The Efficiency Analysis of Collaborative Computer-Aided Design

Olga Lebedieva, Oleh Matviykiv, Mykhaylo Lobur

***Abstract* — In this paper the main components of collaborative distributed CAD, the basic requirements to realization of collaborative distributed CAD levels, collaborative project management model and collaborative project efficiency parameters are given.**

***Index Term s*— collaborative project, project management model, collaborative project efficiency.**

I. Introduction

The term "collaborative design" becomes today the key technique in CAD/CAM/CAE for complex product development, especially for highly complicated multidisciplinary objects and systems. Last decade several collaborative methodologies have been developed and proposed by scientific groups and CAD vendors as well. Nevertheless the high importance and necessity, these tools and systems still didn't receive wide popularity among design engineers and users. The main reason is low collaborative project efficiency because of discrepancy between distributed project management methodologies, CAD-based collaborative design tools and project workflow requirements.

The purpose of any engineering design project is creation of the set of project documentation according to the specification requirements and workflow standards. Usually, special software tools for workflow planning and project management are applied for these purposes. Distributed teams especially heavily rely on IT technology, which supports many communicative and collaborative processes. Project management software must include a set of tools that help to plan work based on time, resource and cost estimates for a range of works [1-3]. In CAD collaborative design process, all project management tools have to be included directly in collaborative Design Environment with minimal added overhead. Thus, among regular project management tasks, in distributed collaborative CAD it become necessary to choose and set such project parameters, which will maximize the project efficiency and design output.

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II. Distributed Computer-Aided Design

A specific feature of distributed collaborative CAD is a presence of separated structural units (teams or persons), which are responsible for definite project parts and its functionality. Each unit of a distributed team adds a distinct set of knowledge and experience to the design process.

The main components of distributed CAD are [4]:

– Personal engineer work stations (with different instrument platforms and operating systems);

– Distributed calculable modules which give calculable resources;

– Distributed data bases and knowledge bases;

– Joint collaborative environment for project coordination between engineering groups;

– Industrial CAD tools for direct designing of project parts or whole object.

All components can be physically and geographically distributed and linked between itself by communication sub-system via Internet/Intranet/Extranet networks.

Usually, such distributed collaborative system can be divided into several hierarchical levels. The basic requirements to realization of different CAD levels are:

– Association of various Hardware CAD facilities in a unique infrastructure (creation of the unique distributed environment for the compatible resource use in dynamic virtual organizations).

– Scale which allows the dynamic grant of calculable powers for the problem decision.

– Providing the reliability and fault tolerance of design process (tracking of the task state so that in the case of death one or a few units in a calculable pool, design process will not suffer).

– Providing safety and data confidentiality (the safety context must be related to the task or data and to provide them such safety services as integrity, confidentiality, authentification and authorizing) [5].

– Storage, access grant and treatment of enormous data content in many additions without their physical moving between calculable resources).

– Heterogeneity (using of heterogeneous resources and creating of calculable environments with using different instrument room platforms and operating systems).

III. Requirement Analysis in Collaborative CAD

In the distributed collaborative design each member will develop distinct ideas and opinions concerning project goals, task priority, and other key decisions. In poorly coordinated teams its members usually focused on individual tasks and not able to work as a cohesive unit. In well-coordinated teams, on the contrary – members are focused on the project object, as a whole.

Project management necessity, namely coordination necessity of the use of human and material resources during the project life cycle by modern methods and management technique to achieve the income proper level of project participants, high product quality, which related to mass growth of scales and project complication, requirements to the terms of their realization, quality of executable works.

Project important element is his environment, in which project arises up, there is and finished. Project environment are the influence factors on his preparation and realization. They can be divided into internal and external.

The political economic, public, legal, scientific and technical, cultural and natural factors belong to external.

The factors related to project organization belong to internal. Project organization is a distribution of rights, responsibility and duties between the project participants.

As a rule, successful completion of large projects depends on performer ability to decide large tasks which seem difficult from the organizational point of view, and to divide them into the row of organizationally less intricate problems separate. There are a few factors which are general for the similar type tasks. Experience shows that the most essential factors are:

--design management process;

--distributed data management between the work performers;

--construction space management and control their mutual allocation.

A. Design management process

Every organization has an own, already formed design technology, which came from the specific industry features. Therefore design process management systems must adapt to the terms of project organizations. It allows co-operating with existent CAD without the change of the formed structure and without the losses of time effectively. And it is achieved by the module of distributed CAD, which provides maximal flexibility and efficiency of project work implementation.

B. Distributed data management between the work performers

It is necessary, that project information was constantly synchronized, represented actual information and was accessible for all members of project group for large projects. The checking system gives an opportunity to the users to decrease time of data verification and considerably to shorten time of project development in the conditions of simultaneous work of a few distributed designer groups.

Project time development diminishes due to the presence of dynamic flow lines between the technological drafts and project database, which also allows making operative alterations in the design process. In addition, users which are busy at development of certain drafts can instantly take advantage of reference project data that are on other sites.

C. Construction space management and control their mutual allocation

The necessity of the spatial component object location management is the fundamental requirement at the MEMS design. Design objects can be parted on separate components which are distributed between a few groups of designers by CAD. The level of responsibility is set for each group.

Basic descriptions of project management systems:

--automation possibility of the territorial distributed industrial enterprises and project organizations of a different specialization;

--operative receipt of analyst reports both on one project and on organization on the whole;

--flexible distributing of access rights to data and reports for the users of the system;

--the system must provide high data protection from the unauthorized division, physical and logical data saving and simultaneous work of large number of users;

--supporting the most widespread operating systems (MS Windows NT, MS Windows 95/98/2000, Novell NetWare); easy bearable;

--openness to development of programmatic complex in connection with the changes of standards and readiness to the dialog with clients on the revisions of the system;

--accordance to the domestic and foreign standards;

--project work term control, reports about the project work state;

--history of all engineering changes in a project;

--integration with the external systems of e-mail;

--saving of variants which did not enter in a basic project.

IV. Collaborative Project Management Model

Today, traditional project management methods are not sufficient to manage multiple tasks in the design and development. They do not include all sources of change, interaction problems and the need for distributed planning. They also do not provide proper notice of changes.

Today's distributed project management tools are still based on a model of planning for a single user, and notification of changes must be specified by users.

Development of collaborative project management (CPM) includes:

1) shared distributed design,
2) workflow design management,
3) shared distributed calendar design,

4) modeling for product alternatives,

5) stages: synchronization and coordination, concurrency and consistency.

The basic requirements to realization of different collaborative distributed CAD levels are:

– Association of various Hardware CAD facilities in a unique infrastructure (creation of the unique distributed environment).

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– Heterogeneity [6-7].

Effective management of collaborative projects should:

1) be easy to use, providing collaboration and communication throughout the project or program team,

2) support the entire building life cycle that includes a plan, construction and operating phases [8-10].

CPM should improve communication through the distribution of coordinated reliable information which comes from data modeling, and it is available to participants in the process.

In [11] CPM model was presented (fig. 1), it consists of four main components: the client space, the level of collaborative support, supervision and project management processes and project cycle. Collaborative Software provides an intermediate level of communication between the main components and instruments to their limits.

Input system data includes goals, mission, future specification requirements, budget, team and time. Final results of the system include product, message, processes and metrics. Considering the more input data and final results, the participants have more design metrics to clearly specify what resources are available, what requirements have to consider, and what criteria products must meet. Analysis of input data and final results will help plan the entire project on a detailed level, initially in the project life cycle.

To justify the use of CPM model for collaborative design will use a software system "CHOICE". We use such evaluation criteria: project time (0,072), project complexity (0,093), collaborative support (0,290), project efficiency (0,290), number of participants (0,023), project cost (0,102), input / output data (0,121).

So, it is required easy to use solutions that simplify collaboration, communication and the entire life cycle during managing a collaborative project. They provide effective collaborative project management and allow companies to complete projects on time and within budget.

The advantage is that project information is stored in one place, centralizing documents, drawings, communications, contracts, lists, budgets and forecasts, messages, etc. In addition, collaborative project management automates the process of project management, communication flow and cooperation in teams through a project life cycle.

V. Efficiency Analysis of Collaborative CAD

In [12] the author selected the main set of project parameters, which were used in corresponding state equation of project:

$$N \times T = \frac{(S - R) \times D}{P} \quad (1)$$

where T – project time, N – number of project participants, P – team productivity, S – project size, D – project complexity, R – project reuse.

In case of distributed collaborative design, when complete CAD project is divided on several parts and distributed among several teams, the significant impact on its efficiency has stakeholder's collaboration. To support this effect, we propose to modify the project efficiency (*E*) by adding collaborative parameter "*C*":

$$E = N \times T \times C \quad (2)$$

Thus, the project state equation changes its view into:

$$N \times T \times C = \frac{(S - R) \times D}{P} \quad (3)$$

As it was mentioned, this representation does not depend on the application field of the project, because all engineering projects have the same set of parameters.

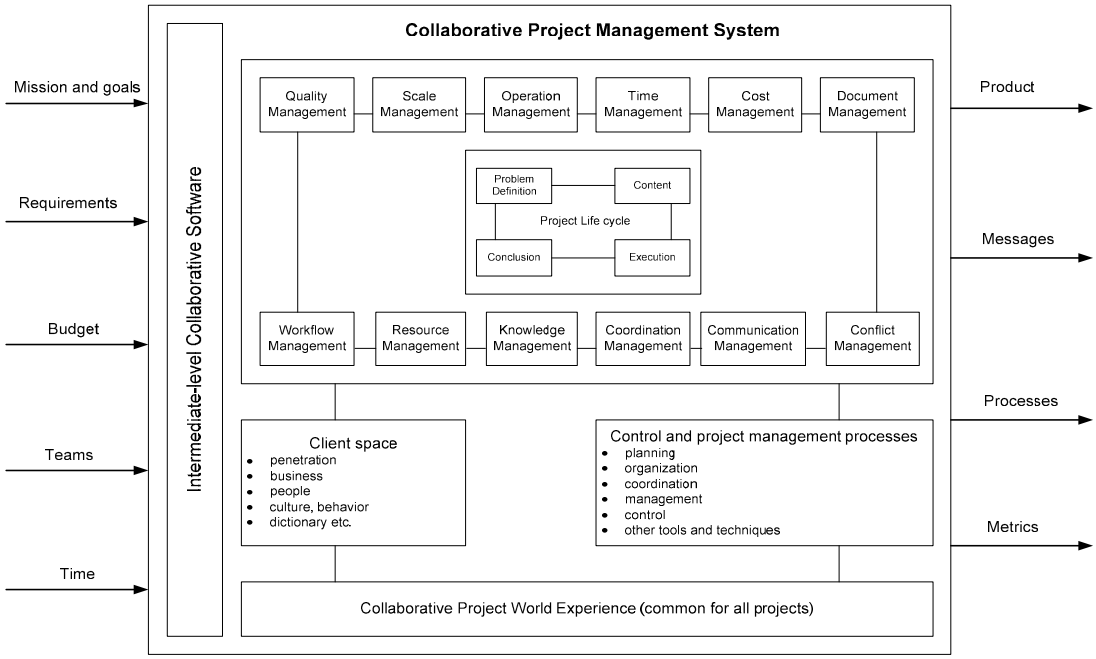

Fig. 1. Collaborative project management model

VI. Application of Efficiency Analysis

In order to test collaborative influence, let's calculate the project efficiency by the formulas (2) and analyze the project balance (3) on the example of sportswear collection distributed design with the help of custom-developed Fashion Office Software. The calculation results give in the table below:

T	N	P	S	D	C	E
4	50	5	250	1,6	0,4	80
4	40	6,25	250	1,6	0,4	64
4	50	5	250	1,8	0,45	90

Really, in this case any change of the one of parameters leads to unpredictable chain changes of other parameters.

In [12] the author had developed a set of approaches for analyzing the influence of main project parameters on project efficiency. In case of distributed collaborative design the most interesting is the change of project duration from the point of view of project goals and priorities when the project size is constant and fixed.

For this analysis it was introduced a new variable – the power of the team *H* as the product of team size *N* and team productivity *P*. In case, when we have *n* distributed teams, this equation will looks like:

$$H = \sum_{i=1}^{n} N_i \times P_i \,. \qquad (4)$$

This introduction of the new variable (team power H) allows representing the project complexity W in the form of the product of the team power and total project duration:

$$W = T \times \sum_{i=1}^{n} (N_i P_i) \,. \qquad (5)$$

According to the above mentioned approach, we have built the relation between teams power (*H*) and total project time (*T*) for three projects with different complexity Fig. 2.

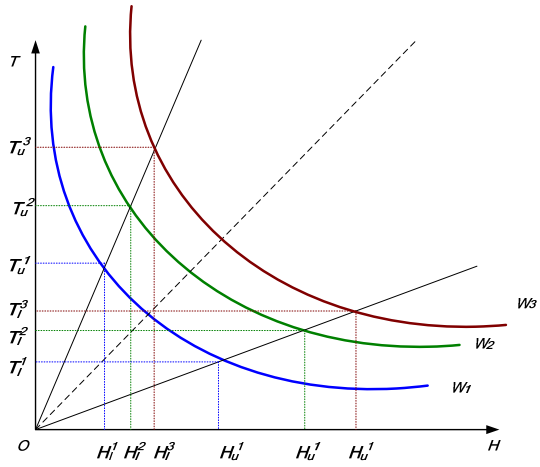

Fig. 2. Project quantity (complexity) changes of distributed collaborative project in time-power coordinate space

Recognizing the importance of the collaborative project efficiency, the experts, however, has not yet agreed on the method of calculating its value [13]. It is believed that along with the main project parameters, which influence on the project effectiveness, one can use various partial parameters. For instance, to calculate the total value of project efficiency, which incorporates the quality of work,

one may use following formula:

$$E = \frac{W}{N} \times Q \qquad (6)$$

where W – the amount of project work (or complexity), N – number of employees, Q - Quality of work.

Besides this one, as additional partial indicators of project efficiency may be included:

– work productivity and its change;

– percentage change in production due to changes in the intensity indicator;

– qualifications of the project teams;

– communication data;

– efficient of time use and others.

VII. Conclusion

In this paper the basic requirements to realization of collaborative distributed CAD levels, collaborative project management model and collaborative project efficiency parameters were provided.

Thus, the modified state equation of project proposed in can be applied to collaborative distributed project management in clothing CAD. Its application may improve the project organization of clothing companies. For example, it shows that: if project number of participants *N* is increasing, team productivity *P* increases too, but project efficiency *E* decreases; with increasing project complexity *D* increases a collaborative support *C* and project efficiency *E*, etc.

In calculating the collaborative project efficiency, besides main project parameters, it would be ideal, if calculating technique would allow us to:

– Estimate social relationships between project teams;

– Consider the commensurability of the general and partial indicators of the project efficiency;

– Consider relationship between the quantity and quality of collaborative work.

These items are the main aim of future research.

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