on. According to the military conventional, a subordinate must follow the superior’s command decision without any conditions, thus the orders made for the subordinates should not contradict with each other.

2.2. To Form a Coordination Action Class
During this course, on the basis of the above coordination analysis on the task, the command decision entity makes an analysis and classification on the coordination action, to make up different action classes, the actions of which must rely on and impact with each other. During this period, sometimes, the command decision entity is not sure whether there are coordination relations existed among these actions, but they can make a warning to their subordinate entities to remind them of possible coordination during the course of action execution. Therefore, when the subordinates are executing the actions, they will positively maintain coordination with their superior or partners.

2.3. To Form a Combat Action Plan
To make a combat plan by analyzing the logic relation of the actions among the action class (collateral, string or branch selection relation). Then the command decision entity should transmit not only the combat plan to the other relevant entities but also the coordination plans.

2.4. To Execute the Tasks
During this course, to execute the planed combat plans is the most important stage. In order to execute the action tasks within the frame of combat plan, entity should know not only the Joint plan, but also the action tasks that needed to be fulfilled in the Joint plan. During the execution course, the command decision entity should supervise the execution condition. And when there is something wrong with the planed coordination, the command decision entity should adjust and replan the coordination.

3. Coordination Matrix
The concept of the Coordination Matrix is quoted to express that subordinates of the command decision entity executes a team of coordination action to realize a task. CM is the description of task, action formation of corresponding task and the coordination relation among the actions. CM, a level model, not only contains the general intension of the command decision entity, but also the individual intension of each entity.

CM, an action scheme to realize task, is created by command decision entity via combat situation and entity task of the same grade. During the execution period, CM drives and instructs the entity coordination that subordinated to its subordinates, and in fact, it has set up a system for the coordination to confirm the mutual rely, mutual impact of the actions, and the special demand of action execution. CM can be divided into two styles. One is the Constructed Coordination Matrix, CCM. When the command decision entity realizes that it should be divided into several coordination actions in order to fulfill the task, a CCM is created. The descriptions of the CCM are: the task execution steps of the command decision entity, and the action execution steps of subordinates being coordinated by all the subordinate entities, when each task is being executed. And at the same time, CCM also describes the corresponding relations between the all the actions of subordinate entities and its corresponding superior tasks.

There are two usages for the CCM, first, it can be used by the command entity to supervise the action execution of the subordinate entity; second, it can used as orders sent to subordinate units.

The other style is the Instructed Coordination Matrix, ICM, which is the coordination matrix that the subordinate units of the command entity get from the command decision entity, and is the same as the CCM of the superior command decision entity. The ICM contains not only the action tasks that must be fulfilled, but also the relations between it and the superior corresponding tasks, as well as how it and other brother entity action coordinate information. Thus, when an entity receives ICM, it will receive not only the orders themselves, but also the combat situation of the action execution orders.
When command decision entity receives the ICM for superior, each of its action tasks can be divided into several branch tasks; and each branch task can make up its own CCM to command and coordinate its subordinate units.

There are s group of regulations for each command decision entity to deal with coordination of the subordinate entity action. And these regulations are depended on all the entity joint intension of the command decision subordinates, they also reserve all the subordinate entity situations, by which coordination is made.

4. The Coordination Realization Based on the Coordination Matrix

From the analysis above, it is known that the command entity transmits its CCM to its subordinate entity. And the ICM that the subordinate entity receive is the same as the CCM of the its superior. If the subordinate entity is also a command decision entity, it will make up its own CCM on the basis of the ICM it received and its own actual situation, and then transmits the CCM to its subordinate entity. And this will keeping on until the receiver is the combat entity.

The CM realizes the supervision on the action task executions via common target and plan. The action task will be reorganized if the entity responsible for a action task can not fulfill its duty, or new tasks are found without appointed entity to fulfill them.

What make this model different from some common multi-agent systems is that it contains action class, which explains the team joint action, making it different from normal individual action which can only explain the individual action of this agent. The same as individual actions, action class also contains three kinds of regulations: prerequisite regulation; application regulation; termination regulation. To judge whether an action is an action class or individual action, you just have to know that whether the action is executed by an individual agent, or a team of agents.

In the model, each agent contains two conditions: individual personal condition and team condition. The group condition is usually initialized by the information of this team, and it contains knowledge relative to common belief of the team. To confirm the accordance of the team condition, the model contains one key restrain condition: only the action class explaining the Joint intension can make a amendment to the group condition.

1. The execution of action class

When action class is executed, the command decision agents have to set up the Joint intension, that is to say, when the command decision agent chooses an action class for execution, it must execute the following process for establishing promised agreement:

When the command decision agent broadcasts some information to its subordinate entity to set up PWAG of the task OP. the command decision agent has already set up the PWAG; and if the Joint intension \([OP]_\Theta\) has not been set up within the given time, then the command decision agent has to broadcast again.

The subordinate Agent \(v_i\) of the command decision agent will be in waiting situation, until receiving the information from the command decision agent, and then it will be broadcasted to the members of the superior and brother agent, to set up PWAG of the task OP.

As far as \(v_i\) is concerned, as soon as the PWAG of the task OP is set up, then the Joint intension \([OP]_\Theta\) is set up.

Problems from the coordinations among the agents of the systems will be avoided, after the multi-agent has set up the promise negotiation. that is to say, the flexibility on the communication and coordination of the system will be improved.

The execution of the action class \([OP]_\Theta\) can only be terminated by group situation, which avoid the problems caused by lack of communication, after the Joint Intension \([OP]_\Theta\) is set up. The agent has to inform its superior and brother agents when it wants to terminate an action in the action class. Moreover, there are three termination conditions in each action class. And if an agent’s personal situation contains the belief that is suitable for the termination conditions of the action class, then it will create a
communication demand, to tell this belief to the other agents of this group, update the group’s situation, and then terminate this action class.

During the course of information broadcasting from the multi-agent system, the information relying relationship should be checked between the coordination model and following action tasks. If the relationship does exist, then relevant information should be drawn from the condition of the outer environment for broadcasting. This information relying relationship can be individually defined according to each termination condition of the actions.

2. The supervision and replan for the execution progress of the action class

To realize the coordination among the entities of command decision system is the execution progress of supervising action class via the expression system of the action class. When actually realized, it is fulfilled via the clear definition of the termination conditions of the termination action class from the model. And at the same time, it also provides clear definition on the relationship between the action class and subordinate individual action and relationships among the actions of the subclass. And with these defined relationships, it can be judged whether the execution progress of the action class meets the termination conditions, during the course of the CDS operation.

These relationships contain the relations between the action class termination conditions and their corresponding individual actions or the execution conditions of the group subclasses, as well as the comparison between the forces of us and the enemies, combat time and so on.

The relations between the action class and subordinate individual action, and relations among the actions of the subclass, are found on the basis of action classes that the single agent and agent subclass are responsible for in the while task. That is to say, this relation can only be restrained in the range of the task and its corresponding actions.

Three basic relationships being defined: AND relationship: AND-combination; OR relationship: OR-combination; NO relationship: Not-combination.

These three basic relationships confirm the relationship between the action class and its action, defined as following: AND-combination: \([OP]_i \Leftrightarrow \bigwedge_{i} op_{st} \); OR-combination: \([OP]_i \Leftrightarrow \bigvee_{i} op_{st} \); No-combination: \(op_{st} \Rightarrow \neg op_{st}\).

These relations can carry out the further compound calculation, to form a more complex relations. For example, \([OP]_i\) is the action class of a given command decision agent \(v\), and three of the subordinate agents of the command decision agent are \(v_i, v_j\) and \(v_k\), thus, \([OP]_i\) is made up by \(op_{st}, op_{st}\) and \(op_{st}\), which are the corresponding actions of agent \(v_i, v_j\) and \(v_k\), that is the AND-OR relationship \((\bigwedge\bigvee_{i} op_{st}) \bigwedge op_{st}\). And this relation means that when Agent \(v_k\) finishes the action \(op_{st}\), together with Agent \(v_i, v_j\) having finished at least one actions of \(op_{st}, op_{st}\), thus the action class \([OP]_i\) is finished. Or, it will not be finished.

The forces of us and enemies, and the combat time can make up compounding calculation, together with subordinate actions, to be treated as a acquiescence condition for the action class to terminate the conditions. For example, when our military forces are cut down to 1/5 of the enemy’s, or the time to execute the action class \([OP]\) has exceeded a certain time, it is believed that the task to execute the action class \([OP]\) is failure. According to these relations, we can found action class and supervision restrain conditions among its subordinate actions.

According to the supervision restrain conditions defined above, we can judge that action class \([OP]_i\) can not be finished, then it will activate the \([Re\ pair]_i\) action to replan the team actions.

Because \([Re\ pair]_i\) is a set of actions, it can confirm the whole team’s Joint promise to replan this task, moreover, after the team action \([Re\ pair]_i\) is executed, agents should not only inform their members the possible results, may also inform some information that the replan can not be fulfilled or is relevant and so on[10]. The actions of the team action \([Re\ pair]_i\) are depended on the actual usage background. If it is activated by relative conditions, then the replan methods relative to actual knowledge should be
activated; or if it is caused by the unsatisfaction from the supervision restrain conditions, then the coordination model will analyze the reasons. If the failure to satisfy the supervision restrain condition is caused by the failure of some key actions, then the replan action will be realized by the team reorganization, that is to replace this key action by an agent or agent’s subclass in the team. The detail progresses will be showed as following:

To confirm the agent or agent’s subclass that will carry out action replacement: that is to say, according to specific field knowledge, each agent should mate the ability of itself, the other agents or agents’ subclasses with the demand of this key action, to confirm who is going to take the action replacement.

To check the combat questions among the key promises: once an agent is confirmed to be the candidate for the action replacement, then it will check the combat questions between this candidate executing this action and the promises that the candidate made to the team recently; if these promises are very important, then this candidate will be given up.

To inform the other agents of the team about the information of action replacement: and the candidate who is not given up in the step 2 can realize the action replacement. It can be the agent that applies for the action replacement, or one of the agent’s subclass that confirmed by the command decision agent.

Because Re\[pair\] is a set of actions, it will inform this information to other agent of this team, when the action replacement is finished.

Delete all the unnecessary promises: after the single agent or the agent’s subclass has finished the action replacement, it will delete all the former positions and promises.

If the reason for the failure to satisfy action restrain conditions is that all the subclass actions are not realized, that is to say, all the action execution of the subordinate agent are failure, then, this situation is unrepairable. Besides, if there is not agent or agent’s subclass suitable for the replacement for the key action, during the course of replay in the team, then the Re\[pair\] itself can not be finished. Thus, these two situations will lead to the failure of the OP, which will activate the failure of action class execution. Through this action, the coordination model can avoid the execution false happened before the negotiation between the agents in the team and other agents.

5. Conclusion

It is difficult for traditional combat simulation models to depict the complex situation variation of battlefield and the dynamics mechanism of it. The modeling and simulation method, based on PGP and the tactical decision-making structure, makes use of Coordination Matrix and multi-agent to achieve cooperation among the entities in TDMS and offer a new consideration of combat simulation research. On this basis, we can build action model based on action base and propose its algorithmic in a further step according to the task hierarchical structure. Besides, we can also compose the tactical decision-making system structure provided with coordination function.

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