A Three-Faceted View of Information Systems:
The Challenge of Change

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Dealing with change is one of the most fundamental challenges facing information systems professionals today. Business process restructuring, shifting alliances and new competitors, deregulation and globalization, legacy system migration and new technology adoption, are but a few of the economical, organizational, and technological forces contributing to the pervasiveness of change in today's IT environment. Flexible and adaptable information systems can be powerful enablers for organizational and business innovations, whereas rigid, inflexible systems are serious obstacles to organizational effectiveness and success.

The computing field has responded to the challenge of change and the need for flexibility in a number of ways. For example, *systems* and software architectures have been developed to offer various notions of independence at many levels of abstraction (e.g., data independence and orthogonal persistence in databases, distribution transparency in distributed systems, code mobility in programming languages like Java). Richer conceptual *models* are beginning to be used to support traceability in requirements and in design and new kinds of systems based on e-mail, groupware and shared intranet workspaces have gained wide acceptance .

However, conceptual cohesion among these efforts is still missing. In this article, we argue that in order to deal effectively with change, one needs to adopt a comprehensive approach that recognizes the many types of system evolution and their inter-dependencies. Recognizing that various areas of computing, business administration, and social sciences have made substantial advances in understanding and dealing with change from their respective viewpoints, we advocate a strategy that builds on these advances and practices. In the context of understanding and managing change, we propose to group issues under three interacting facets: the *systems*, *group collaboration*, and *organizational* facets. We should emphasize that this article aims at gaining a broader understanding of the change management problem, rather than offer a comprehensive solution.

The Three Facets of Information Systems

We envision that change-related issues for information systems arise from three areas of concern -- systems, group collaboration, and organization -- and the interactions among them (Figure 1). We call these the three *facets* of information systems [4].
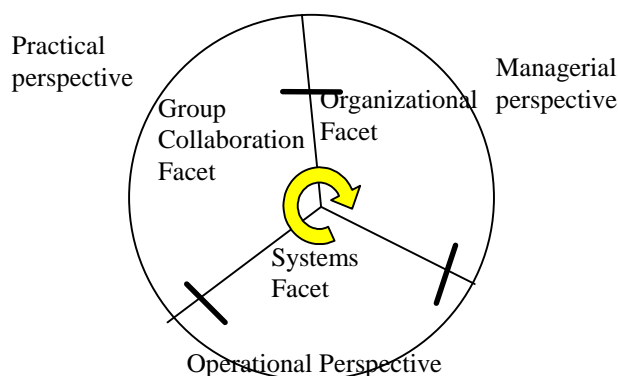

Figure 1: The three facets of information systems

The *group collaboration* facet is concerned with people working on a common process (e.g., handling a purchase order) or on an ad-hoc project (e.g., co-authoring a report). During such collaborations, people

coordinate their activities, deal with contingencies, and change their practices through discussion and learning. The nature and style of work fluctuates and is often not predictable. Some problems in this facet have been addressed in terms of personal tools and groupware which facilitate group work across temporal and spatial boundaries. The problem this facet poses to the systems facet is that group collaboration, by its very nature, requires a high degree of flexibility and malleability in the systems that support human work. The open-ended, fluid nature of group collaboration is also in constant tension with the more formal and prescriptive nature of organizational structures and processes. From a group collaboration facet, organizational models can be seen as helpful tools for guidance, invoked on demand by the workers. Alternatively, such tools can be seen as means for stifling creativity and enabling bureaucratic centralization.

The *organizational* facet is concerned with managing work from a formal organizational perspective. This facet addresses global organizational concerns, including organizational objectives and business goals, policies, regulations, as well as resulting workflow or project plans. This facet has been extensively studied in Organizational Theory (see, for instance, [5, 8]). In connection with IT, the facet has been addressed using models of organizational processes and entities (as in ERP system models), and more recently, models of business rules and policies, or goals and interdependencies among organizational agents. The organizational facet is where initial requirements for large systems typically originate because organizational goals or problems are often the only formal means to justify large investments. However, subsequent refinements usually take into account group collaboration issues and the constraints and capabilities of the supporting technologies.

There are many different theories on how the formal organization interacts with the group collaboration facet and with the system facet when developing information systems. These range from traditional "rationalistic" approaches that derive work practice and system specifications top-down from organizational goals, to worker-oriented or political approaches where both the organization and its systems are seen to emerge from practice patterns in the group collaboration facet [5]. However, there is increasing agreement that work practice, organizational structures, and the way information systems are developed and deployed, are all inter-dependent [7], but also independent factors in that none can be reduced to the others. What this kind of literature is typically missing in comparison with our approach, is a more in-depth analysis of how new information systems technologies influence the interplay between different facets.

The *systems facet* accounts for systems developed through the application of information technology. Such systems generally deploy conventional technologies, such as programming languages, DBMSs, files, and workflow systems. Moreover, they operate on heterogeneous hardware and software platforms, were developed in a bottom-up fashion and were intended to serve local and often less-than-permanent needs. Others were systematically developed by the organization to serve goals which later became obsolete or too narrow. To support change in this facet, one needs to deal with issues of heterogeneity and incompatibility among systems. Much work has been done in the past decade under the rubric of system interoperation and middleware, addressing concerns like data transfer, syntactic and semantic compatibility, as well as control integration [1]. This is to ensure that all systems within an organization (and increasingly across organizations) can share data and use each others' functionality, independently of the platform on which they were developed or are currently executing, also independently of their original purpose or origin. The problem that this facet poses to the group collaboration facet is that once built, systems tend to become inflexible, and are not easily adapted to rapidly changing work situations. The systems facet also poses problems to the organizational facet in that traditional system development efforts are costly, involve long lead times, are hard to manage and even harder to change in order to align them with a changing organizational reality.

The three facets reflect three complementary points of view for understanding an organizational information system. More specifically, work within an organization can be viewed
- as executions of operations on a system (the operational perspective), or
- as events in the history of group practice (the practical perspective), or,
- as performances intended to fulfill organizational objectives in accordance with organizational rules (the managerial perspective, see also Figure 1).

Traces of the history of an organization are, therefore, different in the three perspectives. From the operational perspective, a trace consists of sequences of operations executed by various systems. From the practical perspective, traces are partial orders of events characterizing the history of a group activity. Finally, from the managerial perspective, traces document how well tasks were performed in accordance with existing rules and constraints in order to reach pre-established organizational objectives, possibly also how well the established organizational rules actually work in practice. Although users can switch from one perspective to another, in

order to pay more attention to a facet that is becoming more relevant, there are no rules allowing them to either anticipate or avoid these switches.

A third way to understand our three-faceted view is to regard it as a foundation for defining *cooperative information systems* [6]. An agent is *cooperative*, if it shares goals with other agents in its environment, and if it contributes positively towards the fulfillment of these common, but possibly changing goals. Definitions of cooperative information systems from the 1980s focused on cooperation with a single user, for instance, through natural language interfaces or semantic query processing [2]). Recent definitions [3, 4], on the other hand, tend to see such systems as computational agents that share and continue to share goals with other information systems, human agents, as well as the organization within their operational environment. While the basic tensions between formal organization and group practice will certainly not vanish, the main goal of this article is to point out that there is a large number of new technological options with some potential to mitigate these tensions in new ways. A secondary goal is to show that these technological options and the opportunities they offer constitute no excuse for computer scientists to continue to ignore the other two facets.

Characterizing Change in Terms of the Three Facets

The three-faceted framework is useful for classifying the origins and impacts of change. Change can originate in any of the three facets. From the systems facet, a change entails the introduction of new systems that need to be integrated into an existing information system architecture (for example, to set up a corporate Web server). Such changes need to be propagated within the systems facet by addressing questions such as:

- How can the given system interoperate with other systems within the information system architecture? (e.g., publish existing product catalogues on the Web)
- How does the information managed by the new system relate to that of other systems? (e.g., HTML corporate profile and printed corporate profile)
- Is there new software that needs to be written to automate or semi-automate required new functions? (e.g., a bridge to enable Web-based order processing accessing a back-end ERP server like SAP R/3)

Changes within the systems facet also need to be propagated to the group collaboration facet, by answering questions such as:

- How can the new system contribute to human collaborative work? (e.g., improve post-sale customer-support by setting up public FAQ-lists, bulletin boards, and interactive knowledge bases on the Web)
- Are there any required changes to the collaborative processes, to enable the use of the new system? (e.g., documents entered in the knowledge base by support staff have to be proof-read by editorial staff prior to publication on the Web)

As well, the introduction of the new system entails changes to the organizational facet:

- How can the new system enhance the achievement of organizational objectives? (e.g., does our Web server improve customer satisfaction? Does it reduce post-sale customer support costs? Does it improve the time to market of new products? Does it expand our business to international markets?)
- Is there a need for new rules and/or constraints to ensure effective use of the new system? (e.g., support staff is obliged to identify frequently-asked questions to be published on the Web; Web administration is the task of a team of people from marketing and the IT department; Legal issues arising from Web publishing are taken care of by a contract with a law firm).

Likewise, changes may originate from the group collaboration facet:

- Can a system still function smoothly when there is a change in team membership? (e.g., sales staff needs access to a configuration management system used by the production department to improve the responsiveness to customer requests).
- How can new organization models be learned from positive and negative experiences in group practice? How can knowledge present in group practice be preserved as personnel changes?

Changes can also originate from the organizational facet:

- How quickly can a system adapt to new objectives or different prioritization of existing objectives, or the introduction of new business rules? (e.g., multi-lingual Web publishing, in response to new national or international regulations)
- When business processes change, how readily will they be reflected in the workflow models residing in the systems? More importantly, how quickly will they be integrated with work practice, i.e., will people work with, rather than around, the new processes?

For each of these, the three-facet framework suggests a set of questions that needs to be answered, such as "How should a change of type X be propagated internally, and from one facet to another?" Just as importantly, each facet has its own laws of inertia. For the systems facet, it is legacy systems and the lack of interoperability. For the group collaboration facet, it is people wanting to continue doing things the way they were before. Thirdly, for the organizational facet, it is unwillingness to risk change , or invest in change.

It is important to emphasize that the three facets -- though interdependent on each other -- cannot be reduced to each other. For example, Suchman [9] has argued convincingly that people tend to act in a "situated" manner and employ organizations, plans and software systems merely as tools that may or may not be used. For example, an organizational rule, enforced by a computer-based information system, might require the bank teller to obtain either a phone number or an address from a new customer before opening a bank account. However, an intelligent bank teller, facing a new customer who just arrived in town, might ignore this rule and open an account manually, bypassing the computer. The teller is acting here in a situated manner. In a similar spirit, others have argued that the behavior of social entities, such as organizations, cannot be reduced to that of their constituent elements. Thus, there is a continuous interplay between the work practice of the group collaboration facet and the organizational facet, but neither can be reduced to the other and both are influenced by the systems they are using. The rules, roles and goals characterizing the interaction within a work group are defined in the organizational model. Conversely, to resolve problems, group collaborators may modify the organizational model (Figure 2).
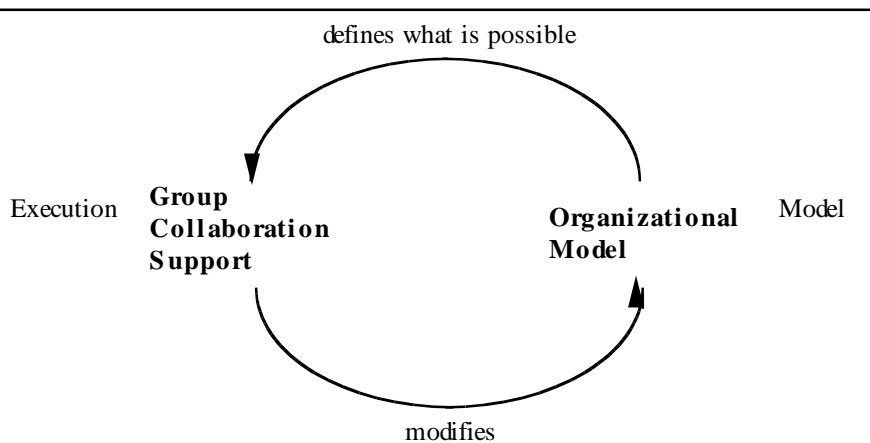

Figure 2: Inter-dependencies between group collaboration and organization facet

In a similar way, systems are artifacts intended to facilitate group work, contribute to the achievement of organizational objectives, and support the enforcement of organizational rules, policies and constraints. While each group member's working space is populated by activities supported by systems (e.g., group calendar, financial management software), the systems are populated by the information they have accumulated from group members and the communication protocols they support for the group members to cooperate.

Finally, there is clearly a two-way interaction between the organizational and systems facets. The former provides the basic organizational structure to the systems which operate within an organization (roles and privileges of system users, business rules governing the use of the systems, etc.). But the organization is also influenced by existing systems and work practice, which provide useful feedback to organizational objectives and policies. For instance, the workflow models stored in the systems facet make reference to the roles defined in the organizational facet and should be consistent with constraints and rules of the organizational facet. Conversely, the roles defined in the organizational facet are characterized in terms of access rights to the system components.

This relationship is not only crucial in propagating organizational changes rapidly to the supporting information systems but also in providing feedback on the organization's performance in meeting business objectives.

New Technologies to Support Traceability Across Facet Boundaries

As change processes transcend the boundaries of the three facets, tracing their changing inter-relationships is becoming a critical prerequisite for understanding, consistency management, and continuous evolution. A number of recent technological developments have the potential to improve requirements traceability beyond the systems facet to the group collaboration facet and to the organizational facet, and thus may lead to future information systems that better accommodate changes originating from any of the three facets.

One such development involves *compartmentalized information system architectures* favor small, light-weight, modular components and applications that are linked directly to individual organizational needs, goals, and structures. As a consequence, the cost and time required for the initial construction and for the long-term maintenance of these applications, and of the gateways between them, can be attributed much more directly to specific business objectives and processes with positive consequences for project management and business process re-engineering. This should be seen in contrast to the architectural rationale of centralized information systems (economies of scale, high level of system consistency, full data integration, division of labor between users and the IT department). It is also in contrast to the vision of grand unifying system frameworks (*switchboard architectures*) like DCOM or CORBA which require a heavy investment to set up and to maintain a common, corporate-wide system infrastructure.

Factoring out control from individual information systems is another strategy, which facilitates the design, implementation and trace of business process changes necessitated by changing work practice or organizational rules. This can be accomplished through the use of technologies such as workflow systems, active database rules, scripting languages, flexible transaction models, or even visual component toolboxes such as Java Beans. Note that "factoring out control from individual information systems" does not mean that control should be relocated in a central control model or system. On the contrary, control should be given "back" to individual workers or organizational units, which may thus be reshaped as required by changing organizational needs. For example, scripting languages in CSCW or software engineering allow locally controlled automation of stereotypical subprocesses.

The *integration of human and system communication* , exemplified by e-mail, HTTP, or Lotus Notes demonstrate the synergy that can be obtained from a clever interplay of human and system resources to achieve a given business goal. Ideally, such systems support a smooth transition between ad-hoc cooperative work of humans (e.g., for problem solving and exception handling) and standardized, automated interaction between autonomous information agents (e.g., via EDI messages or workflow management software).

The *maintenance of links* between systems, their users and organizational models through metadata is a yet another strategy adopted from databases. Here, schema information is used to maintain links to other information system components and higher-level data models, through schema translators, re-engineering tools, access control tools, IDL stub generators, user form generators, and the like. Likewise, *explicit links* between individual information system components (applications, agents, transactions, schemata, workflows, etc.) and corresponding organizational model components (business objects, business objectives, role definitions, design decisions etc.) are not only crucial for propagating organizational changes rapidly to the supporting information systems, but also for providing feedback on an organization's performance in meeting its business objectives. The adoption odf such mechanisms makes it possible to monitor the time and (human) resources consumed by standard business processes that span multiple information systems, or to track the probability of exceptions (for instance, because of human interventions) that occur during a particular process step.

Recent releases of ERP software such as SAP R/3, Baan and Oracle Financials make heavy use of such metadata links between analysis and design models on one hand, and data dictionary and software repository elements modified during system customization and operation on the other. These links support computerized change management agents and human system analysts and developers in charge of system evolution and maintenance.

Reflective languages and systems such as Java, Smalltalk and Visual Basic provide mechanisms to inspect (and possibly modify) their own structure and behavior in the course of their long-term operation in an organization.

Reflective systems have the potential to eliminate the need for meta languages and meta models to manage links between the system and its models at higher levels of abstraction. Meta information such as types, protocols, architectural descriptions, or patterns is represented by ordinary "objects" of these languages (e.g. objects, methods, strings, ...) As a concrete example, the component model of Java Beans is based on ordinary Java classes; they not only provide the component implementation, but also the component properties, protocols and tools for customizing these properties. As another example, the "interception" mechanism in CORBA helps in rerouting messages between distributed objects to enforce network security policies in an organization or to generate work histories. However, without an adequate notion of long-term system integrity and automatic integrity control mechanisms (type systems, data models, consistency rule checking) self-modifying reflective systems end up being hard to understand and difficult to adapt to changing evolution strategies.

Research advances focusing on the group collaboration facet and the organizational facet have also been very much concerned with connectivity and traceability. For example, CSCW has developed various forms of support for communication, coordination, and sharing to transcend spatial and temporal separation as naturally and unobtrusively as possible. Current CSCW discussion on group awareness (i.e., when and how am I informed that another group member has done something that is relevant to me?) is focusing on the tradeoffs between privacy concerns of the trace generators (workers in the group collaboration facet) and analysis goals of organizational management. Requirements engineering techniques, including ones for enterprise and organization modeling, have begun to facilitate the modeling and analysis of complex organizational domains. This is in sharp contrast to earlier work which had an explicit and exclusive focus on the construction of software systems.

As the results of this research begin to find their way into products, methods, and everyday practices, "cross-facet" issues are inevitably being encountered. CSCW systems can benefit from the structure of organizational models with roles and responsibilities, which in turn need to be aligned with the execution models in workflow systems. Enterprise integration approaches are beginning to face the inherently "soft" nature of human and social organizations, and their implications on continuous change. Conceptual modeling techniques are found to be immensely useful in both forward and reverse engineering, as these are becoming increasingly intertwined in order to support ongoing evolution. Goal- and agent-oriented modeling concepts are being introduced to explicitly and systematically deal with aspects of cooperation and change. These and other issues are discussed in more detail in [4].

Challenges for Research and Practice

There is an urgent need to develop information systems that are capable of supporting and managing change in all its manifestations and ramifications. In dealing with change, we need to address not only technological issues, such as "How do I build a system that does X?" but also human and social ones ("How does a group of people accomplish task Y?") as well as organizational ones ("How can we ensure policy Z?"). Even more importantly, answers to such questions have to be continuously updated and revised to ensure continued alignment of systems, work groups and organizational structures. This article has argued that all three facets are necessary for a comprehensive account of change, and none of the facets is redundant in the sense that it can be reduced to the other two.

Despite the great need for a comprehensive solution to the problem of managing change, none seems within grasp. Current research communities tend to be focus on one or at best two of the three facets. For example, the CSCW community focuses on work practice and systems, the Cooperative Information Systems community addresses primarily systems issues, while Information Systems (represented by conferences such as ICIS and CAiSE) deal largely with organizational issues without considering the technical options in depth. We hope that this article can serve as an agent to further the state of research and practice on change management for information systems.

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