Paper proposal accepted by the Human Factors and Ergonomic Society 46th annual meeting to be held 23-27 September, 2002.

Work Centered Support System Design: Using Frames To Reduce Work Complexity

Robert G. Eggleston

Human Effectiveness Directorate
Air Force Research Laboratory
Wright-Patterson, AFB, OH

And

Randall D. Whitaker

Northrop Grumman Information Technology
Dayton, OH

Work Centered Support System Design: Using Frames To Reduce Work Complexity

Introduction:

Typically the design of the form of a user interface is dominated by concerns over information object design, incorporation of good human factors, and meeting general style guidelines for human-computer interaction (e.g. Microsoft Windows user interface guidelines). To date, little effort has been devoted to establishing the design principles for form representation that is explicitly work centered, in the sense of treating the interface as a support system in its own right. The purpose of this paper is to propose three design principles for work-centered forms or representation that we have used successfully in developing interface clients in an airlift services organization. Our thesis is that global form properties of the interface system can be important interface features that serve to reduce work complexity. Here we describe three form-based principles that achieve this goal.

Findings: Form-Based Design Principles

<u>Work Centered Support System</u>

We have recently embarked on a program to develop interface clients for the enterprise system environment, using the general work oriented philosophy (Rasmussen and Vicente, 1990). We call these clients *Work Centered Support Systems (WCSS)*. In this view, the interface system itself is conceptualized as a work support aid. It attempts to provide multiple forms of support (e.g. decision support, product development support, collaborative support and work management support) within an integrated work-oriented framework. Support is provided using both direct aiding, through the use of intelligent automation, and indirect aiding, through the use work centered frames and data forms. Both the direct aids and the structural form properties of the interface must be suitably coordinated to achieve the twin goals of reducing cognitive complexity while maximally supporting flexible problem understanding and action taking. We have approached this task by developing intelligent interface agents that meet the dictum of being "team players" (Roth, et al., 1997) and embedding them in work-centered frames and data forms (Eggleston, et al. 2000; Young et al., 2000).

A key concern in WCSS design is determining what should be presented to the user at the interface and in what form. Simply presenting the entire information space relevant to a given task is rarely feasible, owing to physical display constraints. Beyond this, full presentation is a questionable practice because it promotes information overload. We must therefore effectively define and partition the information space in a manner that supports fluid work. This is accomplished in the WCSS design paradigm by using work context frames and data elements. Information selection and form development interact and are guided in part by three form-based principles.

<u>Problem-Vantage-Frame Principle</u>

The work-centered approach treats work as an unfolding series of situated problem solving events. Effective interfaces must be attuned to these events so as to both portray the situation and work problems, while also providing action affordances in terms of the work itself (e.g., key referents, actionable objects). We do this by developing for each intrinsic problem/event category a specification for the information subspace within which users can adequately manipulate the referential coordinates, level of detail, and level of abstraction for work domain variables. The goal is to have the interface accommodate the vantage point a user may adopt to meet the current situations. A WCSS frame instantiates such a vantage with specific display and control elements. A single WCSS can include multiple such frames (Eggleston et al., 2000). Because this design strategy progresses from problem to vantage to frame, we refer to it as the *Problem-Vantage-Frame* principle.

An interface frame derived from this Problem-Vantage-Frame principle (called a Port Viewer Tool) is illustrated in Figure 1. The work context is mission planning in an airlift services organization. One work problem solving issue occurs when newly-scheduled missions affect the feasibility of previously planned missions, thus forcing a cognitively intensive replanning task. Our design task was to define interfaces minimizing the cognitive burdens for predicting and resolving such conflicts.

Based on cognitive task analysis of the mission planning work, we identified three recurrent vantages planners adopted on mission issues. One involved focusing on a given aerial "port" (i.e., an airfield). The second involved focusing on the "package" (cargo, passengers, etc.) moving between ports. The third involved focusing focus on the "passage" (the en route activities for moving between ports). We focused on a class of problems (e.g., managing planes on the ground) for which the "port vantage" was appropriate. The Port Viewer shown in Figure 1 represents a comprehensive frame for this vantage.

Figure 2 outlines one way of interpreting the Problem-Vantage-Frame principle. Classes of work domain problems were identified through knowledge acquisition and our analyses. For the sake of illustration, we shall concentrate on the problem class of managing aircraft on the ground. For example, there's a problem when a port's parking capacity is insufficient for the number of aircraft scheduled to be on ground at a given time. This problem class entails critical elements of reference such as individual aircraft, times of arrival, and departure. The appropriate vantage associated with this problem class was therefore one emphasizing visualization of these and related features. This allows displays to facilitate recognition of on-ground problems in terms of their critical domain features.

The Port Viewer's vantage centers on visualization of an aerial port in terms of its traffic and its timeframe. The Port Viewer's central display graphically depicts overlapping on-ground presence for arriving and departing aircraft during a 24-hour time span. Periods in which capacity is exceeded are actively highlighted to illustrate the problem's existence and duration. As a result, the representation is directly and meaningfully informative on specific problems in their immediate referential context (e.g., the 24-hour span at the given port) thus facilitating evaluation of corrective adaptations.

Focus-Periphery Organization Principle

The Port Viewer was designed around a central display form affording a focused vantage on the features most pertinent to port problems (the "center visualization" in Figure 2). In other words, the Port viewer frames content to expedite problem identification and understanding through ready access to the most important information. This theme of central frame focus has become a canonical element of our WCSS designs. However, changing a complex mission plan usually involves reference to factors other than those emphasized in the Port Viewer's central display area. Information on non-focal factors (but ones essential to decision making) is accessible at suitable levels of abstraction and detail via the peripheral components of the Port Viewer interface (the "surround" areas in Figure 2). This *focus-periphery organization* preserves cognitive engagement with the entire referential context while focusing attention on the most crucial features. This combination of central focus and peripheral reference minimizes mandatory digressions for the sake of problem interpretation and data retrieval, thus reducing the cognitive and procedural burdens on the user.

First-Person Perspective Principle

WCSS design approaches work representation in terms of how workers sees and engages work. This *First-Person Perspective* principle is a core element of WCSS design. It means the user's own work ontology (terms and meaning) should be the primary source for information elements in the interface display. For example, all labels used in the Port Viewer are taken straight from the work domain and reflect the terms in which the worker addresses the mission-planning job in practice. They connote the work itself, as opposed to (e.g.) procedures or components of the technology itself.

The importance of this principle was demonstrated more forcefully in a second WCSS project addressing a new "Flight Manager" (FM) position in the airlift organization. A recently introduced portal application provided unified access to a wide array of isolated (i.e., "stovepiped") applications and databases and thereby greatly facilitated FM work. However, the portal design did not exploit the form-based principles of a WCSS, and our analysis indicated that work complexity would grow as planning demands increased to handle the full complement of flight planning activities for the organization.

The portal interface was organized as a large tabular display, with each row dedicated to a mission and each column providing data about a mission variable. While this scheme provided all relevant information for all active missions, it is not sensitive to the mission-by-mission manner in which the FM's actually conduct their work.

An FM is assigned responsibility for a set of missions during a work shift. In the course of a shift we observed that the FM's encountered frequent interruptions and digressions, resulting in their simultaneously working on multiple flight plans in different stages of completion. Significant amounts of time were being invested in figuring out what mission to work on and what to do with it. The tabular display failed to reflect the user's first-person perspective because (a) it didn't focus on the set of missions currently being addressed and (b) it gave no cueing on where each mission's task process stood. As a result, after interruptions the FM's had to mentally reconstruct what he was working on as well as what remained to be done on it.

Our WCSS solution involved the design of a mission context frame that included a work management support vantage. This vantage acted as a meta-level visualization of each mission as a progression of work problems. It included the ability for automated and manual modifications of this visualization to proactively track and record progress over the set of planning problems.

This remedy takes the same unit of analysis (the mission) as of the original portal interface, but recasts it in terms of the user's first-person perspective as a set of problems for each of multiple assigned missions. This WCSS design was validated by the FMs and embraced as a system development requirement.

Designing a Frame for Dual Use

We are currently working on a new WCSS to support weather forecasting work in airlift operations. In this work domain, the user is responsible for rendering a worldwide weather forecast emphasizing certain variables most relevant to flights and for maintaining situation awareness on current weather patterns. In addition, the weather expert is responsible for producing mission-specific weather charts as part of flight plan documentation. These are two distinct job functions, each with its own primary vantage. The vantage for the first is the complex natural phenomenon of weather; for the second it is the interaction of weather with mission performance.

A strict interpretation of our Problem-Vantage-Frame principle might suggest there would have to be two frames required to support these two functions. However, in this case there are points of intersection among the users and these functions; thus both vantages can be accommodated within a single reference frame. A geographic map frame can serve as the ground for both vantages, with different overlays tailored to each one. By allowing users to perform both functions with a single flexible frame, we minimize the performance costs for switching between functions and the cognitive burdens for knowing how to use tools for both. However, we suspect that careful analysis is required to determine under what conditions such dual use can be justified.

Discussion

We have presented three work-centered design principles that concentrate on the form properties of an interface client system. Our analysis and experience suggests that they can be used to reduce work complexity in a manner that supports adaptive problem solving. A key component of these principles is that a vantage is defined in terms of work problems, expressed both abstractly in problem terms and concretely in work domain terms. A complex interdependency among variables is common in real-world work domains. Use of the Focus-Periphery Organization principles offers a work-centered way to preserve critical dependencies that need to be understood in problem solving and yet present them in way that help minimize information overload. By using a consistent work-centered ontology for objects, frames, and labels, we minimize the cognitive costs associated with switching between separate environment/domain, task, and tool ontologies. In sum, these three work-centered and form-based design principles help reduce work complexity and have contributed to the success of our WCSS client designs. In the future, we hope to assess their value empirically in terms of user learning and work performance.

References

Eggleston, R.G., Young, M.J., and Whitaker, R.D. (2000) Work-Centered Support System Technology: A New Interface Client Technology for the Battlespace Infosphere. *Proceedings of NEACON 2000, Dayton Oh, 10-12 October, 2000* ,pp 499-506.

Rasmussen, J. and Vicente, K.J. (1990). Ecological interfaces: A technology imperative in high-tech systems? *International Journal of Human-Computer Interaction,* 2, 93-110.

Roth, E.M., Malin, J, and Schreckenghost, D. (1997). Paradigms for intelligent interface design. In M. Helander, T. Landauer, and P. Prabhu (Eds.), *The Handbook of Human-Computer Interaction. 2nd Completely Revised Edition.* Amsterdam: Elsevier, pp 1177-1207.

Young, M.J., Eggleston, R.G., and Whitaker, R.D., 2000. Direct manipulation interface techniques for interaction with software agents. Paper presented at the NATO/RTO symposium on Usability of Information in Battle Management Operations, Oslo, Norway, April 2000.

Figures

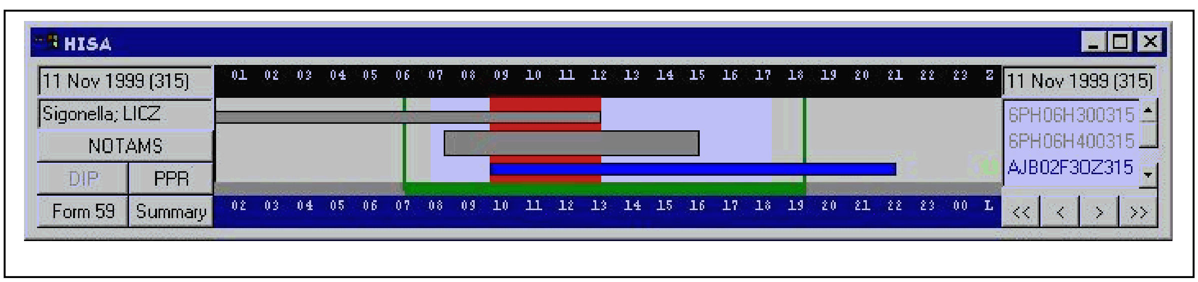

Figure 1. Port Viewer Tool. The central visualization directly presents meaning about a parking space problem (bar overlap region) and contains domain objects that aid details of problem understanding in situated terms (e.g. local and zulu time, aircraft size class). The peripheral (surrounding) portion of the frame presents other domain information useful of course of action planning.

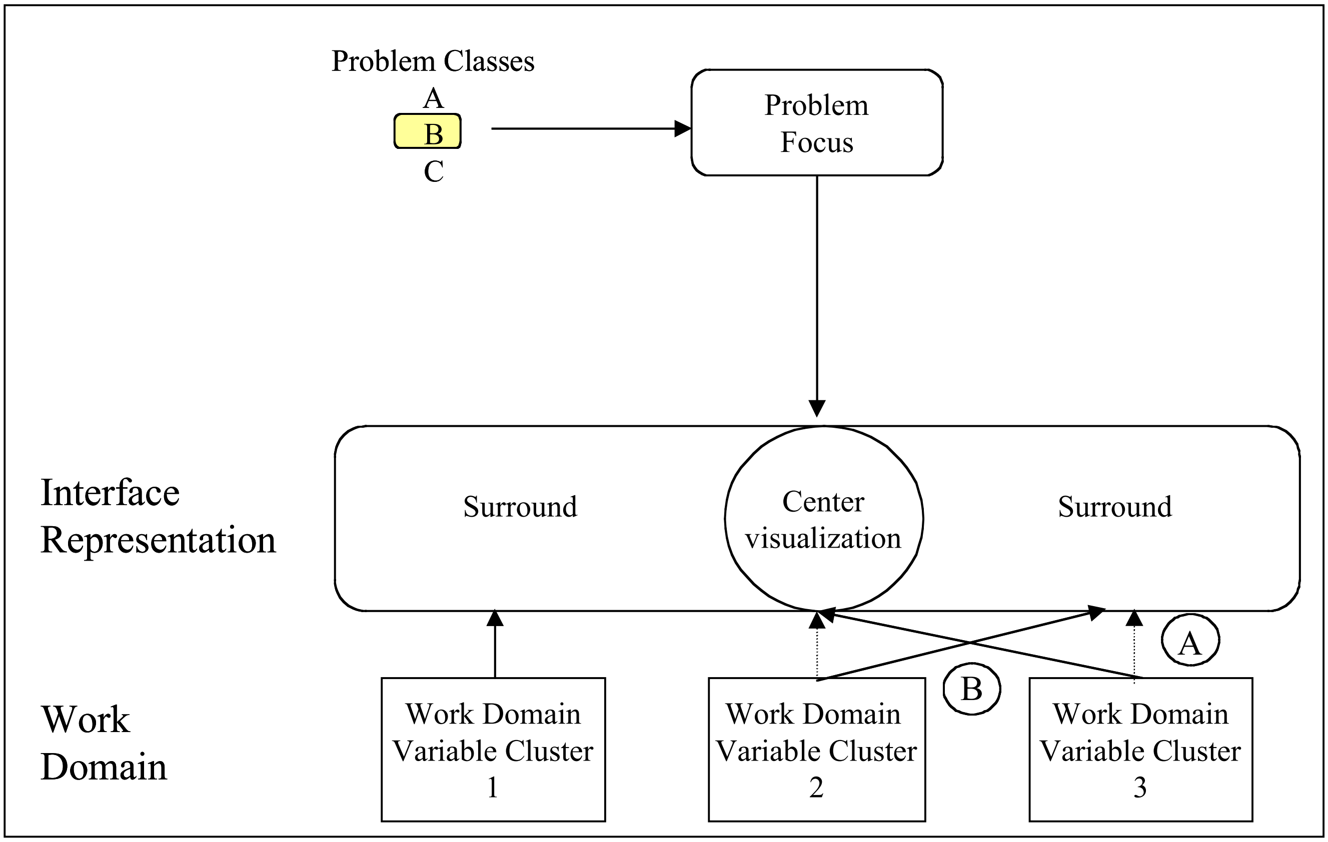

Figure 2. Illustration of the Problem-Vantage-Frame Principle. A specific problem (e.g., of type "B") demands the actor's attention and entails a particular vantage. The WCSS presents a visualization of the problem in terms of this vantage's key elements as derived from work domain variables. Presentation of secondary work domain variables occurs in the peripheral regions of the frame surrounding the focal display. As problem focus changes to type A, other domain variables are now represented in the focal region.