3D Mobile User Interfaces

A Discussion Paper by IKIVO

Abstract

The availability of mobile hardware which supports 3D graphics has opened the possibility for the use of 3D in the mobile user interfaces. IKIVO user interface (UI) solutions provide handset manufacturers and carriers the best alternative for delivering unique and compelling interfaces. In this paper, IKIVO examines the possibilities and limitations of 3D mobile UI solutions.

INTRODUCTION

The emergence of software and hardware to support 3D user interfaces in the mobile device domain has opened up the question of why and how 3D should be used in mobile user interfaces.

IKIVO has a successful track record in delivering attractive and performance UI and application solutions on a range of operating systems. IKIVO does not develop or manufacture hardware, and does not develop or sell 3D design tools. As such IKIVO is well placed to give a balanced analysis of the use of 3D in mobile UI.

This paper breaks down the key issues necessary to consider when answering these questions.

BRIEF HISTORY OF 3D USER INTERFACES

Silicon Graphics[1] first shipped 3D graphics workstations in 1982. The development of 3D for user interfaces has been slow to develop since, limited by the significant hardware and software technology required to render an interface in three dimensions fast enough to be used effectively.

The introduction of 3D in consumer interfaces was pioneered in the early 1980s in the computer games industry. Titles included 3D Monster Maze (ZX81); Battlezone (Atari) and Elite (Acorn)[2]. These games used vector graphics and simple math to create 3D environments which could be navigated and interacted with. These games and their sequels incorporated features such as 'hidden line removal' and 'filled 3D polygons'.

The adoption of home PCs in the 1980s and 1990s led to rapid evolution of 3D capabilities in consumer PC technology, which supported the development of dedicated hardware in the form of graphics cards. 3D support was introduced in the mid-'90s by nVidia[3] and ATI[4], in the form of cards which supported mipmapping, z-buffering and anti-aliasing, and the support of SVGA (800 x 600) screen resolution.

The graphics cards were used almost exclusively for 3D games and industrial 3D design tasks. During this period, the proliferation of Microsoft[5] Windows™ and Apple[6] MacOS as the dominant consumer PC interfaces provided an almost entirely 2D interface. The only 3D element to these interfaces was the use of beveled window edges and buttons which animated to give the appearance of being clicked.

The first use of full 3D UI concepts in Windows were released with Windows Vista in December 2005, called 'Windows Aero'[7] and 'Windows Flip 3D'[8].

Windows Aero was available in a configurable solution (allowing the user to match the processor-heavy effects with the PC capabilities) and allowed a glass-like semi-transparent window border to view windows underneath the top window or menu.

Windows Flip 3D is an evolution of the 'Alt-Tab' window switcher which has been in existence since Windows 95 introduced multi-tasking. Pressing 'Alt-Tab' in Vista and Windows 7 enables a 3D view of open windows which can be 'flipped' through using the mouse scroll-wheel.

Apple, who has pioneered development in hardware, OS and user interfaces, has limited the 3D effects in its MacOS implementations to drop-shadows, 'wet floor effect' and zooming.

In 2006 Apple introduced the now familiar Cover Flow 3D interface into its iTunes jukebox software with widespread acceptance. The Cover Flow interface is now widely used in iPod and iPhone devices, and is also included in Apple's Safari browser software. This effect has been widely adopted by consumer electronics manufacturers to produce similar animation effects for browsing through lists of data such as music library, contacts, application screens and web pages.

The drive for 3D games provided some of the first mobile 3D experiences in 2003 with titles such as Namco[9] 'Ridge Racer' (Nokia N-Gage[10]) and Digital Chocolate[11] 'Extreme Air Snowboarding' (Java). The demand for 3D games has driven handset manufacturers to implement the Mobile 3G Graphics API (M3G / JSR184) for Java, which has allowed widespread development of 3D games. The demand for faster, smoother 3D experiences has, in turn, driven the development of mobile chipsets incorporating dedicated Graphics Processing Units (GPUs), such as those found on the ARM[4] 200/400 Mali chips, and the Apple iPhone™.

Although the iPhone™ has the specification to implement rich 3D environments, which have been put to good use in 3D games for that device, the interface remains resolutely 2D, with only the Apple Cover Flow interface bringing any 3D interaction to the screen.

The most prominent example of a 3D interface for mobile devices was launched in 2007 by HTC[12] called 'TouchFLO™'. This interface had 3D 'Cube-Style' screen transitions between multiple home screen (e.g. Today, Contacts, Launcher) which were enabled when the user dragged a finger across the touchscreen. This was followed in 2008 by 'TouchFLO™ 3D', first delivered on the HTC Touch Diamond™ device.

The 'TouchFLO™ 3D' interface introduced a menu bar of tabs to navigate between the multiple home screens, which could also be 'flicked' through with finger swipes. The 3D 'Cube-Style' screen transitions had been replaced by a simpler 3D background transition and almost 2D sliding between screens for the screen content.

The 3D element was introduced through screen objects such as a contact 'rolodex' and photo album, email envelope and music album 3D animations.

In 2009 LGE introduced a '3D Interface' in the form of the S-Class interface on the LG[13] Arena™ device, which gave a '3D spinning cube' task switcher application. This feature used pre-defined dummy screenshots of the applications mapped to the sides of the cube. When swiped, the cube rotated, and when clicked the cube zoomed to full-screen, disappearing momentarily before replacing the dummy screen-shot with the actual full screen application. The presentation of contacts and multimedia objects is also given a 3D feel, arranged in a wheel that can be swiped to spin and clicked to stop.

In 2008/2009, a number of chip vendors (TI[14], nVidia, Samsung[15], Qualcomm[16]) have created a variety of 3D user interface demonstrations, showcasing the graphical power of new chipsets to be used for mobile devices in 2009/2010. Although graphically impressive, it is not clear if or how these concepts will evolve as the hardware comes to market. They are, however, impressive and allude to the possibilities for using 3D in mobile UIs in the near future.

SOFTWARE TECHNOLOGY

The demand for 3D games has driven handset manufacturers to implement the Mobile 3G Graphics API (M3G / JSR184) for Java, which has allowed widespread development of 3D games.

Making use of these additional capabilities across multiple devices and platforms, and the requirement for smoother faster graphics, has seen the emergence of two key new technologies.

For devices supporting Sun Microsystems[17] Java Platform Micro Edition (J2ME) the Mobile 3D Graphics 2.0 (M3G2 / JSR 297) specification is encouraging the development of new and exciting games, applications and interfaces.

For OpenOS devices M3G2 support is being adopted alongside support for OpenGL ES 2.0[18] and Microsoft's proprietary Direct3D Mobile[19]. These technologies are competing, but likely to be adopted for differing requirements. The Microsoft Direct3D Mobile solution is being oriented towards mobile gaming, as it comes from the Direct3D development for the Microsoft XBOX™. The OpenGL ES 2.0 solution is more general and likely to be used in broader implementations such as UI and multimedia applications.

Mobile interfaces have, until now, utilized very little true 3D capability to render the UI elements, with most of the 3D effects being managed through transforming images and using 2D presentation of perspective scenes to create a 3D impression. These animations are almost pre-defined by necessity and cannot be significantly adapted to the content or context of the information presented.

HARDWARE TECHNOLOGY

The demand for faster, smoother 3D experiences has, in turn, driven the development of mobile chipsets incorporating dedicated Graphics Processing Units (GPUs), such as those found on the ARM 11 and ARM Mali chips.

Until 2008 the support of 3D in mobile handsets was limited to software implementations.

The most advanced mobile device generally available is the iPhone3GS™ which has a 600 MHz CPU and PowerVR™ SGX 100MHz GPU. This provides a possible 3.5 million triangles per second, which is equivalent to high-end PC graphics cards from 1998, and 5x more powerful than the Sony[20] Playstation™ (1) launched in 1995.

The hardware in 2009/10 will evolve to deliver impressive 3D capabilities for use in games and entertainment applications. One area that is not well defined as yet is the ability to create clean crisp interfaces incorporating 3D objects. A simple comparison of the difference between Pseudo 3D and true 3D is provided below.

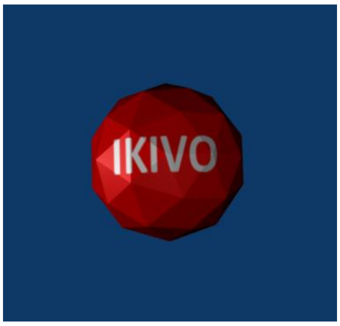


Fig.1 Low polygon count

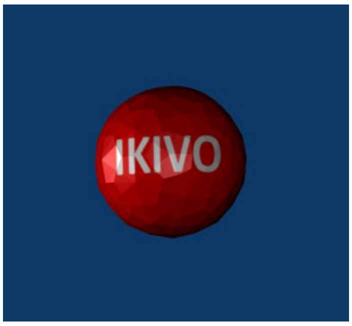


Fig.2 High polygon count

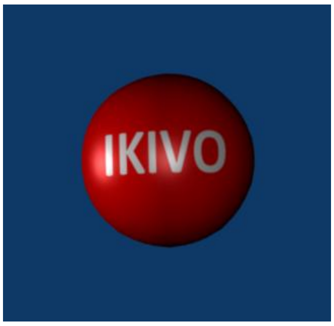


Fig.3 Pseudo 3D

Today, it is clear that producing a true 3D interface with text and images mapped to a polygon rendered and light-source lit 3D object – even with a high polygon count – may not produce a clean, crisp interface when compared to a pseudo 3D interface which gives the illusion of 3D but does so without implementing a 3D data model.

3D CONCEPTS IN UI

The concepts of 2D user interaction design apply equally to 3D user interfaces. The navigation, selection, manipulation and system control requirements are common to both 2D and 3D.

Navigation

The concept of 3D navigation through an interface seems a logical progression from navigating a 2D interface. The third dimension allows an extra axis of travel which could be used to add to the current 2D 'up-down-left-right' navigation concept.

The key difficulty in enabling navigation in 3D is how the user is to control that navigation. The traditional joy-pad or nav-pad provides only a 2D control mechanism. Incorporating the third dimension into the interface has been attempted through specific forward-backward buttons, and through orienting the nav-pad to deliver 'left-right-forward-backward' motion leaving out the 'up-down' axis.

Neither of these interaction designs has been particularly successful in allowing control in a three-dimensional space. This is perhaps because the mobile experience is divided into two interaction models:

> 'Thumb-Driven' where the user cradles the device in the palm and uses the thumb to operate the keypad of a non-touchscreen device.
>
> 'Stylus-Driven' where the user cradles the device in one palm and uses a stylus, pen or finger to operate the touchscreen device.

Neither of these two models facilitates navigation in 3D, but do allow for 2D scrolling/panning with click-through selection and menu control.

Navigation with touch devices has evolved to incorporate touch 'gestures' such as a finger swiping across the screen. If touch gestures are used to indicate movement, they become counter-intuitive in a 3D environment, owing to the 2D nature of the gesture.

Selection

The mobile device experience is dissimilar to the PC WIMP (Windows, Icons, Mouse, Pointer) experience, in that there is no virtual pointing device. The WIMP method of selection allows the user to point to an interface element and click to interact.

On a non-touchscreen mobile device, the user typically navigates between on-screen elements, with the 2D nav-pad – and is made aware of the 'cursor' location through 'in-focus' object highlights, such as a bright border or animated icon.

Furthermore, touchscreen devices do not have a visible pointer mechanism, but allow clicks and 'gestures' (such as a finger swipe) to differentiate between navigation and selection. In both cases, a click with button or finger is required to act upon an interface element.

This slight change of interaction brings with it a number of conceptual challenges for UI designers. To give the user access to more options than a simple click, there are different ways that a user can interact with an interface. Double-clicks can be used to open applications, or confirm inputs. Touch-and-hold can be used to bring up additional options for the next click. These additional options are implemented in different ways on different mobile devices, requiring a 'learning process' for each user upon encountering a new device.

This situation makes it difficult for users to accept the 3D interface concept, with selection of objects in a 3D space becoming more problematic than in the 2D space.

However, research by Baddeley et al (1974)[21] found that the human memory is more effective if items to be remembered are arranged in a virtual 3D environment in the memory. The most familiar method of remembering the order of playing cards in a deck is to associate each card with a memorable object, and to arrange these objects in 3D space in the mind whilst mentally imagining a familiar physical journey. So if the interface designer can implement a 3D journey into the user interface such that this 'spatial memory' can be utilized, it could have significant benefits to the user. 3D interfaces can make this concept a reality, and UI design should benefit from this human trait.

Manipulation

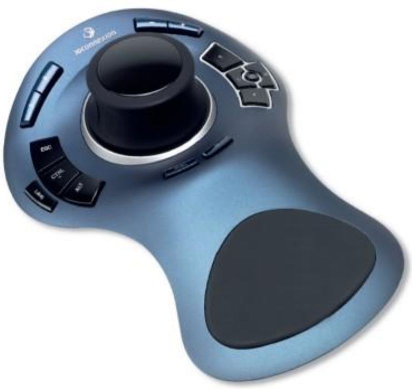
In the PC environment, objects (such as windows and icons) are frequently manipulated – either by dragging and dropping or by expanding, aligning or hiding. In the non-touch mobile experience, this is very rare. Interfaces to date have been fairly static allowing only navigation, selection and data entry.

Touchscreen devices with larger, higher resolution screens have enabled manipulation of windows, and objects, such as widgets and browser content. Typically through touch and drag interaction, or more recently in 'pinch' gestures where two fingers are used to expand or minimize interface elements.

The use of gestures has developed to incorporate selection mechanisms which feel more like 'manipulation'. Browsing your albums or photos by touching the screen and flicking it to one side, resulting in a horizontal 'rolodex' animation (as used in the iPod 'Cover Flow' interface) feels like object manipulation, but is more similar in functionality to a clever navigation and selection mechanism.

True manipulation involves manipulating an object on the screen in the dimensions available to you in real time. To date that manipulation has been limited to two dimensions. Manipulation of objects in three dimensions requires a more complex interaction than can be achieved with a 2D touch interface or a nav-pad and buttons.

An example of a professional 3D manipulation controller is provided below for comparison.



Logitech[22] SpaceExplorer™ 3D Manipulation Controller

System Control

Today, mobile devices incorporate a variety of functions. Control of these functions is typically maintained by the operating system through device APIs which allow software to access hardware functions (e.g. camera, softkeys, touchscreen). The functions that need to be controlled on a mobile device tend to be digital, one- or two-dimensional. Thus, producing a 3D control mechanism is generally surplus to the requirements for system control in mobile devices.

3D EFFECTS

The use of 3D effects in mobile user interface screens can be split into two fields.

Artistic Effects

Artistic effects provide gloss and interest to a user interface without adding function. These effects can enhance the user experience, but do not significantly alter the functionality or usability of the device.

Examples of artistic effects are:

- Screen transition effects (cross-fade, sliding, spinning, expanding, etc.)
- UI element growing, shrinking and flipping
- Smooth list scrolling
- Animated backgrounds

Systematic Effects

Systematic effects provide functional benefit to the user. These effects provide the user with feedback, information or functions which are important to the utilization of the UI.

Examples of systematic effects are:

- Button click animation
- Mouse-over highlighting, or selection highlighting
- Zoom in / zoom out
- Drag and drop animation

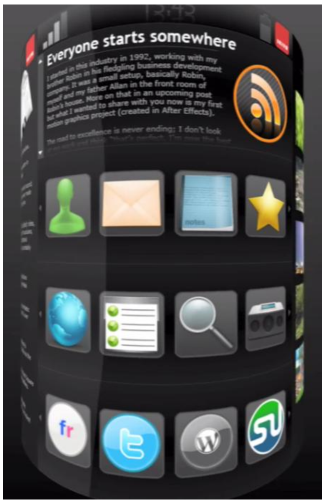
3D TRANSITIONS

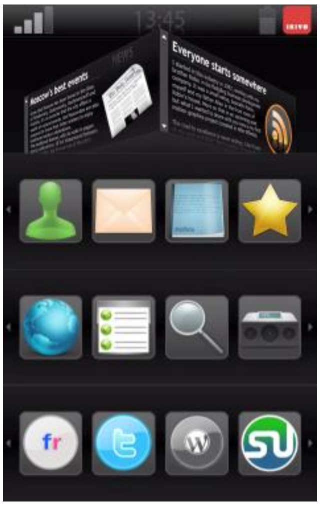
Mobile user interfaces typically consist of a number of different full-screen applications, which group functionalities into logical groups such as messaging, photo viewing, web browsing, and contacts. The user is provided with a mechanism to switch between these different 'home screens', which can be through physical buttons, touchscreen buttons or touchscreen gestures (e.g. a finger swipe).

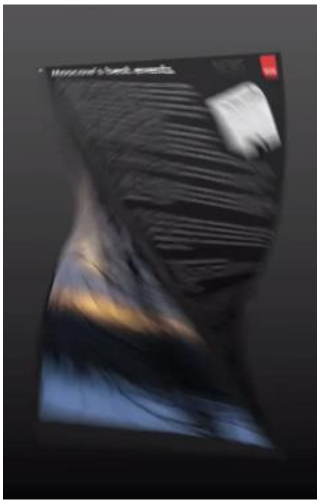
To aid the comprehension and intuitiveness of the navigation between these screens, a number of device manufacturers have introduced transition effects which occur when the user switches between 'home screens'. Normally the transition is designed to show the previous and destination screens for a brief period, with an animation to indicate moving to the new screen.

Before 3D UI effects were possible, screen transitions were limited to simple 2D effects such as sliding or expanding from a small area to fill the screen. With 3D effects now possible, a variety of transitions can be achieved.

Examples of 3D screen transition effects:







Some of these transition effects are more difficult to achieve than others, as detailed in the following table:

3D Effects	Rhomboid image transformations	Curved images	Triangulated 3D model
Cube-style screen switcher	Yes	No	No
Multi-cube-style screen switcher	Yes	No	No
3D book pages task switcher	Yes	No	No
'Rolodex' style switcher	Yes	No	No
3D twirling icons	Yes	No	No
Twisting cube-style	Yes	Yes	No
Perspective horizontal scrolling	Yes	No	No
Fold up / down	Yes	No	No
Cylinder screen switcher	Yes	Yes	No
Touch ripples	Yes	Yes	No
Page turn / peel	Yes	Yes	Yes
Business card flip	Yes	Yes	Yes
Floating elements with shadows	Yes	Yes	Yes

These transitions add interest to the interface, and help the user to understand the navigation between the different home screens. However, the animations can take up to one second to complete. This can be frustrating for the user, who may simply want to access different functions, rather than watch interesting effects.

Therefore, the design of screen transitions has to add value as well as interest to the user interface to avoid user frustration.

Screen transitions can add value in the following ways:

- Allowing the user to peek at a different screen without fully switching screens
- Allowing the user to mentally arrange the home screens on the faces of a familiar shape (e.g. cube) and thereby remember them better
- Allowing the user to view the most important information on the next screen first (e.g. old screen peels away from top of new screen, allowing user to start reading new screen from top)
- Allowing the user to quick flip through multiple home screens, glancing the information presented on each
- Allowing the user to see all the current home screen pages, and choose which one to navigate directly to
- Allowing one important home screen to remain partly visible whilst another home screen takes up most of the full screen (e.g. the main menu screen may stay partly visible whilst the user checks the 'weather widget' home screen).

COHESIVE 3D UI ENVIRONMENTS

The conception and design of a 3D UI environment needs careful consideration. The aims of any UI should be to allow the user to use the functions of the device as easily and effortlessly as possible, while providing a pleasant and logical visual experience.

The improving abilities of mobile devices to support 3D visual interface elements have opened up the possibility that 3D can become an important part of the mobile user interface experience.

Each of the major mobile device operating systems (Symbian[23] S60™, Windows Mobile™ and Google[24] Android™) provides a wealth of functionality, configuration and personalization options. Currently, only Android makes any effort to present a pseudo 3D experience (with the native Android™ home screen background moving in the distance behind the home screen elements). This provides handset manufacturers with a problem. The OS user interface of a typical mobile device runs to more than 200 different screens. If a 3D home screen or application experience is delivered on a new device replacing the native 2D home screen or application, the manufacturer will have to either design the whole of the native OS functionality in the 3D design (all 200+ screens), or accept that the user will have to move from a 3D UI back into the native 2D OS UI for deeper level screens.

The economics of producing a complete replacement UI are prohibitive and ensure that however good the 3D UI experience is, the user will fairly quickly find themselves interacting with a native 2D user interface when undertaking more in-depth tasks (such as changing connection settings, and changing application preferences).

Thus, when designing a 3D environment, the handset manufacturer or application developer must always consider the fallback to 2D experience, and ensure that there is a logical crossover and cohesive feel to the overall experience.

CONCLUSIONS

The historical development of 3D user interfaces has been constrained by technology and the difficulty of evolving interaction concepts to 3D. The technology is now capable of a reasonable 3D UI experience on mobile devices, but the difficulty of evolving interaction concepts to 3D remains.

The logical application of 2D control mechanisms in a 2D interface has been the dominant paradigm since the creation of the GUI in the 1970s. This continues today, even for the most advanced PC systems. However, the immersive experience that 3D provides has been driven by the games and design industry to deliver capable technology which will soon be available as standard to large sectors of the mobile user base.

The evolution of 3D mobile interfaces is at a crossroads. Innovations in 3D UI in the PC world have been widely available since Microsoft Windows Vista™ in 2005, but have largely been ignored by the user community who prefer the faster performance that turning off the 3D effects can bring. The 3D user experience for mobile devices has only recently been introduced, and has delivered significant 'wow' factors to a number of devices, but this innovation needs to deliver real user benefit if it is to be widely adopted and developed in the coming years.

The popularity of the iPhone™, with its largely 2D interface (but impressive 3D gaming) has indicated that the mobile user is more interested in usable functionality (such as pinch zoom on a responsive touchscreen) than impressive 3D graphics effects.

However, the possibilities of delivering a 3D UI environment have only been superficially explored in mobile, and the real benefit of 3D in the mobile interaction paradigm is not yet clear. The continual improvement in hardware support and intelligent middleware to manage these capabilities will make crisp 3D interfaces more responsive and functional in the coming years. Handset manufacturers and carriers alike will have significant opportunities to differentiate their products and services by implementing 3D user interfaces that offer improved function, ease-of-use and graphical ‘wow’ factors.

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ABOUT IKIVO

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IKIVO Enrich is a framework of products focusing on client side technology, delivering graphically rich, embedded applications and user experiences for mobile devices and consumer electronics products. It is based on open web technologies and supports multiple platforms. For more information, please visit www.ikivo.com.