EXHIBIT 21

Future Computing Environments

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CyberDesk: A Framework for Providing Self-Integrating Context-Aware Services

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ABSTRACT

Applications are often designed to take advantage of the potential for integration with each other via shared information. Current approaches for integration are limited, effecting both the programmer and end-user. In this paper, we present

CyberDesk, a framework for self-integrating software in which integration is driven by user context. It relieves the burden on programmers by removing the necessity to predict how software should be integrated. It also relieves the burden from users by removing the need to understand how different software components work together.

Keywords

Context-aware computing, automated software integration, dynamic mediation, ubiquitous computing

INTRODUCTION

Software applications often work on similar information types such as names, addresses, dates, and locations. Collections of applications are often designed to take advantage of the potential for integration via shared information. As an example, an electronic mail reader can be enhanced to automatically recognize Web addresses, allowing a reader to select a URL to automatically launch a Web browser on that location. Even more complex and useful integrating behavior is available in a number of commercial suites of applications (e.g. Microsoft Office 97, Lotus SmartSuite, WordPerfect Suite).

We recognize the utility from the user's perspective of integrating the behavior of a number of software applications. With the emergence of Web-based applications and personal digital assistants (PDAs), there are even more opportunities to provide integration of software applications. There are some limitations, however, to the current approaches for providing this integration. These limitations impact both the programmer and the user.

From the programmer's perspective, the integrating behavior between applications is static. That is, the behavior must be identified and supported when the applications are built. This means that a programmer has the impossible task of predicting all of the possible ways users will want a given application to work with all other applications. This usually results in a limited number of software applications that are made available in an integration suite.

From the user's perspective, integrating behavior is limited to the applications that are bound to the particular suite being used. Further integration is either impossible to obtain or must be implemented by the user. In addition, the integrating behavior has a strong dependence on the individual applications in the suite. If a user would like to substitute a comparable application for one in the suite (e.g. use a different contact manager, or word processor), she does so at the risk of losing all integrating behavior.

The project described in this paper, CyberDesk, is aimed at providing a more flexible framework for integrating software behavior. We aim to reduce the programming burden in identifying and defining integrating behavior, while at the same time retaining as much user freedom in determining how integration is to occur. The main objective of the ubiquitous computing project CyberDesk is to provide the infrastructure for self-integrating software in which the integration is driven by actions of the user. We refer to this as *context-aware* integration, and it is aimed at producing a paradigm shift in human-computer interaction that is fundamental to ubiquitous computing. Rather than settle for the current situation in which the user must seek out and find relevant software functionality when she wants it, we instead want the ubiquitous computing infrastructure to seek out the user when and where she wants it. In this paper, we will demonstrate how CyberDesk provides for this paradigm shift.

WHAT IS CYBERDESK?

CyberDesk is a component-based framework written in Java, that supports automatic integration of software applications. The framework is flexible, and can be easily customized and extended. The components in CyberDesk treat all data uniformly, as a Java object, regardless of whether the data came from a desktop application, a PDA-based application, or a Web-based application.

The intelligence in CyberDesk's user interface comes from applications automatically providing their services to the user. Rather than displaying all the services to the user at all times, the interface is limited to those services that are

relevant to the user's context. A service is an action that an application can perform or data that an application can provide. A user's context is any information about the user and the environment that can be used to enhance the user's experiences. This includes the data the user is working with, the time of day, the user's physical location, emotional state, social environment, objects in the room, etc. Initially, CyberDesk was only able to work with simple strings that a user was working with in a desktop application. Now, CyberDesk is also able to work with time and location in a desktop environment, networked environment, and mobile environment.

Desktop applications incorporated into CyberDesk include e-mail browsers, notepads, schedulers, and contact managers. Network applications include phone number lookups, e-mail writing, mailing address lookups, Web searches, Usenet searches, e-mail address lookups, map lookups, and Web page browsing. PDA-based applications include contact managers and notepads. All applications make their services available to the user via a common interface. The services available at any particular time depend on the user's context at that time. By providing relevant suggestions and data to the user, the user receives useful, and possibly unexpected, help in completing their task.

User Scenario

To illustrate this behavior, an actual user experience follows. (All the scenarios described in the paper can be executed at http://www.cc.gatech.edu/fce/cyberdesk/iui.) As seen in the figure below, a user is checking his e-mail, and reads an e-mail from a friend about some interesting research.

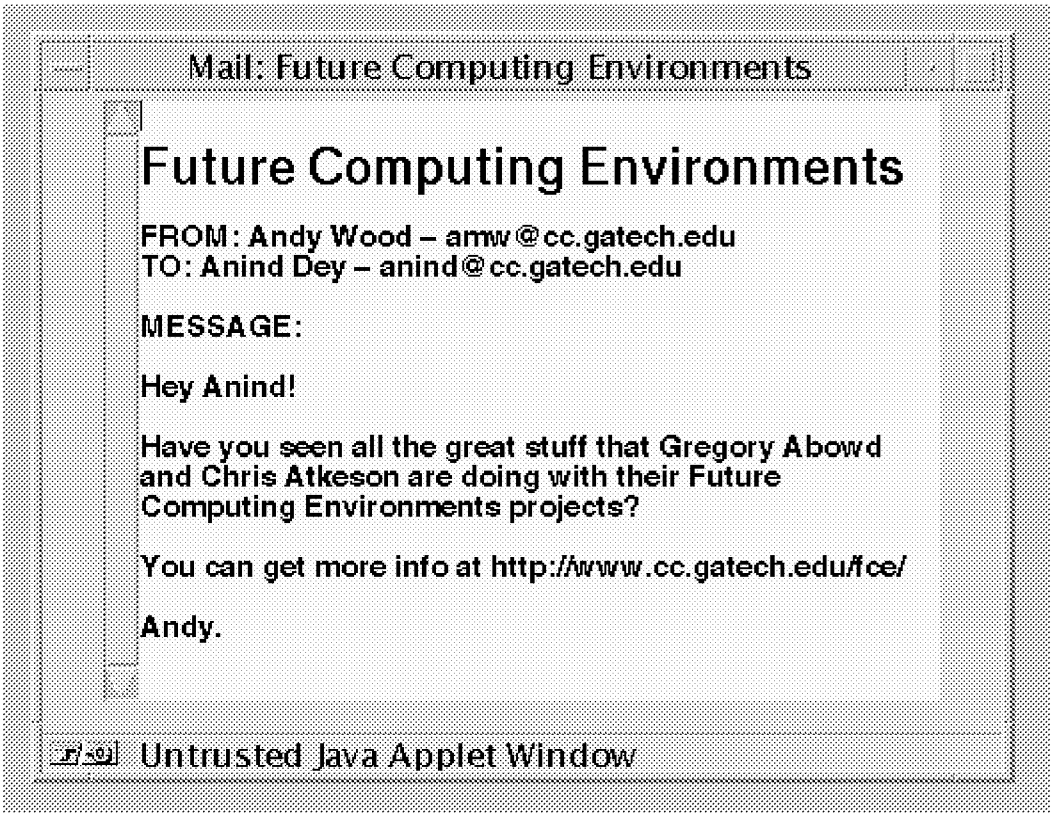

Figure 1. Content of User's E-mail Message.

The user is interested in the research discussed, highlights the URL in the message, and CyberDesk offers the following suggestions through its interface (Figure 2): search for the selected text using AltaVista, find pages that reference this URL using AltaVista, and display the URL in Netscape.

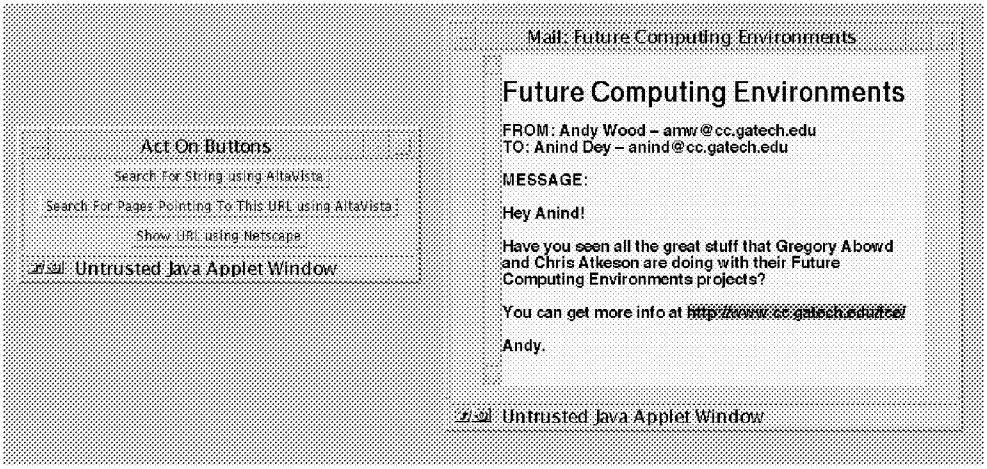

Figure 2. User selects the URL and is offered suggestions by CyberDesk.
Click on the screenshot to get an image with better resolution.

He chooses the last option and views the URL listed in the message (Figure 3).

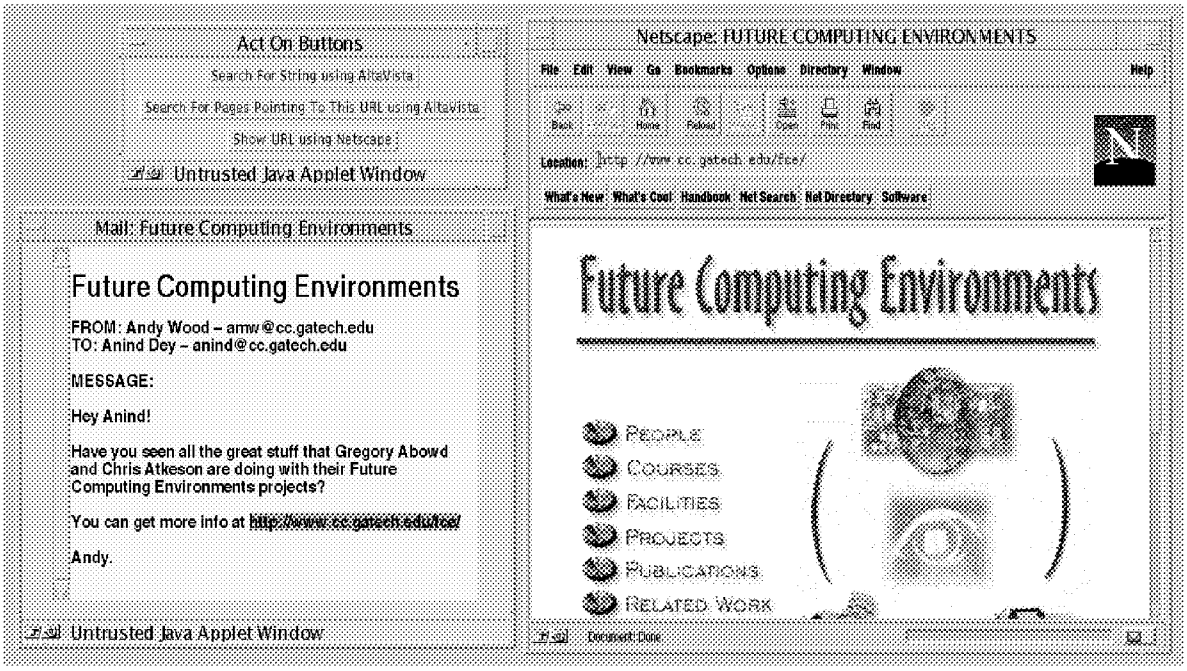

Figure 3. CyberDesk executes the service and displays the URL.
Click on the screenshot to get an image with better resolution.

The user then selects the name of the person in charge of the research and is offered the following suggestions (Figure 4): search for the selected text using AltaVista, search for a phone number and mailing address using Switchboard, lookup the name in the contact manager. The user wants to contact this researcher so he checks to see if the name is in his contact manager, but it isn't.

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