Supporting Collaboration in Large-scale Multi-user Workspaces

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Abstract. CubIT is a multi-user, large-scale presentation and collaboration framework installed at the Queensland University of Technology's (QUT) Cube facility, an interactive facility made up 48 multi-touch screens and very large projected display screens. The CubIT system allows users to upload, interact with and share their own content on the Cube's display surfaces. This paper outlines the collaborative features of CubIT which are implemented via three user interfaces, a large-screen *multi-touch interface*, a *mobile phone and tablet application* and a *web-based content management system*. Each of these applications plays a different role and supports different interaction mechanisms supporting a wide range of collaborative features including multi-user shared workspaces, drag and drop upload and sharing between users, session management and dynamic state control between different parts of the system.

1 Introduction

The Queensland University of Technology (QUT) recently opened an interactive exhibition and learning space as part of its newly established Science and Engineering Centre. The facility named "The Cube" features five very large interactive multi-panel wall displays, each consisting of up to twelve 55-inch multi-touch screens (48 screens in total) and massive projected display screens situated above the display panels. The Cube represents a demanding real-world setting that supports large numbers of visitors and users (see [1] for a more detailed description of the Cube infrastructure).

The Cube's technical infrastructure was developed in parallel with a set of five interactive applications that showcase the Cube's capabilities while providing a unique end-user experience. Our team developed one of these applications, "CubIT", a large-scale multi-user presentation and collaboration platform, specifically designed to allow QUT staff and students to utilise the capabilities of the Cube. CubIT's primary purpose is to enable users to upload, interact with and share their own media content on the Cube's display surfaces using a shared workspace approach. User can log into CubIT on any of the wall surfaces using their RFID-enabled staff or student card. When they do so, they are given access to their user workspace. The user workspace contains media content they previously uploaded to the system, including images,

video and text files as well as presentations. The system supports up to 12 simultaneous users per wall surface, allowing users to display, interact and share media content across the shared workspace and the large-scale projection surfaces situated above the display panels (see Fig. 1).

Fig. 1. CubIT used at a conference

In this paper we outline the collaborative features of CubIT and describe how they were implemented via the system's different user interfaces. This includes features for easily sharing content from mobile phones and tablets on the large multi-touch walls, simple drag and drop sharing of content between users, a large shared workspace to jointly discuss and share work, session management to maintain the layout of content across sessions. Further collaborative features include dynamic state control between different parts of the system allowing for content to be available through different interfaces, and the use of mobile devices as remote keyboards. We will briefly discuss the design background of the system and provide an overview over the some of the interface elements and system components of CubIT[1].

2 Background

Recent advances in multi-touch display technology, such as thin-bezel LCD displays[2], have led to the availability of large, high-resolution displays that can be combined very into large interactive surfaces. These large interactive screen surfaces create a range of new opportunities, as well as challenges for the designers of interactive applications. An obvious use for this technology is to build applications that enable multiple users to simultaneously interact on a continuous shared workspace. There are many examples of applications that utilise large interactive screen surfaces in such a manner[3]. For instance, CityWall [2] allowed multiple users to interact with a single given content pool on a large-scale, rear-projected, multi-touch wall display. Similarly, in 2009, Schematic implemented a multi-touch wall display[4] that allowed multiple users simultaneously log into the system using their RFID pass cards. Once authenti-

[1] The system was developed using a user-centred design approach, which is not covered in this paper due to space limitations

[2] e.g. http://www.multitaction.com/products/ultra-thin-bezel/, for the displays we used

[3] While the examples provided here use large, but lower resolution rear-projected displays, we expect to see LCD-based high resolution wall displays, such as the one used in the Cube, to become significantly more widespread over time.

[4] http://www.possible.com/news-and-events/cannes-lions-touchwall

cated users were able to browse schedules, access way-finding information and exchange social networking information.

The definition of what constitutes a large display surface varies widely. In the literature the notion of "large displays" range from single screens, such as large TVs [3] to very large multi-projector interactive tabletop surfaces [4] and large rear-projected wall displays [2].

CubIT system was specifically designed to make use of the very large available pixel space of the Cube[5]. The overall brief for CubIT was to make the Cube facility accessible to QUT's academic and student population, by allowing them to upload, interact with and share their own content on the Cube's display surfaces. While the design of CubIT shares similarities with some existing approaches to large-scale display interaction, such as those mentioned above, it differs from previous systems in a number of ways. Specifically, it is the combination of the following features that make the system unique:

- CubIT was specifically designed as a true multi-user system that allows multiple users to upload, and simultaneously interact with and share their own content on a large multi-touch enabled canvas.
- Users can log in and authenticate themselves at the display walls using RFID authentication to access their individual workspaces on a shared canvas.
- Interface mechanisms for uploading and sharing content have been designed to be as simple as possible, allowing for simple drag and drop interaction.
- CubIT has multiple user interfaces that serve different purposes (see below).
- CubIT uses an external object store and pubsub notification service (Redis) to dynamically maintain the state of the application across different interfaces. Changes to content on each of the interfaces are dynamically represented on all of the other interfaces (e.g. changes to the user name in the web interface are dynamically applied to a user's workspace on the multi-touch wall).

3 The CubIT System

3.1 System components

CubIT features three distinct user interfaces, each of which has different functions and interaction mechanisms: a *multi-touch interface* running on the Cube large display walls, a *web-based content platform* and a *mobile interface*. The web-based interface (implemented in Ruby on Rails[6]) allows users to upload and manage content and further supports system administrators in the moderation of content and the administration of user accounts. The multi-touch interface (implemented in Python us-

[5] The total resolution for a 12-screen wall plus top mounted projectors is 12960 x 1920px (multi-touch) & 5360 x 1114px (projected)

[6] http://rubyonrails.org/

ing the Kivy[7] framework) enables users to interact with content on the large-scale multi-touch displays of the Cube and share content between users. The mobile interface (built in iOS, supporting iPhones and iPads) presents an alternative mechanism to upload and create content on the fly.

Each of these interfaces provide different user interaction capabilities and support different usage scenarios. We will discuss each of these interfaces and the functions they support in detail below.

3.2 Multi-touch Interface

The CubIT multi-touch interface allows users to display and interact with the media content they uploaded to the system. Users log in by swiping their RFID card on one of the readers located underneath the multi-touch screens[8]. Once a user logs in, their user workspace handle (see below) appears on the shared workspace. The application is location-sensitive, the workspace handle appears on the screens that is associated with the closest RFID reader. This feature allows users to log out from one screen and move to a different part of the screen (or a different wall altogether) to log in again, effectively moving their content to different locations.

User workspace handle. The user workspace handle (see Fig. 2) represents a user's content in the system. It consists of an avatar, username label, scrollable workspace containing the media content and two function buttons, "pin / unpin content" and "minimise / maximise". The scrollable workspace displays the media content in the form of thumbnails. CubIT currently contains four different types of thumbnails for images, videos, text and presentations. Thumbnails can be dragged or clicked to be

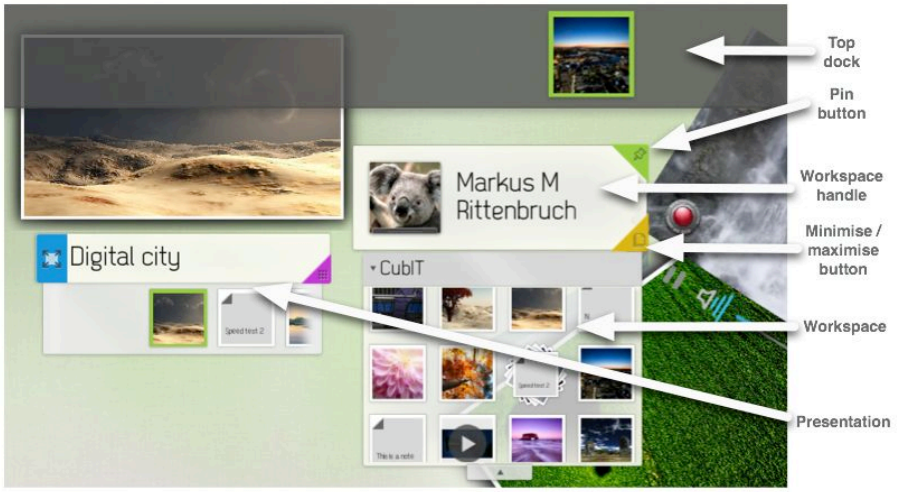

Fig. 2. CubIT interface elements

[7] http://kivy.org/

[8] Each of the Cube's display walls is equipped with a number of RFID readers, generally one reader per 2 panels.

opened on the workspace. Thumbnails can also be dragged around the workspace handle to be reordered. An option to delete an item from the system is presented if a thumbnail is pressed for a slightly longer period of time. The z-order for user handles is set to be higher than any other content on the screen ensuring that the user workspace is always accessible, and not obscured.

Media items. Media content items are *images*, *videos* or textual *notes* that appear as zoomable, rotateable and translatable widgets on the screen. The zoom factor is limited to allow images to scale up to no more than the width of three portrait panels (3240 pixels) to prevent individual content items from obscuring the whole canvas. Videos can be played on-screen and have a standard set of video controls (pause, play, seek, volume). When opened from the workspace, each media item can be opened multiple times, spawning multiple instances on the canvas. If items are permanently deleted from the workspace (or the system via the web interface) all of the items currently open instances of an item are closed. All content widgets use dragging physics to allow for content to be thrown. The friction settings are designed to limit the throwing distance to approximately 2-3 panels, preventing users from interfering with the workspace of users at the other end of a display wall.

Pinning. Each user workspace handle has a pinning button (see Fig. 2) allowing users to "pin" down the content relative to their handle and move all the content at once. This allows users to navigate the screen and move all their content to a different part of the screen while maintaining the relative content layout.

Minimize / maximize. User workspace handles further contain a minimise/maximise button (see Fig. 2). Minimising content means that the content is animated back into the handle. Minimise and maximise maintain the relative position and layout of content items. The layout is saved as a session and is persistent across logouts. The sessions is shared between different instances of CubIT running on different walls. As a result users can lay out their content in a particular way (e.g. for a poster presentation) and re-apply this layout to multiple setups (e.g. CubIT running on 3 different walls).

Presentations. CubIT includes a custom presentation widget (see Fig. 2) that allows users to display stacks of images, videos and notes in a more convenient manner. Presentations can be created using the web and mobile[9] interfaces. The presentation widget contains several components. The display section allows content items to be displayed, scaled and swiped like a slideshow. The handle identifies the presentation. The selection box underneath the handle allows easy access to the surrounding slides and can be used to scroll through and navigate the presentation. Presentations can be edited dynamically using the multi-touch interface. In order to edit a presentation users can press the presentation workspace button and open the presentation's work-

[9] Creating presentations is enabled on the iPad interface only

space. A presentation workspace provides the same functionality as a user workspace and allows users to reorder, delete and add content on the fly.

Top dock & Top dock view. The layout and design of the Cube includes large projection screens on top of walls of interactive panels. As a result each project implemented on the Cube had to find ways to design their system to make use of the projection screens while maintaining control over the interaction on the interactive touch panels below. In the case of CubIT we decided to allow users to "throw" individual media item up to the projection screen to be displayed at full resolution. The rationale for this design option was to allow users to interact with content closely on the touch panels, while using the projection surfaces for presentations to larger groups.

The mechanism in CubIT that controls the content on the top projection screen is called "top dock". It consists of a docking area stretching along the top border of the multi-touch panels. Media items that are dragged into the dock are displayed on the top screen. The top dock supports all media types images, note and videos, which auto-play when dragged onto the top dock.

Drag and drop sharing. The multi-touch interface supports sharing of content between users. In order to copy content items between accounts, users drag thumbnail representations of images, videos, notes or presentations into a different workspace. This creates a new instance of the copied object, which is now independent of the original. Because the system does not differentiate between users, objects can be freely copied between accounts by any user who touches the screen. To account for this, user accounts can be put into a "safe" exhibit mode to display of content over longer periods of time, in case users want to leave bits of content on screen for others to see (e.g. notice board).

3.3 Web interface

The CubIT web-interface is one of the two mechanisms allowing users to upload and maintain content on CubIT. The interface uses a standard user registration and login system. As part of the registration process users can register their RFID cards allowing them to log into the system on the multi-touch wall. The web interface for a standard user account consists of two main sections. The "Media" section allows users to upload image and video content and create notes. Users can browse existing content and delete items. The "Presentation" section enables users to create and manage presentations. Users can add content already uploaded to the system to new and existing presentations, as well as delete existing presentations.

3.4 Mobile interface

The CubIT mobile interface is a native application (see Fig. 3) running on iOS6 for iPhones and iPads. The purpose of the interface is to allow users to easily upload content while away from their desks, and in particular, while standing in front of one

of the touch screens. The mobile interface has four modes (represented by four icons at the bottom of the screen). Three of those modes are dedicated to different media types allowing users to upload images, videos, and notes respectively. The fourth mode allows users to change their avatar picture and log out of the application. The iPad version, due to its larger screen real estate, features an additional function. It allows users to create presentations from existing media sources and upload these presentations to CubIT.

Users can scroll through their iPhone/iPad's media library in a scrollable section in the middle of the application. An "add icon" links to the device's camera application and allows users to create and upload content on the fly.

The upload mechanism consists of a simple drag and drop mechanism. To upload, users drag images into the upload icon on top of the screen. An animation gives the appearance that the item is "sucked" into the screen and then uploaded. The upload mechanism has been designed to give the appearance of being able to "flick" multiple content to the multi-touch walls.

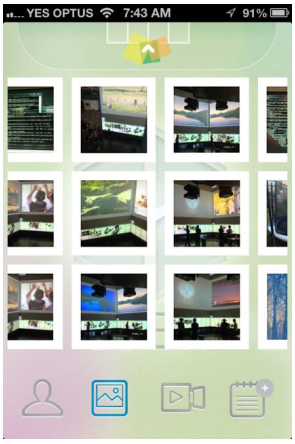

Fig. 3. Mobile interface

4 CubIT Collaborative Features

CubIT has been designed mainly to support co-located synchronous collaboration within the context of the Cube. One of the main intended uses for the system is the joint access to and sharing of media content between multiple simultaneous users, for instance as part of a design discussion or shared presentation. CubIT supports this use case through the combination of features and interfaces described above. We summarise some of the collaborative features in turn:

- *Shared workspace and workspace control:* Multiple users can share a large workspace canvas, each user providing content using their user workspace handle. The system provides several mechanisms for users to manage the shared space. User can "pin" their content and move it simultaneously to a different part of the screen. Users can minimize content, thus saving the layout of their current session and move it to a different part of the screen or a different display wall altogether. Interface elements have been designed so that users can work together without obscuring each others view of the workspace.
- *Drag and drop sharing:* Users can simply share content by dragging and dropping content between user workspaces. This function extends to presentations by allowing users to create shared presentations on screen, with content provided by several users.
- *Easy upload from mobile devices:* Drag and drop upload of content into workspaces allows users to dynamically add content to a shared workspace while working with others. Users can, for instance, capture the outcome of a joint discussion in an image or video and upload this directly to the shared workspace.

- *Dynamic state control between different parts of the system:* The system dynamically passes on changes between the multi-touch mobile and web-interfaces. This allows users to dynamically update content on screen from a remote location (e.g. as part of a share co-located and remote design session).

5 Conclusions

In this paper we described the basic features and collaborative capabilities of CubIT, a large-scale, multi-user collaboration and presentation framework. While CubIT has been build within a very specific context, QUT's Cube facility, we believe that many of its design and interaction principles transcend the physical setup and can be applied to different contexts and systems.

We are currently working with QUT Teaching and Learning Support division to extend the use of CubIT in to *lecture theatres* and *collaborative learning spaces*. Collaborative learning spaces, which are equipped with multi-touch display units on wheels can run multiple local copies of CubIT, allowing students to interact with and share their own content, as well as content provided by a lecturer.

CubIT has been used successfully over the past 7 months and has resulted in a multitude of different usage scenarios, as well as a number of valuable lessons learnt. For instance, users adjusted the size and ratios of images to fine-tune the presentation of their content and create custom one-per-screen presentation layouts and to best utilise the available pixel space of the top projection screen.

In addition to our ongoing observation of system use, we are currently conducting a formal evaluation of CubIT that explores a wide range of usability and user experience factors. We are excited about the prospect of using CubIT as a platform to further develop and study a wide range of collaborative and interactive features in the demanding real-world context of the Cube.

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