New Ways of Accessing Information Spaces Using 3D Multitouch Tables

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***Abstract*—Multitouch-Multiuser Table Computing is the new paradigm for accessing rich information in public spaces. As revolutionary natural user interfaces provide new ways of interacting with virtual information spaces, visual information developers must rethink their methodologies in the design of new applications that augments multiple user interaction and collaboration. This paper addresses a specific aspect of the multitouch-multiuser paradigm for virtual artefacts. Particularly, the paper addresses pilot developments of 3D multitouch-multiuser table applications in the presentation of heritage information in order to begin to qualitatively understand group behavior and user interactions on 3D information spaces using touch. The qualitative observations here pave the way for more structured quantitative usability studies.**

Multiuser, multitouch, surface computing, digital heritage, interactive 3D

I. Introduction

We are living in an increasingly information-oriented world [1]. Users interact with computers and devices in various forms in order to extract information from them. Information of the real world digitised and represented on LCD and OLED displays of various devices in this context has functional values. Information can be presented in different formats – textual and non-textual. Together they are interpreted by users, and as users interact and learn, information becomes meaningful and knowledge is formed.

In the sphere of heritage, information is of high valuable. Consider a stone monument of archaeological significance. The stones are made up of bits of information in its very atomic structure (as all physical objects within our universe are [2]), these defines the physical nature of the stone. The visible surfaces of the stones recorded information pertaining to the forces of nature and tool marks made by ancient inhabitants. Even the arrangement of the stones contains information of past cultures. The stones themselves are no different in physical nature to other stones, but due the story behind these stones, they are declared heritage. Heritage here refers to cultural heritage, which can be defined as "that complex whole which includes knowledge, belief, art, morals, law, custom, and any other capabilities and habits acquired by man as a member of society" [3], and natural heritage which, in the context of this article, is the legacy of fossilised organisms. Scholars excavate information and build evidence that unveils deeper stories related to these stones in the surrounding landscapes. As more information is structured in a meaningful way, the value of the monument becomes greater. The valorisation of heritage is important in contemporary societies due to its direct and indirect economic benefits [4-6], and can facilitate the betterment of society [7].

Museums have been attempting to add value to heritage by representing heritage information in various formats with the purpose of educating visitors through better story telling. Animatronics of dinosaurs, interactive displays of mechanical nature, and interactive digital displays have been created to complement museum collections. Information associated with a particular heritage artefact may be deep, and it may not be good use of the display space to arrange piles of information on paper and plaques attached to the glass casing of the exhibit. In this case, a digital screen can resolve the issue as information displayed on screen can have multiple layers, changeable, updated and enhanced with new media formats. Museums are finding such practice more beneficial to visitor learning and are exploring technologies to complement their collections. External to the physical museum spaces, interactive virtual information spaces such as online museums have become popular.

The single-user-single-touch interactive display that complements old exhibits solves a particular problem of representing structured heritage information. The advent of multitouch-multiuser devices raises interesting questions related to their utility and usability. How will visitors react to this new technology? How will the provision of multiple finger gestural interfaces affect the way visitors access information? Can a familiar table-oriented computer facilitate more round-the-table collaborative behaviour within museums and art galleries? Will powerful stereo 3D computer graphics that faithfully captures and represent tangible heritage objects change the way people perceive digital representation and value them? Can digital simulacra [8] replace their originals in time to come? New ways of thinking and a deeper examination are required to answer these questions. Before these questions can be answered however, multitouch and the physics of interaction, user collaboration, group learning and teaching, and basic group behaviour will need to be examined. This chapter is an initial approach to the understanding of the questions presented earlier. The aim is to construct 3D multitouch-multiuser applications for touch-table computers that will allow us to understand aspects of user behaviours so that we may structure further quantitative research later. As we explore new territories we must come to a point where we can practically test out new ideas. The development in this article aims to facilitate this cause.

II. The Virtual Space within the Physical Space

Museums are similar to libraries and art galleries. They are places of great learning opportunity. A sense of awe encompasses the visitors as they admired past material cultures, they are inspired by the curator's work in structuring materials in a way that facilitates the human need to see and to know – "A museum is a complex cultural organization, which is made up of a site that is frequently spectacular, a body of people with rare and fascinating expertise, a collection of objects that in its totality is unique, and a range of values that are currently under intense scrutiny from within the institution, from the academy and from government. All of these elements are susceptible to study, and therefore present learning opportunities. The level of learning can range from early childhood education to postgraduate research." [9]. Such a space however has limitations. The ultimate limitation is the restricted number of objects and information that can be displayed at any given time within that space. This is perhaps one of the reasons that museums follow the well known 40-40-20 proportion of exhibits-collections-facilities [10] – Not all items can be displayed at a given time. A solution to this problem may be to install virtual information spaces within the physical information space. These virtual spaces must allow the flow and accessibility of large amounts of data. The interface must be intuitive and familiar to a wide range of audiences. Such a space must support high-definition and real-time computer graphics, with the possibility of Stereo 3D to engage the aural and visual senses. The screen must be robust and the software content and application well designed. Finally, in order for large amounts of physical data from the archives to be made virtual, they must be digitised via high-speed digital scanners (laser and structured light).

There are advantages in allowing unlimited access to collection archives for visitors and researchers. An unrestricted access to the archives provides two major benefits. The first is that it allows the rediscovery of hidden source of information that may bridge relationship or chronological gaps amongst objects. This helps extend current knowledge for researchers. The second advantage brings economic benefits to the place that hosts heritage objects, through regional and international heritage tourism activities. A good example is the recent rediscovery of a new species of dinosaur hidden in the archives for almost a century at the Natural History Museum (NHM) [11]. The discovery allows species to be compared and assists with identification between individuals in the classifications of these animals. According to Paul Barrett, the palaeontology researcher at the NHM, "These embellishments are central to determining relationships between the groups of horned dinosaurs and are a sign of evolutionary relatedness". The second advantage is the social and economic benefits heritage brings to a country [4-7].

III. The Multitouch Paradigm

The technology for an ideal virtual space is presently available, but applications that are being developed are few and far between. Content creation tools that support native multitouch are at its infancy, but various large software corporations such as Microsoft, Adobe, and GestureWorks are working on Integrated Development Environments (IDE). Games engines such as UDK, CryEngine and Unity3D support iOS and Android OS native multitouch but emulation is required for multitouch on table computers (E.g., UniTUIO). Furthermore, the understanding of human behaviour surrounding such spaces is not understood. The lack of a physical keyboard on smaller multitouch devices are also discouraging content creation on touch-based devices [12]. Progress however, is being made in these areas. Below are observations from current literatures.

A. Market Trends Suggest Maturity of Multitouch Displays

Market trends in research shows that multitouch technology are reaching a stage of maturity in North America and Europe. Prices are expected to drop dramatically over the next few years. The market is expected to grow 18.18% in the next five years to reach USD5.5 billion by 2016 [13]. A smaller survey sample [14] in the Far East between multitouch hardware and software provider, and end users suggests increasing usage of the technology in advertising, education, retail, museums and art galleries, and media. Clients generally felt that the prices are too high but are positive about the multitouch market.

B. Mobile Multitouch Influencing How Users' Interact with Computers

Natural User Interfaces [15, 16] (NUI) as applied to touch and gesture-based devices such as the Apple iOS (iPhone/iPad Operating System), Google Android and Windows supported mobile phones have revolutionised the way in which users access information via wireless communication networks. These developments are revolutionising both work flow and leisure and for that reason, the mass public are getting used to the natural interactions styles in these devices. This implies that users are in the process of implicit learning of multitouch gestures in preparation for the future when multitouch interactions pervade general computing, i.e., when all digital displays support multitouch.

C. *User Behaviours in Multitouch-Multiuser Tables*

Direct touch-table computers evokes confusion on first time users in touch interactions, organisation of content, and occlusion in uncontrolled environment [17]. However, a study suggests that touch screens is providing a scope for interactions that are more like physical interactions than classical windowed interfaces [18]. Research on user-defined gestures [19] suggests that the Windows desktop paradigm has a strong influence on users' mental models; that users rarely care about the number of fingers they employ; that one hand is preferred to two, and that on-screen widgets are needed. The habits of users however, may be changing due to the implicit learning of multitouch mobile devices (see section III.B). Observations on larger crowd behaviours in uncontrolled environments demonstrated mutual learning. An observation [20] with 1199 participants reveals that users attract other users, and that a user's actions on the touch wall are mimicked by observers. An interesting phenomenon was the collective nature of the crowd – "how these people were configured in groups of users and crowds of spectators rather than as individual users. They were able to use the display both in parallel and collectively by adopting different roles" – the use of the display was highly non-individualistic.

IV. 3D MULTITOUCH APPLICATIONS

Multitouch-multiuser applications on the market presently are essentially 2D – they are basic media viewers that provide browsing capabilities for 2D images and videos. These early adopters of multitouch tables in museums utilise very basic multitouch functionalities (see examples [21, 22]). As hardware, Application Programming Interfaces (API) and Software Development Kits (SDK) become established, more creative use are expected.

Going beyond 2D into 3D environments has its advantages. An additional dimension in the virtual space facilitates the visualisation of richer and deeper information. Furthermore an additional axis allows a greater freedom in visualising information. Using 3D means that digitally captured objects can be examined in 3D and their surfaces can also be 'peeled' to reveal volumetric information internal within the objects. Furthermore, stories can be embedded within the objects, and other media formats could contribute to narratives about the objects. The advancement of computer graphics techniques means that objects within the 3D space are able to take on physical and visual characteristics that are similar to their physical version. This means that the mapping of Newtonian physics, weight and volume, realistic textures and materials can all be visualised. Furthermore, it is also possible for living organisms to be simulated within the virtual information space. In this respect, extinct creatures, lost landscapes and ancient people can be brought back to life.

This section explores the author's two experimental developments. These developments are for the purposes of understanding how users initial react to 3D multitouch applications so that more structured research can be conducted to facilitate natural interaction. The hardware setup for both applications is similar. The multitouch-multiuser University of Birmingham commissioned table measures 178.75 (length) x 115.57 (breadth) x 74.77 (height) in centimeters. The diagonal screen size of the Samsung made 3D-ready display is 65". The compute is Intel Quadcore XEON 3.06GHz with 8 threads, and 12 GB of memory. The graphics card is NVIDIA Quadro 5000 with 2.5GB GDDR5 SDRAM. The 3D display is driven by NVIDIA's Stereoscopic 3DTV and MonsterVision's Max3D high speed shutter glasses. The applications are developed within the Unity3D Integrated Development Environment (IDE) with multitouch simulation from the uniTUIO libraries.

A. *Interactive 3D Objects and Relationships*

The purpose of the first application is to allow user access to hypothetical heritage artefacts via 'touch' as they would any physical objects that were inaccessible due to conservation purposes. The interface could be extended to allow access by museum visitors to treasures such as the Staffordshire Hoard, and the discovery of 52,500 Roman coins in Somerset. This application attempts to simulate how heritage items from the archives and conservation could be represented on touch tables for user engagement. The multitouch-multiuser application described here allows users to 'touch' and 'manipulate' objects. Using natural gestures such 'pinch-zoom', 'swipe', 'poke', 'drag', rotate, users were able to interact with objects in an intuitive way. Each object is computationally 'tied' to physical laws such as weight and gravity, collision, inertia, and inflatable effects such as bounciness, and pressure. Object materials describe it's bending and stretching stiffness, cloth, metal, wood, rubber, etc. Some objects are chain-linked with inverse kinematics when interacted upon. Material surface can be described by textures and graphics Shader effects; materials can take on the appearance and 'feel' of any physical material. Gold would look like gold with glittering effects, silver, wood, fabric, plastic, etc. Using active stereo glasses, the objects appear to 'pop-out' of the screen. Touching the objects however, requires a direct interaction with the screen. 3D Objects can be created with content generation software and from laser scanning data.

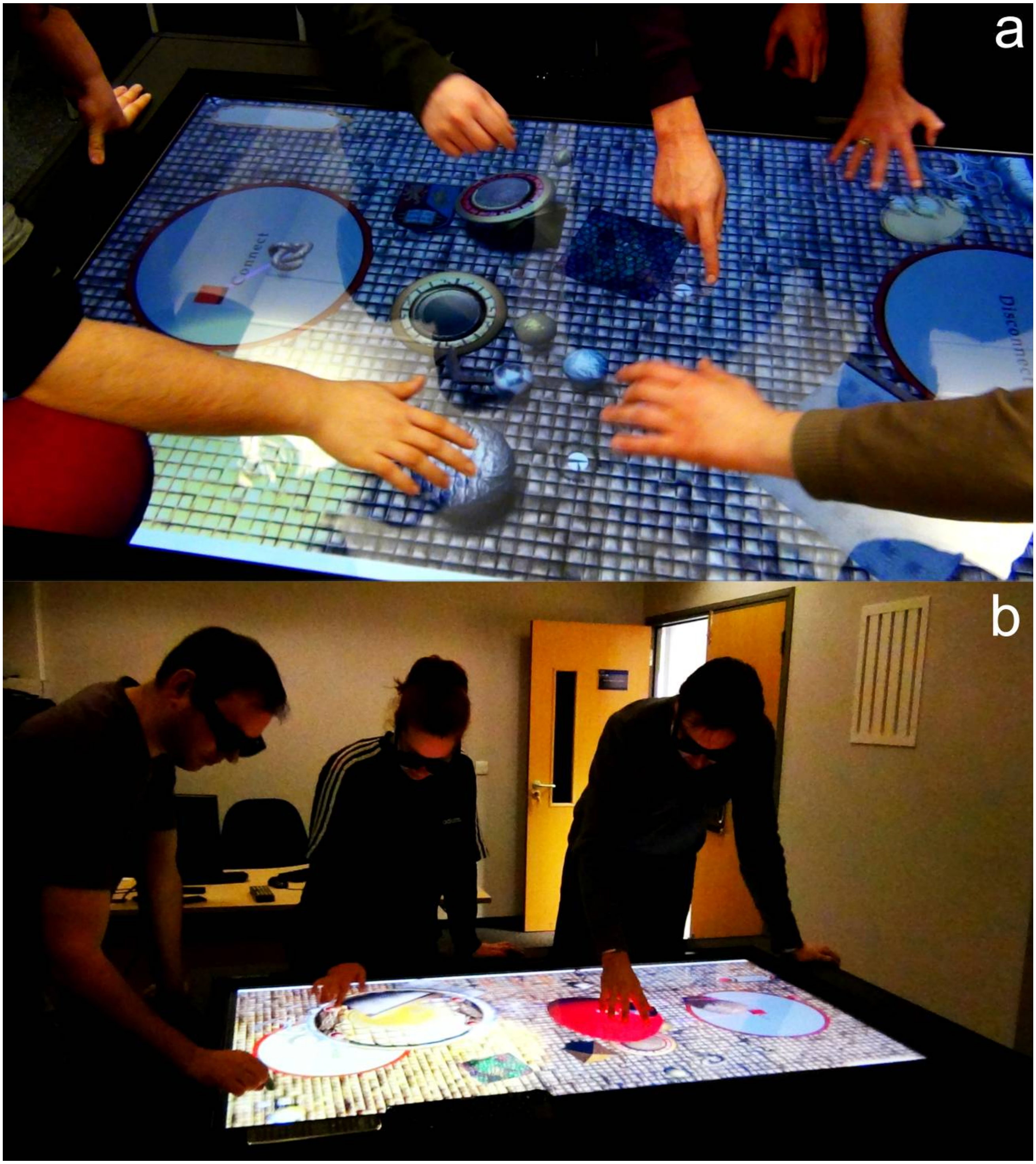

Figure 1. 3D multitouch table for accessing heritage objects. a) users simultaneously exploring the 3D objects via touch, b) Users donning the active stereo 3D glasses whilst interacting with the objects. Viewing of Stereo 3D requires users to be within the viewing angle directly facing the front of the display.

Tools within the virtual space such as a lamp and a magnifying glass are used for inspecting objects, which can be connected and disconnected to form relationships. The objects too can have information outside of itself such as user comments embedded within them. The embedding of information and the relationship-building facilities for objects aim to provide an environment for users to use natural gestures as they would a physical work space to sort, categorise, retrieve and record information. The realistic environment and its rich affordances aim to allow visitors and researchers to make meanings and relationships with objects on the table, in a natural way.

B. The Trilobite Pit

The multitouch table application described here attempts to bring ancient creatures back to life. The aim is to find new ways of learning about creatures in palaeoenvironments. Traditionally, studying fossils teaches us about ancient plants and animals; artists' impression based on fossil remains illustrates their morphology, with backgrounds portraying the environment and potential predator-prey scenarios. Geological museums display fossil remains and reconstructed models of large land-creatures that awed visitors; these are accompanied by little textual descriptions of the animals. Better reconstructions are animatronics of dinosaurs, which sit boringly within perimeters and bellows roars on occasions, frightening children and some adults alike. These are rarely interactive. This application hopes to adopt new ways of engaging with the public, and also demonstrate the possibilities with multitouch screens.

The application prepares an ecological environment for trilobites and a certain type of zooplankton as prey. Users tweak environmental 'sliders' to simulate effects of local climate change with temperature, sunlight, and oxygen levels in the ecosystem. Creatures react to the environment in various states of fitness that affects the creatures' speed and survivability within the space; death occurs if the environment surpasses their rate of adaptability. Users interact with the ancient creatures by dropping capsules containing zooplanktons into the pool. Users can also use gestures to rotate and move the trilobites around the space. Zooplanktons within the virtual space have built in behaviours that allow them to swim faster when pursued and avoids predators via turns and twists. Energy levels decide their ability to survive predation. In the agent-based model, each creature has different preferences and capabilities such as speed of movement, slope climbing capability, energy levels, turning angles, feeding distance, predation thrust, and adaptability to sunlight, temperature, and oxygen levels. The morphology are created based on fossil records; movements are slightly exaggerated to

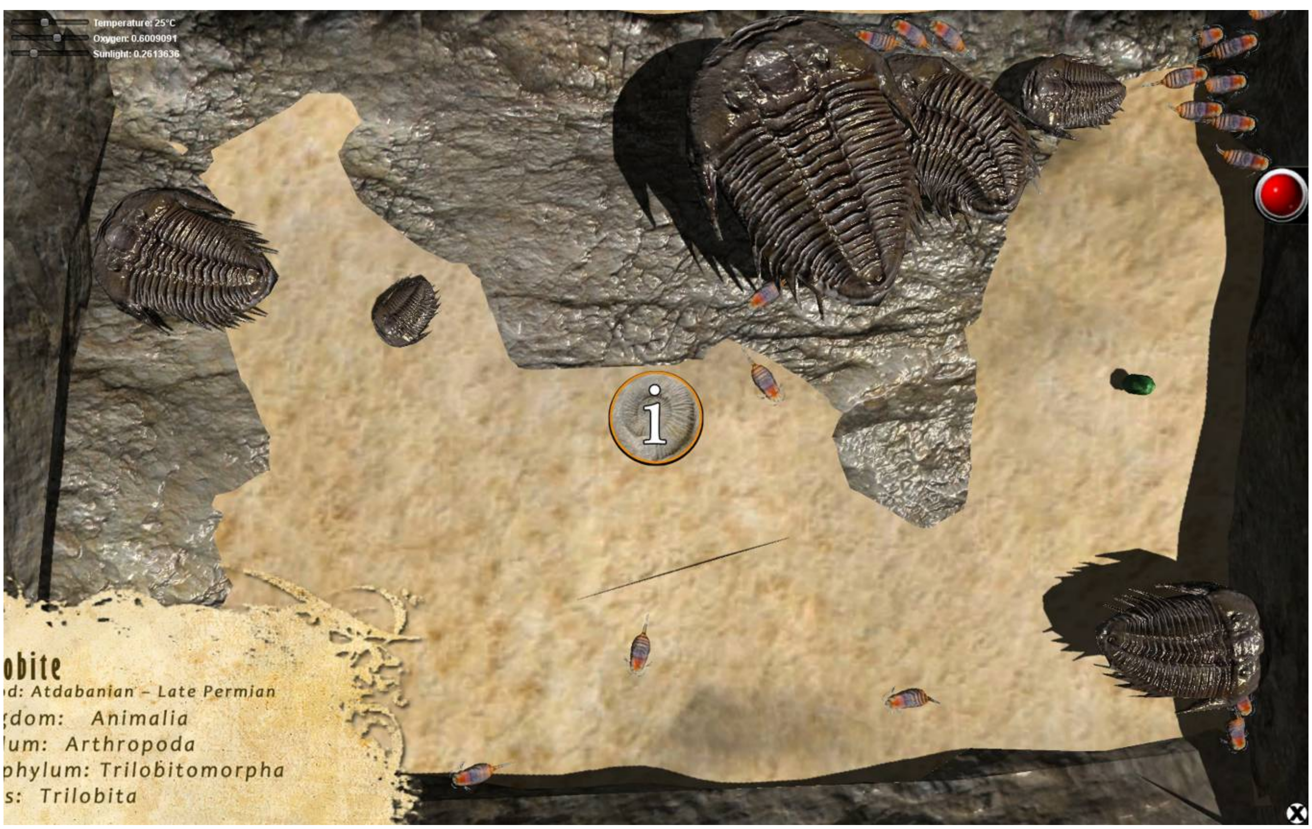

Figure 1. A touch table application for facilitating new learning experience about ancient creatures. The group of trilobites agressively feeding on the copepods at the top right edge of the screen. The 'i' mark leads to further information about the behaviour and health of each trilobites. The text panel at the lower left gives factual information about trilobites as a whole.

create a game ‘drama’ effect – creatures ‘breathes’ with inflating and deflating abdomen animation during the idle state, they also wiggles during movements and feeding.

I. Observations of User Behaviour

It was not immediately clear how first time users will behave around the table but hypotheses could be formulated based on a general understanding of human behaviours for adults and children – 1) Unless being encouraged by the person in charge, new users (adults) will observe others before touching the tables 2) Children will just not care. Below are some observations of a range of visitor’s first encounter in one of the University of Birmingham’s open days and various private viewing at the do.Collaboration prototyping hall:

- Users new to multitouch tables will first observe before touching the screen.
- User behaviours are affected by the number of users actually using the MTMU table and whether they are acquaintances or not.
- Adult users are not acquaintances are courteous in their use of the table. i.e., they will ‘queue up’ (standing a short distance away from the table and watching for a short time) before they actually touch the table. Children participate freely regardless of whether they know each other or not
- If a user is working on a task on the table, others will only watch
- Children will crowd around a table at close proximity whereas adults tend to leave some personal spaces between each other. This occupation of space reduces the number of users that can surround a table at a given time.
- Children of equivalent elbow heights to the table have a tendency to lean on the table, this occupies touch points. On devices where touch points are limited, multiple user interaction will not work.
- A facilitator giving encouragement warms up users to use the table
- Users are finding the virtual keyboard difficult to type without auto-correction due to the non-haptic, flat surface of the display.

The points below are observations of users actually using the applications.

- Users were surprised that the virtual objects behaved in a similar way as real world objects
- Some users did not realise until they were told that you can actually pinch zoom and rotate the objects using multiple fingers. Users that are familiar with the Smartphone interaction paradigm immediately recognise the capability of the table.
- When a single object is scalable using the pinch-zoom gesture, users expect all objects to have similar functions
- Both hands are used when moving objects from one location to the other
- Users find it easier to flick heavier objects to move them as compared to lighter objects not affected by friction
- Users were confused as to why there is the need of a magnifying glass when there is a gesture-zoom function
- When told that an object is comparatively heavier than another object, users attempted to use more fingers to move them (The heavy objects are more difficult to move due to the gravity and friction simulated by the physics engine).
- Users have the wrong perception that they can touch ‘holographic’ 3D active stereo objects popping out of the display. Users find it difficult to judge the distances between their fingers and the table when 3D is turned on. One way of solving this issue may be to use Microsoft Kinect for Windows/XBox, or the new Leap motion sensing device that tracks depth above the display.
- The lack of a mature haptic feedback is a general problem in multitouch tables.

II. Conclusion and Future Work

The multitouch-multiuser computing paradigm is revolutionising the way in which information is being generated, stored, accessed and manipulated. The PC-era of working with inputs from the mouse and keyboard is being replaced by natural user interfaces involving touch. The viewing of information can now be on a table format rather than vertical monitors. This reproduces the traditional way of learning and teaching, and the way in which people collaborated on tasks on a digital table that has the ability to present rich information. These two interaction paradigms will allow a wider range of users and group interaction opportunities that were previously not possible. In this article, an attempt was made to apply 3D multitouch-multiuser technology to the access of heritage information through the development of two multitouch applications. These pilot studies have provided some information on user behaviours and interaction habits with 3D objects and how groups will behave around multitouch tables. The qualitative study here has established areas in which to conduct formal quantitative usability research. Four areas were identified needing the research:

1. Manipulation of 3D Objects – How natural gestures in physical environments can be transferred to 3D objects manipulation on a flat 2D screen, and how Windows-era habits can be used for facilitating the usability of the applications using real-world metaphors.
2. Group Behaviours around the multitouch Table – How can collaboration be facilitated amongst groups

of 'friends' and groups of unfamiliar people can be coerced to participate in collaborative tasks.

3. Stereo 3D Interaction – How Stereo 3D interaction can be made more realistic using above-surface sensors such as Microsoft's PixelSense, Kinect Windows or Leap's motion device.
4. Haptic Feedback – The lack of a mature haptic feedback system on multitouch tables is an issue. The presence of haptic feedbacks, even small vibration motors will help users realise that they are touching an object without having to look at them.

There are more to be discovered as different multitouch table applications are developed. Future work based on these initial findings aim to create more collaborative, learning and teaching tasks through quantitative studies.

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