WHITE PAPER

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Design Considerations for a Natural User Interface (NUI)

Overview

More than just a pretty face, user interfaces have come a long way in recent years. Not long ago, buttons and dials were the mainstays of a user interface, and they were called a human machine interface (HMI). Recent revolutionary advancements have shown that a more intuitive, engaging and captivating user interface will not only improve the effectiveness of the system, but also boost the productivity of users. As a result, the goal is now a natural user interface (NUI) for applications. Of course, one application's NUI will probably not be appropriate for another's. Even though touch screens are the basis for some of today's most effective NUIs, such as those found on smartphones, tablet PCs and other types of consumer devices, the touch screen may not be the optimal solution for every application. A myriad of issues and tradeoffs arise while designing a NUI:

- *Should the screen's graphics be two dimensional (2-D) or three (3-D)?*
- *Would voice control work better?*
- *Is secure access to the system an integral part of the NUI?*
- *How about a new technique, like touch-responsive haptics or 3-D gesturing?*

With so many considerations, the design team tasked with developing a system's NUI must adopt a methodical, deliberative and comprehensive approach.

Design considerations for a Natural User Interface (NUI)

The first step toward designing an NUI might actually be considered a step back. The eventual NUI will contribute more effectively to the success of the system in the marketplace if the design team first analyzes the application and determines the type of user experience – which is mostly dictated by the NUI – that will engage and energize users. In many market segments today, the user experience is just as critical as the functionality provided by the system itself.

Cost and size parameters

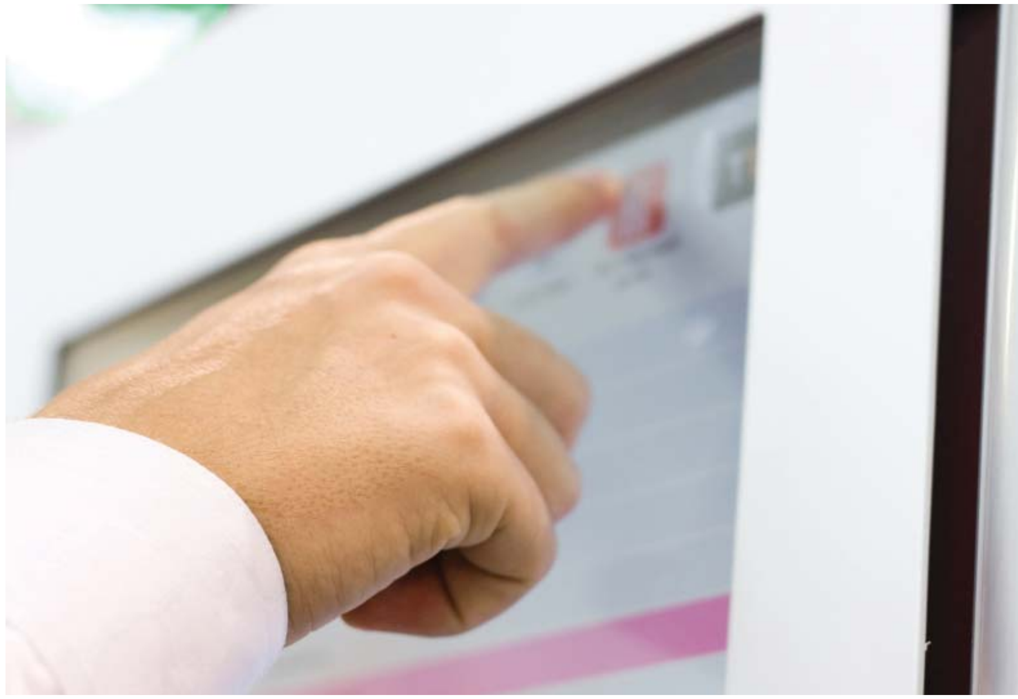
Not unexpectedly, cost will play a major role in the type of user experience provided by a system. A leading-edge NUI may drive up the overall cost of the system to the point where the price of the product will hinder its adoption. Often, the tradeoff NUI designers must consider will involve developing a differentiated interface that may command a premium or implementing a more established NUI that is already understood by users in the marketplace.

The size of the end product also has a significant effect on the type of NUI that can be implemented. Large, immobile systems like DVD kiosks or industrial factory automation control panels can have a very different user interface – from small portable systems like smartphones and GPS systems – or very small control panels such as those found on certain white goods like refrigerators and thermostats.

Connectivity and power issues

This is a connected world, and most systems are either connected to the Internet directly or to a local area network, which in turn may be connected to the Internet. The type of connectivity – wired or wireless – will factor into the system's NUI.

Some wireless connectivity technologies like near field communications (NFC) and ZigBee® have a fairly low data transfer rate. A large and ponderous NUI might needlessly downgrade the responsiveness of the system if it depended on a low-speed wireless connection. Moreover, many systems that rely on a wireless connection are special-purpose, handheld devices like package tracking devices for shipping companies or point-of-sale devices for car rental check-out. Since the functionality of these sorts of devices is limited to one or a few specific tasks, the NUI can be fairly simple and intuitive. This will require less processing cycles and conserve battery power. The requirements of some applications determine the wireless protocol implemented, which, in turn, will affect the look and feel of the NUI. ZigBee-based wireless



communications, for example, is often deployed in certain medical systems because it meets the security requirements of the U.S. government's Health Insurance Portability and Accountability Act (HIPPA).

Systems wired into a network are more often wired into a power source too. The power budget for such a system would certainly be larger and more relaxed than the power budget for a handheld portable device. Some wired systems have significant power needs for certain ancillary processing functionality. An ATM system, for example, will have a card reader to power. Other wired systems might require bar code readers for access. Some wired systems combine their network connection with their power source by using technologies like Power-over-Ethernet (PoE) or Powerline data communications.

The larger power budgets that are typical of wired system give NUI design teams more options to consider since their choice of technologies to implement will not be narrowly limited to just the low-power technologies.

Processing and power issues

The relative complexity of an NUI will have ramifications on the processing resources in the system. Many NUIs will run on their own processor or controller, distinct from the application processor(s). Other NUIs share the system's processor, which may contain multiple processing cores. Regardless of the system's processing architecture, the NUI will have certain processing requirements which must be accounted for.

Various factors of the NUI will determine the processing capabilities needed to support a particular NUI. For example, the larger the size and the higher the resolution of any display screens will place a greater processing load on the NUI's processor. System security measures might be integrated into the NUI. Some security subsystems are quite elaborate, involving extensive image or video processing for telematic security measures like fingerprint recognition, retina scanning or facial verification.

The graphic content of the NUI is another consideration that affects the NUI's processing requirements. To provide a more engaging and captivating user interface, many NUIs are migrating from 2-D display graphics to 3-D icons and images. This places an extra burden on the processor since 3-D graphics are much more computationally intense. Indeed, many designers have found that executing 3-D graphics in software often places too great a processing burden on the system's or the NUI's processing resources. One of the most effective alternatives is to deploy processors that include graphic accelerators in hardware so that the NUI's 2-D or 3-D graphic processing load does not degrade responsiveness.

Some NUIs involve cameras and other sorts of visual recognition equipment. Often, visual technologies are either a function of a security application, such as a surveillance system for protecting access to a building, for example, or they provide security to the NUI and the underlying application. Vision processing-based systems, like gesture recognition, require a very high amount of computational power from the multicore architectures. These multicore architecture-based systems have to provide adequate processing capacity for image processing, pixel processing and feature recognition and tracking algorithms.

A strategic decision arises when the manufacturer is delivering multiple systems to the marketplace within a product line approach. Typically, each member system in a product line addresses a different price point in the marketplace. As a consequence, each system is likely based on a processor with the capabilities and cost needed to meet the expectations of the targeted market segment. Given the range of processing power that will be deployed throughout the product line, the NUI for the various systems will likely vary according to the capabilities of the processor. At the same time, the manufacturer will want to reduce development costs as much as possible by re-using software and firmware across all the systems that make up the product line. Therefore, it behooves a manufacturer to consider a platform or generation of processors that are software-compatible and offer software portability, while delivering a range of processing capabilities at various cost levels.

NUI algorithms in general require a high amount of complex computational decisions, and hence the scalability aspect is very much needed when building a product pipeline.

Operating systems

Developers of a system's NUI invariably will be affected by the design and architecture of the rest of the system, such as the type of operating system (OS) – high level or real time – that has been chosen. Requirements of the application usually dictate the choice of an OS. High-level OSs (HLOS) like Windows®, Linux™ and Android™ provide an intuitive and easy-to-use layer of abstraction between complex computing or communications technology and users. For developers and designers, most HLOSs also include extensive tools. These can be of great assistance to NUI developers for integrating complex functionality such as multimedia processing. But, because of all their capabilities, HLOSs usually have a large code footprint, which can hinder their real-time responsiveness.

Latency involved in dealing with the processing algorithms are very time critical, and require faster, lighter-weight processing. Also, when multiple cores are involved in processing, the handshake between the cores should not take a long time.

Real-time OSs (RTOS) are typically implemented for applications where responsiveness and predictability are critical. Many embedded applications use an RTOS because they can ensure a system response in a pre-determined period of time or a certain number of clock cycles. To meet these types of requirements, RTOSs like VxWorks, Nucleus®, QNX/Rim, Neutrino®, Integrity®, SafeRTOS/FreeRTOS, Micrium® and RoweBots usually have a small code footprint, and they do not include many of the tools and support mechanisms found in HLOSs. As a consequence, NUI design and development could be more laborious, especially if advanced functionality such as multimedia processing is being incorporated into the NUI.

NUI technologies to consider

There are a myriad of user interface technologies that can be deployed in an NUI to make it the kind of engaging interface that draws users into the application while increasing their productivity. Each technology comes with its own set of tradeoffs. In the end, the application and the circumstances surrounding its use will determine the optimum NUI technologies to implement.

Touch screens

Touch screens were introduced as a keyboard and mouse replacement almost two decades ago. The first type of touch panel was resistive. This features a flexible outer layer typically made of a plastic film which makes electrical contact with an inner layer when it is deformed. Capacitive is a newer type of touch screen which is prominently featured on many smartphones and tablet PCs today. The outer layer is typically rigid glass. The capacitive effects of a finger touch are sensed by the panel. In both instances, the coordinates of the touch is processed by a touch screen controller and provided to the NUI. Other types of touch panels such as surface or sonar acoustic wave (SAW) and infrared are also available, but the adoption of these later two technologies has not been widespread.

Voice control

Voice recognition is a well-established technology, but noisy environments are not conducive to its deployment. In addition, the more sophisticated voice recognition algorithms – those that understand a wide range of vocabularies, languages and accents, and which can be trained to a many different voices – require significant processing cycles. Implementing an NUI with a sophisticated voice control component could require a quite powerful and more costly processor.

Graphic considerations

The graphical composition of on-screen displays will affect the performance capabilities of the processor, as well as the amount of memory and read/write memory bandwidth in the NUI. For example, the user interface could be based on 2-D (raster), 2.5-D (vector) or 3-D graphics. Each step up involves improvements in the vibrancy of the graphics, the on-screen colors, the depth of objects, the gradient range of light on the screen and other user perceptions. Each step up also comes with requirements for greater processing power, more memory and faster bandwidth. For higher-order graphics, designers must consider carefully whether the processor which will be running the NUI includes hardware acceleration for graphics. Without hardware-based graphic accelerators, sophisticated graphic processing such as alpha blending, rotation, picture-in-picture and others types of graphic functionality could severely burden the processor. Of course, the size and resolution of the display screen supporting the NUI will also dictate the type of graphics incorporated into the user interface. For example, small, low-resolution screens do not provide an adequate basis for 3-D graphics.

Short-range wireless

Certain short-range wireless communications technologies like NFC, radio frequency identification (RFID) and ZigBee® are being incorporated into some NUIs, such the interfaces on handheld terminals used by shipping and logistics companies. Of course, the limited operational range of these wireless protocols restrict their implementation to a few types of applications, but they do have certain advantages. The limited distance their signals can travel ensures they will not interfere with other wireless communications in their vicinity. They also consume little power, which extends the battery life of the handheld devices where they have been deployed.

Emerging NUI technologies

Development is progressing on several emerging technologies that will eventually be employed in NUIs. Stereoscopic-3D is the most recent example of an emerging technology brought to life in the NUI space.

Stereoscopic-3D (S3D)

Stereoscopic-3D (S3D) is quickly emerging as a prime technology across various markets, and is proving to be a hot trend that adds an additional dimension of reality to existing 2-D videos, games, movies and images. With the advent of 3-D TVs hitting store shelves, consumers are now getting acquainted to large-screen, realistic S3D effects in home entertainment. Today, S3D experiences are migrating from the large screen to mobile devices, providing realistic and glasses-free, personalized viewing experiences on the go.

Overall, S3D video and imaging use cases can be categorized in two ways – S3D content creation and S3D viewing – both of which have a unique set of challenges in mobile design and development. Next-generation ARM®-based architectures, such as the OMAP™ processors, address design challenges, and help successfully establish S3D experiences in the mobile world.

Extension of dual-camera-based 3-D leads into more natural 3-D gesturing and can potentially scale to many applications, including interactive signage in shopping malls. Cameras and other sensors are used to recognize the touchless gestures that users perform in front of the system to control it. In one interactive signage application, shoppers in a mall use 3-D gestures to zoom in or out on a particular portion of the mall's floor plan.

Haptics

Another emerging NUI technology is haptics, which refers to the sense of touch. Specifically, haptics implements vibration feedback through interaction with a NUI device. You'll find haptics in tablets, handsets, control interfaces, white goods – really any device that involves human interaction through touch. The typical cycle of haptics feedback starts when a touch event occurs and the applications processor is notified of the event. From there the applications processor finds the correct feedback to be implemented and sends that information to a haptics driver which then drives the vibration actuator which generates the vibrations that are felt by the user.

Haptics enhances a typical user experience by stimulating the currently under-utilized sense of touch. Imagine a typical game of Angry Birds, instead of just watching your bird make impact with the barricaded pigs you feel the impact, this is achieved with haptics. Researchers predict that haptics will improve task performance, increase user satisfaction and provide a more realistic user experience.

TI solutions

Today's and tomorrow's NUIs will certainly involve a broad range of capabilities and technologies, including smart multicore processors, embedded microcontrollers and microprocessors, power devices like converters, supplies and managers/supervisors, precision analog devices for touch-based interfaces and other purposes, interface components, wireless transceivers and standard linear devices for driving LEDs, as well as a variety of other functions. TI is one of the few technology suppliers with a broad product portfolio to meet all of these needs. Moreover, TI supports its technology through hardware development kits specifically for HMI, a wide range of software tools, development kits and already-ported code. Community is also a huge benefit to designers. The TI engineer-to-engineer (E2E™) community includes peer collaboration and an ecosystem of complementary third-party suppliers and service providers. All of this is at the disposal of design teams that are building the next, revolutionary NUI.

For more information …

For more information, go to the TI website at **www.ti.com/touch**.

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