CollabCAD: A Toolkit for Integrated Synchronous and Asynchronous Sharing of CAD Applications

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Abstract

We are developing CollabCAD, a novel software architecture and toolkit, that supports sharing of arbitrary user-defined objects or applications over intranets and the internet. Developers can use CollabCAD to rapidly re-engineer existing CAD applications to be collaboration-capable or build new collaboration-capable CAD applications.

CollabCAD provides the following functionalities:

1. Support for flexible forms of sharing in which users can interact with multiple presentations of CAD applications or objects.

2. asynchronous and synchronous sharing, as well as a mixture of both,

3. effective communication between users by supporting direct manipulation of user-defined objects, and a new form of sharing called para-synchronous sharing,

4. support for asymmetric collaborations between users with (1) different roles, or, (2) systems with different input-output, hardware and network capabilities.

We plan to test and evaluate CollabCAD by building collaboration systems in several CAD-oriented application areas: these include virtual reality for mechanical, architectural and molecular CAD, and volume visualization and volume graphics for CAD applications.

1 Overview

We are developing CollabCAD, a novel software architecture and toolkit, that supports sharing of arbitrary *user-defined* objects or applications over intranets and the internet. Developers can use CollabCAD to rapidly re-engineer existing CAD applications to be collaboration-capable or build new collaboration-capable CAD applications.

Sharing of CAD applications and objects presents special challenges that are not adequately addressed by current collaboration technologies such as browsing, e-mail, chat[OR93] or window sharing[Cor96a]. Browsing and e-mail support the sharing of standard pre-defined data types, with a single fixed presentation, such as text, program files or multi-media data. Window sharing tools like XTV and NetMeeting support a limited form of application sharing, by duplicating the user-interface of an application, so that each user views an identical presentation. In contrast, CAD applications create and manipulate complex, long-lived user-defined objects with multiple presentations. Different presentations of an object are required for users with distinct needs and equipment, such as designers, mechanics, managers and clients.

CollabCAD supports flexible forms of sharing in which users can communicate with each other by interacting with different presentations of CAD applications or objects. CollabCAD also supports a powerful new form of sharing, called *para-synchronous* sharing, wherein users can share a transcript of their individual or group actions.

2 Example: VR for CAD/CAM

To understand the capabilities provided by CollabCAD, it is useful to consider a scenario where a new aircraft engine has been built by design engineers, and is being evaluated by aircraft mechanics at a number of geographically distributed sites. In addition, managers and potential clients, such as major airlines, are also interested in the dialogue between mechanics and design engineers. Managers and clients may also participate in the discussion and may themselves be located in geographically distributed locations (e.g., managers in Seattle, clients in Beijing and Bombay).

Each type of user may have a different view of the aircraft engine. Design engineers may have a detailed view including all the sub-assemblies of the aircraft engine, such as electrical, mechanical and thermal sub-systems. Such a view might be best presented using a Virtual Workbench [OWD+96, KBB+94] which supports a 3-D view of the model in front of the user.

The aircraft mechanic may have a presentation that is more constrained and reflects the operating conditions under which the engine must be serviced. One possible scenario would involve the mechanic wearing a head-mounted display, a data glove to grasp components of the engine, a force-feedback device (such as a Phantom [MS94, SBM+95]) and 3-D sound feedback. The mechanic may be evaluating the modification (e.g., spark plug placement, placement of fuel/oil heat exchange) of a standard design which is meant to improve the routine maintenance of the engine.

Managers and clients will have a higher-level presentation of the engine with fewer details.

This presentation could be given on laptops or standard workstations and would involve 3-D or 2-D graphics and voice input/output. This presentation may also involve budgetary and historical data concerning costs of engine maintenance.

Each of the different types of user may not be available for collaboration at the same time. Due to differences in time-zones, some users may only be able to interact and contribute to the collaboration in an off-line mode (asynchronous collaboration). Other users may need to intermix on-line (synchronous) interaction with off-line interaction (e.g., initiate a meeting personally, leave and review final results the next day).

3 CollabCAD Functionalities

The aircraft engine example above demonstrates the variety of presentations, hardware and input-output devices, roles, and issues of time differences and user availability that need be addressed in developing a realistic collaborative CAD application. In order to address these needs, CollabCAD provides the following major functionalities:

- *Building sharing technologies directly into CAD applications.* There are many sophisticated single-user CAD applications (e.g., AutoCAD, Multigen) that have been constructed over the past two decades, and large investments have been made in the development of such applications. Developers can use CollabCAD to *re-engineer* such applications so as to make them collaboration-capable, as well as to build new applications that are collaboration-capable.

  When working with an application extended using CollabCAD, users do not need to be aware of the mechanisms used to achieve sharing; neither will users need to interact with many different software systems to collaborate with other users.

- *Effective communication between users by direct manipulation of objects of interest.* Users working with a 3-D visualization of a molecule could communicate by adding or removing bonds between atoms, changing the molecule geometry, pointing to parts of the molecule, annotating parts of the molecule with voice, graphics or text. These actions could be communicated to other users in either synchronous or asynchronous mode.

  User communication is further aided by a new form of sharing called *para-synchronous* [MS97] sharing. Para-synchrony involves the creation of a transcript of the interactions during a solo or collaborative session, which can then be re-played at a later time in an appropriately chosen presentation format. For example, an aircraft mechanic's actions during routine maintenance of an engine synchronized in time with his voice comments, annotation and gesture could be recorded over a standard period of time (e.g., 15 minutes). This could be played back in a presentation suitable for the design engineers, summarized (e.g., which components did the mechanic misplace or comment on?), or archived for future reference.

  CollabCAD supports an extensible library of *annotation* and *gesture*, including domain-specific actions. These an-

notations and gestures could be derived from individual and group actions with devices and media like data-glove, audio comments, and 3-D and 2-D graphical marking (e.g., pencil marking, sprite movement). For example, the mechanic may record an audio comment combined with an indication of 3-D position and movement, concerning the strain on his back, when he twists to pick up a component from within the engine.

- *Uniform method for synchronous or asynchronous sharing at the application level.* It is possible for all collaborators to interact while all are simultaneously present, or for one or more collaborators to interact asynchronously at a later time. This is specially important as the different groups participating in the design and evaluation effort might be located in many different time-zones and regions of the world.

  CollabCAD supports integrated synchrony and asynchrony in the same framework, so that users at a meeting can switch between the two at most times. Users arriving late may use para-synchrony to overview highlights of the meeting; users leaving early can asynchronously add annotation to the shared CAD objects, which can be later explored by other participants at an appropriate time. Para-synchrony can also be used as part of version control system for CAD models.

- *Asymmetric collaborations.* CollabCAD provides the capability for asymmetric collaborations, wherein (1) different users have different roles, and hence different presentations and privileges with respect to the shared object (role asymmetry), and (2) different users use hardware with different computational, network and input-output capacities (hardware asymmetry), making necessary the use of different presentations for differentially equipped users. Developers will represent knowledge about user roles and hardware in classes without modifying the shared application.

  CollabCAD achieves this by supporting separation between the data model from the device-dependent attributes. A single object may be viewed using a graphical-presentation, haptic-presentation based on force-feedback, or an audio presentation, using some combination of these presentations. Operations or changes to an object may also be viewed in a variety of presentations and formats, such as 3-D graphical view, 2-D overview, and haptic-view.

  CollabCAD supports a rich language for describing time-varying roles [CM96] for collaborative interaction. At different times individuals may have different rights and privileges over the shared objects (e.g., jet engine). This allows for a flexible meeting format while ensuring that data consistency is maintained.

- *Support for archiving, indexing and search of past, current and future collaborations.* Users can create a transcript of individual or joint interactions with the application. Archived collaborations are treated as *first-class objects*, and users can discuss and refer to them using all the techniques available for user-defined objects. CollabCAD also supports the capability

of domain-dependent indexing and search: e.g., What did researcher X say about image 17 at our last meeting?

Systems built using CollabCAD could be combined with video or audio conferencing systems and used for a variety of applications, including distance learning, training and education in the application domain, conferencing, and discussion groups. CollabCAD is specially helpful in situations where users learn about complex applications by (synchronously or asynchronously) observing experts working with the application.

CollabCAD is based on standards such as MIME, WWW, http and the Java programming language. It is platform and operating system independent. We plan to describe our architecture and provide bindings for our toolkit within the CORBA framework[COR96b].

We can compare CollabCAD to other software infra-structure packages like PVM, X and Tcl/Tk. For example, PVM[GBD+96] provides infra-structure for parallelizing arbitrary user-defined applications. It hides details of network organization, communication protocols and system architectures by providing standard interfaces and software layers that encapsulate these complexities. Similarly, CollabCAD provides infra-structure for sharing of arbitrary user-defined applications and objects over the internet.

CollabCAD is usable with a broad class of objects and applications and incorporates extensibility to new problem domains as an essential component. We plan to test and evaluate CollabCAD by building collaboration systems in several CAD-oriented application areas, where we possess experience and expertise: these include virtual reality for mechanical, architectural and molecular CAD, and volume visualization and volume graphics for CAD applications.

4 Related Work

The CollabCAD project builds on previous work at SUNY, Stony Brook and in the CSCW community. These include the design of toolkits for synchronous sharing including Rendezvous[PHRM90], DistView[PS94] and GroupKit[RG92]. Flexible and general techniques for modeling user roles in collaboration systems are presented in [Edw96, CM96]. Implementation of a session recording and replay system has been described in [MP95]. The Habanero [NCS97] project at the NCSA is a recent project that provides infra-structure for collaborative re-engineering of single-user applications.

The ColabView[MSH+96] project at Stony Brook is an investigation of technologies required to support flexible and powerful forms of medical image consultation. A prototype system has been implemented and installed at the University Hospital at Stony Brook for testing and evaluation. Many of the features in the CollabCAD toolkit are derived from our experience with ColabView.

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