The Art of Communication: a Collaborative Decision-Making System among Different Industrial Design Stakeholders  
*The case of the company ASUS*

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**Abstract:** Collaboration benefits the process of complex design. However, there are many communication problems among different stakeholders in the domain of industrial design, because the situation of communication and decision-makings for stakeholders is so complicated. To deal with the complexity requires both a web-based collaborative system to communicate and share information immediately, and a multi-agent system (MAS) integrated with KW architecture to possess different levels of competence at performing a particular task. The goal of our system is to integrate a variety of representational methods of transferring knowledge and to communicate among different stakeholders using a single platform. To demonstrate our proposed concepts, we focus on a prototype system for notebook design for the company ASUS, a leading notebook manufacturer based in Taiwan.

1. **INTRODUCTION**

There is substantial evidence to support the statement that collaboration represents more than just the sum of the parts. Human–human collaborative problem-solving theory suggests that people construct and maintain an understanding through dialog in which meanings are accrued incrementally, as well as evidence of what has been understood to date (Ostwald, 1995). For this reason, collaboration benefits the process of complex design. In the domain of industrial design, a development project usually involves diverse
team members such as sales manager, project manager, industrial designer, and mechanical, electrical, and layout engineers. Different stakeholders have different views of the system, while they also need to be able to communicate with each other using common models and languages (Johannesson and Perjons, 2001). According to Burdman (1999), however, there are 11 factors that cause poor communication: (1) people have backgrounds in different disciplines; (2) a lack of mutual understanding of terminology; (3) personality; (4) hidden agendas; (5) ineffective meetings; (6) proximity; (7) assumptions; (8) poor infrastructure and support; (9) being an expert; (10) fear; and (11) lack of a good communication structure/system. In addition, the sharing of real-time information and updating information can also pose difficulties.

Such complexities in decision-making compel managers to utilize information-analysis tools to support business decisions. Decision support systems (DSS) are becoming increasingly more critical to the daily operation of organizations. Data warehousing, an integral part of this, provides an infrastructure that enables businesses to extract, cleanse, and store vast amounts of data; however, only a fraction of the required information is stored on computers: the vast majority of a firm’s intellectual assets exist as knowledge in the minds of its employees. Knowledge warehouse (KW) architecture not only facilitates the capturing and coding of knowledge, but also enhances the retrieval and sharing of knowledge across an organization (Nemati, Steiger, et al., 2002).

To deal with such complex communication and decision problems, therefore, requires both a web-based collaborative system to communicate and share information immediately, and a multi-agent system (MAS) integrated with KW architecture to possess different levels of competence at performing a particular task. One significant benefit of multi-agent systems (MASs) is their scalability. In MAS, the agents need to work collectively such that, as a group, their behaviour solves the overall problem without disruption, conflict, or glitches. When a task is assigned, the agents are likely to be in need of finding other agents to collaborate with. Such a task is easy if the agents know exactly which agents to contact and at which location (Zhu 2006).

For our particular system, the goal is to integrate a variety of representational methods of transferring knowledge and to communicate among different stakeholders using a single platform. Our system especially focuses on the way in which to efficiently communicate between people in the marketing and design sections of an organization, because the sales manager rarely has a chance to communicate with the industrial designers or engineers. In addition, not all requirements can be incorporated in the industrial product because of design and technology constraints. As the
project manager is involved for both areas, it is important to consider communication between the project manager and the sales manager, as well as communication between the project manager and the industrial designer or engineer (Figure 1).

![Figure 1. Concept diagram of communication flow for suggested system.](image)

To demonstrate our proposed concepts, we focus on a prototype system for notebook design for the company ASUS, a leading notebook manufacturer based in Taiwan. We therefore need to know the entire notebook development process at ASUS and then use this understanding to develop our particular system. First, we acquired knowledge by interviewing different stakeholders to obtain domain knowledge and work scenarios. Secondly, in terms of knowledge management, we analyzed data from the interviews and stored this information in different databases as a knowledge warehouse and a decision instance database. Thirdly, in terms of the combined multi-agent system (MAS), we used MAS to assist in stakeholders’ collaborative work and in assigning tasks. Finally, in terms of Web-based distributed technology, we integrated our system with CSCW technology that enables different stakeholders to communicate with the system and with each other. The system design principles involved in this prototype can be extended to other design domains.
2. BACKGROUND

2.1 New Product Design Development Process in Industrial Design

In addition to considering aesthetics, usability, and ergonomics, product design can also encompass the engineering of objects, usefulness as well as usability, market placement, and other concerns (Wikipedia, 2005).

In business and engineering, new product development is the complete process of bringing a new product to market. There are two parallel aspects to this process: one involves product engineering; the other is marketing analysis. Marketers see new product development as the first stage in product life cycle management, engineers as part of Product Lifecycle Management. There are several stages in the new product development process (Figure 2).

![Figure 2. New product development process.](image-url)
These steps may be iterated as needed. To reduce the time the process takes, many companies are completing several steps at the same time. Most industry leaders see new product development as a proactive process where resources are allocated to identify market changes and seize upon new product opportunities before they occur. Many industry leaders see new product development as an ongoing process in which a new product development team is always looking for opportunities (Wikipedia, 2005).

2.2 Decision Making Process in CSCW

2.2.1 Computer Supported Cooperative Work (CSCW)

Few contest the claim that modern information technology, supported by computers and communications, contributes to a dramatic improvement in productivity and effectiveness among individuals engaged in a wide range of tasks. Computer-supported cooperative work (CSCW) aims to provide similar improvements for ‘multiple individuals working together in a conscious way in the same production process or in different but related production processes.’ If achieved, this aim promises to multiply our productivity, perhaps by more than the square of the number of users, as compared against the productivity improvements that personal computers provide to each of us as individuals (Mills, 1999).

CSCW researchers propose a new type of software called CSCW system or groupware (Ellis, 1994), which is software for teamwork and can aid communication in an organization and helps staff work together on joint tasks. From basic components or ideas within groupware, more complex forms can be created (LePoire, 1999). Groupware can be defined as software that facilitates work within groups and provides three key group functions: communication, collaboration and coordination (Chaffey, 1998).

Groupware characterizations attempt to group disparate technologies such as email, forums, and workflow, file sharing, document management, conferencing, and shared applications. The relationships and boundaries between these are not well defined (LePoire, 1999). Table 1 shows the main groupware functions. The main functions are usually present in groupware applications to help teams collaborate.
Table 1. Main groupware functions (Chaffey, 1998).

<table>
<thead>
<tr>
<th>Groupware function</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Email &amp; messaging</td>
<td>E-mail, electronic forms processing</td>
</tr>
<tr>
<td>Document management and information sharing</td>
<td>Improved information dissemination</td>
</tr>
<tr>
<td>Collaborative authoring</td>
<td>Team development of documents</td>
</tr>
<tr>
<td>Conferencing</td>
<td>Text conferencing, video conferencing, white boarding</td>
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<tr>
<td>Time management</td>
<td>Calendar and group scheduling</td>
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<td>Groupware management and decision support</td>
<td>Remote and distributed access facilities including replication and access control</td>
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<tr>
<td>Ad hoc workflow</td>
<td>Loosely coupled collaboration</td>
</tr>
<tr>
<td>Structured workflow</td>
<td>Structured management of tasks</td>
</tr>
</tbody>
</table>

2.2.2 Project Manager as a Decision Maker (CSCW point of view)

Leading organizations we studied generally hold project managers accountable for meeting cost, schedule, and performance goals. Some of these organizations allow individual project managers to decide what management tools best meet their needs to monitor and track project milestones and to identify cost and schedule variances from the project plan. To do this, project managers have to do several sequences of decision makeings: intelligence, design, choice and implementation (Guisseppi, 2002).

Decision Support Systems (DSS) are defined as interactive computer-based systems intended to help decision makers utilize data and models in order to identify and solve problems and make decisions (Power 1999). DSS are further classified into four main categories: data, model, process and communication oriented. Decision making support has evolved over time and across disciplines. Initial support was offered by a DSS, with the typical architecture shown in Figure 3. In the typical DSS, the problem-pertinent data and models are captured and stored as inputs in the system (Guisseppi, 2002).

The DSS concept presumes that the problem pertinent data and models have been created and made available to the system prior to user processing (Hooghiemstra, Kroon, et al., 1999). It also assumes that the user can utilize the computer technology to perform the technical processing operations and computations required by the system (Lawrence and Sim, 1999).
2.3 Knowledge Management for Collaborative Systems

2.3.1 Interview

Patton (1990) suggests three basic approaches to collecting qualitative data, through interviews that are open-ended: informal conversation, the general interview guide approach, and the standardized open-ended interview. Informal conversational interviews are a spontaneous flow of questions where the subject may not realise that the questions are being monitored. The general interview guide approach predetermines a set of issues to be explored. The standardized open-ended interview pursues the subject through a set of fixed questions that may be used on a number of occasions with different subjects. The three approaches are distinguished by the extent to which the questions are standardized and predetermined, each approach having strengths and weaknesses dependant to some extent upon the purpose of the interview.
In a guided interview, taking notes is deemed to be a distraction in developing an affinity with the interviewee. This is where verbatim transcripts of recorded interviews prove invaluable. The interviewer is free to be attentive to the interviewee, in the knowledge that the transcribed details can be attended to later (Gittins and Bass, 2000).

2.3.2 Scenario-Based Design

Scenario-based design is useful in situations where the design of the system is fragile in the sense that there is no detailed conception of exactly which work activities should be supported and in which way (Bardram, 2000). Such systems are characterized by high uncertainty and risk, and therefore have to adapt an experimental and iterative way of design (Boehm, 1988).

The purpose of collaborative scenarios is to provide support for the overall design of a computer system by describing collaborative work activities that are to be supported and/or affected by the future computer system. Such scenarios are work-driven, open-ended and informal narratives of what people do and experience as they try to perform different activities with or without making use of a computer application (Karat, 1995). The definition provided by Carroll (1995) makes a good starting point for discussing what a collaborative scenario should cover: “The defining property of a scenario is that it projects a concrete description of activities that the user engages in when performing a specific task, a description sufficiently detailed so that design implications can be inferred and reasoned about. Using scenarios in system development helps keep the future use of the envisioned system in view as the system is designed and implemented; it makes use concrete – which makes it easier to discuss use and to design use.”

2.3.3 Knowledge Warehouse

The goal of a knowledge warehouse (KW) is to provide the decision maker with an intelligent analysis platform that enhances all phases of the knowledge management process. Two comments can be made to further amplify and explain the KW goal: first, this goal assumes that the user of the KW is the decision maker; second, an intelligent analysis platform is defined as a PC-based platform that makes available to the decision maker an array of analytical tools, each of which utilizes various technologies to aid the socialization, externalization, combination, and internalization of knowledge management (Nemati, Steiger, et al., 2002).

Compared with data warehouse for data, KW is more complicated. The primary source of data in data warehouses is transaction data (easily stored
in a relational database), but the primary sources of knowledge in the knowledge warehouse include text streams, film clips, mathematical models and their instances (stored as equations, matrices, arc/node descriptions, etc), and analysis results (stored as equations, weight matrices, text streams, etc). Further, for knowledge stored in the form of models and solved model instances, the KW is required to efficiently store, retrieve and manipulate many solved model instances, with each instance tied (logically) to its associated model and/or tied (logically) to a related instance (Nemati, Steiger, et al., 2002).

Development and implementation of KW architecture requires the following generic activities (Nemati, Steiger, et al., 2002): (1) designing and implementing techniques to identify and record both knowledge and ignorance and then designing processes to share, use, and protect such knowledge and to remedy ignorance by learning or knowledge creation; (2) designing and orchestrating contexts, environments, and activities to discover and release what is not formally or explicitly known and possibly coaching and encouraging people to be effective in these processes; (3) articulating and communicating the purpose and nature of knowledge management and connecting it to other strategic and operational initiatives and activities of the organization. These factors are due to the additional tasks that knowledge warehouses should perform. They are the following: (1) Creation of a knowledge management infrastructure. (2) Building a knowledge culture by active promotion of the knowledge agenda, including the development and diffusion of knowledge management models, frameworks, and language. (3) Facilitation of knowledge-oriented connections, coordination and communication throughout, and also without, the organization.

2.4 Multi-Agent Systems (MAS)

One of Multi-agent information systems research goals is to study how an agent adjusts knowledge, goals, skill and plan, to generate the collective behaviours through the interactions among agents. Multi-agent systems are composed of two or more intelligent agents (Figure 4(a)). An agent has detectors, effecters and a decision-making mechanism (Figure 4(b)) (Yamada, Nakakoji, et al., 2004).

A general understanding of MAS is that: (1) each agent has a partial capability to solve a problem, (2) there is not necessary a global system control, (3) data and knowledge for solving the problem are decentralized, and (4) computations carried out among the agent are asynchronous (Flores-Mendez, 1999).
Barbuceanu and Fox (1995) design a multi-agent system (MAS) composed of four components: agents, tasks, organizations, and information infrastructure. Agents in the MAS are distributed geographically, are autonomous but interdependent in their task environments, are embedded with self organization capability, and are adaptive to changes in their environment. For dynamic multi-agent systems, agents need to know how and where to find the other agents. The dynamic nature of agent distribution motivates this research to look at the topological models of MAS and study how these models facilitate or hurdle the agent collaborations (Giampapa, Paolucci, et al., 2000).

3. METHODOLOGY

3.1 Interview with ASUS Staffs

In this paper, we chose one notebook development process within ASUS for which to collect qualitative data by interviewing different stakeholders such as the manager, designer, and engineer (Figure 5). Interviewing not only provided qualitative data for this paper but also demonstrated the way in which the proposed system can operate in the real world.
Within ASUS, the process flow for notebook development is as follows. First, the sales manager is provided with requirements determined from marketing analysis and consumer needs, and then communicates with the project manager. Secondly, on the basis of this information, the project manager decides upon goals, the process schedule, team members for the development, and the sourcing of resources. Thirdly, the industrial designer receives information related to the development goals and draws a 2D graphic that is sent to the mechanical engineer who constructs a 3D graphic and model. Finally, the electrical engineer designs the connector and electronic components and has the layout engineer design the circuit. Over the entire development process, the engineers largely follow the designer’s idea because the technology exists to support any new type of notebook development.

### Establishment of the Knowledge Warehouse

As each stakeholder owns a different domain of knowledge, we established a KW that enables stakeholders to store and retrieve their knowledge. The
project manager uses the KW to make decisions and communicate. Figure 6 shows the location of KW in our particular system. The knowledge related to sales manager is marketing analysis, customer psychology, production cost, etc. For industrial designer, it is design principles, idea generation and drawing representations. The knowledge related to engineer is product mechanics, electrical layout, etc. Those are stored in KW as their domain knowledge. The KW also supplies a management platform for project manager and via KW he/she communicates and makes important decisions with other stakeholders.

![Figure 6. The location of KW in our system.](image)

### Establishment of the Decision Instance Database

For the decision instance database, we take into account the project manager's requirements and the decision principles of ASUS and followed the decision-making process to store necessary information and instances. Here we supply the decision-making history and marketing analysis information for the project manager to add to the decision instance database and thereby help in making important decisions. The project manager must consider the following tasks over the entire notebook development process:

1. Using marketing analysis data to formulate the notebook development goal and design target.
2. Deciding upon which stakeholders to organize into the development team, assigning tasks, and communication with stakeholders.
3. Arranging and maintaining the development schedule.
4. Choosing references and collecting resources and supplies for the industrial designer.

3.4 Different roles in the Multi-Agent System

The multi-agent system (MAS) is a system used to support our proposed system. The stakeholder can communicate with others or the core system via the collaboration of agents in MAS. We established several agents to help with different functions (Figure 7):

1. Interface agent: the interface agent provides a communication platform for stakeholders and sends requirement messages to the Task agent.
2. Task agent: the task agent operates according to the requirement messenger and assigns work to different agents.
3. Knowledge agent: the knowledge agent is linked to the management knowledge warehouse. Each stakeholder can store and share knowledge information via this agent.
4. Instance agent: the instance agent is linked to the management decision knowledge database. It can provide decision cases and suggestions for the project manager.

4. IMPLEMENTATION

4.1 System Architecture

The system proposed in this paper uses Java as a development language, because Java is a general-purpose programming language with a number of features that make the language well-suited for use on the World Wide Web, it meets our requirements in the present paper. The entire system concept is to enable communication between different stakeholders, store and share information in a single platform, store all information in a central database (KW and decision instance database), and provide the data upon which the project manager makes decisions (Figure 8).
Figure 7. Multi-agent system supports for different stakeholders.

Figure 8. The system framework.
When users login to the system, the system will show a customized interface according to the user’s role. Because different stakeholders have different domain knowledge, depending on the roles of the each stakeholder, the system only shows information that is important for the individual stakeholder. We believe that this concept makes the system more convenient and separating information. In the system overview presented in Figure 8, the entire system and interface implementation are focused on the project manager. For the project manager, this system does not automatically make any decision by itself; it provides information from the knowledge warehouse and decision instance database to the project manager or agent and provides suggestions that help the project manager with his/her thinking and decision-making.

4.2 System Interface

The example interface for the project manager is shown in the following three figures. The entire interface operation flow that we used in the scenario description enables the project manager to perform functions step-by-step. In this way, the user can draw on system instructions to appropriately operate the system; this avoids excessive information that can lead to confusion and error.

Figure 9 shows the main interface for the project manager. He/she can select the work that he wants to perform. When the project manager wants to make a decision and to refer the decision history saved in the KW, he/she can connect to decision KW and perform the required tasks, for example, fill the descriptions out, etc. for this interface (Figure 10). After that, our system can display the results according to the user’s query (Figure 11). With the KW and immediate feedback, the system is able to help the project manager to support his/her decision-makings for the project.

5. CONCLUSION

In this paper, we developed a system that can support communication and the sharing of information between different stakeholders, as well as provide data for the project manager to analyze, consider, and decide upon over the entire development process. We expect that our proposed system can support several important decision-making events in product development via improved communication and collaboration within the design team and multi-agent, and via the distribution of multiple information sets to each of the stakeholders, especially the sales manager.
There are several directions the system can be extended in the future:

1. **Support for multi-file formats:** different domain stakeholders may use different software to finish each part of the process, thus producing a variety of file formats. If the proposed system can be adapted to accept different file formats, this will help make communication more convenient and enhance the sharing of information.
2. **Record data within the server**: If the stakeholders are agreeable, the system can record their work behaviour. In this way, we can acquire considerable data concerning cooperative work; such data is useful for research into collaboration design in academia and business.

6. **REFERENCES**


