Multi-User Collaborative Interaction System: Cosy Living Room

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1 INTRODUCTION

The UTS Data Arena is a VR-CAVE at the University of Technology Sydney. It is a 360-degree stereoscopic theatre designed for data visualisation and collaborative decision-making. The display cluster creates an immersive environment wherein twenty visitors can explore large datasets from the same shared perspective. Everyone sees the same display with see-through active-shutter glasses - everyone can still see each other. There's no need to represent users as avatars in an HMD. We believe seeing the actual person leads to better decision making.

The Data Arena's development team created a spatial input & navigation system for visitors to interact with visualisation projects. Large groups of users collaboratively participate with an active visual display. A multi-user collaborative user interface (UI) developed at the UTS Data Arena, is described here.

We have introduced a method where to begin interaction we video-project a QR code. Sometimes the code is inside the environment. Visitors scan this with their smartphone device. Upon connection each user sees a cursor on the theatre projection screen, controlled by a web page on their device. The QR code is on screen, not printed. It's dynamic. The code contains a unique URL which grants one-time access for the session.

A web application runs on a remote cloud service. It listens for user input and broadcasts updates to other connected users. It also relays a single stream to the Data Arena via a secure connection. The data stream is light. Latency is low. The result is a fast and simple interaction experience for users.

Interaction controls are customised per visualisation. In one application, users can arrange furniture in a virtual 3D room. In another, users explore a large collection of written responses from community survey data where each selection is public, but associated additional information is sent to the selecting-device only (private).

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2 INTERFACE AND INTERACTION DESIGN

The interface presented to users is customised within the *Vue* and *Nuxt* frameworks. For the *Cosy Living Room* project the phone screen is primarily used as a touch input surface, similar to a laptop trackpad. A second tab shows scene-based controls to change furniture fabrics, lighting modes, etc. Menu actions are synchronised to the server, with each client sharing the same server state. The *Hammer.js* library recognises multi-touch input events: swipe, tap and hold, and two-finger rotations. Each cursor can be coloured and labelled by users and is rendered as a hand icon which appears open or closed based on interaction.

On the Data Arena's display, each cursor is rendered as a camera-facing 3D object. A vector is calculated from the camera origin through each cursor's 3D location to detect collisions. When detected, user-interactable objects are outlined. Single-finger movement on the trackpad moves the cursor around the "surface" of the Data Arena screen. A single tap selects a highlighted object for interaction. Further single-finger drags will move the selected object around the room horizontally and vertically. A separate near/far slider appears when an object is selected, to bring an object closer or further away from the user. A two-finger rotate gesture will turn an object around its Z-up axis. Multiple users might select the same chair (object). Its position is then an average calculated between each associated cursor. Co-operation is encouraged. The lounge can be shifted by one user while turned by another.

3 SET A COLLABORATIVE TASK

Interesting collaborative challenges can be set. In the *Cosy Living Room* project, users are simply asked to *"Place all the plants in the sunlight"*. This broad goal helps users figure out the interaction controls, discover obstacles, and potentially work together. Unreal Engine's rigid-body dynamics system makes objects bump and move one another. Timing the task duration adds a competitive edge.

4 USER EXPERIENCE AND EVALUATION

3D navigation & interaction with a 2D interface creates a cognitive load, especially for those less familiar with design or gaming within a 3D context. Familiar swipe and tap gestures, ubiquitous across touch-based interfaces, eases the introduction of new controls.

Familiar UI elements such as sliders, toggles and tabs communicate the notion of preference. A connection status at the top of the phone's display is a technical aid and reminder the controls are for a remote environment. The interface is customised for each project. A reduction in UI-clutter reduces the cognitive load for new users. An assessment of the effectiveness of this interaction system has been largely qualitative and ethnographic, focused on user response and behaviour in-practice during demonstrations. The Data Arena team has delivered hundreds of presentations of the *Cosy Living*

Figure 1: Mobile user interface. Protein Visualisation project

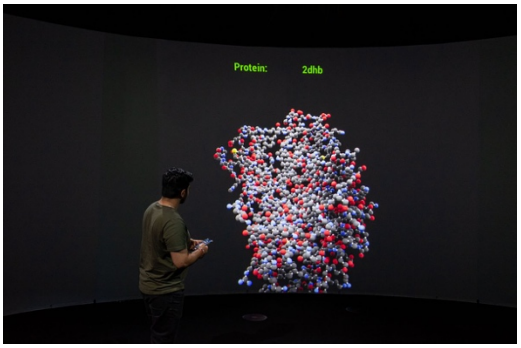

Figure 2: Matt Barrett with the Protein Visualiser

Room project to groups both small (1–5 people) and large (15–20 people). Naturally, all users respond differently due to experience and technical proficiency. Observing instinctive behaviours and patterns in mistakes or confusion have led to UX design improvements. Being group-based, many users learn from the actions of the users around them.

Further work will address haptic feedback via the web interface, expected to be helpful on our shared display. Incorporation of accelerometer & device motion might further enrich cursor movement.

5 PROTEIN VISUALISATION

UTS student Matthew Barrett (School of Computer Science) has used the QR code system in the development of a Protein Visualisation Tool to select, control and navigate various protein models. This tool also compares the many 3D models output from Google's *AlphaFold*. For more information see: https://dataarena.net/projects/protein-visualiser

6 SERVER-CLIENT COMMUNICATION

The components of the interaction system reside within a "*DA Live*" web service created by the UTS Data Arena team. The service uses the SocketIO library for bidirectional communication between clients and server. User phones (web browsers) and Data Arena software instances (eg. Unreal Engine) are all considered clients. Unlike HTTP and REST API requests, SocketIO establishes a single sustained TCP connection. This reduces metadata overhead alongside data payloads. The interaction speed is fast; we have not found the need to reduce/compress the data stream. Typical data payloads for the *Cosy Living Room* project are below:

Table 1: Payload sizes for input events

Action	Payload to Server (bytes)
Initial connection open with headers	376
Single tap or select	140
Cursor move delta	170
Set time of day	70
Set fabric colour	70
Lights slider delta	50

[a] Continuous cursor movement is a 12Kb/s data stream. Average input latency ~40ms. Ping time to intermediate web server is 25ms.

Visitor devices connect to a remote "DA Live" web server, not the Data Arena itself. The Data Arena opens a single secure connection to this remote server which collects and sends all input messages in one feed. A middle-server provides a valuable level of security. Visitors' devices never directly connect to the Data Arena. Any potentially harmful activity, intentional or not, is directed to the intermediate server. Being a web page allows convenient access for users. The libraries used are well-supported by web browsers and phone systems.

The remote server creates a "source of truth" for state management. Interaction adheres to the Model-View-Controller (MVC) pattern to synchronise state shared between clients. In the *Cosy Living Room* project, all users share controls which set the time of day, furniture fabrics, light levels, etc. When a user makes a change, the webserver broadcasts that change to all clients to maintain consistency. The Unreal Engine nDisplay server updates the 3D environment accordingly.

A different example which uses this system is the City of Sydney's Wellbeing Survey, developed in the Processing Language, shown in the supplementary video, and online https://dataarena.net/projects/wellbeing-sydney

7 SUMMARY AND FURTHER WORK

This multi-user interactive system has been in use and on-going development for the past two years at the UTS Data Arena. Various applications include Building Architectural BIM models presented in 360-degree 3D Stereo, 3D protein-structure models, expansive 2D text analyses, and interactive Virtual Production environments for Film & TV. The external plugins required to expand an Unreal Engine project into a multi-user interactive system are published on Gitlab, available for download. Developers can build on a laptop then bring their project into the Data Arena for display on the high-performance linux GPU cluster.

Interested new users are encouraged to get started at the Data Arena website's *Dive In* page. For further information about the Data Arena see: https://dataarena.net