Chapter 91
Multi-Agent Based Architecture Supporting Collaborative Product Lightweight Design

Zheng Liu, Fuyuan Xu, Kai Pan, Xinjian Gu and Yongwei Zhang

Abstract Increasingly notable environmental problems facilitate more and more considerable emphasis all over the world on them that will somewhat effectively be reduced by less utilization of raw materials. Aiming at diminishing using materials and hence resulting in delicate environment, product lightweight design, indirectly promoting economic and social interest, is developed and refined with multi-agent support in this paper. Not only involving in performance parameter designing, such lightweight design also consider environmental influence, manufacturability and maintainability in the product life cycle, therefore being a collaborative design process with multi-objective optimization and iterative repetition. Firstly, multi-agent based architecture supporting collaborative product lightweight design is put forward, including detailed description of structural

Z. Liu (✉) · K. Pan · X. Gu · Y. Zhang
Institute of Modern Manufacturing Engineering, Zhejiang University,
Hangzhou 310027, China
e-mail: athena@zju.edu.cn

K. Pan
e-mail: pankaichn@gmail.com

X. Gu
e-mail: xjgu@zju.edu.cn

Y. Zhang
e-mail: exinanzhizi@sina.com

F. Xu
Business School, University of Shanghai for Science and Technology (USST),
Shanghai 200093, China
e-mail: xufy@usst.edu.cn

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composition. Secondly, the core agent-CAX Agent-is introduced thoroughly. Finally, self-adjusting arm shell, as a case study, is redesigned and implemented with such collaborative architecture to validate the operation process of light-weight design.

Keywords Agent · Multi-agent system · Lightweight design

91.1 Introduction

In the era of rapid technological development and economic globalization leading to severe competition among enterprises, customers claim much more steadfastly for such requirements as due date, quality, cost and individuation. Accordingly, to maintain subsistence and keep competent advantages, enterprises are shifting traditional product developing paradigm, moving away from single consideration on technique requirements such as function and cost to on environmental nature of certain problems [1].

Nowadays, numerous countries place sustainable development on strategic level to decrease consumption of energy to save them, to reduce greenhouse gases that deplete our ozone layer and heat the Earth's atmosphere, and to develop green commerce to protect environment. The strength of lightweight design, diminishing utilization of raw material, perfectly amounts to the target of sustainable development as economic and social benefits are also produced. For example, 10% reduction of the weight of one automobile would correspondingly save 6–8% oil [2].

As a gradual process developing from sketch to detail, product lightweight design not only consider the fundamental performance parameter of a product such as size, intensity, longevity, cost and reliability, but also take into account environmental influence, manufacturability and maintainability, resulting in such characters as high technology, high integration of knowledge, etc. Thus, this design plays significant effect on following process planning, manufacturing, sale and maintenance. Generally, two methods for lightweight design are widely accepted: (1) using the materials with high intensity and low density; (2) optimizing the structure of the parts.

In this research, we propose multi-agent based architecture collaborative product lightweight design to hone cooperative lightweight design. And Sect. 91.2 introduces related work. The generic system architecture supporting collaborative product lightweight and its details are described in Sect. 91.4. Section 91.5 concludes the research and briefly suggests future work.

91.2 Related Work

91.2.1 Agent and Multi-Agent System

Multi-agent system (MAS) represents one of the most promising technological paradigms for the development of open, distributed, cooperative, and intelligent software systems [3, 4]. While no uniform definition of Agent is given, briefly speaking, Agent, with relatively high autonomy, is an entity that operates in dynamic environment and is driven by a target. It has some noticeable characters such as autonomy, social ability, reactivity, pro-activeness, mobility, rationality [5–10]. Since the way agents effectively collaborate with each other is similar to that designers accomplish cooperative lightweight design, multi-agent based lightweight design with excellent superiority transcend traditional design driven by passively knowledge support.

91.2.2 Collaborative Product Lightweight Design Systems

Different geographically location of designers and product cycle reduction in the market gives rise to necessary cooperation of lightweight design with the help of computer technology to enhance the efficiency, performance and economy [11]. Based on finite element analysis (FEA), literature [12–14] research lightweight design methods of coal gondola car, heavy truck compartment, car's engine cover plate respectively. Literature [15] applies FEA to optimize the ribs of car body, resulting in higher rigidity and lower cost.

Furthermore, some dominant CAX software such as Pro/Engineer, SolidWorks provides us fine tools for collaborative design, although they lack integral functions and synchronization. A collaborative CAD system needs two kinds of capabilities and facilities: distribution and collaboration [16]. Hence, multi-agent system serves to realize distributive, parallel and effective lightweight design, also implementing more efficient cooperation than Web and eventually bringing more eminent functions.

91.3 Generic System Architecture Supporting Collaborative Product Lightweight

91.3.1 Generic System Architecture

In the premise of having satisfied essential capabilities of product, multi-agent based collaborative lightweight design includes a group of software agents making joint efforts to achieve as lighter quality and more environmental friendly as

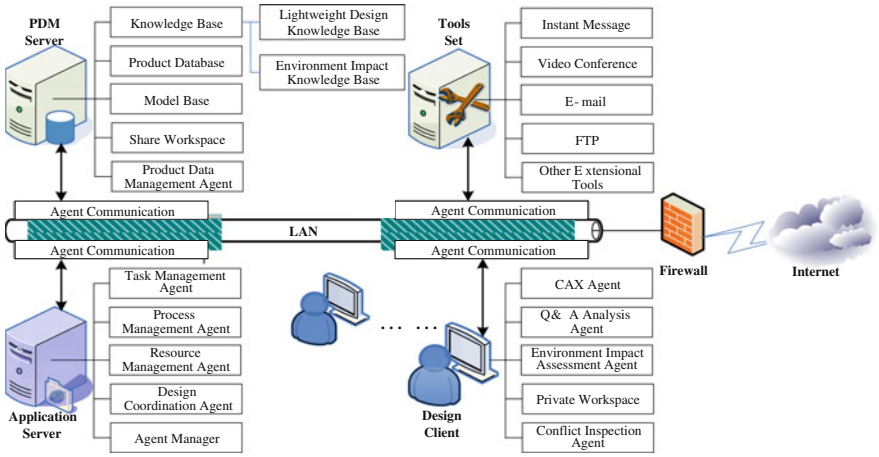

Fig. 91.1 Multi-agent based generic system architecture supporting collaborative product lightweight

possible. Such design, as an intricate process of knowledge discovery, not only demands book learning, but also requires affluent experience and artistry of designers who ought to share and communicate their ideas and knowledge with others to attain the common target.

The multi-agent based generic system architecture supporting collaborative product lightweight is organized as follows, integrating software agents with design tools and designers in an open environment (Fig. 91.1). These agents are Product Data Management Agent, Task Management Agent, Process Management Agent, Resource Management Agent, Design Coordination Agent, CAX Agent, Q&A Analysis Agent, EIA Agent, Conflict Inspection Agent, and Agent Manager while detailed description of them are as follows.

Product Data Management Agent: Managing product information, document and users who should have specific authorization, guaranteeing integrity and logical coherence of data.

Task Management Agent: Dividing complicated tasks into sub-tasks and then rationally assigning them to corresponding designers.

Process Management Agent: Establishing, maintaining and tracking certain task of lightweight design, managing versions of documents in the process of design.

Resource Management Agent: Detecting and managing software and hardware resources in the network nodes.

Design Coordination Agent: Coordinating the design process according to quality & asset assessment, environmental influence assessment and conflict detection results.

CAX Agent: Constituting designing analysis panel to communicate with designers through uniform user interface, providing them the functions of CAD/CAE/CAM/CAPP.

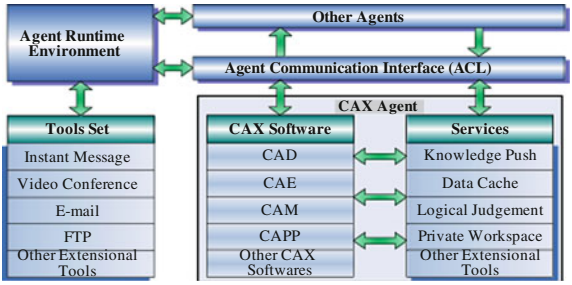

Fig. 91.2 The composition of CAX Agent

Q&A Analysis Agent: Carrying out quality & asset assessment for the results of design.

EIA Agent: Developing environmental influence assessment for the results of design.

Conflict Inspection Agent: Accomplishing conflict detection to help designers solve it with the help of decision knowledge base.

Agent Manager: Managing all the activities of the agents above and utilizing agent negotiation mechanism to uphold their rational, effective, collaborative and timely work.

Connecting with Internet through firewall, LAN serves as a communication channel to connect the entire agents, who could contact with others irrespective of their disparate location, bringing distributive lightweight design into effect. To conveniently allocate and maintain the system, Product Data Management Agent operates in PDM server that is also responsible for managing knowledge base, product database, and model base. Moreover, the knowledge base includes lightweight design knowledge base and environmental influence assessment knowledge base. And Task Management Agent, Process Management Agent, Resource Management Agent, Design Coordination Agent and Agent Manager operate in the Application Server, as CAX Agent, Q&A Analysis Agent, EIA Agent, and Conflict Inspection Agent run in the computer of design client.

91.3.2 CAX Agent

As a key and prominent agent, CAX Agent paramountly assist human designer to develop lightweight design and its composition is shown in Fig. 91.2.

CAX software and some services are integrated and encapsulated in the CAX Agent. On one hand, CAX software carries out lightweight in the design, concerning the effects on mechanics capability, manufacturing and processes. One the other hand, with respect to these services, knowledge push positively provides specific knowledge relating to lightweight to the designers, including the speculative information from knowledge base; data cache help rapidly preread and

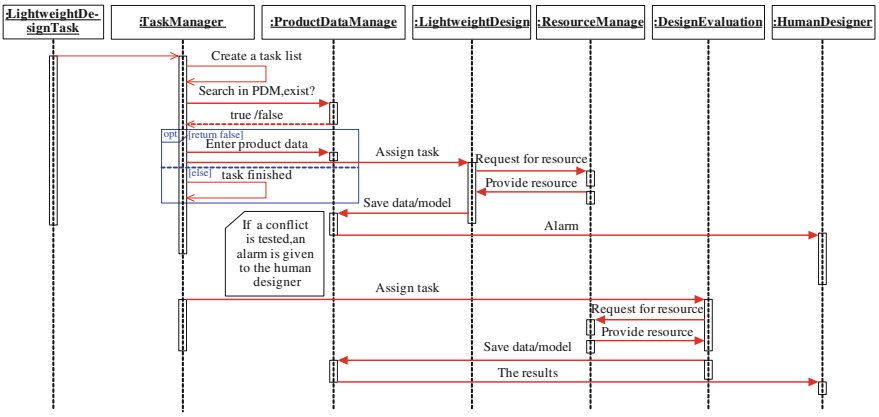

Fig. 91.3 Lightweight design process in the multi-agent system

transitorily store data, therefore promoting the calculation efficiency; logical judgment functions when it is required to decide the status as information is inputted from outside.

Agent Communication interface serves as a channel to help CAX Agent visits the outside, which is realized through Agent Communication language (ACL) defined by Foundation for Intelligent Physical Agents (FIPA). Thereby, different platforms transmit encapsulated information through such communication protocol as Socket, CORBA, RMI, etc.

Tools Set provides auxiliary assistance for lightweight, acting as communication and coordination among human designers.

91.4 Operation Process of the System

Sequence chart is applied to vividly and explicitly show the detailed lightweight design process in the multi-agent system in Fig. 91.3, which is validated perfectly using self-adjusting arm as a case. This arm is an important part of car's brake system. Subsequently, the shell (Fig. 91.4a) of such arm is analyzed and optimized with collaborative lightweight design to describe the design process.

The department of design has been finished the preliminary design of self-adjusting arm shell and save it in the PDM system. Firstly, the lightweight design task of this shell will be sent to Process Management Agent that establishes design task and actuates Task Management Agent, which divides this task to several subtasks in a task list. This list is labeled generally with the parameters such as No, task name, starting time, ending time, status, etc. and stored by Process Management Agent for tracking and version control.

Task Management Agent, through Agent Manager, appoints Product Data Management Agent to check, according to Drawing No, whether there is a

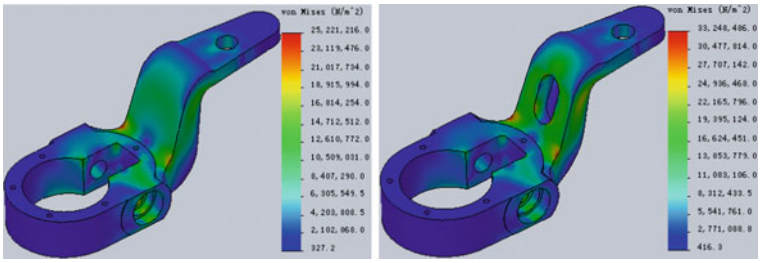

Fig. 91.4 Static analysis results before and after lightweight design for self-adjusting arm shell

lightweight solution of the shell. If there is an extant solution, it is applied directly; otherwise, lightweight design task will be sent to CAX Agent.

After receiving the task, CAX Agent asks for resources from Resource Management Agent. The resources of CAD/CAE serve to accomplish product lightweight design, as CAM/CAPP help to evaluate the effects on processes and manufacturing, such as manufacturability, the facilities to fabricate this product, etc. Then devised model and data will be sent to be saved in Product Data Management Agent, sending messages of task done to Process Management Agent and Task Management Agent.

Task Management Agent continues to dispense different tasks, sending the foregoing solution to Q&A Analysis Agent and EIA Agent to develop assessment on quality, asset and environment. These two agents execute the task also after acquiring resources from Resource Management Agent. The assessment results will be sent to be stored in Product Data Management Agent, sending messages of task done to Process Management Agent and Task Management Agent.

Finally, Product Data Management Agent presents the assessment results to human designers. If the results do not reach anticipatory target, CAX Agent will start another lightweight design solution, involving in successive circulation until the assessment results achieve target.

In the design process above, Product Data Management Agent also activates Conflict Inspection Agent to inspect conflict. If conflict inspected, alert will be sent to human designers and help them solve it. Moreover, quite vital is communication among different agents.

Final lightweight design solution is shown in Fig. 91.4. As mechanics capabilities are satisfied, 15% of previous weight is reduced and no worse effects on quality, asset and environment is discovered.

91.5 Conclusion

With the promising agent technology, this paper proposes multi-agent based architecture supporting collaborative product lightweight design to help designers effectively conduct collaborative lightweight design. CAX Agent, as the key agent,

is introduced at length, and operation process of lightweight design is also demonstrated in detail with self-adjusting arm shell as a case.

Since lightweight design would not become totally automatic, human designers should involve in design. Thus, in future, more concrete work listed as follows should be done.

An endless stream of knowledge and accumulative experience required in collaborative lightweight design reveal that better knowledge base should be designed to carry out significant knowledge push, lending compelling assistance to lightweight design.

Current assessment methods for lightweight design solutions are so sketchy that comprehensive and substantial assessment for such solutions is necessarily demanded.

As a general problem in lightweight design, conflict is very difficult. So, one of provident and considerable emphasis on future research lies on how to excellently eliminate conflicts for human designers.

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