Cooperative Design

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Abstract: This document is the final report of a project supported by the European Community via an individual fellowship through the Human Capital and Mobility Programme. Title of this project is "A Methodology and Computational Support Environment for Cooperative Design of Knowledge Systems". This report is essentially a collection of papers published by the author in the context of this research project. A brief summary of the research problem and final results introduces this work.

This report (i) discusses a method to concurrent design in which multi-functional groups actively participate; (ii) proposes a multi-agent distributed software architecture for the development of computer-based tools to support our design method; and (iii) illustrates the development of a design environment on the World Wide Web, implementing aspects of the conceptual software architecture.

Key-words: customer-centered design, design rationales, distributed engineering, concurrent engineering, software agents, WWW

(Résumé : tsvp)

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La Conception Coopérative

Résumé : Ce document est le rapport final d'un projet financé par la Communauté européenne dans le cadre du programme Capital humain et mobilité et intitulé "Une méthodologie et un environnement d'assistance pour la conception coopérative de systèmes à base de connaissances". Il s'agit essentiellement d'un recueil d'articles publiés par l'auteur dans le cadre du projet.

L'article (i) présente une méthode pour la conception concourante en groupes multi-disciplinaires. L'article (ii) propose une architecture multi-agents distribuée pour le développement des outils d'assistance à la méthode décrite en (i). L'article (iii) illustre le développement d'un environnement de conception sur le World Wide Web fondé sur l'architecture décrite en (ii). Une introduction résume les problèmes de recherche abordés dans ces articles ainsi que les résultats obtenus.

Mots-clé : conception coopérative, logique de conception, ingénierie distribuée, ingénierie concourante, agents logiciels, WWW

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The generous financial means provided through the HCM program enabled us to create a situation in which we could focus in depth and without distraction on our research and on the key objectives of the HCM program. It has enabled and supported numerous publications and international work.

The administrative support and resources provided by INRIA - Sophia Antipolis, the host institute, were efficient and effective. Moreover, the variety of high quality research projects on-going in the institute formed an intellectual source of inspiration and stimulated exciting discussions.

The Acacia project group provided me with an instructive and intellectually rich research environment on a day-to-day basis. I felt well integrated in the group's on-going research projects and its active social life.

1 Introduction

Market opportunities of a company are co-determined by the capabilities and properties of the company's organization. To meet the unpredictable, dynamic market evolutions and global competition, business enterprises seek ways to establish more effective and flexible organizations of their work and people.

We observe that companies dismantle their hierarchies to give autonomy to small multi-functional teams which form the central units in the organization. Some people talk about *project-oriented organizations* to stress that project teams are these central units. Each activity in the enterprise must supply added value to customer satisfaction. Others talk about *virtual corporations* to stress that current organizations are a collection of loosely-coupled and temporal alliances (among people within and across organizations) based on key competences. These alliances emerge around market opportunities. Essential to these flexible enterprises is that focus is on the customer and the enterprise adapts to the customer's (evolving) needs and the market opportunities it wants to respond to.

Enterprises strive at flexible organizations to quickly respond to market opportunities and changes, to improve customer service and product quality, and to reduce costs by increasing its operational efficiency.

Our research contributes to enable and support this trend. We have created an approach to customer-centered design in which customer representatives and design specialists are enabled and stimulated to cooperatively conceptualize a desired system. Each project team member is recognized to have a key competence which is exploited to add to the quality and usability of the overall project result. These competences are unified through a dynamic project organization. Flexible project control supports an opportunistic design process which is driven by the customer's evolving comprehension of its needs, the design, and the design's implications in the customer's work practice.

This research continues our previous line of work in *CommonKads*-like methodologies to analyze and design functionally competent problem solvers (Steels, 1990; Vanwelkenhuysen and Rademakers, 1990; Vanwelkenhuysen, 1993; Wielinga et al., 1993). We shift the technology-centered focus of these methodologies to a customer-centered focus. A complementary methodological component for the CommonKads methodology is designed to work towards a development process which (next to functional competence) stimulates social acceptance to create a feeling of ownership by the customer, a willingness to change work practice (if needed) and to use the final software system. Social acceptance, usability, management of change and quality control are essential targets we stress throughout our research.

Key research problems addressed to design an approach to customer-centered, cooperative design are briefly described below. Next, we overview the research results obtained in this project.

2 Research problem

Customer-centered design refers to a design process in which customer representatives and designers work together to conceptualize a desired target system. Project teams are ideally composed of design specialists and representatives from different communities in the client-organization whose work is affected by the project. For example, to develop products for a wide public, a project team typically groups representatives from design, production, testing, marketing, finance, sales, end-users and so forth. Work practice, work culture, background, responsibilities, and know-how of these project team members are different. Consequently, they are likely to have diverse concerns and specific interests. This heterogeneity causes different viewpoints on what the problems in reality are, on what design problems are relevant, on what makes up usefulness and acceptability.

Our research question can be summarized as *"What conditions and social settings in a conceptual design process enable and stimulate group acceptance and usability whereby a group is composed of people with heterogeneous viewpoints and concerns?"*. Our research hypothesis is that usability and acceptability by a group are related to the ability to change and adapt (*plasticity* and *robustness*), and to encompass multiple points of view (*coherence*) while increasing communication across viewpoints.

To illustrate the intuition behind this research problem and hypothesis, consider the following case from an industrial knowledge engineering project (Vanwelkenhuysen, 1993). In that project, we developed a knowledge-based system to diagnose processor and other digital boards (generally referred to as «hardware devices») which failed their functional acceptance tests (i.e. the hardware devices do not function as described in their functional specification). This diagnostic system is installed in the production plant of a telecommunications company.

During an organizational analysis of the production plant prior to the knowledge-based system (KBS) design process, two processes were identified as involving diagnostic activities as a response to a hardware device failure of functional tests (situation A and B in figure 1. In situation A, first-off productions (a small series of devices produced for (design and manufacturing) test purposes) are tested to verify acceptability of the hardware device's design with respect to manufacturing and testability and to program the functional acceptance tests. Test engineers may benefit from a diagnostic KBS in this work process to improve the fidelity and precision of their work. In situation B, hardware devices are diagnosed which fail the acceptance tests which are executed on each device leaving the high quantity assembly process. Testers may benefit from a diagnostic KBS to improve the efficiency of their daily testing activity. Engineers and testers were identified as target end-users of the KBS. Representatives from these two groups were members of the project team.

Designing a diagnostic system that is useful and acceptable to both type of end-users (engineers and testers in situation A and B, respectively) requires an ability to manage disparate viewpoints and inconsistencies in requirement priorities: As discussed in (Vanwelkenhuysen and Mizoguchi, 1995a) (see also page 17), engineers and testers have different, even incompatible, view points on way the KBS should go about diagnostic problem solving. These differences in viewpoints are due to the fact that the diagnostic problem solving behavior of these two type of end-users have adapted differently over time to the different forces shaping and acting upon their work. For example, for engineers it is important to have precise and faithful diagnosis because an inaccuracy in their work is likely to propagate with an exponential growth of cost to repair the inaccuracy. Testers, on the contrary, need to pay more attention to the efficiency of their diagnosis because of reasons related to the short product life-cycle of the devices to be tested and the marginal cost propagation of inaccuracies in their work (figure 2).

Current practice in software and knowledge-based system design demands that these inconsistencies between requirements priorities are resolved. Different viewpoints about the required/desired problem solving behavior need to be harmonized to converge to one common and homogeneous requirements and behavior specification. However, insisting on this kind of homogeneity endangers usefulness of the designed software system for different groups. In our research we challenge the need for this and other types of homogeneity to appreciate that different groups inherently