

# Research on UAV Flight Dynamic Simulation Model Based on Multi-Agent

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**Abstract**—Simulation technology has been more and more important in the military weapon system. Simulation system has important research and application value. Flying simulation technology plays an important role in design and training period in the UAV (unmanned aerial vehicle) system. The multi-agent and object-oriented technology is adopted in the designing of the UAV flying simulator. The flying simulation system is established through three-layer framework which is based on delamination and modularization method. The delamination and modularization method can provide us a new idea in designing of the high efficiency simulator.

**Index Terms**— Flight simulation; Multi-agent; Simulation system; Modularization

## I. INTRODUCTION

Flight simulation is concerned on the kinetic state of the aircraft, so we should propose the mathematical model based on flight mechanics, aerodynamic elements and flight control theory, and then conduct simulation experiments and perform the analysis of experiment results. Flight simulation is an integrate process based on simulation model, the character and moment law of aircraft [1]. Multi-agent technology is often adopted in system with complex aerodynamic characters, e.g., the formation of the aircraft flight. We can apply the multi-agent as reference in the designing work of the UAV flight simulation system, as UAV system is the complex system and it can be looked as the action platform, it also can be a reconnaissance or attack cell in the air. UAV system includes many sub-systems, each sub-system involves many modules. So the researching work of the flight simulation technology and applying other field technology have important values, as known that the multi-agent technology and combination module design could offer us the new idea in the design of UAV flight simulation system.

## II. MUTLI-AGENT SIMULATION TECHNOLOGY

Now the object-oriented simulation technology is the mainstream technology in simulation field, object-oriented simulation adopts object-oriented modeling method, it consider the external world is consisted of different objects, this method can not only accord with the human thinking mode, but also it has characteristics

of abstract, encapsulation, initiate and multi-state, so the object-oriented technology has advantages of modularize, repeat utilize, maintenance and flexible [2]. In practical application, one system could have many agents which have complicated dynamic characters; one agent can have manifold coupling relationships with each other. The flight simulation system may have many agent modules, but the object-oriented simulation technology could not solve the problem of self-check and preview with each subsystem, compared with tradition simulation technology, the agent-oriented simulation technology have many advantages in modeling, e.g., easily, flexible, inherit and hierarchical.

So we could apply the multi-agent technology in UAV flight simulation field, the flight simulation system is composed of many complicated sub-systems, each sub-system involves many modules, one module could be considered as one agent, one agent has complicated coupling relationships with the other agents under definite restrict condition, one agent will be transformed when other agents are changed, there exists some conflicts between each agent, so the related research will do the benefit to the researching work of multi-agent technology in heighten its effectively.

## III. DESIGN OF UAV FLIGHT DYNAMIC COMBINATION SIMULATION MODEL

Modern simulation technology can be divided into three parts, system modeling, simulation modeling and simulation experiments. In the model aspect, the object-oriented modeling method can describe the abstract mathematics model in naturally style, it also can carry out that model's action through assembling and utilizing class libraries; in the modeling aspect, it adopts apart method in model and experiment, namely the data drive model; in the aspect of experiment, it adopts apart method in simulation operation control and experiment framework, it separates the output model definition and simulation model [3]. Agent is a new designing method in software system [4]. Despite now the agent is used in different fields such as computer science and artificial intelligence field, but the basic function of agent exchanges information from environments and receives outside useful information. As the specifically technique adopted in the information, one agent can be considered as a black box, multi-agent is an independent entity, which

perceives the outside environment according to their own knowledge, ability and faith by themselves, and judgment of its target will affect other agent, one agent can accomplish the complicated task or acquire knowledge from outside environment through working together with others. Agent has the characteristics of independent, reactive, study, initiative, sociality, etc.

It is known that agent has the ability of encapsulation thinking and decision-making ability; therefore it can incarnate the independent of system. The framework of agent is to describe the process from abstract rule to idiographic realization, it is a different describing framework of arrangement for function system, and they are corresponding to different framework of implement arrangement. The work of these aspects includes how to make the system satisfy with each identity which is put forward by experts, the structure of software and hardware framework are perfect, and we should compartmentalize target of the agent according to the structure, agent generally includes cognitive agent, response agent and composite agent[5].

The cognitive agent can realize agent's represent and ratiocination through artificial intelligence (AI) method and expression by applying knowledge. Agent have the ability of cooperation, intelligence and consciousness, it can express inner word model and have definite immaterial state by symbol ratiocination and modify, this mode agent is composed of world model and layout equipment. One basic suppose is to module the cognitive module and research cognitive function in partial, and then combine them to make up of cognitive agent.

The response agent depends upon symbol express but export action is based on input, response agent is simply and it responses by inspirit from outside, which does not have model expression by symbol and complicated symbol ratiocination. Agent can analyze as human being, the behavior of agent can only be incarnated from communication with real world and the outside environment. The brainpower is depend on apperceive and action. Response agent could solve problem with high efficiency but its structure is very simple.

Composite agent has the advantages of the cognitive agent and response agent, which has strongly flexible and quickly response, composite system usually design two or more than two layers framework, the high layer is a cognitive layer which includes symbol world model, it performs the design of layout and decision-making by applying traditional method with symbol style, the low layer is an response layer which could quickly response and deal with paroxysmal matter, this layer does not adopt symbol expression and reasoning system. Response layer often has high preference, when it adopts delamination structure, and the problems should be solved are the control framework and the communicate mechanism of each layer.

## VI. DESIGN OF UAV DYNAMIC SIMULATION MODELING

### A. Analysis of Simulation Object

UAV flight simulation system adopts the design of flight control law and it is one part of the training system. The fidelity of the training system and the control law design are determined by the fidelity of simulation system. So the fidelity of simulation system is very important, the analysis of structure and function of UAV system are necessary. The flight simulation system is based on accurate model, which should reflect the essence of system.

UAV system can be divided into three parts in general, ground system, airplane system and task system. The structure of the system is shown as Fig.1, ground system involves ground assistant system, ground control system, flight and land system in ground station, telecontrol and distance sensing system in ground station; airplane system involves aircraft platform, propulsion system, flight control system, navigation system, take off/landing system of aircraft, telecontrol and distance sensing system of aircraft; task load is the task equipment in the aircraft, which can accomplish specifically assignment, e.g. recon task or attack.

The flight simulation system design in the paper is mainly used for self-contained training system. So we can take the task equipment in aircraft as one module. This module is to accomplish the simulation function of the task equipment in aircraft, namely to achieve the simulation function of recon equipment or attack equipment in the aircraft.

Aircraft system and ground control station communicates through the UAV data-link, which is consisted of telecontrol and remote sensing system in aircraft and ground station. UAV data-link takes charge of communication for instruction, in addition the maintenance personnel is one part of the UAV system which is not lacked, so it should consider the human factor in the design, research and employ process of the UAV system, the aircraft system of UAV can be divided into some independence objects, and the each object should be modeled.

### B. Design Project of the UAV Simulation System

#### • Ideology of the system design

In the object-oriented simulation technology, the external world can be taken as be composed by different objects which affects each other, the describing of the problem is according to the solving method of the problem, which can be easily understood, it is better to solve the reliability, accuracy and flexible for the model, the connection of UAV each subsystem is according to the designing demand and based on software develop theory, then adopt with multi-agent system and module idea by object-oriented technique to put forward a module and hiberarchy framework, take the multi-agent technology into the UAV flight simulation system's design process, so it could accomplish adaptability, fidelity and intelligence, the flow chart of designing idea is shown as Fig.2.

Step1: Make research on the function of the system, analyzes structure and framework of the system, then

make out the noumenon structure and function module by reasonable based on the demand of simulation system, and then set up the framework.

Step2: Choose whole saved or predigest management for the system, make the appropriate management according to the function or task requirement, some unimportant modules should be neglected or predigested and then make the research of important module.

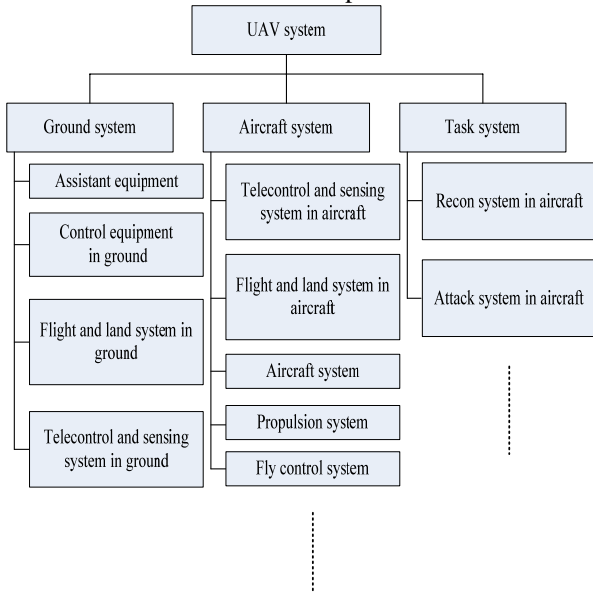


Fig.1 Structure of UAV system

Step3: Mark off the design of subsystem and module model arithmetic, this step is the core of the system design, in order to get the module's framework and operation mechanism of each subsystem, the implement method of every idiographic module. Design corresponding algorithm of the each module, and make them satisfy with the demand of system performance and function.

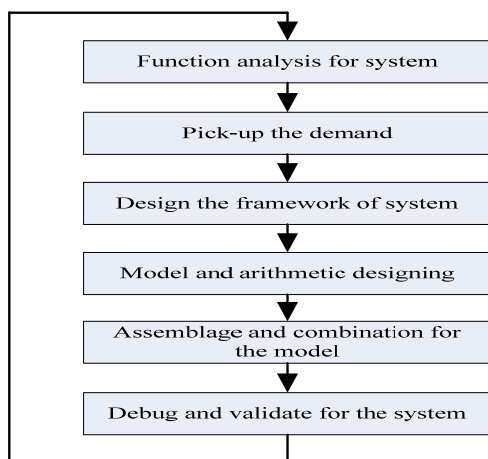


Fig.2 Design process of the simulation system

Step4: Assemble each module and debug the whole system, apply the every function module in the combination of subsystem, and actualize the whole function for the UAV simulation system, which is based on structure of framework, lastly make the analysis of the simulation results and demand design of the system, through the related simulation system, we optimize

framework and model algorithm, finally achieve the optimized function of the whole system. As to some tune UAV system implement part, it is the integrative cooperation model for multi-agent, which has accurately control, because the control of UAV involves aircraft attitude control, flight path control and task equipment control. There exists a coupling relationship between them.

Flight dynamic simulation model subsystem, it can be considered as operation part of the simulation system, some aircraft body part includes the aircraft physical body or function module, its intelligence is between flight computer model subsystem and task control system, it can drive each model module based on real data flow and then make each agent operate.

• **Subsystem Agent design**

UAV flight simulation system could be divided into three subsystems; each subsystem is composed of some different agents, according to function partition and cooperation of each agent, and performs the subsystem function.

Flight control computer subsystem, it mainly involves four agents, telecontrol order receive agent, distance sensing agent, task programming agent and flight management agent. Flight control computer subsystem has self-control ability, the structure of this subsystem adopts cognitive agent or composite agent, and then combine correlative algorithm. The framework of flight control computer subsystem is shown as Fig.4.

1. Receive agent of telecontrol order

Through decode ground telecontrol order (e.g., flight control order or task equipment control order) and translate the received order to switch order signal or continuous order signal, then put this signal into the UAV automatic device or task implement equipment, according to control the flight attitude or task equipment.

2. Send agent of distance sensing information

It adopts various sensor or convertor, in decoding multi-signal (includes UAV dynamic state information or task equipment state information) based on distance sensing decode format through the data link. Ground station can display the flight state parameters and recon the information.

3. Assignment agent of task programming and resource

Task programming needs entireness task order, and the analysis of implement target task, and it need ensure each target location, program of each task, create task queue, and then according to the results of flight path programming and the information synergetic result, it picks up information from task queue and make the whole flight programming combine with flight programming, after the flying of the UAV, it can collect the environment, state information and request by other agent in real time. When program the flight path, it should modify in real time; the resource assignment manages the whole resource for the system, the whole agents are in a dynamic environment, they collaborate with each other. This part could organize system's task and distribute resource for each resource, which could

assign resource by maximum, and then avoid conflict of software and hardware resource.

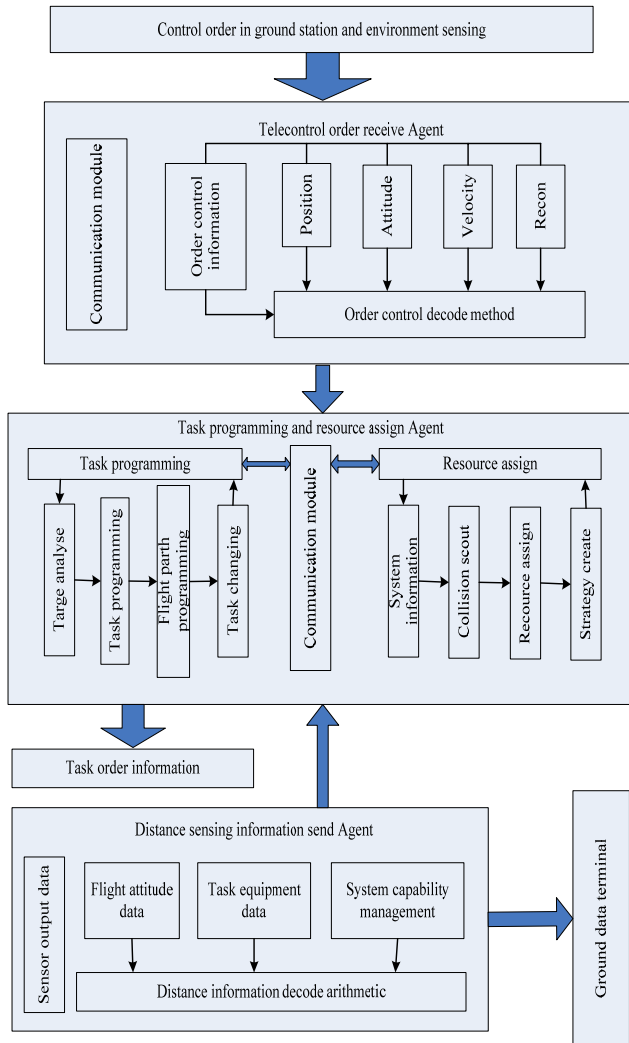


Fig.4 Flight control subsystem

4. Agent of flight management

Flight manage agent is a complicated agent, it mainly takes charge of tactical task, flight data management could manage expert knowledge in flight control field, which could improve navigation capability by itself.

• Control and implement subsystem

It mainly includes three agents, i.e., flight path track agent, flight attitude control agent and independence navigation agent, its structure is shown as Fig.5, they are group response agents, it control the flight attitude through drive aircraft rudder, the subsystems have generally characteristics such as cooperation, work together and achieve flight control under task decision-making.

Flight path track agent is a response agent who is based on control device, it integrate flight path track algorithm inside and could transform the control order to flight order or propulsion force, control flight attitude agent, and then control UAV to fly in the set path.

Flight attitude control agent is a response agent who based on control agent. It integrates flight attitude control

arithmetic inside and export real time rudder running order, then control the flight attitude of UAV.

Independence navigation agent is a response agent which is based on control device, it can receive the UAV current position by GPS or inertia navigation information, and measure the error of current flight path, compute flight path, and it can cooperate with flight path track agent and flight attitude control agent make the UAV flight in the set flight path.

1. Flight dynamic combination simulation model

It mainly includes four agents, flight mode switch agent, environment apperceive agent, aircraft task mode agent, aircraft mobile decision-marking mode. The intelligence of this model is in middle of system, it mainly achieved each agent harmonious operation, and the structure of flight dynamic combined simulation model is shown as Fig.6.

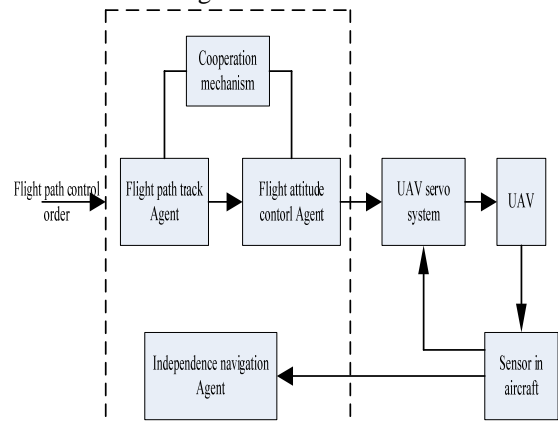


Fig.5 Nontrol implement subsystem

2. Agent of flight mode switch

Firstly, it receive the control mode signal from the flight operator, there are three flight operate modes, telecontrol mode, program control mode and independent control mode. When it selects the independent control mode, if the current state of UAV is out of control from the ground operator, it will be turned into independence executive task state, i.e., the state of take off, callback, landing, motion and mode of instancy flight operation, etc.

3. Module agent of environment apperceive

Environment apperceive agent module is mainly to scout enemy region information based on the sensor in aircraft and its recon or communication system, includes radar, data link, GPS navigation information, vision sensor information and so on. It can pick-up the useful information from abundant uncertain information, then distribute useful information to other agent.

4. Module agent of aircraft task

Aircraft task Mode agent mainly involves aircraft aerodynamic kinematics equation module and task in aircraft module. Aircraft aerodynamic kinematics equation module is the core of system. After calculate out the flight path parameters, It offer the flight attitude parameters to the system, in this module, it integrates every force and moment, compute velocity and angle speed in aircraft coordinate, using integral operation to compute

synthetical velocity. Task of aircraft module is mainly to achieve the task equipment in aircraft fidelity simulate working. Control work of flight attitude control and task equipment control are not isolated and there exists coupling relationships between them.

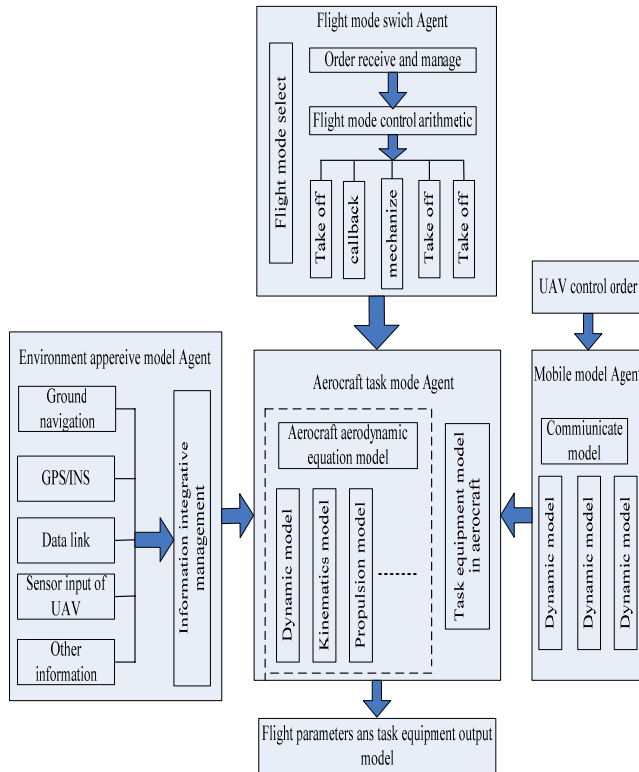


Fig.6 Subsystem of dynamic simulation model

5. Module agent of Aircraft movement decision-making

If we take the UAV formation in the future into account, the system should also be added in the decision-making module, when UAV is flying to the target, it can analyze the received data in time, then obtain the information of enemy firepower threaten, position threaten, landform threaten and so on. It can choose the relevant movement from movement database which can avoid threaten or transmit radar information and visual sensor information to aircraft's sensor, after veracious recognize enemy or ourselves, it can rapid locked the object and independent accomplish the recon task or attack task with high efficiency.

C. Communication and Cooperation Mechanism between Subsystem

Multi-agent communication mechanism plays an important role in multi-agent system. Each agent transmits complicated semantic information in time and ensure the system works effectively, when multi-agent system works in distributing mode, how to realize the multi-agent communicate and collaboration are very important in the whole system, it adopts transfer information mode in distributing multi-agent system and adopts synchrony time mode to realize control event synchronization. The semantic message is the core in the solving distributed problem. In the information mode, one

agent could inform other agent when the event will happen or inquire agent information from other agent. Multi-agent communication mechanism not only has sociality characteristic as the person but also it can distinguish the traditional intelligent system and multi-agent system. Rational and finish intercommunion mechanism are the base of multi-agent system collaboration and arrangement, so the communication is the basic problem in multi-agent system.

• Multi-agent communication mode

Multi-Agent system communication mode always includes two kinds, blackboard mode and message mode [6]. Blackboard mode always make use of sharing data region or database who named blackboard with shareware memorizer, it exchanges message and data between different agents, which has characteristics of speediness and high efficiency, but it make against distributing control mode. Message mode is the direct communication mode for each agent who utilizes protocol; establish communication and cooperation mechanism based on message exchange between different agents. It can realize flexible and complicated strategy. In the message mode, agent communication language is used for message and knowledge exchanging. Agent communication language (ACL) usually generally includes three parts, external language, inner language and noumenon. External language define the meaning of message, inner language is used to express faith, desire and purpose, noumenon and it offer the related vocabulary[7].

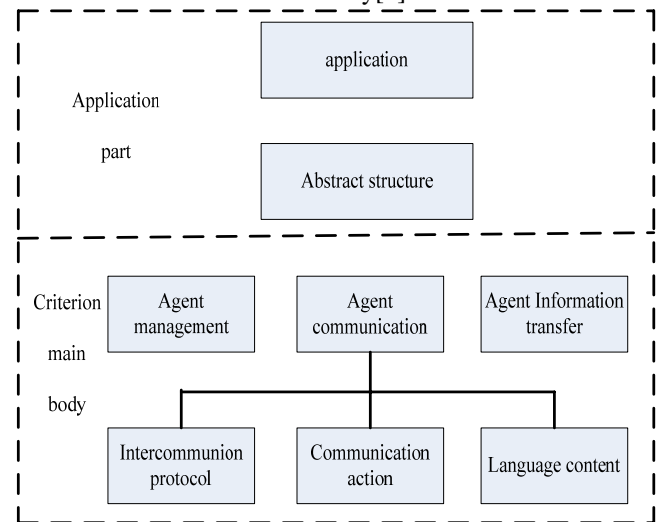


Fig.7 Frame structure of criterion gather for system FEPA

There are two kinds agent communication language, KQML and FIPA-ACL. In FIPA standard, the basic cell for the agent communication is FIPA-ACL message, generally one FIPA-ACL message include five elements, communication behavior type, communication actor, content of message, description of content and dialog control. As to these elements the communication behavior type is prerequisite element, the message sender, the message accepter and the content of message are the main contents. FIPA communicate actor is based on theory of language and action, which can carry out physical action. The corresponding actor involves

message sender, message accepter and revert object of message, there exists relationships between the current environment state and message accepter, it not only can accept request action, but also can refuse it, the message sender only can ensure send the message correctly.

Message content express refer content language, code and ontology. Content language is to show the message content which using formalize semantic description. FIPA offers optional semantic language, if both side of communication system know the current content language; the item can be passed over. Semanteme is expressed by semantic language and allow show the faith, desire and intent for one agent. Agent communication implies notion is one part the communication. The same notion may be described by using different language, communication needs ontology, the function of ontology is like vocabulary, which takes charge to explain the ontology, namely that correspond this ontology to popular meaning. Ontology makes up of expert knowledge database in flight control field, and it could make the agent comprehend by another in the communicate process.

• **Multi-agent cooperation mechanism**

Agent communication can promote multi-agent harmony and collaboration, it is an important characteristic of multi-agent and it is one another operation. The process of the intercommunion, this intercourse is called positive intercommunion, which is as in the person of agent synergic course; there exists influencing intercourse which is called conflict, the concerted process of multi-agent can be regarded as conflict avoid process, because every conflict reason is different, so the method to solve this problem is different, in the environment of multi-agent system, conflict could be considered as the contradiction of target, faith, purpose between different agent, there are much associated method to distinguish conflict, which can be separated into several types[7]:

Cognitive conflicts because of agent have different skill or knowledge background; there have existing different faith, knowledge, attitude, which can be considered as the cognitive conflict. Behavior conflict one member's behavior could result in others member could not run. In the result conflict, when the colony member is working, contrapose one problem each subsystem maybe obtain the different conclusion. In the target conflict, one member achieved the target result in the other could not achieved that target. In the resource conflict, when colony member use same resource at one time, the system could not satisfy the demand at this time, so it will bring on this member scramble for the same resource.

Though the conflict representation is different, but we could manage the conflict action and make the multi-agent behavior toward the same target, because of each agent in multi-agent system have independence, which appear conflict according to their purpose and ability in calculation process, so it should be correspond, concerted problem which are to manage inner depend on relationships between different agents, if there exists

mutual action agent action, the concerted mechanism is needed.

Multi-agent system concerted method can be separated into showing concerted method and concealed method. Showing concerted is that the agent is designed to ratiocination for intercommunion and could consult with other agents if necessary, this method has clear and direct mechanism, when agent action is not consistent, it could adopt it to solve the problem. However this concerted method needs enough time for sustain, it is not applicable in some dynamic and real time environment; concealed method is the agent which is designed to follow some action rule in part.

• **Cooperation mechanism of subsystem Agent**

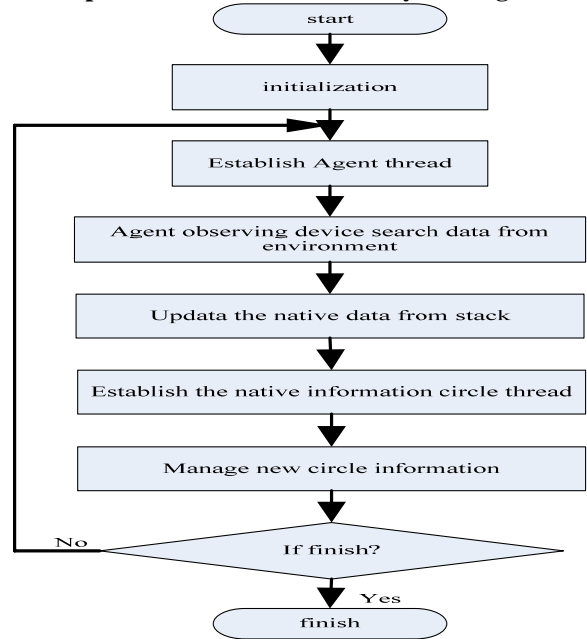


Fig. 8 Data active flow chart of each subsystem Agent

In the paper, it mainly studies on flight simulation system. The simulation system is face to signal personal computer, so it adopts windows operating system to establish the simulation software. Therefore, subject design of multi-agent system mostly complete the data in real time and it is based on windows operating system. The communication between process and inside process, in the communication process it adopts share memory pool mode, the inside communication process adopts thread synchronous mode. They can accomplish real time communication of inside process by share memory pool and thread synchronization [7]. The working step of each subsystem is as follows: 1)Initialize construct function, accomplish agent register, make message distributing; 2)Start message working process; 3)Observed register message, take out data from environment, then activate the message thread, at that time message thread pop-up message and transfer call-back function, it's working flow chart is showing as Fig.8.

The member of each UAV subsystem of agent template class includes the environment name, the environment crunode name and agent name. The member function mainly includes, initialization, bespeak, simple

call-back function and complicated call-back function. Observe and message manage thread implement by operation environment. When we empolder subsystem agent, only need to achieve member function in template.

UAV subsystem agent sort and layer are different, the concerted action between them need to be analyzed based on different layer and grade, as to different grade agent, when superior agent concerted with inferior agent, it adopts command, the inferior agent must perform the order by superior agent, then return the executive result to the superior agent; it adopts advice between the same level agent, the other side can evaluate this advice, then it can accept or refuse this advice based on actual status[8].

UAV flight simulation system based on multi-agent which can be divided into some autonomic agent, each subsystem have relative independence, when it perform local simulations, it may bring the confliction, so it should correspond with the decision-making of each agent and avoid conflicts, and make each unattached agent toward the same direction, then it will accomplish the holistic function of flight simulation system [9-15].

V. CONCLUSION

Multi-agent technology is a new researching direction of computer science and artificial intelligence(AI), which have a wide foreground, construct logical agent can fall down the complicated system, and improve the efficiency of system, the flight simulation system based on multi-agent and modularize idea can not only satisfy the independence, real time and information distributing of the simulation system, but also can expand the system function by maximum, fall down complexity of the system and heighten the efficiency of system. Contrast with tradition flight simulation system, the flight simulation system based on multi-agent could achieve self-control and intelligence to certain extent, which have large potential in opening and modularization aspect, and it is the develop direction of the flight simulation system.

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