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CAIRO: a concurrent engineering meeting environment for virtual design teams

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Abstract

This paper presents the software architecture for a next generation concurrent engineering environment that helps geographically separated designers and engineers to collaborate effectively. The paper highlights research in computer-supported collaboration work (CSCW) based on various models of group interaction, social communication theory, negotiation theory and distributed artificial intelligence concepts. The paper describes CAIRO (Collaborative Agent Interaction and synchROnization) system, a distributed conferencing architecture for managing designers and engineers in a distributed design meeting. The CAIRO system allows designers and engineers to work together in virtual teams by supporting multi-media interactions over computer networks. CAIRO aids the concurrent engineering effort by relaxing the physical, temporal and organizational constraints experienced in traditional design meeting environments. CAIRO provides both media synchronization, i.e. ensuring that all information exchanged between users is synchronized, and agent synchronization, i.e. ensuring effective structuring and control of a distributed conference. This paper also details the prototype CAIRO system with a detailed example, illustrating its use in concurrent design settings. © 2000 Published by Elsevier Science Ltd.

Keywords: Collaboration model; Concurrent engineering; Conference management; Meeting environment; Virtual teams

1. Outline

The following statement from Peter Senge, Director of the Center for Organizational Learning at MIT's Sloan School of Management, summarizes the importance of teams in modern organizations [1].

> …teams, not individuals, are the fundamental learning unit in modern organizations…unless teams can learn, the organization cannot learn.

Today, structural design is more complex than ever before. It is beyond the scope of a single person, a single team or even a department to comprehend fully all the aspects of the design effort. Availability and communication of expertise remain the key factors in the success of modern organizations. The problem is compounded in the architecture/engineering/construction (A/E/C) industry, marked with growing sizes and geographic dispersion of large-scale projects. It has been a challenge for the designers and engineers in traditional organizations to work together as teams to improve the quality, while reducing costs and time in the design process. Enter concurrent engineering (CE) — a systematic approach to integrated development that embodies the team values of cooperation to share decision-making. To identify the role of CE and document our research in distributed design environments, this paper is divided into five sections. The primary principles of CE are highlighted in Section 2. This section also identifies the importance of supporting distributed design teams with comprehensive computer environments. Section 3 describes the system design of the software architecture developed by the authors to create a CE environment. Section 4 provides an illustrative example depicting structural design carried out by a team of geographically distributed designers over the computer network. Finally, concluding remarks are provided in Section 5.

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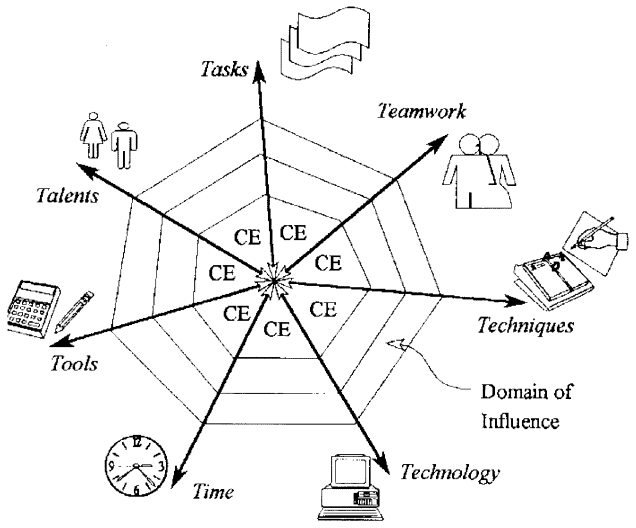

Fig. 1. 7T's — seven influencing agents of concurrent engineering (from Ref. [6]).

2. Concurrent engineering and teams

The concept of CE was initially proposed as a means to minimize product development time [2,3]. Since then, many definitions of CE have emerged in literature:

- Concurrent Engineering is a 'systematic approach to the integrated, concurrent design of products and their related processes.' This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal [2].
- Concurrent Engineering is a 'goal-directed effort, where *ownership* is assigned mutually among the entire group on the *total job* to be completed, not just *pieces* of it, with the understanding that the team is empowered to make major design decisions along the way.' This definition is more suited to a virtual CE enterprise with geographically separated designers as it highlights the importance of distributed teams [4].

The above definitions indicate that most of the basic principles of CE, revolve around the notions of teamwork affinity and shared knowledge leveraging. Indeed, CE strives to create teams of people working together to create global optima in their efforts [5]. Individuals, working remotely in separate locations are likely to create designs, which may be optimal in their individual local domains but will seldom remain optimal in a unified domain. The core components of any CE effort are highlighted next.

As shown in Fig. 1, Prasad has identified seven agents that influence the domain of CE: *talents*, *tasks*, *teams*, *techniques*, *technology*, *time* and *tool* [6]. One of the primary *team* issues in CE is the decomposition of *tasks*. *Teams* are often used to cooperatively solve the problem. *Technology* issues arise in CE due to drive for competitiveness. *Tools* include computer networks, hardware and software required to make geographically separated *teams* to work together. From the *time* perspective, CE has the goal of reducing the length of the product cycle time.

Amongst the above-mentioned influencing agents, cooperative work teams remain the single most important component of CE [6,7]. This is primarily because the 'organizational angle' of CE involves many constantly changing variables that are more difficult to control than any other variable. There are four primary elements to cooperative work teams:

- *Communication* involves the exchange of information, events and activities in any CE effort. Effective communication is a necessary, though not a sufficient condition to meaningful collaboration.
- *Co-location* involves dealing with the infrastructure to provide seamless communication among distributed designers and engineers.
- *Coordination* involves control of the workflow and communication process, allowing efficient control mechanisms to coordinate group effort. Coordination involves managing the various interdependencies between activities and events in any CE effort.
- *Collaboration* describes the process of sustainable value creation that creates a shared understanding in the CE effort.

Communication has always been a well-known threat as well as an opportunity in large-scale complex projects [8]. Costly breakdowns in communications occur regularly even in the traditional A/E/C projects of physically collocated teams that are engaged in design and construction [9]. In the engineering domain, communication is an integral component of the design and problem-solving processes. Systems that are currently developed contain large numbers of components and encompass the knowledge of thousands of person-years. Clearly, this is much more than one individual can retain in their limited mental storage capacity. Hence, the modern engineering process necessitates the engagement of several individuals in the realization of an artifact or product. Engineering meeting processes particularly highlight several issues in communication: representation — different standard terminology and acronyms; transportation — in the form of symbolic drawing, sketches, specifications and associated multi-media; organization and control — inter-linkages of system components and the need for diverse expertise in problem-solving, beyond the capacity of one individual [10].

Design teams provide a significant challenge to current communication technologies. Design processes require highly coordinated interaction to resolve design disputes and to align design goals within the team [11]. In addition engineering design also typically involves ill-defined design problems that are composed of interrelated components designed by different individuals that must work in tandem