FORMAL MODELING FOR WORK SYSTEM DESIGN

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1. Introduction

Work system design is a process of changing organization, technology, and facilities to improve business practices (Scientific American 1992). A redesign team includes workers, management, organizational specialists, and system analysts. The redesign process focuses on worker reflection on how work is typically done (Greenbaum & Kyng 1991). Different techniques are used to understand current practices: empirical observation (ethnography), worker interviews, information flow analysis, and computer simulation (Jordan 1992). New designs focus on facilitating communication that encourages “end-to-end” responsibility. This is accomplished by reducing “functional silos,” and encouraging spread of ongoing local innovations (e.g., Hammer 1990, Nonaka 1991, Lave and Wenger 1991).

This approach for changing the workplace relates to socio-technical systems methods used for many decades (e.g., see Hirschorn 1984, Ehn 1988, Zuboff 1987, Clancey in press). However, today’s redesign teams emphasize worker involvement, multidisciplinary collaboration, and the use of computer tools for visualizing work flow and measuring or comparing alternative processes (Kukla, et al. 1992). Furthermore, today’s redesign efforts bring together cognitive psychologists and social scientists, making each redesign process itself a research project in integrating alternative theories of knowledge, learning, and organizational change (Brown 1991, Kling 1991, Scientific American 1993).

Work system design occurs today in a complex organizational and business environment. Competing values, power structures, and change methodologies influence a redesign project:

- Competitors, often more flexible smaller companies, capture market share by providing comparable or better services at lower cost.
- Short-term assessment of cost cutting conflicts with less measurable processes of individual growth and organizational learning.
- Technologists seek to remove people and automate all possible aspects of work flow.
- Existing and often redundant computer systems may only be changed or replaced incrementally.
- If management style seeks to impose change on workers, the redesign team may believe that this is how their plan will be implemented.
- Management not immediately involved in a redesign effort may seek to preserve turf and jobs; unions may seek to maintain job definitions separating workers and managers.
- Many work system modeling tools promote a static, functional view of routine work, oriented around work products, rather than human interaction and learning.

In our collaboration at NYNEX we are investigating methods for changing how change occurs. We give high priority to better understanding the uses and limitations of formal modeling tools. We want to develop tools that are conducive to the shift in mindset about business functions and responsibility that we believe is necessary for lasting change to occur (Schön 1987). These tools must help workers articulate and visualize their own experience, if possible by manipulating models directly, without intervention by others.

Our approach is to combine knowledge-based representation techniques, situated action theories of human cognition (Winograd and Flores 1986, Suchman 1987, Lave 1988, Gasser 1991), and ethnography to critique existing models, understand our past redesign efforts, and develop new tools and methods. To illustrate how this combination of perspectives provides a starting point for resolving some of the contextual issues raised above, we present a strawman example of how work systems design might otherwise be carried out.

2. The Job Multiplexer Architecture

Consider an example of an order processing office, in which customer orders, material requisition, and installation procedures are handled by a half-dozen, non-integrated computer systems. Office workers repetitively copy material between paper and computer screens. It isn't possible to go to any one person or inquire in any one computer information system to determine the status of a customer's order. Difficulties are handled by continuous communication between people, shouting between desks or by the phone.

A team of technologists and system analysts proposes an integrated computer system, called the "Job Multiplexer" (Figure 1). This artificial intelligence system will dynamically transform a customer order into a work plan. The goal of this project is to drive people out of the system and hence cut costs. The job multiplexer will automatically transmit messages between the diverse databases and scheduling programs. The information systems will validate and complete orders, confirm resource availability, order supplies, and schedule tasks. Individual workers will receive on their workstations an ordered queue of tasks to do. These tasks involve getting information from outside the system (e.g., contacting the customer, confirming credit worthiness) and assembling the actual work product (e.g., telephone circuits). As new jobs enter the system from customers, the job multiplexer dynamically reassigns tasks to workers to satisfy the company's objectives of timeliness and resource priorities for different customers. In so far as different workers are trained to accomplish different tasks, the job multiplexer will dynamically reconfigure the office. Workers sitting at their terminals will constitute new organizations, integrated and focused in new ways, under control of the job multiplexer, without any management intervention or communication between workers.

Dynamic reconfiguration of people, technology, and facilities will maximize efficiency. This design allows for real-time and seamless flow of information throughout the business. Tedious and error-prone human copying of information is eliminated. The overall system is easily modified and updated. Formal proofs of correctness demonstrate that the scheduling algorithm is correct.

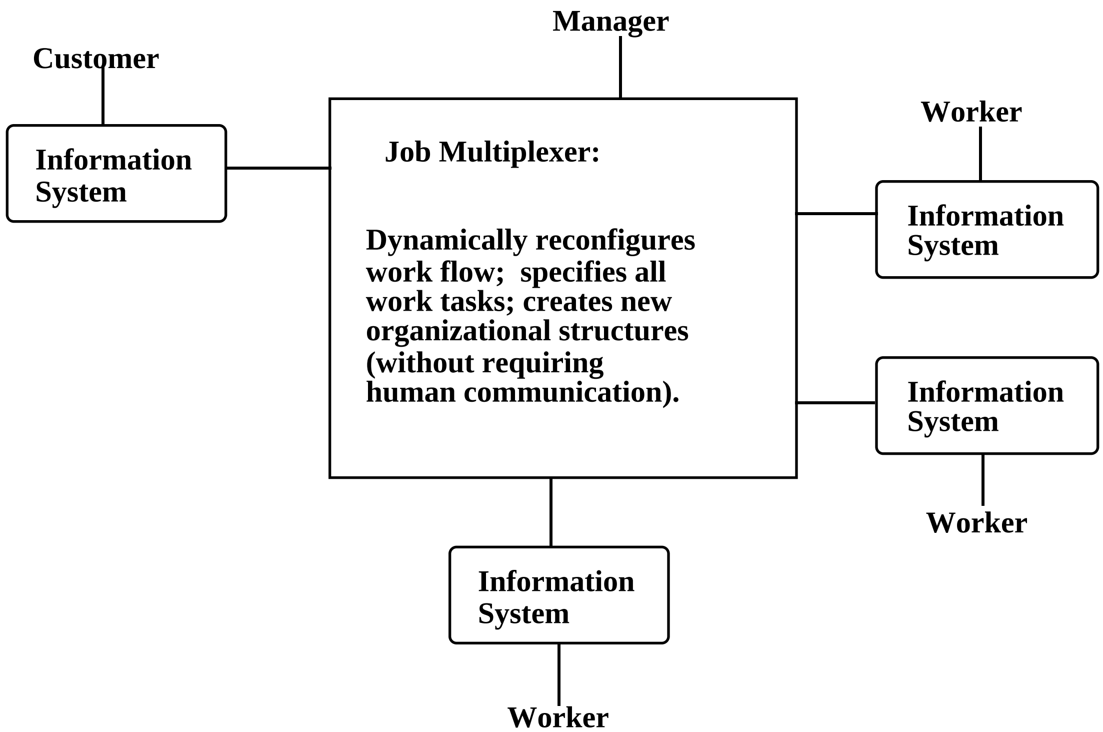

Figure 1. Job Multiplexer AI project: Automated interoperability of information systems allows dynamic reconfiguration of work flow.

By this design, people stay in place and work is reconfigured around them. The opportunity for unnecessary and distracting communication between people is eliminated. Unusual situations will be handled by the manager, who will be notified of delays and error conditions. Automatic reporting to supervisors on a daily basis will quickly show and compare each worker's throughput, revealing where training is required.

Without certain assumptions about the nature of people and work, the system analysts and technologists would of course not have conceived of this design:

- People performing a given business function are interchangeable.
- Practice—what people know and do—can be completely inventoried and captured by models of work (e.g., methods and procedures).
- A "Tayloristic" analysis will reveal variances and bottlenecks that can be systematically eliminated to improve efficiency.
- Cost can best be reduced by eliminating worker time spent "off task" (e.g., social talk).
- All training can occur on the job via computer-based methods ("intelligent tutoring systems") integrated into the information systems.

Furthermore, the Job Multiplexer is designed and implemented following established software engineering principles for large-scale office information systems:

- **System in a box:** The system being design can be conceived as a workstation on the desk of each worker.
- **Workers as subjects:** Workers can be viewed as subjects who will be interviewed and asked to try prototype systems when they are demonstrated in the laboratory.
- **Transfer of expertise:** Necessary knowledge for the job multiplexer will be transferred from experts via knowledge engineering methods.
- **Objective meaning:** “Glass box design” will enable developing interfaces and explanation programs that will make the job multiplexer’s operation transparent to all users.
- **Input-output evaluation:** The overall system will be tested and evaluated in the laboratory by a set of cases involving realistic job mixtures.
- **Technology delivery:** Implementation of the completed and tested system will be accompanied by extensive training of workers. Organizational and facility design will be handled after the design for the system is complete.

Following these assumptions and principles, we can rest assured that the promise of AI technology will be realized in the 1990s.

3. Discussion

To be clear, we believe the assumptions, approach, and designs described above are generally inappropriate. Many of these perspectives on automation, work, and computer system design have value. For example, input-output testing is necessary. But in general, computer systems developed only according to these narrow perspectives are unlikely to be successful (Greenbaum and Kyng, 1991).

This strawman example of the use of computer systems technology is of course not imaginary. We all recognize this view of how technology should be applied in business (Zuboff 1987, Scribner and Sachs 1991). When computer systems people work alone, it may be even inconceivable that there are alternative views. The discussion within the AI community about situated cognition is just one manifestation of the paradigm shifts underway (Clancey 1989, 1991 a,b, 1992 a, b, 1993, in press).

At the workshop, we will discuss our experience in work systems design and how a team of social, cognitive, and computer scientists collaborate to develop new modeling tools integrated with ethnography of the work place and worker management of the redesign process.

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