

# Product Conceptual Design Based on Agent Federation

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**Abstract.** A cooperative Agent Federation was used in the complicated products conceptual design after studying the characteristics of the conceptual design. Each Agent Federation designed products cooperatively under the control of the chief Agent Federation. Thus, the mapping of 'function- behaviour -structure' was achieved, and the whole process of the conceptual design was accomplished. The functions, communications, cooperation and the theories about running of the key Agent Federation were discussed, and the frame of the conceptual design based on cooperative Agent Federation and work group was established in this paper.

## 1. Introduction

Conceptual design is the most creative section of the whole design process. Compared with other phases, this phase occupies so less resource that belongs to the low cost part but which will decide the most costs of the product's whole life cycle [1]. It is not easy to get a reasonable scheme for complex product conceptual design that just rely on a single designer, so the conceptual design is the process of group cooperation [2-3]. Due to multi-agent having the advantages of obvious stability, high efficiency, dynamic adaptability and easy realization [4], it has been applied in many fields, such as collaborative design, manufacturing, communication, medical treatment, management, etc. Wenxian Tang from Shanghai University [5], Qianfan Zhang from Hua zhong University of Science and Technology [6], Gek Woo Tan [7] and other researchers have researched cooperation design technology [8] and framework of multi-agent [9-10]. Facing the conceptual design of complex product, the above-mentioned pure distributed Agent structure will confront with complicated control, communication complex, difficult to coordination and other disadvantages.

According to the characteristics of complex product conceptual design and the structure of the pure distributed agent, this paper proposes agent federation-based conceptual design on the basis of previous studies, and it will overcome the drawback of pure distributed Agent structure and solve the coordination problem in conceptual design.

## 2. Conceptual Design

### 2.1. The Definition and Characteristic of Conceptual Design

Conceptual design has many definitions from different angles, two present authoritative definitions as: in Engineering Design, G Pahl and W.Beitz [11]defined it as "After the mission determined, through abstraction propose function structure and seek appropriate action principle and their assemblies, etc., then determine the basic solving approach, last get the solving scheme, all these designing working is called conceptual Design." M. J.Frence [12]defined conceptual design in Conceptual Design for Engineers as "Conceptual Design is a design phase that need consider the content of the design problem and put forward a variety of solutions."



Conceptual design has many characteristics, such as innovation, diversity, hierarchy, disability and so on [13-14].

*Innovation:* Innovation is the “soul” of conceptual design, include modify and innovate function structure and other things.

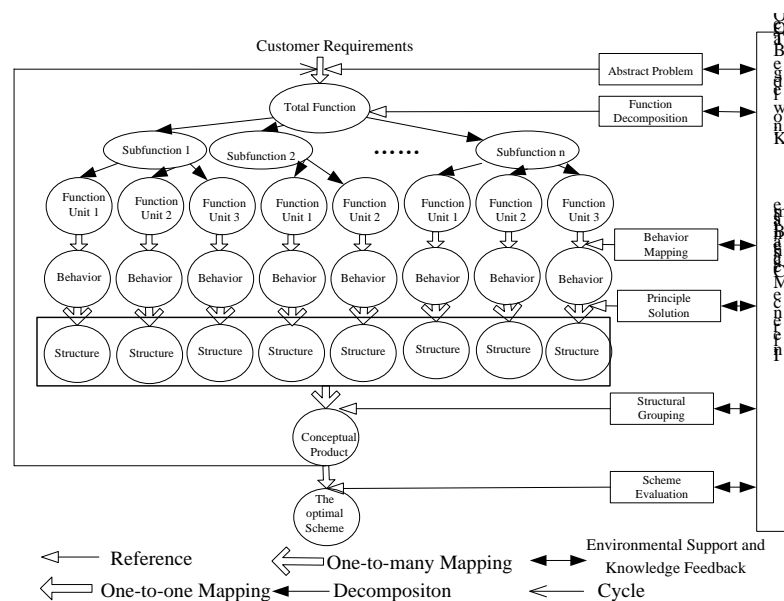
*Diversity:* The diversity in conceptual design refers to the designing path and result.

*Hierarchy:* The process of conceptual design is divided into function layer, behavior layer and structure layer, each layer also has hierarchy.

*Disability:* This characteristic mainly reflects in the acquired product information is qualitative, inaccuracy, inconclusive and incomplete.

## 2.2. The Process of Conceptual Design

Found and satisfied the requirements are the starting point and ending result of product design. The task of conceptual design is to satisfy the market demand, and the creative and conception are also coming from the understanding of market demand [15-17]. So the first step of conceptual design is to investigate and analyse the market demand and establish demand assemble. Based on previous knowledge and experience, analyse and abstract the demand, then get the exact product global function. Decomposition the global function into exhaustive function unit, make the function unit mapping to behaviour. As for using different structures will achieve the same behaviour movement, according to some regular, combining those structures to get conceptual product family which can achieve global function. Finally evaluate the conceptual product family and get the optimal conceptual product scheme. The layer structure and process of product conceptual design as shown in Figure 1.



**Figure 1.** The layer structure and process of product conceptual design

## 3. The Conceptual Design Frame of Agent Federation

The Agent Federation includes many sub-agents and mediators, mediator harmonize the behaviour of Agent in Agent Federation and communicate and cooperate with other Agent. According to the process of conceptual design mentioned in chapter 1.2, the system adopts five Agent Federation and blackboard structures. The five Agent Federations are: global control Agent Federation, function analysis Agent Federation, substructure design Agent Federation, product design Agent Federation and domain service Agent Federation.

The function of global control Agent Federation is to distribute tasks and resources, cooperate with each Agent Federation behavior, and interact with information between systems and outside and so on.

The function of function analysis Agent Federation is abstract the total function and decompose it into function unit.

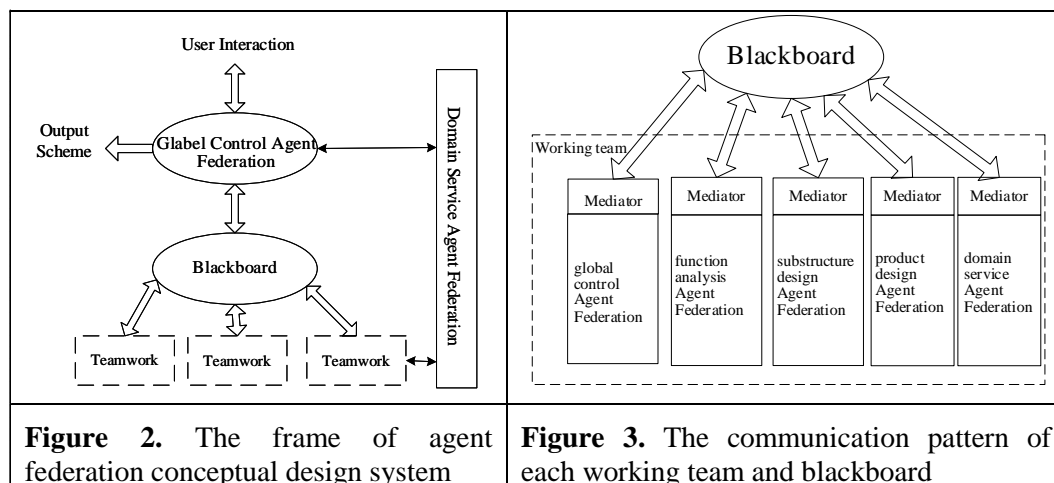
Substructure design Agent Federation is the core of the system; the process “function- behavior-structure” can be completed. According to the conceptual design process, the substructure design Agent Federation mainly including: principle of function unit analysis Agent, behavior map Agent, principle solve Agent.

The function of product design Agent Federation is to form the conceptual product and get the optimal scheme, mainly including: structure composes Agent, scheme evaluates Agent, and scheme saves Agent.

The function of domain service Agent Federation is to provide a variety of tools, knowledge and examples to support the designing smoothly.

The blackboard is system for each Agent Federation communicating to share storage. There four regions: public region and every exclusive region, public region decomposed to information release area, conflict coordination scheme area, cooperative scheme area and problem area, exclusive region on the basis of team is divided to several conceptual spaces.

If there are multiple products simultaneously concept design, each Agent Federation of the product design will compose to Teamwork, the Agent Federation served as collaboration. The System frame is shown in Figure2, the communication pattern of Teamwork and blackboard is shown in Figure 3, and the structure of blackboard is shown in Figure 5.

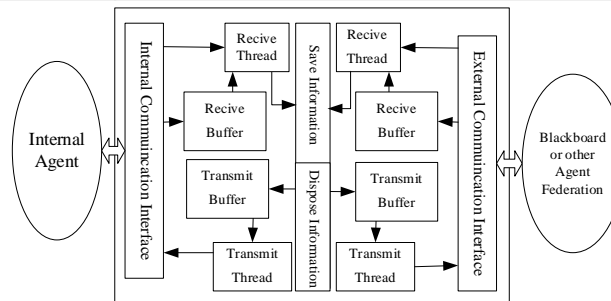
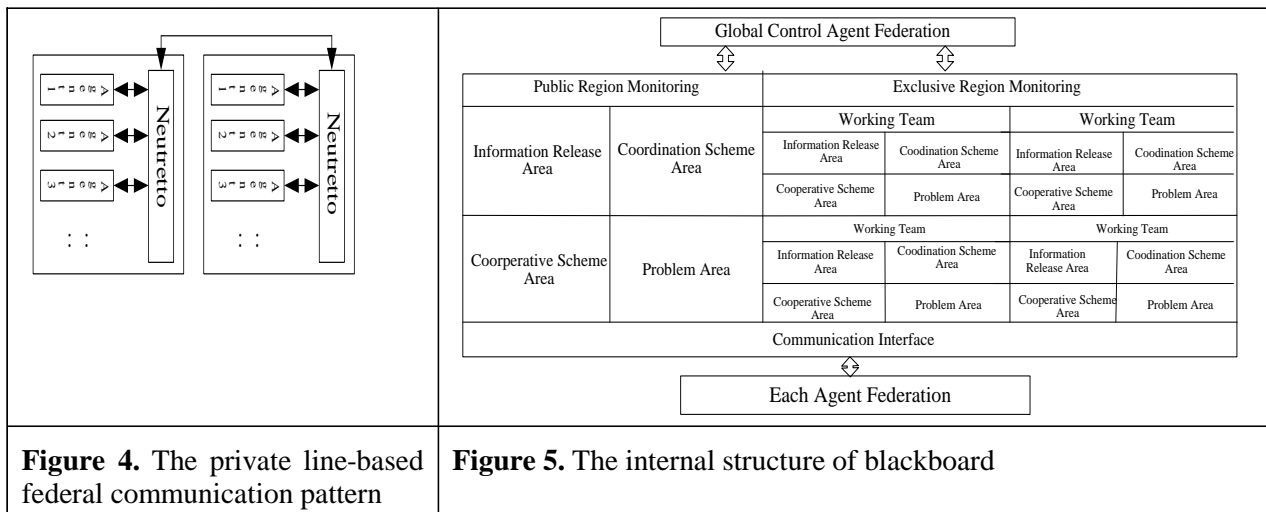


#### 4. The Agent Federation Cooperation in Conceptual Design

##### 4.1. The Agent Federation Communication

The Agent Federation communication has two communications: one communication is in federation interior, another communication is between federations, they all adopt hybrid communication. One communication method is adopted by “Private line”, that means only by calling and called process can see the communication information (Figure 4 is the private line-based federal communication pattern). Another method is blackboard-based communication which divided into public region and exclusive region, according to working nature, the exclusive region will be divided into several conceptual regions, each Agent Federation in teamwork only pay attention to the regions that related to itself (Figure 5 is the structure of blackboard).

All the Agent in federation communicate with mediator through the mediator coordinate the behavior between internal Agent, the mediator stand the federation communicate and coordinate with outside. The structure of mediator communication interface system in this paper is as shown in Figure 6, the information processing module make evaluation and analysis for received information, coordinate internal Agent or release the result.



**Figure 6.** The structure of mediator communication interface

#### 4.2. The Agent Federation cooperation

When make conceptual design for complex product, it is impossible for any single Agent or Agent Federation to accomplish, it need the cooperation between Agents. The constructed Agent Federation system (shown in figure 2, 3) can classify the cooperation in conceptual design into cooperation between teams, cooperation between internal Agent Federations and cooperation between Agent Federation's Agents. Cooperation and competition are two behaviors in the process of cooperation. Competition occurs mainly between isomorphism Agent Federation, such as substructure design between Federations is interested in the same task, and then they will compete. Otherwise, heterogeneous Agents have different functions, so there is no competition between them, such as there is no competition between substructure design Agent Federation and functional analysis Agent Federation.

The process of cooperation includes three steps: (1) Determine goals; (2) Seek for cooperation company and confirm the cooperation scheme; (3) Achieve the goals.

The goal of cooperation includes two parts: Mission object, namely the work to be done; and function object, namely the constraints and requirements in the process of cooperation. The general task object is to get the optimal scheme of product design, specific Agent Federation has specific submission objectives. The function object includes the ability the Agent Federation design, resources conditions, constraints in designing requirements and so on. Global-control Agent Federation will realize the general task aim and bring about the subtask aim determine.

After determining the design aim, the next step is to seek cooperation partner and determine the cooperation scheme. The process of seeking cooperation partner is equal to the process of determining the cooperation scheme and distributing the task. Distribute the task in this way need to make effectiveness evaluation for the bidding Agent Federation, and choose the most effective Agent Federation or teamwork to cooperate. We can assume  $U(t_i)$  is the effect of finished task  $t_i$ , so the formula  $U(t_i)$  can be shown as following:

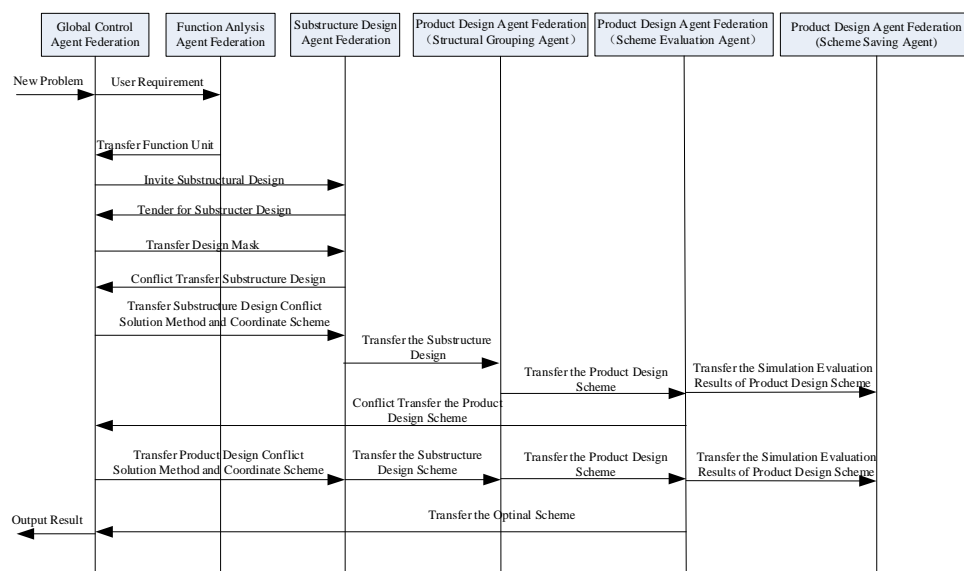
$$U(t_i) = \alpha T_i + \beta M_i + \gamma C_i + \lambda B_i + \nu O_i \quad (1)$$

$T_i$  stand the time for finishing task  $t_i$ ,  $M_i$  stand the quality of finishing task  $t_i$ ,  $C_i$  stand the cost of finishing task  $t_i$ , namely occupy resources,  $B_i$  stand busy idle state,  $O_i$  stand conflict situation happened between  $t_i$  and dealing  $t_i$ .  $\alpha, \beta, \gamma, \lambda, \nu$  is the weights of  $T_i, M_i, C_i, B_i, O_i$ . Global control Agent Federation through blackboard bidding, task distribution, supervise and cooperate the behavior of Agent Federation.

After determined the cooperation scheme, under the supervision and coordinate of global control Agent Federation, each designing Agent Federation will mutual response, fulfil the promise, and meet the corresponding constraint in collaboration process, and achieve the goal together.

### 5. The Operation Mechanism of Agent Federation Conceptual Design

System operation mechanism is as show in Figure 7. It uses man-machine interaction of the global control Agent Federation to input new problem, function analysis Agent Federation and make function abstract and decomposition, the global control Agent Federation according the function unit to invite. Evaluate each bidding substructure designing Agent Federation, distribute tasks to the winning federal and sign the contract. Substructure design Agent Federal enforce the contract, when the structures of federal designing encounter conflicts, the solving scheme from global control Agent Federation will be feedback to each Federation until the conflict solved. After finishing the substructure designing, structure composite to Agent and compose twice in product designing Agent Federation. By Agent product design evaluation in the federal Agent to evaluate product solutions, when the product can't meet the designing constraints, it will conflict. Transfer the conflict to blackboard, the global control Agent Federation will propose solutions, according to the solutions, substructure design Agent will modify the design of the structure or decompose the function, allocate the task and redesign. Repeat these steps until the scheme meet the customer's requirement, and then save the optimal scheme. Finally, the global control Agent Federation will output the result and form to a file or drawings.



**Figure 7.** The operation mechanism of agent federation conceptual design

### 6. Conclusion

With the development of Internet technology, artificial intelligence and other technology, multi-agent has been widely applied in many fields. Based on deep research conceptual design, this paper proposes a conceptual design frame of Agent Federation cooperation. Each agent in the form of distribution

coordinates to finish the conceptual design of product that makes the whole system operability, flexibility and extensibility. Agent Federation-based product conceptual design will reduce the complexity of pure distributed multi-agent communication, practice have been proven that is a good way to solve the problem of complex products' conceptual design, and it is easy to come true.

## 7. Acknowledgments

This work was supported by Postgraduate Research & Practice Innovation Program of Jiangsu Province under Grant number KYCX17\_0532, Sany enterprise special under Grant number XZX/14B001-05 and Guangxi Key Laboratory for manufacturing system and advanced manufacturing technology under Grant number 13-051-09S09.

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