Multi Agent Systems in Concurrent and Collaborative Engineering: A Review

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Abstract

Increasing the products design and manufacturing complexity also increasing the benefits of concurrent and collaborative working made the concurrent and collaborative working more important and recognized in engineering field. The issues associated with using of concurrent and collaborative engineering are solved with using of agent technology. Same existing attention has been given to the using of the multi agent system (MAS) in concurrent engineering (designed and process planning), this paper surveys the literature in the using of MAS for in concurrent engineering.

Keywords: Concurrent engineering, Collaborative engineering, Multi agent, Design, Process planning.

1 Introduction

Concurrent engineering (CE), also known as simultaneous or collaborative engineering, is a systematic approach integrating design activities with their related processes, including manufacturing and support [1, 2]. CE is an effective way of organizing and coordinating all the processes towards minimum lead time and development cost, while maintaining product quality to the total satisfaction of the customer. This is vitally important for manufacturing enterprises to survive the existing competitive market situation [1],[3]. Concurrent engineering is an efficient method for achieving the successful design and planning of large and complex products or projects, such as ships, offshore oil platforms, automotive, structures and aero planes, require the collaboration of multi-disciplinary design teams. in which the teamwork in different areas run the different stages of project at the same time. These teams utilize specialized computer systems to aid their design process. [4],[1],[5].

Many issues associated with implementation of CE like integrating the product design and planning and manufacturing stages, process planning in the CE, coordinating and communication between the teamwork members[4],[6]and [7], conflicts that can appear between team work members decision in design or planning or during phases of concurrent engineering project [7] and [8] Cooperative awareness among distributed participants is one of the most important issues associated with collaborative pattern design[9].

The agent is defined as a computer system located in some environment and capable of autonomous action, in order to meet its design objectives [10].A multi-agent system (MAS) is formed by a network of computational agents that interact and typically communicate with each other [11]. MAS have brought new interesting possibilities. Therefore, researchers have been trying to apply agent technology to manufacturing section [12].Many research gave attention for applying the MAS in the Concurrent engineering to solve the issues which associated with implementation of CE. This present work surveys the literature in the using of MAS for in concurrent engineering.

2 Multi-Agent Systems

In recent years, many of research works on the applied of multi-agent systems (MAS) in manufacturing sectors. This approach is no the same traditional centralized or multilevel hierarchical approaches.
A MAS consists of a group of agents that interact through communication and cooperation to achieve both individual and collective objectives [10]. This approach assumes the presence of several decision-making entities, distributed inside the manufacturing system, interacting and cooperating to achieve global performance [13]. In MAS, an agent has to coordinate its actions with other agents. The MAS coordination can be done through both indirect communication via the environment, or direct information exchange between specific agents. In any case, communication needs some language(s) with syntax and semantics, at least partially known for each communicating agent. [11].

3 Concurrent Engineering

The traditional conception of product design and development relies on the vision that activities are conducted in an isolated and sequential manner. In CE, there is a shift in work organization and execution, since activities are assigned to multiple and different teams, and can be performed concurrently, i.e. at the same time, in parallel and/or in an overlapping manner, in addition to the sequential manner. This new way of work results in different kinds of problems [14], which are explained in the following subsections.

3.1 Conflicts in design choices and decision-making

Conflicts in design are collisions between two or more viewpoints about the same decision in a design [15].
There are two types of conflicts in CE. The first type of conflicts occurs between requirements and design, when a CE participant proposes solutions that do not satisfy customer requirements. The second type of conflicts occurs between the participant designers, when conflictual suggestions are proposed for the same problem [16],[17].
Several factors favour the appearance of such conflicts, including differences in expert specialties, in technical and social backgrounds, in responsibilities within the same project, and in individual objectives [7]. The classical case is the conflict between the design engineer, who cares about product performance, and the manufacturing engineer, who is more concerned with ease of manufacturing at low cost [18]. Another example of conflicts are those which occur during materials selection stage, when different designers having different specializations evaluate a candidate material from different points of view, resulting in different choices and subsequent decisions [6].
Conflicts can also appear at different design stages, for example between design and manufacturing, design and process planning, or between design and validation [8]. However, such conflicts are less intense and important because they are part of normal design and development processes, and can be handled through iterative improvement work procedures.

3.2 Communication

One requirement of CE is the ability to communicate the effects of a design change to all concerned disciplines and team members within a distributed environment. However, the successful communication of such a change faces many hurdles. For example, different design tools may be based on different system architectures or methodologies. Such tools will often be located at different sites, and each tool may have a different data model of the design process. Consequently, the difficulties in understanding the diverse knowledge and information generated from these multiple design disciplines may reduce the effectiveness of a distributed design environment [8]. If the necessary communication amongst the concurrent team members does not exist, greater parallelism may make the project longer because there may be delays caused by greater reworking [19]. Insufficient information and communication between phases of the product development cycles result in loss of information and optimization opportunities [20]. For example, the marketing collects the customer requirements and product specifications, and passes the information to the design team. The designers generate several design alternatives that meet the customer requirements but only pass one of the proposed designs to the manufacturing engineers. In this case, the first problem that arises is the loss of abstract information. Also the insufficient communication is that much time and effort is required to return the invalid design to earlier phases to correct the design mistakes that are discovered.

3.3 Interoperability

Recently, with the use new technologies in the manufacturing industries, manual are replaced by Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) to implement concurrent engineering [21], [22]. However of the high in development of the technology is resulted in variation in hardware and software that used in a distributed and heterogeneous design environment like different hardware, different operating systems, different network protocols and architectures, different programming languages and different and multidisciplinary knowledge all of these lead to create interoperability problem on of distributed design. It is important to integrate these distributed resources to make them interoperate or cooperate in efficient way [23], [24]. Interoperability of engineering components describes their ability to collaborate with each other across their tool borders. Interoperability is considered as an important indicator for engineering tools efficiency [25]. Data transforming among CAD/CAM/CAE systems is recognized for a long time as a key concept for concurrent engineering, so any Interoperability among CAD/CAM/CAE systems [26].

4 Multi-Agent Systems in Concurrent Engineering

MAS represents one of the most promising technologies for the development of concurrent/collaborative engineering [27]. Many researchers employed this technology to solve some of the issues explained in the previous section, and to improve the performance of collaborative work.

4.1 Conflicts detection and resolving

Detection and resolving of a conflicts among cooperative group design are concerned as a central issue in CE [28]. It is one of the main factors that shows whether the teamwork can work together successfully or not[15].In order to remove the conflict in the CE Sycara [1991] proposed a negotiation model for resolving the conflict in the design process. The proposed negotiation model was based on knowledge-based reasoning, previous design information, and constraint relaxation. Each agent during the negotiation process involved in design decision recommendation, justifying recommendation, search possible alternatives, and adjust a rejected compromise. A set of negotiation protocols were also suggested by the author [29].

To remove the conflict which generated from the difference designers viewpoints during material selection in CE Barker et al [2001] developed support tool and computational means based on agent for material selection in concurrent design team that help for taking the decision. In the CE the designers are supported with personalized computer-based agents each representing an individual designer's viewpoint on a design artefact. The material is selected according to the calculated similarity based on material properties. Each agent proposed a material, and made an offer, however, based on peer modelling concept, a statistic value 'd' is calculated that depends upon common or similar material property required by two or more agents [6].

MAS also used to remove the conflict in process planning stage. To devolve process plan (optimum features operations manufacturing order) on STEP-NC manufacturing without conflicts and interactions between the plan steps by Allen (2005) Design a multi-agent framework involving several models (component model, resource model, multi-agent model and message board) to support feature-based manufacturing. The framework involved four feature agents (Autonomous, Compound, Enclosed and Thin Wall Agent) in which each feature type represented by agent. Also facilitator agent process is also involved to manage the feature agents. Agents interact based on a message board (black board) protocol and considered type of features and features precedence to generate an optimal operations sequence based on the features of prismatic components[30]. The same problem is considered also by Nassehi (2006) multi-agent systems is also used with different structure of the MAS. In this study MAS involved two different kinds of agents. General feature Agent for each feature and Police Agent which act as the facilitator between the agents .The agents evaluate the interaction between the features before generating the plan. The agents are collaborative agents communicate with each other using signals. There are two possible signals the agent might receive, an 'introduction signal', when the agent should interact with another and a 'die signal' when the overall program is finished and all entities should be destroyed [31]. Using MAS to solve the conflict between CE activities (Design, process planning and manufacturability evaluation) is considered also by several research .Sun et al (2001) Developed a framework to improve integration between the different phases (Design, Planning and Manufacturing) of a concurrent engineering project to detect and remove conflicts(poor manufacturability or assimilability of a design.) between them. The framework comprises a console agent, a facilitator agent, and six service agents. Console agent acts as an interacting interface between designers and the system Facilitator agent: coordinates execution of tasks between agents and manages conflict solving due to poor designs Service agents include: Design agent: is used by a designer to submit the design information and it also advises the designer to make necessary modifications to the design. Identification agent: retrieves attributes for each feature in a design. Manufacturing capability agent: looks for a suitable capability model if the Facilitator informs it of a manufacturability evaluation failure. Manufacturing evaluation agent: acquires capability models from the Manufacturing Capability Agent and evaluates manufacturability of a product design Assimilability evaluation agent: this agent is responsible for the assimilability evaluation of the product design Process planning agent: generates optimal process plans based on the design and selected resources Cost estimation agent: this agent makes a cost estimation for each factory based on the generated process plan and makes a ranking of factories for the design according to the cost estimation results. MAS resolve the conflicts by using the negotiation between the agents. All agents in the system use the common communication protocol, KQML, for concurrent negotiations. KQML is conceived as both a message format and a message-handling protocol to support run-time knowledge sharing among agents[8]. Also Tang et al [2004] suggested a MAS framework in which they use agents to integrate die-maker activities into customer product development process. Integration means that agents will improve communication and information exchange between designers and manufacturers, and that agents will allow designers to take into account manufacturer capabilities and limitations. The used MAS involved three agent:

- Part design agent, which take care about material selection, configure the part geometry by-feature fashion and product modelling.
- Die maker involvement agent responsible for part stamp ability evaluation, Cost analysis and processing planning.
- Coordination agent responsible for task assignment, conflict detection and Conflict resolution.
  The authors proposed AKQML/XML communication and data exchange method between agents. The result showed that substantial potentials with using MAS for integration of the die-maker into the process chain of the customer [32].

4.2 Communication improving

Same researches gave attention to using the MAS for improving the communication between CE team work for example Tanet al [1996] developed a multi-agent framework to improve communication between different phases of product development so that design mistakes can be discovered in early stages of product development. The framework involved several agent with different functions.

Personal assistant agent enables the team member to communicate with other agents.

Support agents like Knowledge Base agent and I/O resource agents (e.g. printers): provide services to other agents, such as information storage and retrieval from data bases, or printing documents.

Mapping agents: perform the translation of the design information from one representation to another

Conflict Detection (CD) agents: detect conflicts in a design with process plan and cost evaluation.

Conflict Resolution (CR) agents: suggest solutions to solve the conflicts.

Critique agents: make suggestions to improve the design manufacturability without compromising the functionalities of the product Special function agents: perform special functions like performance evaluation (in terms of cost and/or time) of the development process.

The author developed algorithm for his own methodology for agents interaction [20]. Han et al. developed a framework to provide a common communication platform for chemical plant design engineers. The developed system used multi-agents that interacts with each other using KQML and KIF (Knowledge Interchange Format). The rule-based knowledge system supports in the decision priority process. A case study was presented for chemical plant layout design, in which, different agents are assigned different task, such as, an agent is assigned for plot layout, while the other is assigned for site layout, and so on. Therefore, each agents communicates with each other, and simultaneously performed its assigned task, thus augmenting the concurrency in design process [33].

Also Jin [2004] developed an agent-based negotiation framework (ANF) for collaborative design decision-making. In the developed framework an agent is associated to both a designer and the computer system on which the designer works. The agent handles all communication processes and facilitates the application of negotiation protocol and strategies. The agent has responsibilities of track issue dependencies between designers and design systems, identify issue discrepancies and notify designer, provide proposal preparation templates, facilitate negotiation communications, suggest strategic actions based on selected strategy, Track all negotiation processes and commitments and report statistics of negotiation processes. The Agents interact through developed a speech-act and argumentation based negotiation protocol [7].

4.3 Improving the Interoperability

Same attention has been also given to the interoperability in CE. To Improve the interoperability in cooperative design systems [34] improved the software interoperability, data exchange, and collaborative platform using the KQML

(Knowledge Query and Manipulation Language) based agents. Zhao et al[2001] proposed a multi-agent cooperative design environment called CLOVER. The proposed MAS involved four agents. Process management agents (PMA) which are managing the design process based on representation. Design task agents (DTA) each DTA autonomously takes actions to process some part of product. Tool agents (TA) which are responsible to find, provide and manage general tools for any design task, which is often independent of specific projects. These agents used a common agent communication language (KQML), common format for the content of communication (EXPRESS and XMLon the Web) and shared ontology (STEP), they can communicate and cooperate on a high level in a uniform way[23].

5 Conclusions

- This review discusses the implementation of MAS in CE. Particular attention has been given to the contribution of MAS for solving CE associated problems. Several conclusions that can be drawn from this survey are as follows:
- CE is more in demand for large and complicated manufacturing systems. It is a beneficial approach to reduce the product development time and cost.
- Several problems appear with implementation of CE such as conflicts in decision making, interoperability, problem in communication channels, etc.
- Intelligent agents and distributed artificial intelligence show a lot of potential in development of process planning systems.
- MAS has a lot of potential in solving above mentioned issues faced during CE, and thus augments its performance.
- This research project also identifies a few important aspects that needs further investigation. For example: using the MAS to remove the conflicts between the CE team work and customer requirements. Also using the MAS to integrate the CE designers with engineering analyzers could be considered.

References

Nategh M. Concurrent engineering planning on the basis of forward and backward effects of manufacturing processes. International Journal of Production Research 2009;47:5147-61.

Pullan TT, Bhasi M, Madhu G. Application of concurrent engineering in manufacturing industry. International Journal of Computer Integrated Manufacturing 2010;23:425-40.

Tang D, Zheng L, Li Z, Li D, Zhang S. Re-engineering of the design process for concurrent engineering. Computers & Industrial Engineering 2000;38:479-91.

Chao K-M, James A, Norman P. A framework for Intelligent agents within effective concurrent design. Computer Supported Cooperative Work in Design, The Sixth International Conference on, 2001: IEEE; 2001. p. 338-43.

Anumba C, Ugwu O, Newnham L, Thorpe A. Collaborative design of structures using intelligent agents. Automation in construction 2002;11:89-103.

Barker R, Holloway L, Meehan A. Supporting negotiation in concurrent design teams. Computer Supported Cooperative Work in Design, The Sixth International Conference on, 2001: IEEE; 2001. p. 243-8.

Jin Y, Lu S-Y. Agent based negotiation for collaborative design decision making. CIRP Annals-Manufacturing Technology 2004;53:121-4.

Sun J, Zhang Y, Nee A. A distributed multi-agent environment for product design and manufacturing planning. International Journal of Production Research 2001;39:625-45.

Jiang B, Chen C, Bu J. CoDesign-A collaborative pattern design system based on agent. Computer Supported Cooperative Work in Design, The Sixth International Conference on, 2001: IEEE; 2001. p. 319-23.

Li J, Nee A, Fuh J, Zhang Y. Multi-Agent Based Distributed Manufacturing: INTECH Open Access Publisher; 2006.

Monostori L, Váncza J, Kumara SR. Agent-based systems for manufacturing. CIRP Annals-Manufacturing Technology 2006;55:697-720.

Shen W, Hao Q, Yoon HJ, Norrie DH. Applications of agent-based systems in intelligent manufacturing: An updated review. Advanced engineering INFORMATICS 2006;20:415-31.

Caridi M, Cavalieri S. Multi-agent systems in production planning and control: an overview. Production Planning & Control 2004;15:106-18.

Ramesh B, Sengupta K. Managing cognitive and mixed-motive conflicts in concurrent engineering. Concurrent Engineering 1994;2:223-36.

Zhuang R. Conflict Detection in Web Based Concurrent Engineering Design: University of Florida; 1999.

Matta N. Conflict Management in Concurrent Engineering: Modeling Guides. Proceeding in Conflicts in AI Workshop. Budapest1996.

Müller HJ, Dieng R. Computational conflicts: Conflict modeling for distributed intelligent systems with contributions by numerous experts: Springer Science & Business Media; 2000.

Mitchell Fleischer JKL. Concurrent Engineering Effectiveness: Integrating Product Development Across Organizations. Cincinnati: Hanser Gardner Publications 1997.

Haberle K, Burke,R.,Graves,R.,. Anoteonmeasuringparallelism in concurrent engineering. International Journal of Production Research 2000;38:1947–52.

Tan GW, Hayes CC, Shaw M. An intelligent-agent framework for concurrent product design and planning. Engineering Management, IEEE Transactions on 1996;43:297-306.

Yusof Y, Newman S, Nassehi A, Case K. Interoperable CNC system for turning operations. Proceedings of world academy of science, engineering and technology: University of Bath; 2009. p. 941-7.

Chungoora N, Young RI. Semantic interoperability requirements for manufacturing knowledge sharing. Enterprise Interoperability III: Springer; 2008. p. 411-22.

Zhao G, Deng J, Shen W. CLOVER: an agent-based approach to systems interoperability in cooperative design systems. Computers in Industry 2001;45:261-76.

Vergeest JS, Horváth I. Where interoperability ends. Proc of the 2001 Computers and Information in Engineering Conference, DETC2001.

Drath R, Barth M. Concept for interoperability between independent engineering tools of heterogeneous disciplines. Emerging Technologies & Factory Automation (ETFA), 2011 IEEE 16th Conference on: IEEE; 2011. p. 1-8.

Bianconi F, Conti P, Di Angelo L. Interoperability among CAD/CAM/CAE systems: a review of current research trends. Geometric Modeling and Imaging--New Trends, 2006: IEEE; 1993. p. 82-9.

Wang JX, Tang MX, Song LN, Jiang SQ. Design and implementation of an agent-based collaborative product design system. Computers in Industry 2009;60:520-35.

STEPHEN MKa. Conflict resolution in cooperative design. Artificial Intelligence in Engineering 1989;4:4.

Sycara KP. Cooperative negotiation in concurrent engineering design. Computer-Aided Cooperative Product Development: Springer; 1991. p. 269-97.

Allen R, Harding J, Newman* S. The application of STEP-NC using agent-based process planning. International Journal of Production Research 2005;43:655-70.

Nassehi A, Newman S, Allen R. The application of multi-agent systems for STEP-NC computer aided process planning of prismatic components. International Journal of Machine Tools and Manufacture 2006;46:559-74.

Tang D. An agent-based collaborative design system to facilitate active die-maker involvement in stamping part design. Computers in Industry 2004;54:253-71.

Han S-y, Kim Y-s, Lee T-y, Yoon T. A framework of concurrent process engineering with agent-based collaborative design strategies and is application on plant layout problem. Computers & Chemical Engineering 2000;24:1673-9.

Batres R, Asprey SP, Fuchino T, Naka Y. A KQML multi-agent environment for concurrent process engineering. Computers & Chemical Engineering 1999;23:S653-S6.