Handheld Devices for Applications Using Dynamic Multimedia Data

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Abstract

Growing demand for ubiquitous and pervasive computing has triggered a sharp rise in handheld device usage. At the same time, dynamic multimedia data has become accepted as core material which many important applications depend on, despite intensive costs in computation and resources. This paper investigates the suitability and constraints of using handheld devices for such applications. We firstly analyse the capabilities and limitations of current models of handheld devices and advanced features offered by next generation models. We then categorise these applications and discuss the typical requirements of each class. Important issues to be considered include data organisation and management, communication, and input and user interfaces. Finally, we briefly discuss future outlook and identify remaining areas for research.

CR Categories: I.3 Computer Graphics; I.4 Image Processing and Computer Vision, I.7 Document and Text Processing, D.1 Programming Techniques

Keywords: handheld devices, multimedia, computer graphics, image processing, collaborative.

1 Introduction

As the demand for mobility in work and lifestyle increases, handheld devices have become increasingly popular. Not only that people travel more and collaborate widely, workers in some professions spend more time in the field rather than at their desks as a normal practice (e.g. surveyors, archaeologist, medical practitioners in the outback, farmers). To be able to work effectively, they need to have access to data and applications anywhere and at any time. At the same time, the usage and demand for multimedia data are growing exponentially due to increasing availability of computing power and advanced knowledge on how to manage such data. They are now routinely required not only for presentation and marketing purposes, but also as core material which many important applications are built upon. For example, 3D virtual environments for surgery, mining, urban planning, design and digital movies. Such applications exert extensive demand on resources in terms of computation, communication and memory. Yet, handheld devices and mobile wireless environments possess some inherent limitations: low bandwidth, power, CPU, memory and storage.

Most of the PDAs today have a screen size of about 3.5" x 5" with 16 bits colours while a mobile phone generally has a smaller screen size and lesser colour. The top of the range model of a PDA comes with 640 x 480 resolutions screen, 400 MHz CPU and 128 Mb RAM. Even with these high resolutions, the small screen size poses a lot of difficulties in displaying graphics and text. To overcome the problem of small screen, a number of approaches have been proposed. Some researchers used a proxy system (Bjork, 1999) for pre-processing of multimedia data. Text data is reduced, filtered or summarized (Boguraev et al., 2001) and videos or images are transcoded by reducing frame size, bit rate, or frame rate (Li et al., 1998). Data is displayed in a card format on mobile devices with thumbnail for navigation. To manage multimedia content efficiently and effectively, (Curtis et al., 1999) proposed to use metadata to describe the data content for validation and display. For example, if the multimedia content requires high processing power of the device, an alternative content can also be provided for lesser devices.

It is thus pertinent to question if it is feasible to use these devices instead of a PC to access and execute such applications. What should be done to adapt the applications as well as the way to manage and present information so that users are able to operate in an effective manner despite these limitations? To what extent that these needs are catered for and how to improve the design of handheld devices for better capabilities? The aim of this paper is to investigate these questions in depth, with the view to assess current trends of development and identify issues for future research. In section 2, we categorise applications that use dynamic multimedia data into four levels of requirements in terms of complexity and resources. In section 3, we discuss ways to adapt the organisation and management of multimedia data to enable appropriate type of information with the right amount to be accessed via handheld devices. Section 4 focuses on communication issues while section 5 deals with user interfaces issues. Finally, in section 6, we examine potential improvements which are currently available in research laboratories and may be able to be integrated in the next generation of these devices. Remaining issues for future research are also identified.

2 Requirements of Applications Using Dynamic Multimedia Data

There is a wide range of applications that need multimedia data and much research work has been devoted to find effective and efficient ways to index, retrieve, compress, transmit and integrate different types of data (text, image, video and audio). Some applications only require passive multimedia data that have been generated or captured in advance. Other applications, on the other hand, require active data such as 3D interactive graphics and animation, that are generated on the fly during an application session. In order to be able to adapt handheld devices to these applications, it is crucial to have insight into the extent of complexity of the tasks and resource demand. We therefore categorise these applications into five types and analyse the requirements of each type.

2.1 Managing external devices and running applications

Handheld devices have been used as convenient interfaces to control external devices such as digital whiteboard (Rekimoto et al., 2000), scanner, printer, camera to capture and transfer image and video data. They have also been used to execute simple applications without any modification such as power point presentations. The interfaces in these cases mainly involve the selection of options via picking appropriate text commands or icons. This mode is also useful to allow multi users to enter their selection in a cooperative application such as answering questions or voting for a contestant of their choice in a TV contest.

Another less demanding type of application involves the delivery of electronic text-based content via wireless handheld devices. The aim here is to design data formats and interfaces that allow an effective access to such data, mostly via pen input. Some examples are e-grocery (Bellamy et al., 2000), patient records (Miah and Bashmir, 1997) structured audio (Roy and Schmandt, 1996), stock exchange (Interaction Design Awards 95), and news (Boguraev et al. 2001). In these cases, content is adapted to overcome the limitation of screen size and input mechanism. For example, news are summarised in terms of simplified sentences that bear content highlights. However, the main challenge lies not in the way a generic summarisation is formed, but in how a multi-perspective and scalable summarisation may be constructed. The latter would provide specific items of relevance or of interest to users. A hierarchical organisation of content also allows information be gradually displayed. Such content adaptation can be implemented by using a transcoding proxy which communicates between a server of full content and a handheld client.

2.2 Wireless image processing environments

Wireless imaging environments have taken off due to application demands from various sectors: digital photography, security, military, teleradiology, just to name a few. In such environments, it is essential to be able to capture image and video, to manage external devices and transfer images from them, to remotely perform image processing tasks on images, and to display images and results from these tasks. For example, a distributed image processing service can offer new markets to provide extra information for emergency rescue operations, military scenarios planning, home security, etc. (Guarnera et al., 2002). The portable nature of handheld devices can also provide an edge for some applications. For example, for a face recognition system, a PDA can take a face image from an optimal position and angle, focusing on specific features that are more discriminating (Yanget al., 2002). These options would not be possible if a fixed camera is used. To make such systems run at real time rate, it is crucial to optimise image processing algorithms to reduce computational load and input/output operations. In a previous paper, we discussed in detail how to achieve this optimisation for small embedded devices (Wardhani and Pham, 2002). The optimisation was achieved through the adaptation of compiler optimisation techniques and various strategies for power reduction and scalability.

2.3 Interactive access of multimedia databases

The next level of complexity is to use handheld devices to interactively access multimedia databases which may contain a mixture of text, image, video and audio. Some applications are: digital library, medical information systems, GIS, web services, interactive TV, and multimedia kiosks, e.g. (Kawachiya and Ishikawa, 1998, Abowd et al., 1997, Lattanzi and Bogliolo, 2002, Kirda et al., 2001, Robertson et al., 1996). Low bandwidth connectivity and low memory capacity cause significant problems for effective real time delivery. Not only images have to be provided in different formats and sizes, the content of input queries and query results also needs to be partitioned and structured appropriately. The way queries are constructed should be examined to allow intermediate searches which take less time to complete, yet are able to filter out irrelevant information while gradually zooming into what users require. To be able to do this effectively, multimedia databases need to be re-structured with more attention paid to high level context which embodies the logic of the core business of the application and a clear guidance on information usage from different perspectives. Another problem is concerned with the limitation of using HTML browser because the frequent need for scrolling does not suit handheld devices. It is necessary, therefore, to provide a variety of other web formats such as XHTML, XML and WML (Wireless Markup Language) (W3C WAP Forum, 1998).

2.4 Interactive manipulation of 3D graphical objects

Applications such as CAD, games, virtual theatre, sculpting and animation, require 3D input and interactive manipulation of 3D graphical objects. To be able to operate these applications on handheld devices, we need to address the feasibility of providing this functionality in addition to the problem of re-structuring graphical data for easy access, query and manipulation. Conventional PC environments allow this interaction via a number of ways: mouse input, track balls, joysticks, sensoring devices and haptic devices. There have also been some alternative designs for direct 3D input device and 3D shape deformation. For example, Murakami and Nakajima (1994) designed a cubic input device made of polyurethane foam which can be deformed by bare hands and allow users to directly deform a 3D object on a computer screen using tactile feedback. Frohlich and Plate (2000) constructed a cubic mouse with three perpendicular rods passing through the cube centre and buttons on the top of the cube, to allow users to specify object 3D coordinates. A six degree of freedom tracking sensor makes it possible to control the orientation and position of the object. The movement of the rods control the cutting and slicing of the object along orthogonal planes. The Toolstone, designed by Rekimoto and Sciammarella (2000), expands the functionality of a 3D input device further by letting users select different functions by changing the way the device is held by the non-dominant hand (e.g. rotate, tilt). Optical tracking has also been used for interacting with a virtual 3D object. To offer additional functionalities in a more ergonomic manner, Stefani and Rauschenbach (2003) introduced a combination of two devices: a dragonfly-shaped device for the dominant hand to fluidly specify object position and orientation, and a bug-like device with a jog dial for menu selection. A pertinent question to ask is whether it is feasible to connect one of these 3D input devices to a handheld computer? Alternatively, is it possible to integrate similar functions for 3D input and object manipulation to existing handheld devices?

2.5 Collaborative virtual environments

The next level of complexity is to use handheld devices as interfaces to collaborative virtual environments which enable users to interactively access, manipulate, share and exchange a mixture of all data types mentioned in previous subsections. Major applications include telemedicine, collaborative design, and distributed computer games. In a previous paper, we presented a review of progress in this area and analysed major issues for standard PC environments from four perspectives: functionality, data type, communication and scalability (Pham, 2002). It would be unrealistic to expect handheld devices to be able to cater for all activities in such virtual environments. Instead, we should examine this problem from the usage perspective in order to identify specific tasks that are most needed and suitable to adapt to a mobile environment.

3 Data organisation and management

It is a common practice for fixed desktop environments to be organised in a generic manner, with standard screen size and multiple windows to allow applications to be run and viewed simultaneously. Handheld device environments, on the other hand, are highly individualistic and are often customised to suit specific applications. The level of customisation varies from the adaptation to suit specific devices, to specific application requirements, to specific types of users, when and where they use these devices. The aim is to maximise usability with compact representation and screen display. In order to achieve this aim under the above-mentioned limitations and constraints of these devices, there are some fundamental issues to be addressed in the following aspects: data reduction, data organisation, data transmission, data presentation, metadata, and search and retrieval schemes.

Data reduction is necessary to enable these devices to perform in an acceptable manner, in terms of readable display and real time performance. A crucial question is how to reduce data without losing too much substance and power for their interpretation and analysis. There are two main approaches: the generic approach finds ways to transcode data to match the resource limitations of devices, without paying attention to the users, who they are, what they wish to do and when they do it. The specific approach, on the other hand, aims to provide a minimal amount of selective information required by the users for their specific tasks. In the generic approach, text can be summarised into paragraphs and sentences which contain the gist of the content. Images and videos can be provided in lower resolution by averaging pixel values in a neighbourhood or by sampling (e.g. image thumbnails, animation keyframes). The resolution of audio signals can also be reduced in a similar manner. Such multi-resolution schemes for data reduction are commonly used. However, they do not pay attention to the context and semantics of the content.

More recent research efforts aimed to provide multiple abstraction levels which contain features, semantics, context and metadata extracted from raw data. Such high level information would provide more insight into the content and enable meaningful queries and searches to be conducted. For example, a news article which typically comes in as a linear text stream can be replaced by a generic summary which contain highlights from different perspectives, following a set of related topics. Features (e.g. cancer cells, vertebrate fractures, annotations) can be extracted from medical images and specialists to give a more meaningful description of the content. A summary of a sport video may contain highlights, breaks, goals, whistles, etc, which are the most interesting and relevant information that users would wish to see. Many types of feature and metadata have been proposed for the MPEG-7 standard for multimedia content interface with the aim to improve the searching, indexing and managing of multimedia content (MPEG-7, 1997). An example is the InfoPyramid proposed by Li et al (1998) to provide a framework which is multi-resolution, multiple-abstraction as well as multimodal (e.g. X-Ray, MRI, PET for medical images). Methods and rules for generating these descriptors and their representations in XML are also included in the framework. The multi-resolution may include intensity and colour as well as spatial resolution.

Content adaptation can be extended further to make it user profile sensitive in addition to being device and context sensitive. Information contained in users' profiles can be extracted by tracking the location and behaviour of users while they perform tasks. This can be supplemented with interviews to obtain extra information on personal preferences and users' feedback to continuously improve their profiles. A big advantage of customisation is that one can follow a minimal approach to focus only on selective information while removing irrelevant information. Hence, it is easier to improve the coherence and readability of the presentation. Metadata which conveys the semantic and structure of the content can be expressed in terms of a grammar-like representation and used to automate tasks, and to extract users' feedback, the profiles of users and user environments.

For 3D graphics data, commonly used representations and formats such as scene graphs used in VRML and OpenInventor have already been organised in this hierarchical manner. For example, a scene graph may be made up of nodes of three primitive types: shape nodes for geometric data, property nodes for attributes, and group nodes for pre-built grouping of nodes. Dynamic behaviour is controlled by a sensor object (detecting a change) and an engine object (describing how objects are connected and constraint during motion). However, up to now many software packages have not taken advantage of these features to reduce the size of VRML files and make them more efficient. These approaches are scalable in both information depth and breadth and are very useful for adapting multimedia content to be accessed and managed by handheld devices because the content can be queried, searched, delivered and displayed in a progressive manner at different levels as required by users and applications. Users can extract information content in an elaborative and controlled manner, starting at a high level context to get an overview, and then gradually zoom in for more details in areas of interest. This would reduce the amount of information that needs to be displayed on the screen at each stage.

In Computer Aided Design (CAD) area, the need of remote access to CAD software in applications such as construction, architecture and facility management has pushed the development of CAD software versions which are more suited for handheld environment while working in the field. For example, PocketCAD PRO (Arc Second, 2004) allows sketching and editing existing drawings, recording work plan and communicate design changes. ZIPCAD (123-D Software, 2003) allows verification of designs uploaded from a server, design development and detailed drafting. Pocket Corona is another software product that aims at the wireless market. It provides a 3D browser for viewing VRML objects or scenes and has been used for field maintenance, marketing, and location-based services (e.g. linking 3D maps with GIS or GPS systems). Some platforms support the development of mobile graphics applications, for example, Mobile 3D Graphics API (Sun Microsystems, 2004a) for J2ME (Sun Microsystems, 2004b) and OpenGL ES (Khronos Group, 2002).

Another rapid development is in the area of scalable vector graphics because vector graphics are "resolution independent" in the sense that they can be rescaled without losing quality. SVG is a scalable XML-based language for describing two-dimensional graphics and graphical applications (W3C 2003b). SVG is recommended by World Wide Web Consortium (W3C) as an appropriate format for transmitting graphical data over internet. In particular, SVG Full version (W3C 2003b) can be used on the server while SVG Basic version (W3C 2003a) is used on PDAs. Vector drawings must be converted to raster grids for printing or screen display and saved into raster files. This rasterising process which converts a vector model to a raster image is relatively easy. A common practice is for raster files to be calculated on the server and sent to customers for perusal.

Current W3C SVG specifications are for 2D graphics and do not provide flexibility for different viewer requirements and browser capabilities in terms of layout, screen format and font preferences. However, SVG is actively under development. For example, Badros et al. (2001) have introduced a constraint extension to SVG called CSVG which supports flexibility viewing conditions, layouts, interaction and animation. In addition, some explorations on SVG applications in 3D context has already been performed (Kallio 2003; Otkunc and Mansfield 2003).

The above-mentioned hierarchical representation scheme for multimedia data enables data to be selectively reduced for query, access and display. However, while we can reduce the amount of data to the level that a handheld device can cope with, an important question is whether such reduced data is acceptable for practical purposes? For example, whether an image or a video has a good enough quality for the task required? What should we do if that is not the case? Can a display be arranged so that only a portion of a displayed image or scene is visible on the screen at a time? There are two issues that need to be addressed. The first issue is how to synchronise the execution of an application task with the download of multimedia data from a server and format conversion so that an application can run smoothly given the low bandwidth constraint? This can be done with a pre-emptive scheme, where the download starts before the current display finishes. Lattanzi & Bogliolo (2002) has demonstrated this scheme successfully using the multithreading capability of Java for pre-emptive download to allow continuous mobile access of 2D maps via a PDA. The second issue is concerned with appropriate user interfaces to facilitate a user's navigation method to access a relevant portion of the display. Location-aware handheld devices can be useful for effectively navigating through 2D documents or maps (e.g. Small and Ishii, 1997), where the relative position of the device held in the non-dominant hand is mapped to the relative position in a document or a map. Thus, by moving the device in the physical space, the user can smoothly access the information space and view different parts of the document or map. The problem of partitioning and navigating through 3D graphical data is more complex and will be addressed in section 5.

4 Communication Issues

As the mobile devices gain popularity, communication options for these devices become more mature. Initially, there are the Infrared and serial links which are only useful for peer-to-peer communication. Wireless networking technologies have now become widespread and are growing rapidly. First, there is Bluetooth, and then there are the 802.11a, b and g standards. Bluetooth works in 2.4 GHz spectrums and operates within a small range with low bandwidth. Thus it is not applicable for multimedia application with large data volume. 802.11b and g operate at 2.4 GHz while 802.11a operates at 5 GHz regions with smaller range. 802.11b has a maximum bandwidth of 11 Mbps and the other two standards have a higher bandwidth of 54 Mbps. With higher bandwidth, 802.11a and g can support more simultaneous users with higher data rate then 802.11b (Akpeneye et al., 2003). There is also the possibility of using both 802.11a and 802.11g in a hybrid mode. The 802.11a channels can be used to deliver video data packets and the 802.11g channels can be used for text data. The bandwidth of the hybrid mode is therefore enough for interactive access of multimedia databases.

One problem with wireless networking is interference due to obstruction and multi-path problem. This problem affects the planning of the wireless network, which needs to take into account possible increase of devices in a section of the network. Any increase of devices within the network will drastically decrease the shared bandwidth for each user. This is particularly important as multiple users are working collaboratively.
Wireless communication requires a lot of power and can be very draining on the mobile devices' batteries. To prolong the operation time of a device, some researchers proposed to offload processing to proxy servers (Li et al., 2001). However, the more processing of data are offloaded, the less interactive manipulation of data can be performed on the mobile devices.

Low communication bandwidth of wireless network, combining with limited power resources leads to another problem of failure recovery. In case of loss communication or power failure, mobile applications must be able to recover to its previous consistent state. It was suggested that a proxy-based recovery system with check pointing and message logging could be used to recover from network disconnections and client crash failures (Yao et al., 2000). However, even if the application can fully recover from the network or system failures, the wireless communication for mobile devices has to be further improved in order for it to be suitable for collaborative virtual environments.

With the current advance in communication technologies, handheld devices can comfortably run applications such as digital whiteboard, or instant messaging. These applications can operate in asynchronies mode with peer-to-peer architecture and require little bandwidth (see Fig 1). In general, applications that communicate simple text data, like text commands, can operate with ease under today's wireless technologies. It would not be a surprise to see applications like Windows messenger, or email clients on handheld devices become very popular when wireless networks become more widely available.

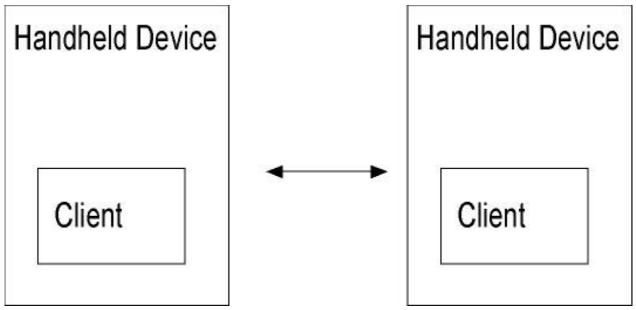

Figure 1: Peer-to-Peer Architecture

Applications that involve large amount of text content or multimedia data are more demanding in communication bandwidth. In order to ensure the quality of service, client-server architecture has to be employed with synchronised communication (see Fig 2). However, even with a maximum bandwidth of 54 Mbps, 802.11a and g standards can only support about 3 simultaneous users with 320 x 240 pixels at 10 frames per second. To support multiple interactive users, a proxy server must be employed to transcode the data and to offload some processing work (see Fig 3). For example, in order to provide wireless video streaming service to a number of simultaneous users with handheld devices in a stadium, either multiple wireless networks are set-up for the high bandwidth or the video data are pre-processed to a lower resolution. The requirement on CPU speed and battery power also restricts the amount of data rendering that a handheld device can perform locally. Some rendering processes must, therefore, be offloaded to the proxy.

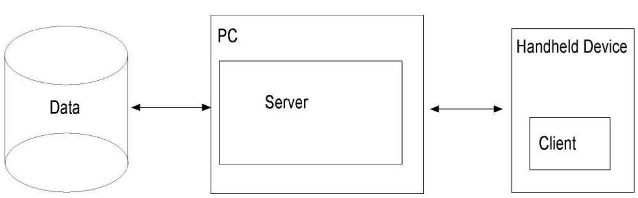

Figure 2: Client Server Architecture

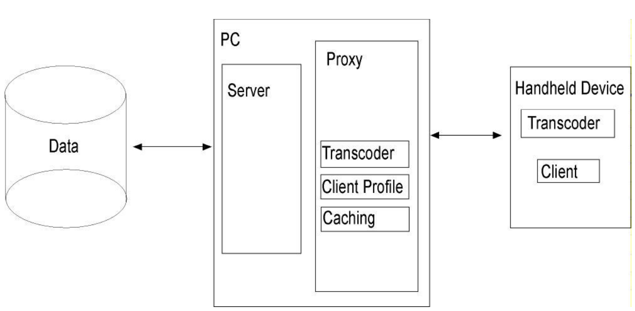

Figure 3: Proxy architecture

With the diversity of devices in existence, the design of the proxy must include a module that maintains information of the client's hardware and software profiles. This information (e.g. display size, etc.) is important to the proxy for the selection of the best transcoding method that can reduce transmission cost without sacrificing quality. The design of the proxy should also include a local cache. This is to ensure the integrity of data in cases of loss packages due to the uncertainty nature of the wireless network.

Recently, some interactive computer games are beginning to appear commercially on mobile devices. However, the graphics of these games are still relatively primitive. Further improvement on the processing power of the handheld devices and also further development of wireless networks are needed before handheld devices can be used as interfaces to collaborative virtual environment. To improve the efficiency of communication, both client-server and peer-to-peer architecture will have to be used. Multimedia data will be stored on a server with proxy; while object manipulation commands can be transmitted directly between peer devices. The data transmitted must also contain information on the properties of data, manipulation methods etc. so that data can be self-contained and workload can be evenly shared among devices.

5 User Interfaces

Mobile devices generally use pen entry on touch screen with handwritten recognition software and they also come with a QWERTY virtual keyboard. Some devices nowadays have build-in thumb-typing keyboard. There is also the optional full-size fold-out keyboard. Recently a novelty idea like virtual keyboard is invented which detect the user's movement and translate that into keyboard entry. With the use of a micro-switch and stress sensor, researchers at IBM Tokyo developed an input device called NaviPoint (Kawachiya et al., 1998) for easy browsing with one hand only. This device which consists of a stick and a horizontal plate allow three functions – scrolling, item highlighting and selecting – to be operated with only one finger.

The developments on UI, so far, cater mainly for text data manipulation and browsing. This is not surprising because most of the current users of handheld devices are business managers or technical personnel. The main functions of these devices are for data entry or reading simple documents, e.g. getting stock prices etc. However, as prices of mobile devices become lower and as more functions are available, more users will buy these devices for other purposes. This is already happening as the latest model of mobile phones comes with camera nowadays. The future development of mobile devices must, therefore, be able to accept user interaction for the manipulation of multimedia data.

Most of the present handheld devices use the non-dominant hand for holding the devices vertically. In some limited cases, the non-dominant hand is also used for scrolling the view area. At the same time, the dominant hand uses a pen for selecting items or actions. The use of both hands is, therefore, very restrictive and asymmetric. Lately, a few devices try to allow more cooperative action between the two hands. These devices require both hands to hold it horizontally with keyboards on both sides. They allow only the thumbs to interact with the keyboards simultaneously. However, a multi-dimensional interaction with both hands is needed in order to be able to manipulate efficiently and quickly with 3–D multimedia data.

A recent trend is to design manipulative UI to enrich the capabilities of navigation through virtual space and manipulation of virtual objects in an intuitive manner. These functions are embedded into a handheld device in such a way that its physical movements correspond to the movement in the virtual space. This correspondence is achieved via tactile sensors or optical tracking. For example, Harrison et al. (1998) used the metaphor of a Rolodex card system to design a device which can be pressed with a finger tip to turn a virtual document page, tilted to flip through many pages, and squeezed to indicate the wish to navigate or to select the item of interest. Other researchers used actual physical objects to intuitively manipulate the positions, orientations, transformations, movements and deformations of 3D virtual objects. Some examples of these input and UI devices have already been mentioned in section 2 (e.g. cubic mouse, dragonfly and bug-shaped input devices). Currently, they are used in a wireless mode or plugged into a PC. For handheld computers to be effectively adopted for applications that require the manipulation of 3D virtual objects and environments, it is imperative to empower them with similar capabilities of these input and UI devices. Two approaches might be possible. The first approach is to design these devices separately from the handheld computer and connect them to the handheld computer via wireless mode. As the manipulation would be done by the dominant hand (while the non-dominant hand holds the handheld computer), this might cause some awkwardness because this hand is also responsible for selection and picking objects. One way of solving this problem is to design buttons located at appropriate positions on these input and UI devices which can be controlled by the fingers, especially the thumb in the dominant hand. An alternative approach is to re-design the shape and functionality of the handheld computer itself in order to incorporate more advanced input and UI functions. For example, can a future handheld computer adopt an usually irregular shape to provide easy and flexible access control by both hands: fast and precise functions for the dominant hand; and fast navigation through multimedia documents and fast manipulation of 3D graphical objects by the non-dominant hand; or by both hands?

Another mode of UI communication is by touch, via the conversion of hand pressure into vibrational intensity. This technique was originally used to provide an alternative communication method for the blinds. However, it has gradually been adopted for subtle non-verbal communication in general (e.g. Chang et al., 2002). Some mobile phones have already provided tactile responses and feedbacks. Tactile devices have a number of advantages over force feedback devices. They are cheaper to build, less cumbersome to carry and can be implemented using not only fingers, but also other parts of the human body. Thus, a well–designed mapping of a tactile space onto an information space and a 3D object space would extend the power of navigation and manipulation. It would also augment the visual and audio communication capability during a collaborative work session such as collaborative design and surgical training.

Another trend is to design personal devices that can be worn as accessories that could reflect one's lifestyle, taste and personality. Bracelets, buttons, jackets are a few of such examples (e.g. Constas and Papadopoulos, 2001) which can store, collect and share information. If such personal devices were widely embraced, then this trend would significantly open up the range of diversity and capacity of input and UI devices for handheld computers. Thus, a futuristic UI for a mobile environment might no longer rely totally on hands and fingers (handheld), but instead might take advantage of different body parts for performing specific tasks.

6 Conclusions and Future Work

We have taken a holistic look at the feasibility of using handheld devices for applications that require dynamic multimedia data, in both single and collaborative modes. We have categorised these applications into five classes according to the complexity of their requirements, and discussed how well each class is served by current handheld models. In particular, we examined ways to organise and manage 2D and 3D multimedia data for effective access and navigation in a mobile handheld environment. We also covered important issues on communication and user interfaces, and identified their suitability and limitations for these applications. In order for handheld devices to be widely accepted as effective platforms for all five types of applications, a number of areas of research remain to be investigated from both technical and social perspectives. Better communication channels will be required in terms of higher bandwidth, more efficient architecture, and better rate of transcoding and compression of multimedia data. For collaborative applications, not only data, but also codes (to perform different functions) will need to be organised in a more convenient manner to make the task of work distribution easier. Furthermore, data should not be treated as a static entity, but should be embedded with extra information that indicates how the data should be manipulated or operated upon under changing conditions and special circumstances. Effective 3D input and UI devices still remain a worthwhile area for research. Innovative designs will be needed to improve both the useability and functional requirements.

However, these research directions for technical advancement give rise to a number of problems that need to be examined from a social perspective. As handheld and personal devices become more ubiquitous and more "intrusive" to our personal space, do they have adverse effects on our lifestyles, personalities and society? Would people become so immersed with computer gadgets and lose sight of reality? Would the nature of communication between people then become more mechanic and less humanised? Furthermore, would our health be jeopardised by the extensive use of microwave signals for wireless communication?

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