CITYSCAPE: Civil Infostructure Technology System for Collaborative Analysis, Prediction, and Evaluation

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ABSTRACT

The goals of Project CITY (Civil Infostructure TechnologY) are to provide a technology demonstration of information infrastructure for civil infrastructure management and to demonstrate the Team Engineering Analysis and Modeling (TEAM) methodology in the analysis, design, and evaluation of that information infrastructure. The community of practice of Project CITY is the Directorate of Public Works (DPW) at a major Army installation. This paper focuses on the design of CITYSCAPE, the suite of software tools that have been developed for the DPW.

INTRODUCTION

The management of civil infrastructure systems is a complex process that involves distributed decision making and negotiation among people with heterogeneous agendas, activities, and expertise. Project CITY (Civil Infostructure TechnologY) is a research project intended to support and facilitate public works activities (within the Public Works Division of a major Army installation) via collaborative information technology. The Team Engineering Analysis and Modeling (TEAM) methodology is applied systematically to the study of individual work practices, group meetings, and organizational communication and workflow (Case et al., 1992; Jones et al., 1994, 1995). The methodology in turn informs the choice of scenarios and requirements for technology demonstration prototypes.

In this paper we focus on the technology prototypes that were the products on this analysis. We summarize the requirements analysis process and its outcomes, describe the CITYSCAPE technology, and briefly discuss deployment and evaluation.

REQUIREMENTS ANALYSIS

The TEAM methodology is a framework for organizing data collection, modeling, design, and evaluation of complex sociotechnical systems into a systematic process in which a model of competence of the organization is central (Jones et al., 1994, 1995). Competence is defined with respect to the particular goals of the organization; in other words, elements of competence are situated and grounded in context, rather than being generic goals such as "be productive".

The Directorate of Public Works (DPW) at an Army base is responsible for the management and maintenance of facilities: buildings and their subsystems, water and sewage systems, utilities, design and construction of new facilities, environmental and natural resource management aspects such as monitoring lead paint and

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asbestos levels, compliance with regulations such as the Clean Water Act. The mission of the DPW is to ensure mission-ready infrastructure to support the military missions of the Army.

In the DPW context, organizational goals that structure the competence model include reducing unplanned maintenance, organizing and making visible heterogeneous information from a variety of sources and perspectives (e.g., engineering and environmental constraints on landscaping and architecture of new buildings), and having more efficient work processes to respond to customer needs. In our work, we have used a variety of representations to elaborate upon these goals and activities, including the abstraction hierarchy, operator function model, IDEF models, and social network analysis (see Jones et al., 1994 and 1995).

From the goals or ends of the competence model, we view technological interventions as one means of supporting these goals. Related to these goals are also metrics of evaluation, some of which are quantitative and objective (e.g., percentage of unplanned maintenance requests) and some are subjective (e.g., subjective ratings of satisfaction and group cohesion).

CITYSCAPE DESIGN AND ARCHITECTURE

Based on the above analysis, over the course of two years we formulated a conceptual design and software architecture that was distributed, heterogeneous, and modular. The overall system is called CITYSCAPE (Civil "Infostructure" Technology System for Collaborative Analysis, Prediction, and Evaluation). The major functions of CITYSCAPE are to support:

- a shared space of a rich variety of data and information to support a wide array of work contexts. This is the CITY-INFO component.

- a flexible workflow support tool for the most ubiquitous process in the DPW: the processing of work request (DA 4283) forms. This is the CITY-WORK component.

- access to spatial data manipulation, particularly for real property, environmental, natural resources, master planning, and CAD functions. This is the CITY-MAP component.

- access to organizational data, particularly for managers and new hires. This is the CITY-MANAGER component.

- a public kiosk for members of the community who submit 4283s to the DPW to do so electronically. This is the CITY-DESK component.

Each of these major components is described below, and the overall architecture of CITYSCAPE is shown in Figure 1. The architecture includes not only the above-mentioned end-user applications, but also intermediate services (Virtual Workspace System (VWS), ontology, permissions) and a heterogeneous set of databases that contain organizational, facility, spatial, and environmental data.

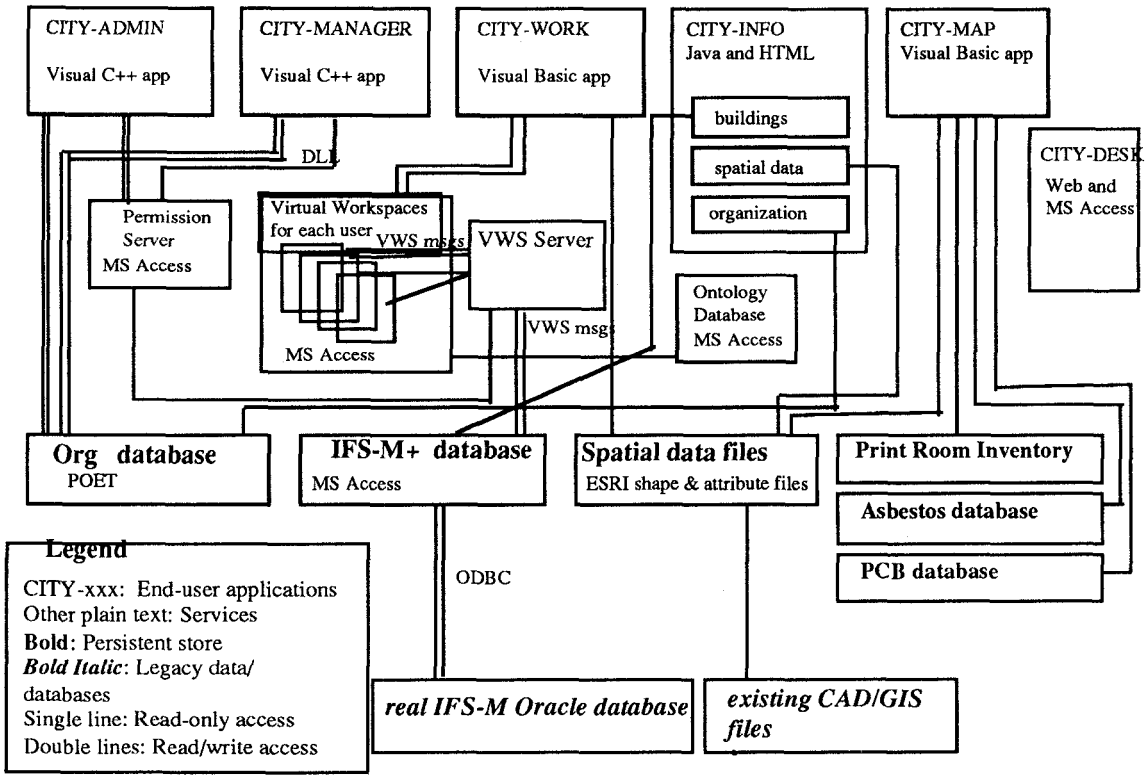

Figure 1. The CITYSCAPE architecture.

A. CITY-INFO

CITY-INFO is a collection of Web pages implemented in Java that are organized around three substantive categories of information: Facilities, Maps, and Organizational Data. The major design effort was in organizing the very rich and diverse data about facilities, which are the core objects of work for the DPW. We spent a year doing ethnographic work and iterative prototyping studies to arrive at the current design. The map and organizational data are relatively straightforward subsets of data from CITY-MAP and CITY-MANAGER.

B. CITY-WORK

CITY-WORK is a Visual Basic application that relies upon the Virtual Workspace System (VWS) as enabling technology. CITY-WORK is a workflow application, which supports the most ubiquitous process in the DPW: 4283 processing. Rather than having an explicit process model that drives the movement of information around the system, CITY-WORK uses a loosely-coupled model of sharing information based on interests (Case, 1994). In this model, each user has a virtual workspace of objects of interest. As users work alone in their virtual workspace, they may periodically publish their results to the system, and copies of their objects propagate to other users' virtual workspaces. Of course, this may lead to conflicts; i.e., if Joe changes an object definition that now is different from the one in Mary's workspace. CITY-WORK supports rudimentary conflict detection.

CITY-WORK also integrates a number of information sources together that in the material world are relatively uncoordinated and ad-hoc. The electronic 4283 also supports links to spreadsheets, the real property checklist, environmental impact checklist, and other tools

and representations relevant for successful completion of 4283s.

As users use CITY-WORK to work on 4283s, their data are transferred back to the "IFS-M Plus" database. This database is relational, while CITY-WORK is object-oriented. Thus, the VWS server includes a translator to accomplish this activity.

C. CITY-MAP

CITY-MAP is a Visual Basic application that allows users to individually make use of some key features of geographic information system (GIS) technology. Based on GIS focus groups and observational studies at the DPW, we determined a core set of functions that are a subset of current commercial GIS viewer technologies, including simple overlays and annotations of the site map, electric utilities, and environmental data sets such as PCBs and asbestos.

D. CITY-MANAGER

CITY-MANAGER is a Visual C++ application that allows user to browse and edit organizational data about personnel, roles, and activities.

E. CITY-DESK

CITY-DESK is a Web and Microsoft Access application that allows designated users at the base to initiate a work request electronically and submit it to Production Control at the DPW. Production Control can then harvest these requests from a Microsoft Access database and cut and paste them into CITY-WORK.

F. Integration

A key issue in the development of CITYSCAPE was integration among many diverse components. Several components rely on the same database system, the "IFS-M Plus" system that is a copy of the DPW's actual IFS-M database in addition to other information that our design exercises showed to be important. The organizational database is deliberately separate and is used both for CITY-MANAGER and as part of the control structure of how CITY-WORK publishes objects among users' virtual workspaces.

G. Experimental Components

In addition to the above components, which are meant to be deployed (i.e., "leave behinds") at the DPW, we are building some experimental components for short-term empirical evaluations. One component is a more sophisticated version of CITY-INFO which uses the notion of boundary objects to aggregate information needed for cooperative problem solving (Chin, 1997). Another component, CITY-COLLAB, offers an alternative model to CITY-WORK in that it supports synchronous and asynchronous work via a centralized database and flexible collaboration infrastructure (Lucenti, 1996).

H. Implementation

CITYSCAPE, per Army standard practice, runs in a Windows environment under both NT and Win95. We have relied upon several state-of-the-art developments to accomplish our work: Symantec's Visual Cafe Pro™ for Java connectivity to relational databases, ESRI's MapObjects™ and MapObjects Internet Map Server to support integration of spatial data into applications and the Web, and POET™ object-oriented active database technology which greatly facilitated the development of the experimental CITY-COLLAB component.

CRITICAL ISSUES AND FUTURE DIRECTIONS

Training and deployment at the DPW is the largest critical task that remains to be accomplished. Going back to the competence model and design scenarios that were used in development, we are creating training scenarios for group instruction that are problem-driven, activity-centered, and context-bound (Woods, 1997). This instruction is supplemented by individual assistance at the desktop to help users integrate the technology into their regular practice in reasonable and useful ways. We will do pre-training and in-depth demonstrations, evaluation of the experimental components, and deployment and training over the course of three months.

The evaluation of CITYSCAPE technologies in the context of real practice at the DPW is a multidisciplinary effort. We shall engage in social network surveys, as we have done in the past two years, to assess differences in communication, social, and knowledge network patterns. We shall also do selected ethnographic observations and informal interviews at individual, group, and organizational levels to systematically describe the effects of technology on working life.

One key issue in our work has been the representation and use of permissions: who in the organization is authorized to read and write what information? CITY-INFO and CITY-MAP are intended for general use and as such do not constrain interaction with permission systems. However, this is an issue for CITY-WORK and, to a lesser extent, CITY-MANAGER. A combination of organizational information in CITY-MANAGER and a permissions system that is distributed between CITY-WORK and the VWS Server is our current solution for the CITY-WORK application.

Future work in civil infrastructure management focuses on richer and more integrated models of facilities that include predictive components (e.g., Engineered Management System (EMS) technologies from USA CERL) as well as a greater variety and integration of spatial data. For organizational modeling, the ability to track activity and update the model in real time is attractive, but also raises serious questions of privacy.

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