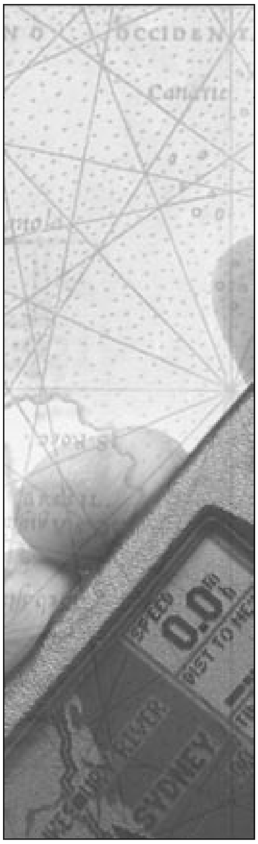
Going Mobile: Mobile Technologies and GIS

Quick Study URISA



GOING MOBILE: MOBILE TECHNOLOGIES AND GIS

By David R. Green

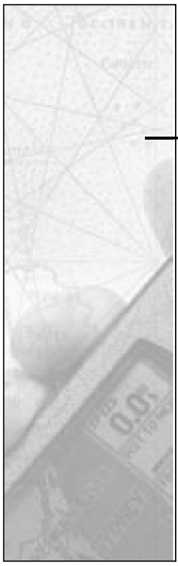
Center for Marine and Coastal Zone Management (CMCZM)
Department of Geography and Environment
School of GeoSciences, College of Physical Sciences
University of Aberdeen, Elphinstone Road
Aberdeen, AB24 3UF, Scotland, UK
+44 01224 272324
(Fax) +44 01224 272331
d.r.green@abdn.ac.uk
http://www.abdn.ac.uk/cmczm

Disclaimer: Mention of commercial products in the text does not necessarily indicate endorsement of the hardware and software named

Disclaimer: Mention of commercial products in the text does not indicate endorsement of the hardware and software named.

Printed in the United States

ISBN #: 0-916848-43-4



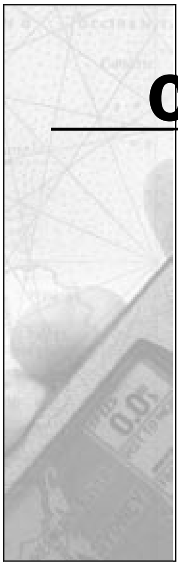
CONTENTS

Glossary of Terms

BAN – Body Area Network
BMP – Bit Mapped
CAD/D – Computer-Aided Drawing/Drafting
CD – Compact Disc
CDMA – Code Division Multiple Access
CIR – Color Infrared
CSV – Comma Separated Value
CZM – Coastal Zone Management
DARC – Direct Access Radar Channel
DGPS – Differential Global Positioning System
DIP – Digital Image Processing
DSS – Decision Support System
DVD – Digital Versatile Disk
DXF™ – Data Xchange Format
ECW – Enhanced Compressed Wavelet
EDGE – Enhanced Data Rates for GSM™ Evolution
EGNOS – European Geostationary Navigation Overlay System
EL – Electroluminiscent Lamp
FGDC – Federal Geographic Data Committee
GDSPDS – Geo-Information Decision Support Processing and Dissemination System
GIF – Graphics Interchange Format
GIS – Geographic Information System
GML – Geographic Markup Language
GPRS – General Packet Radio Service
GPS – Global Positioning System
GSM™ – Global System for Mobile Communication
GUI – Graphical User Interface
HTML – Hypertext Markup Language
ICZM – Integrated Coastal Zone Management
IR – Infrared
IrDA – InfraRed Data Association
IWS – Image Web Server
JPEG – Joint Photographic Expert Group
LAN – Local Area Network
LBS – Location-Based Services
MIF – MapInfo
MIPS – Million Instructions Per Second
MMC – Multimedia Card
MMS – Multimedia Messaging Service
NTF – National Transfer Format
OS – Operating System
OSGM – Ordnance Survey Geoid Model

PC – Personal Computer
PCMCIA – Personal Computer Memory Card International Association
PDA – Personal Digital Assistant
RAM – Random-Access Memory
RISC – Reduced Instruction Set Chip
ROM – Read Only Memory
RTCM –Radio Technical Commission for Maritime Applications
SD – Secure Digital™
SDIO – Secure Digital Input/Output
SDRAM – Synchronous Dynamic Random-Access Memory
SH3 – Hitachi Processor for PDA
SIM - Subscriber Identity Module
SMS – Short Message Service
SVGA – Super Video Graphics Adapter
TFT – Transreflective
3GSM – Third Generation Mobile Multimedia Services
TIFF – Tagged Image File Format
TIR – Thermal Infrared
URL – Universal Resource Locator
USB – Universal Serial Bus
VGA – Video Graphics Adapter
VKB – Virtual Keyboard
WAAS – Wide Area Augmentation System
WAN – Wide Area Network
WAP – Wireless Application Protocol
WLAN – Wireless Local Area Network
WML – Wireless Markup Language

Sources: Various Web sites. Accessed September through December 2004.



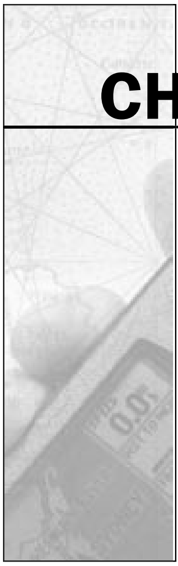
CHAPTER 1

INTRODUCTION

Many environmental sciences, as well as environmental applications, require regular collection of data and information in the field. Using a clipboard, pencil, and paper is perhaps still one of the most common methods of field-data collection and recording. This may be supplemented by using voice recorders and photographs from traditional or digital cameras. With rapid advances in computer hardware and software technology, however, it is now possible to take palm-sized personal digital assistants (PDAs) or handheld computers into the field, equipped with Global Positioning Systems (GPS), to collect geographical data directly into a digital spatial environment, thus collecting field data more efficiently and effectively, and improving the way this data is then added to and stored in a database and integrated with other data sets. With mobile phones it is also possible to transfer data collected in the field to a remote computer and to both upload and download data collected in the field or for use in the field. Tablet interfaces, folding keyboards, handwriting recognition, and voice activation have all played important roles in recent years in improving mobility. As the technology has become more affordable, portable, and easier to use, more applications have been found, ranging from simple map updating exercises to tracking and recording the location of an individual, to accessing information on the move through an Internet browser on a PDA or mobile phone.

This Quick Study Guide provides an introduction to mobile technologies and the Geographic Information System (GIS) and how they might be used for data collection and access to spatial information. This booklet is written for students, teachers, academics, managers and practitioners, and professionals in local government and environmental organizations who are interested in finding out more about the subject, or evolving, extending, and streamlining their data-collection capabilities.

The Guide provides readers with background information about the availability of mobile hardware as well as mobile GIS software, and the potential for utilizing this rapidly evolving technology for geospatial data collection in the field. The reader is also given information about GPS and how they may be used with mobile computing technology for field-data collection. Field-data collection using large-scale airborne platforms for remote sensing is also touched upon. Examples of a number of applications of this technology in day-to-day data-gathering operations provide information on how this technology is already being used. Supplemental reading and Web links are suggested for additional study. Although the technology is continually evolving the basic concepts and framework provided here will remain the same in the future.



CHAPTER 2

MOBILE COMPUTER TECHNOLOGY

The concept of a lightweight, portable, and interactive computer has been around for quite a long time. In the late 1960s and early 1970s, Alan Kay developed the idea of the DynaBook, which included many of the features now found on mobile computers (http://www.thecore.nus.edu/writing/ccwp10/james/pda_history). Although Kay claims that his vision has still not fully become a reality (http://www.honco.net/os/kay.html), mobile computers currently available in the marketplace do contain much of the technology that he originally described.

Today, a mobile computer can be defined as a lightweight, compact, portable machine with a flat color screen and an interactive graphical user interface (GUI) that is accessed using a keyboard, pen, or stylus. A mobile computer is compatible with a desktop computer and its applications and has memory expansion slots. It can be used to communicate wirelessly with other devices and can be connected to the Internet and the intranet.

Current mobile computers found in the marketplace can be divided into four main categories:

1. Laptop computers
2. Personal digital assistants (PDAs)
3. Handheld computers and devices
4. Tablet personal computers (PCs)

A number of different operating systems are available, including the following systems:

a) Microsoft® Windows (95 to XP) for laptop computers
b) Palm OS, Microsoft Windows CE and Pocket PC (Microsoft Windows Mobile 2003) for PDAs
c) Microsoft Windows CE for handheld computers
d) Microsoft Windows XP Tablet PC Edition for tablet PCs

Laptop Computers

Laptop computers do not strictly meet the definition of mobile computers as described previously. Although portable, they can still be quite heavy and bulky to carry, are generally not designed for fieldwork (a prime requirement for mobile GIS), and usually do not have a pen- or stylus-based input device. There are, however, some exceptions, certain laptops have been specifically designed as mobile and outdoor computers, the latter often referred to as "ruggedized"; for example, the Panasonic Toughbook (http://www.panasonic.com/toughbook) series of laptop computers is designed for portability and durability. The computers are designed to be shock-, spill-, vibration-, and dust-resistant, and come with a magnesium casing for protection. Some models have additional features that are important for mobile GIS applications, including wireless communications, built-in GPS, and outdoor-viewable and touchable screens for navigation software.

Portable Digital Assistants (PDAs)

The first mobile computers to be called PDAs were the Apple Newton MessagePad and Amstrad's PenPad. Introduced in the early 1990s, both were the first truly palm-sized computers. In 1996, Palm Inc. (owned by U.S. Robotics) released the Palm Pilot 1000 and 5000 PDAs, beginning the mass production and use of palm-sized computers. Today, the two main types of PDAs are those using the Palm Operating System (currently Palm OS 5 — http://www.palmsource.com) and the Microsoft Pocket PC Operating System (currently Pocket PC 2003 or Windows Mobile 2003 — http://www.microsoft.com/windowsmobile/products/pocketpc/default.mspx). Palm claims that Palm OS runs on almost two out of every three handheld computers in use. Despite this, the Pocket PC is gradually becoming more prevalent, and most mobile GIS software is designed for use with a pocket PC rather than with a Palm OS, with some exceptions, which are, notably, GeoGIS (http://www.geoinsight.com/Products/Mobile/GeoGIS.cfm) and GPSPilot (http://gpspilot.com).

Table 1 shows some of the main manufacturers developing PDAs for the different operating systems, as well as some of the current models.

Table 1 – Manufacturers of PDAs

Palm OS http://www.palmsource.com	Pocket PC http://www.pocketpc.com
PalmOne http://www.palmone.com Zire and Tungsten	HP http://www.hp.com iPAQ
HandSpring http://www.handspring.com Treo and Visor	Toshiba http://pda.toshiba.com
Sony® http://www.sonystyle.com Clié	Dell™ http://www.dell.com Axim
	MiTAC http://www.mitac.com Mio
	Acer http://global.acer.com
	ASUS http://www.asus.com MyPal
	Packard Bell http://www.packardbell.co.uk Pocket Gear
	ViewSonic http://www.viewsonic.com ViewSonic Pocket PC
	Yakumo http://www.yakumo.com Yakumo PDA Alpha

Both types of PDA usually have similar types of standard software and functionality installed, including tools for creating the following:

- Tasks
- Diary
- Address book
- Calculator
- Word processor
- Spreadsheet
- Graphics
- E-mail
- Web browser

Palm and Microsoft Windows–based PDAs also have software for connecting them to a desktop PC or laptop. In Palm's case, the software is called HotSync, while for Microsoft Windows, it is ActiveSync™ (http://www.microsoft.com). With this software, a PDA can be used to communicate with a desktop or laptop PC and to share data, information, and files. Using the connection software, data and information files from the PDA can be backed up and synchronized on the PDA. For example, address files, tasks, and calendar items held on a Pocket PC can also be stored in Microsoft Outlook on a desktop PC. Likewise, similar information held on a Palm OS computer can be stored on a desktop using Palm's Desktop software. The communications software can also be used for the bidirectional transfer of data files, such as word-processor documents, spreadsheets, and GIS data files. Many other software applications can be installed on both operating systems (for examples, see http://www.palmsource.com and http://www.handango.com).

Palm and Pocket PC PDAs both employ a graphical user interface (GUI) for system navigation and data input. A penlike stylus is used to point, tap, and write on the screen. Pocket PCs allow the user to write directly onto the screen, and handwriting recognition software converts this into text. Over the years, the handwriting recognition interface in particular has been improved greatly (Figure 1) and once the user is trained, he or she should be able to enter text relatively easily without too many edits. Peripherals such as folding keyboards are also available for most PDAs, although these are not really practical if the user is carrying out fieldwork and wants to use the computer on the move, unless the device is being used on a hard surface, in a vehicle, or in an aircraft.

Figure 1 – A typical PDA (courtesy of Hewlett Packard - http://www.shopping.hp.com/)

When the Amstrad PenPad PDA was first introduced, it had a 240 x 320 resolution monochrome screen, 192 Kb RAM, a PCMCIA slot for memory cards (up to 2 Mb), a serial interface, and a lithium battery, and it weighed 400 grams (http://amstrad.cpc.free.fr/article.php?sid=19). By comparison, today's PDAs have advanced significantly in their specifications, with smaller, brighter, and higher-definition color screens e.g., transflective (TFT); larger RAM capacity; faster microprocessors; larger memory cards; and longer-life batteries. They are also lighter. For example, the HP iPAQ 5555 Pocket PC has (http://www.hp.com):

- A 400 MHz Intel® XScale™ processor
- 128 Mb SDRAM, 48 Mb Flash ROM
- 240 x 320 16-bit color TFT screen
- Weight 206.8 g
- Removable, rechargeable lithium-ion battery
- Secure Digital (SD™) card slot, SDIO, MMC, and PC card support; CompactFlash
- (CF) and other iPAQ expansion packs
- Bluetooth®, WLAN 802.11b wireless connections.

Likewise, the Palm Tungsten T3 has (http://www.palmone.com)

- A 32-bit 400 MHz Intel XScale processor
- 64 Mb storage
- 320 x 480 color TFT screen
- Weight 156 g
- Rechargeable lithium-polymer battery
- Supports SD, SDIO, and MMCs
- Built-in Bluetooth.

Figure 2 – Different Keyboards for PDAs

2a. Virtual Keyboard (VKB) http://www.internity.co.uk/vkb.asp

2b. iPAQ Folding Keyboard http://www.mobileplanet.com/product.asp?cat_id=101&cat_name=Pocket+PC+Devices&pf_id=MP965238&dept_id=3715&listing=1

2c. Wireless PDA Keyboard http://www.mobileplanet.com/product.asp?cat%5Fid=101&cat%5Fname=Pocket+PC+Devices&dept%5Fid=3715&pf%5Fid=MP600773&listing=1

http://catalog.belkin.com/IWCatProductPage.process?Merchant_Id=&Section_Id=200588&pcount=&Product_Id=144042

2d. Folding keyboard for Palm http://catalog.belkin.com/IWCatProductPage.process?Merchant_Id=&Section_Id=200588&pcount=&Product_Id=125935

The rapid evolution of this technology often means that specifications for PDAs, such as those given previously, are continually changing, and almost as soon as a device is purchased it is out-of-date, and more often than not has been superseded by a faster processor and improved specifications.

The specifications of these PDAs have increasingly made them particularly suitable for fieldwork and mobile GIS data collection. The bright color screens are now much easier to read outdoors in sunlight and are often backlit for poorer light conditions. The color screen helps display graphics and images and the interpretation of map data. The fast processors enable mobile GIS software to run more quickly and smoothly, and to manipulate and display large data sets more quickly and more easily. With the increased internal memory and larger expansion cards, more software can be run on the PDA, and larger data sets can be taken out into the field, collected, and stored. Bluetooth and other wireless connection devices make it easy to connect with desktop and laptop PCs for data transfer, and to mobile phones to connect to the Internet.

A wide range of hardware accessories and software is available for PDAs that increases the potential use of these devices in the field. The hardware accessories facilitate easy interaction with folding keyboards (http://www.belkin.com), wireless keyboards using infrared (http://www.pdamods.com/products.asp?cat=62), snapNTYPE keyboards from Belkin (http://www.belkin.com) and (http://catalog.belkin.com/IWCatProductPage.process?Merchant_Id=&Section_Id=200588&pcount=&Product_Id=126066) that simply clip on to the base of the PDA, and, more recently, projection or virtual keyboards (VKBs) (http://www.internity.co.uk/vkb.asp) (Figure 2). The storage capacity of PDAs has improved markedly, making more software available to the user, and large files to be both accessed and stored. Innovations in screen display also overcome the limitations of the small screen size when using map and image files. A wider range of software also offers the user more capabilities and functionality in the field. This may range from the capability to upload and display Microsoft Powerpoint files (http://www.conduits.com/products/slides/default.asp) to display Macromedia Flash files (http://www.antmobile.com/). With the appropriate connectors, these can also be used in conjunction with data projectors (PDA — http://www.indezine.com/articles/pdapowerpoint.html; Palm — http://www.mobl.com/software/).

Handheld Computers and Devices

Handheld computers are similar in many ways to PDAs—they are small, lightweight, and portable devices suited for use with mobile computing applications. However, they differ from PDAs because they usually have far larger screens and built-in keyboards. Most also have stylus input devices as well. Other handheld computing devices also include mobile phones (such as the Nokia Communicator) and GPS systems with built-in computer operating systems (such as the Trimble GeoExplorer). Several different operating systems exist for handheld PCs, including Symbian from Psion (Psion formerly produced Epoc) that is currently being used on a number of mobile phone platforms. Microsoft Pocket PC is also used on many handheld devices as well as Microsoft Windows

CE, now known as Windows CE.NET.

The Itronix Husky FeX21 (Figure 3) is a handheld PC specifically designed for outdoor fieldwork applications that is ideal for mobile GIS. Some of its key specifications are (http://www.itronix.com):

- Rugged case (die-cast magnesium)
- 129 MHz MIPS R3922 RISC processor
- 6.5-inch TFT 1/2 VGA color, or color TFT/touchscreen, or monochrome (16 grayscale with EL backlight)
- Screen input using finger or pen/stylus
- 32 Mb SDRAM; 32 Mb Flash ROM
- 67-key keyboard
- Wireless communications support

A handheld Husky computer with a hand strap is designed for mobile use. With its larger screen size, it is easier to see the image or map that is displayed with less need for "pan" tools. However, many of the handhelds also have monochrome displays that can be very difficult to read in daylight, especially in bright sunlight. To overcome this to some extent, backlighting can be used, although this incurs higher battery consumption.

A recent development is the handheld platform combining GPS and Windows-based GIS and mapping. MobileMapper® CE from Thales Navigation is one such device that is affordable and ruggedized for field use. Sub-meter GPS is combined with integrated Bluetooth wireless technology, embedded Microsoft Windows CE.NET, and the capability to support Windows CE software for GIS and mobile mapping applications (http://products.thalesnavigation.com/en/products/product.as?PRODI D=928) (Thales 2004).

A laser rangefinder, e.g., the LaserTech Impulse series (http://www.lasertech.com/index.html), is another portable device that can aid in the field capture of distance and height data. These are lightweight, rugged, and portable handheld tools designed to be easy to operate and carry in the field for measuring distances and heights. They can be used in areas that are inaccessible and to position remote objects with a high degree of precision.

Tablet PCs

Tablet PCs (Figure 4) are the very latest in currently available mobile computing devices. Placed somewhere in between a laptop PC and a PDA, the tablet PC incorporates the best features of both, combining the availability of a keyboard, mobility, and handwriting recognition of PDAs with a larger screen, together with a fully featured operating system and the computing power of laptops (Engelhardt 2003). However, tablet PCs are still quite sizable and heavy.

Figure 3 – The Itronix Husky FeX 21 Handheld Computer (courtesy of Itronix – http://www.itronix.com)

Figure 4 – A Tablet PC (courtesy of Hewlett Packard and Compaq - http://h18000.www1.hp.com/products/tabletpc/)

Tablet PCs currently run Microsoft Windows XP Tablet Edition. This is the same as Microsoft Windows XP Professional except that it also has handwriting recognition components and can be used with a mouse as the stylus. Several different configurations of tablet PCs meet different user needs. Convertible tablets have keyboards that can either be concealed or completely removed to create a digital writing pad. Slate tablets are more like large PDAs, where input is only through the pen/stylus using handwriting or the digital on-screen keyboard. While many of the emerging tablet PCs have been designed for mobile office use, ruggedized versions are available from some manufacturers and are specifically designed for outdoor use.

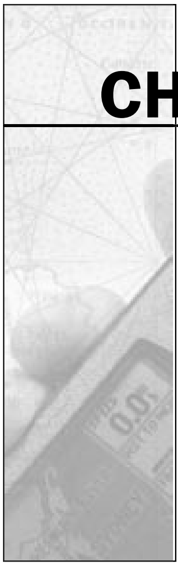
An example of a convertible tablet is the Compaq Tablet PC TC1000, which has the following specifications (http://www.compaq.com and Engelhardt 2003):

- Transmeta Crusoe 5300 processor
- 1.0 GHz processor speed
- 10.4-inch color TFT screen (1024 x 768 resolution)
- 256 Mb SDRAM (up to 768 Mb max)
- 30 to 60 Gb hard drive
- 56 Kbps modem, 10/100 Ethernet, 802.11b wireless
- CRT, 2 USB 2.0, PC card, CF, speakers, audio-in, earphone ports
- 5-hour battery life
- Weight 1.36 kg (1.81 kg with keyboard).

An example of a ruggedized slate tablet is the Itronix GoBook Tablet PC with the following specifications (http://www.itronix.com):

- Mobile Intel Pentium III processor
- 866 MHz processor speed
- 8.4-inch SVGA TFT outdoor transmissive display
- 256 to 640 Mb SDRAM
  40 Gb shock-mounted hard drive
- 56 Kbps modem, 10/100 Ethernet, GPRS, CDMA, 802.11b wireless, and Bluetooth
- PC Card, CF, built-in RJ-11 and RJ-45 jacks, 2 USB 2.0, external speaker, and microphone jacks
- Weight 1.68 kg
- Die-cast magnesium construction for structural components.

In practice, tablet and portable PCs provide all the functionality of desktop computers, albeit in much smaller packages, but without some of the constraints of a PDA such as screen size, storage, and speed. The added benefits of Bluetooth and USB ports also mean that it is possible to use a wider range of computer peripherals, many of which are also becoming smaller in size, including various Bluetooth devices, mobile phones, and storage such as flash drives and JumpDrive® from Lexar (http://www.digitalfilm.com).



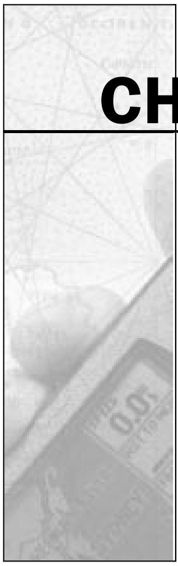
CHAPTER 3

MOBILE GIS DATA STORAGE

Data collected in the field (e.g., text, map, image) need to be stored either temporarily or for a longer time period. Although portable computers and tablet PCs often come with internal CD-ROM or DVD readers/writers as standard, or external devices, one of the initial problems with many mobile devices (PDAs and digital cameras) has been their limited storage capacity and memory. Compact Flash Memory or Storage Cards are forms of storage currently available. This technology has developed quickly and is now widely used in notebook computers, digital cameras, PDAs, GPS, cellular telephones, and personal computers. Many brands of Compact Flash Cards utilize the Compact Flash slot built into PDAs. They offer varying storage capacities, ranging from 128 Mb to 3 Gb (http://www.dpreview.com/articles/mediacompare/; see also http://www.kingston.com/products/DMTechGuide.pdf). Advantages of this type of media storage over other types of storage such as floppy disks are its portability and its long life, and its rapid read/write speeds. Alternatives are Smart Media™, Secure Digital (SD), xD-Picture™, and Multimedia Cards, Memory Sticks®™ (e.g., Sony®), and Microdrives (Figure 5). Perhaps the only disadvantage associated with these media is that digital card readers are needed to plug into a USB port on a desktop, portable, or tablet PC to access the data on these cards. Digital card readers come in single and multicard versions and are increasingly becoming standard components of desktop computers and printers.

Figure 5 – Typical Examples of Mobile GIS Data Storage (courtesy of Belkin Devices (http://catalog.belkin.com/), Sony (http://www.sony.net), Lexar (http://www.lexar.com), IBM (http://www.ibm.com) and Olympus (http://www.olympus.com))

USB jump drives or flash drives also provide a handy alternative for storage if a USB port is available on the portable device, e.g., laptop or tablet PC. These devices are compact in size and usually have capacities ranging from 64 Mb to 1 Gb. Their advantage lies in the fact that no separate media card reader is required, and they are therefore usable with any device that has a USB 1.0 or USB 2.0 port as a plug-and-play device.



CHAPTER 4

MOBILE GIS AND RELATED SOFTWARE

There are a number of benefits to using a mobile computer or PDA equipped with GIS software out in the field for on-site data collection. These include:

- No longer having to collect data using pen and paper and then transferring it manually to a computer via a keyboard
- Not having to take various (often unwieldy) paper maps out-of-doors (where they can get wet, creased, and torn)—although lamination or placement in a plastic sleeve helps to avoid damage
- Being able to store and use many different maps and images of various scales and resolution either directly on the computer or on a peripheral (CD, DVD, memory card, or jump drive)
- Being able to take data sets out into the field and edit, add to, or update them
- Make remote connections to office-based databases and edit them (add/delete records) in the field

The rapid development of handheld computers and PDAs in recent years has provided the hardware necessary for mobile, field-based computing. Many GIS software vendors have subsequently developed GIS software specifically for use on these smaller computers and their operating systems (Table 2).

More recently, the introduction of tablet PCs has meant that it is now possible to take full-scale desktop GIS software out into the field.

Table 2 – Some examples of GIS software for Different PDA Operating Systems

Palm OS	Microsoft® Pocket PC and Windows CE
Geo Insight - GeoGIS http://www.geoinsight.com	ESRI® – ArcPad™ http://www.esri.com
	Intergraph - IntelliWhere OnDemand http://www.intergraph.com
	Autodesk - OnSite View http://www.autodesk.com
	MapInfo - MapX Mobile http://www.mapinfo.com
	Pocket Systems - PocketGIS™ http://www.posres.com http://www.pocket.co.uk
	Survey Supplies - FastMAP CE http://www.surveysupplies.co.uk
	HandyGIS - HandyGIS http://www.handygis.com
	GeoConcept - GeoConcept Pocket http://www.geoconcept.com
	Espire Infolabs - MapInPocket 1.0 http://www.palmix.espireinfo.com/newpalmix/products/mapin_home.htm

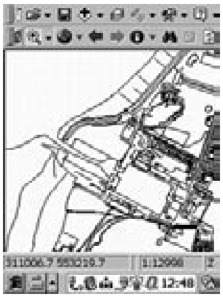


Figure 6 – A Screen Grab from ESRI's ArcPad (courtesy of ESRI (http://www.esri.com) and Author)

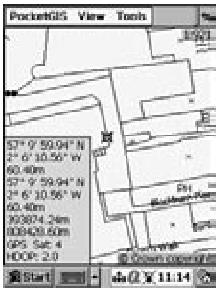


Figure 7 – A Screen Grab from Pocket System's PocketGIS (courtesy of Pocket Systems (http://www.pocket.co.uk) and Author)

ArcPad™ from ESRI®

ArcPad™ software is the mobile GIS solution from ESRI® (http://www.esri.com) and part of its ArcGIS™ suite (Figure 6). For users who are familiar with ESRI ArcGIS products or ArcView® 3.x, ArcPad has similar ESRI tools, icons, functions, and layout. ArcPad offers the following features:

- Support for industry-standard vector and raster data formats, including ESRI Shapefiles (.shp), DXF™ (.dxf), JPEG (.jpg), Windows Bitmap (.bmp), and MrSID (.sid)
- Map navigation that includes zoom and pan, spatial bookmarks, and centering on the current GPS position
- Data query by identifying features, displaying hyperlinks, and locating features
- Measuring distance, area, and bearings
- Navigating by connecting a GPS
- Edit data by creating and editing spatial data using input from the mouse pointer, pen/stylus, or GPS

As part of the ESRI ArcGIS solution, ArcPad's additional functionality includes the capability to add data from the Internet and tools for preparing data in ArcGIS Desktop or ArcView 3.x.

ArcPad can also be used to access data on the Internet by connecting with ESRI's ArcIMS. ArcIMS is ESRI's Internet map server solution for delivering maps via the Web. Like most of the current map servers, its GIS functionality is limited to map interface tools and queries. ArcIMS Web servers can also be used to host a number of map services. ArcPad can act as a client to these services and will connect when a valid ArcIMS Web address (URL) is provided. Data is downloaded and stored on the mobile device as a JPEG image file. Connections with GPS are also possible.

ArcPad tools are available as downloadable extensions for ArcGIS Desktop and ArcView 3.x. These allow data to be prepared in either ArcGIS or ArcView (in the office) for use in ArcPad (in the field). The tools allow the following:

- Preparation of data sets for use in ArcPad
- Export of ArcGIS and ArcView 3.x symbology into ArcPad layer files
- Creation of ArcPad map files
- Packing of shapefiles

PocketGIS™ from Pocket Systems

PocketGIS™ (Figure 7) from Pocket Systems (http://www.pocket.co.uk) is another example of mobile GIS designed for field-data capture using handheld and palm-sized computers. As with ESRI's ArcPad (and most other mobile GIS software), PocketGIS offers basic GIS functionality, including:

- Identifying features
- Measuring distances and areas
- Editing feature geometry
- Capturing new features
- Viewing and modifying data attributes

The functionality is specifically targeted at mobile data collection, providing the end user with the capability to undertake a variety of mobile mapping tasks in the field, e.g., recording information and updating. It is similar in concept to a number of other software products from different suppliers e.g.,ESRI's ArcPad and Survey Supplies FastMap. PocketGIS is supplied with a data-exchange utility called PocketGIS Connection to allow data to be transferred from a desktop computer to a mobile computer and vice versa. PocketGIS handles a number of different vector and raster file formats (NTF, Shapefile, MIF (MapInfo), DXF, CSV, BMP, and TIFF). PocketGIS Connection also allows the user to define the structure of the data sets collected, such as the attributes associated with features. Facilities are also provided to define legends and display schemes (the scale ranges at which map features are displayed).

Connection to a GPS receiver allows:

- Location tracking by displaying the current position and panning the map display
- Data capture by which GPS positions are easily digitized
- Real-time projection by placing the GPS position into the user's chosen coordinate system
- GPS trail by digitizing the current GPS position at a defined time interval (useful for mapping, e.g., footpaths)

Additionally, PocketGIS can be connected to a laser rangefinder for data capture, and when used in conjunction with a GPS user, it can define a position and digitize points from laser offsets.

Customization of PocketGIS can be carried out to suit user requirements and applications. This includes "picklists," tables, data and time stamps, category lookups, and digital camera and sketchpad images (Positioning Resources Factsheet, 2004).

FastMAP

Another similar product is FastMAP CE from Survey Systems (http://www.surveysupplies.co.uk). The specifications of this product are:

- Standard Windows graphical user interface
- Import/export many GIS data formats
- DGPS link with OSTN97 (Ordnance Survey National Grid Transformation), OSGM (Ordnance Survey Geoid Model) transformation (see http://www.gps.gov.uk/info.asp for more details)
- Pocket Access Link (part of Microsoft Pocket Office)
- Link to laser rangefinder for offsets, heights, etc.
- Map display (OS land line or DXF) and other map data
- Definition of point, line, and area features with user-defined database attributes

Related product is FastMAP's GPS Video Surveyor, which provides the capability to capture, display, and process digital imagery with GPS positions.

HandyGIS™

HandyGIS™ (http://www.handygis.com) is also a similar PDA-based GIS application software package designed to provide GIS functionality in the field for PDAs. The two versions (Professional and Lite) differ by providing data-capture and editing capabilities and a viewer, respectively. As with other such products, HandyGIS provides display, zoom, pan, data capture, editing and measurement tools, a gazetteer, and the option to integrate with GPS.

Botanical Garden Mapping

As well as mobile GIS software that provides a generic toolbox, other mobile data- collection/GIS packages have been designed for specialized applications. BG-Map, Botanical Garden Mapping System/GIS is a GIS desktop software package for collecting and storing information about plants in botanical gardens. BG-Map will store base map information about the garden and information about plant species in a database (BG-BASE™). Two associated handheld products from BG-Map (Garden Notepad and GreVid™) now extend the desktop product to the collection of data directly in the field for input to BG-Map (http://www.bgmap.com).

Other GIS Software

Quite a number of other less-well-known GIS software packages are also available. These have been developed as low-cost alternatives to commercial software or as specialized application-specific solutions. Some examples for PDAs are as follows.

HGIS®

StarPal™ HGIS® Basic, Plus, and Professional (http://www.starpal.com) is a GPS-based field-mapping software package for desktop computers as well as for low-cost mobile systems for field-data collection. This software can be used for point-data collection, display of vector and raster images, measurements, and creation of templates and picklists, georeferencing, mapping, analysis, and data-logging tasks.

MobileSTAR©

MobileSTAR© (http://www.star.be/uk/solutions/MOBILESTAR.asp and http://www. gistek.net) is a wireless GIS for pocket and tablet PCs and PDAs. It provides a direct link to a desktop GIS for data that is to be prepared and used on a mobile device and synchronized with the central server. Availability of a wireless Internet connection makes it possible to have Internet access to STAR NeXT© or to any other "Web Mapping" OpenGIS® compatible server for real-time query of databases.

MapInPocket

Viewers such as MapInPocket (http://www.palmix.espireinfo. com/newpalmix/products/mapin_home.htm) provide an alternative to GIS on a PDA by allowing users to view GIS data in the standard formats such as ESRI's vector shapefile (.shp) or image file formats such as BMP, JPEG, or GIF. Limited functionality is available in the form of drawing tools to allow end users to annotate maps using text and sketches. MapInPocket is designed to run on all handheld devices using SH3 or MIPS processors running Windows CE 2.0 or later applications.

MapInfo® MapX® Mobile

MapInfo® MapX® Mobile (http://extranet.mapinfo.com/products/Overview) is software designed for the creation of map-based applications running on PDAs, and can connect to Pocket Access and Microsoft SQL™ Server 2000 Windows CE Edition. Applications created with this product can also be used in conjunction with a wireless connection. An application developed with MapX Mobile can also display maps generated by other MapInfo products such as MapInfo MapXtreme®, the Internet/intranet mapping application server.

FieldWorker

FieldWorker (http://www.fieldworker.com/prod_enterprise.html) is another software package designed for mobile fieldwork using a PDA. It consists of the following components:

- Presentation layer
- Mobile database
- Validation engine
- Online queries
- Data sources and GPS module

FieldWorker is part of FieldWorker Enterprise and is built on the J2EE architecture to provide a mobile data collection and synchronization solution to exchange information with mobile fieldworkers.

The interface to this software allows the end user to view various types of data in different panels, including spreadsheet, GPS, map, and photographic image views (Figure 8). User and application data can be stored in the mobile database. Validation rules for an application are enforced by a validation engine, while online database queries can be used in conjunction with offline data collection. The data sources and GPS module provide the opportunity to gather data from a GPS, as well as from bar-code scanners and other sources.

GBM Mobile

GBM Mobile (http://www.geobasemap.com/products/gbm_mobile.htm) is a map-based GIS toolbox for PDAs running Microsoft Pocket PC (Microsoft Pocket PC 2000, 2002, or 2003). It provides data-entry forms and GPS integration, as well as software to set up a mobile device, transfer data to and from the mobile device, and allow merging of field edits into a central database. Based on MapInfo MapX Mobile technology, it also integrates with MapInfo Professional and works with MapInfo .tab files, although it can also display other GIS data such as ESRI .shp files.

GeoGIS

GeoGIS (Figure 9) (http://www.geoinsight.com/Products/Mobile/GeoGIS.cfm) from GeoInsight is another mobile GIS package for a Palm OS PDA. It allows the user to work with ArcView shapefiles and attributes and to create projects with themes (or map layers) for a project. Each GeoGIS theme includes a database generated from an attribute table in ArcView. Notable features of this GIS software are: themes can comprise points, lines, and polygons; items can be displayed in order and can be switched on and off and displayed in different colors; pan, zoom, and query functionality can be used; it is a measurement tool; attribute display and even "beams" to transfer data to and from other IrDA compliant devices.

GPSPilot

GPSPilot (http://gpspilot.com) is another software application for the Palm OS that offers mapping capabilities. Combined with a GPS and wireless connectivity via a Smartphone or using Bluetooth to link to the Internet, it provides end users with the capability to have online access to cartographic data (including topographical maps, marine charts, aeronautical and satellites images, and street-level or site plans) (Figure 10).

MapXtend

MapInfo MapXtend, Java™ Technology Edition (http://extranet.mapinfo.com/products/Overview.cfm?productid=1065) is an extension to the MapInfo suite of software, especially MapXtreme, designed for location-based applications running on PDAs and Palms as well as mobile phones. It provides access to spatial data and information from the Internet using wireless communications, and allows access to centralized data and provides users with the ability to view, query, edit, and collect data whilst in the field, overall efficiency and productivity.

WShape™

WShape™ is a version of Jshape, the Java-based Internet GIS (http://skyscraper.fortunecity.com/redmond/829/jshape2.htm) designed to run on top of Waba Virtual Machines software from Waba Software (http://www.wabasoft.com).

Figure 8 – Screen Grab of Fieldworker Interface Diagram showing how the end-user can link with data, GPS, maps and Images via a variety of mobile devices in the field (courtesy of Fieldworker – http://www.fieldworker.com)

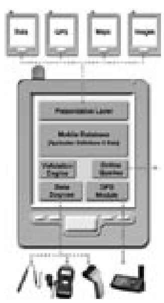
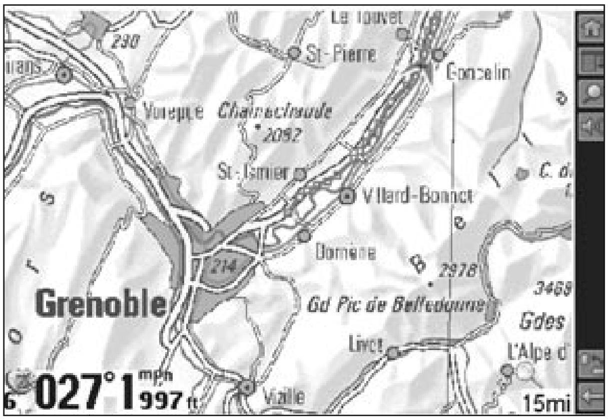


Figure 9 – GeoSight International's GeoGIS Software that runs on the Palm OS (courtesy of GeoSight International - http://www.geoinsight.com/)

Figure 10 – A Screen Grab from GPSPilot GIS Software (courtesy of GPSPilot - http://www.gpspilot.com/products/modules/mapping.shtml#1)



Wshape runs on both Palm OS and Windows CE handheld devices. It provides users with basic GIS functionality such as zoom and pan. The interface uses three windows for displaying the map, legend, and a command line.

FieldSmart®

MapFrame's FieldSmart® (http://www.mapframe.com/products/index.html) is a combination of mobile mapping and field automation software designed specifically for utilities and facilities management. The Mobile Suite™ combines the functionality of all the FieldSmart applications into a single tool: FieldSmart View™, Sketch, Collect, Inspect, Repair, Design, Route, Plot, Secure, and MapFrame's server solution, Field Flow Manager.

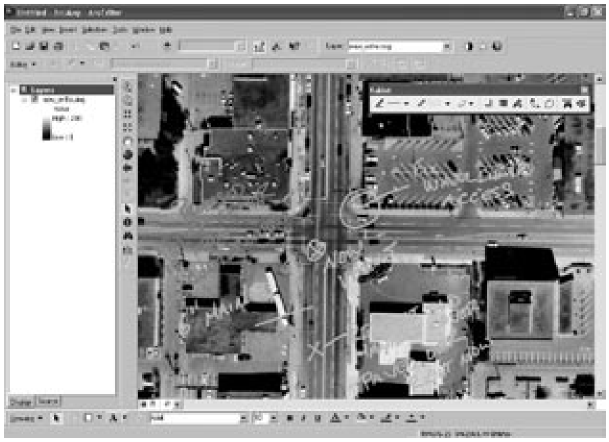
GenGisCad

GenGisCad (http://www.aptop.net/) is another example of GIS software package for the pocket PC. Its basic features include layer control, display of raster images, digitizing tools, and a zoom capability.

MapsGo

MapsGo is a GIS for both desktop and pocket PC systems with the capability to export to MapMap for Palm (http://www.ppc4all.com/appdetail.php?id=2490). It is also possible to import from ESRI's ArcView, export and import text and database files (.dbf), GPS export and import,

Figure 11 – A Screen Grab of the ESRI ArcGIS Software running on a Tablet PC (courtesy of ESRI - http://www.esri.com/news/arcnews/spring03articles/tabletpc.html)



and includes card support, and DXF import and export.

CAD/D

Although not strictly a GIS, the origins of GIS lie in part with CAD/D (Computer-Aided Drawing/Drafting), and in some cases commercial sales of CAD/D packages have benefited from being labelled a GIS or having elements of GIS functionality. A good example for a pocket PC is the CalcSurveying 1.1 software (http:www.calcsurveying.com/) that provides graphic output in the form of .DXF™ (Data Xchange Format) files.

Mobile Phone GIS

Another slightly different product is the Mobile Phone GIS reported on by Microsoft (http://www.microsoft.com/china/eventsmdc/en/case.asp) and developed by GeoKing Info. Co., Ltd. Compared to PDAs, this example has the advantage of being potentially easier to use because of the more familiar, everyday user interface to mobile phones.

ArcGIS on Tablet PC

With the advent of more powerful portable computers, for example, tablet PCs, it is now possible to bring full desktop GIS packages into the field. These take advantage of the unique interface and work environment of this type of computer. ESRI provides a free download for its ArcGIS desktop package that installs tools for the tablet PC (Figure 11) to allow the user to take advantage of the pen/stylus interface with ArcGIS, and Digital Ink technology to annotate map data on-screen. A free download is also available to add GPS support to ArcGIS. Input from a GPS receiver can be displayed as a real-time location in ArcMap, with the user's current location centered on the screen (http://www.esri.com/arcgis).

Using a GIS, such as ArcGIS on a tablet PC, provides certain advantages over using other GIS software running on PDAs, including:

- Larger display screen for viewing maps and images
- Greater processing power and storage capacity of the tablet PC
- Greater functionality available with the full-scale GIS software
- Easier transfer and maintenance of data if shapefiles are being used

Utility Software

In addition to the map and GIS software discussed previously, many other utility software packages can provide support for PDA software applications such as GIS. Typical examples are simple graphics and image-processing software (e.g., iPaint (http://www.cobaltinteractive.com/), PaintWinCE 2.0.2 (http://www.abisoft.spb.ru/), Photogenics (http://www.idruna.com/products_pocketpc.html), Pocket Painter (http://www.aidem.com.tw/), and Pocket Artist (http://www.conduits.com/ products/artist/)) that can be used as the basis for displaying, editing, and processing images for extracting information. Other similar software provides field-sketching capabilities that can aid in recording information in the field and can either be e-mailed as an attachment to another user or uploaded to a remote server. Another example is software that can read and write different data file formats. PDAs are now able to create and display animations such as those produced by Macromedia Flash (.swf) and Microsoft PowerPoint (.ppt), using, for example, CNetX Pocket Slideshow 1.30 (http://www.cnetx.com/).

While not always considered part of the suite of software used in a GIS application, these utilities (including viewers and players) provide useful and complementary tools that can be employed in conjunction with other software. Good examples are Pocket Artist (Figure 12) that provides a powerful toolbox for field sketching; Macromedia Flash Player 6.0 for Pocket PC; and FlashAssist offering the means to create, embed, and play flash animations in the form of .swf and .exe files (http://www.antmobile.com). Animation software such as Animator 1.01 (http://www.home.earthlink.net/~wagnerbc/) is also available. Not only can these tools provide the means to capture and record data and information, but they also can be used to display, communicate, and play back information in the form of animations, slideshows, and video clips. There is also a wealth of other tools for use on PDAs, including graphing software, e.g., PDAGraphiX and emGraph (http://www.pocketpc-city.com/), and image and picture viewers, as well as video players and charting tools such as PocketChart (http://www.mindfusion.org/pocketchart.html).

Questionnaire Surveys

PocketSurvey

Another product available from PocketSurvey (http://www.pocketsurvey.co.uk) in the UK is

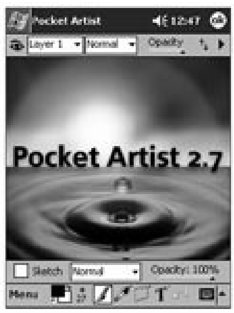
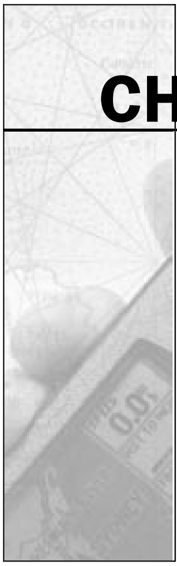


Figure 12 – A Screen Grab of the Pocket Artist Software – An example of Utility Software for PDAs (courtesy of http://www.conduits.com/products/artist/)

a package known as PocketSurvey for PDAs running Windows CE Version 3. Among other applications, its Web site lists the following applications of the software:

- Disabled access surveys
- Stock condition
- Repairs and maintenance
- Health and safety
- Asset management
- Housing management
- Landscape maintenance

The collection of data and information is based upon customized questionnaires designed for each application.



CHAPTER 5

GLOBAL POSITIONING SYSTEMS (GPS)

GIS and mobile GIS software can operate without GPS (Figure 13). However, for a mobile GIS to be truly functional in a fieldwork environment, a GPS connection is necessary to allow for spatial data capture and updating.

GPS is a satellite-based positioning system, currently operated by the U.S. Department of Defense (DOD), which is available to civilians as well as to the military. In the future, the European Union (EU) also intends to operate a system called Galileo (due to come into service by 2008) equivalent to the U.S. GPS, and Glonass in Russia. The U.S. system has 24 operational satellites, orbiting the earth every 12 hours. Each satellite contains several high-precision atomic clocks and constantly transmits radio signals using a unique identifying code. GPS receivers use signals (from at least four satellites) to calculate their own positions on the earth (Chivers 2003). This positional information can then be used within a GIS for data collection and maintenance.

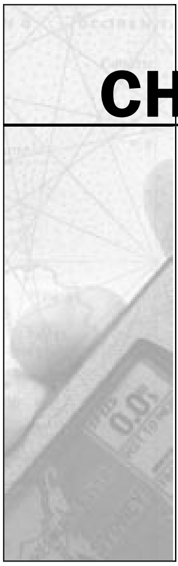
Figure 13 – An Example of a Portable, Handheld Global Positioning System (GPS) (courtesy of Garmin – http://www.garmin.com)

Mention should also be made of the Wide Area Augmentation System (WAAS) program that is being developed by the Federal Aviation Administration (FAA) and the U.S. Department of Transportation (DOT) to overcome the problem that GPS does not meet the requirements for accuracy, integrity, and availability for air-traffic control. In Europe, the equivalent is the European Geostationary Navigation Overlay System (EGNOS) that is expected to be operational in 2005. WAAS provides GPS signal corrections for better positional accuracy without needing additional equipment (such as with a Differential Global Positioning System (DGPS)) or service fees (http://www.garmin.com/aboutGPS/waas.html and http://www.ainonline.com/issues/02_03/02_03_europeanscatchpg66.html).

Handheld GPS receivers are available from a number of different manufacturers, including Trimble and Garmin (http://www.trimble.com and http://www.garmin.com) amongst others. Single receivers are now capable of a positional accuracy of approximately ten meters. However, most mapping applications require a higher accuracy of at least two meters or even a few centimeters. Such accuracies are obtainable using DGPS data.

DGPS works by using two GPS receivers, a base station or reference receiver that is located at a known location, and the roving receiver used for mapping. The base station receiver calculates its position by comparing the signal it receives from the satellites to a known position. The difference is then applied to the GPS data recorded by the roving receiver. This can be done in real time in the field, or by postprocessing after data capture (Chivers 2003). Both methods are likely to incur additional costs: real-time DGPS receivers are far more expensive ($1,000s) than single handheld receivers ($100s); software is also required to postprocess data and base data may also have to be purchased to run comparisons. A further method of obtaining DGPS is by using geostationary satellites. With this system, corrections are obtained from more than one reference station. The base station data is collected, sent to a Network Control Center that then passes the information to the geostationary satellite for verification. The verified information is subsequently sent to the roving GPS receiver in real time. Two commercial satellite differential service providers, Thales Survey LandStar and OmniSTAR Inc., currently offer this service to civilian subscribers (Chivers 2003).

Connecting a GPS receiver to a mobile computer or PDA is now relatively easy, usually using a serial cable and serial port on the computer device. Other types of GPS receivers may also plug directly into the Compact Flash® slot or a mobile device may even have a built-in receiver. Mobile GIS software such as ArcPad and PocketGIS will then detect the GPS signal automatically and convert it into the user's specified coordinate system and map projection.



CHAPTER 6

MOBILE COMMUNICATIONS

Mobile communication devices (mobile phones) have advanced rapidly over the past few years, decreasing in size and weight, but increasing in reliability, portability, and functionality. Today, mobile phones are an essential item for sending and receiving information on the move, either by voice or via the Internet.

Global System for Mobile (GSM™) communication is the standard network by which most mobile communications are now made. There are three component platforms of GSM, including General Packet Radio Service (GPRS), Enhanced Data Rates for GSM™ Evolution (EDGE), and 3rd Generation Mobile Multimedia Services (3GSM).

Mobile phones are useful devices for fieldwork and data collection because they allow the fieldworker to communicate with the office, either by voice, Short Message Service (SMS) text messages, or by e-mail. More recently, Multimedia Messaging Service (MMS), has also been introduced that allows images to be sent to other mobile phones, along with a text and voice message. The image is often a photograph taken using a built-in camera on the phone (Figure 14). This type of service can be useful for mobile GIS applications if a fieldworker needs to send pictures of an event or feature quickly back to his or her office or to another person in the field. The only drawback associated with mobile phone cameras at present (although this is gradually improving) is the relatively poor resolution of the picture captured when compared to higher specification digital cameras with optical and digital zoom lenses.

Mobile phones can easily connect to the Internet directly using Wireless Application Protocol (WAP) browsers, or they can be connected to a PDA or mobile computer and used to dial up to the Inter-

Figure 14 – An Example of a Mobile Phone and Camera (courtesy of Sony Ericsson – http://www.sonyericsson.com)

net. WAP browsers employ a special derivative of Hypertext Markup Language (HTML) that is used to construct Web pages; this is called Wireless Markup Language (WML) and allows Web pages to be constructed that are more suitable for the smaller screens found on mobile phones. Viewing Internet pages on a PDA is usually easier, because of the slightly larger color screens and easier-to-use navigation tools. However, they usually also have to be designed specifically for PDA screens to make them more user-friendly.

GPRS provides "always on" connections to the Internet, where the user pays for the amount of data that he or she downloads or uploads. It also provides faster data transfer than previously possible. EDGE and 3G networks (http://www.3g.co.uk and http://www.mobileinfo.com/3G/3G_Wireless.htm) will further enhance data transfer speeds by increasing the functionality of mobile devices and the speed of viewing Web pages.

Connecting to the Internet using a PDA or laptop via a mobile phone can be accomplished in a number of ways, such as the following:

With Wires

One way of connecting a mobile phone to a laptop, handheld computer, or PDA is to use a cable. This usually plugs into the serial connector on the computer whilst the other end connects to the phone. Software installed on the computer allows it to communicate with the phone. An example of this type of connection is TDK's GlobalPulse™. The GlobalPulse GSM adapter allows the connected computer to be used for SMS transmission, faxes, and phonebook management. To use the Internet and e-mail, browser and mail software also must already be installed on the computer.

A cable connection is easy to connect and it is more difficult to break the connection (unlike Infrared where the phone and computer must remain aligned, as noted in the next section). One problem, however, is because all mobile phones have different connections, the cable will be specific to a certain phone model.

Without Wires

- Infrared

  Infrared (IR) is one way of connecting an IR-enabled PDA to a mobile phone without using wires. With IR-enabled on both devices to be connected, the user simply has to line up the IR port on the PDA with the IR port on the mobile phone to establish a connection. The PDA will then communicate with the mobile phone, either to transfer information (such as the address book), to use the phone to dial up onto the Internet, or to send an image or text file to the printer. Whilst novel at the time of their introduction, and still in use, IR connections tend to be more suited to the office environment than to the field where it may be difficult to keep the IR ports on the devices aligned to maintain a connection. The practicality of finding a flat undisturbed surface in the field or in a vehicle limits the usefulness for mobile work, even if on the face of it the wireless environment is attractive.

- Bluetooth

  Bluetooth is another wireless solution that provides communications between mobile phones and other devices. Figure 15 shows an example of a Bluetooth-enabled PDA device (http://global.acer.com/products/pda/n30.htm). Originally conceived by Ericsson, it is now supported by many different companies and manufacturers. In 1998, the Bluetooth SIG (Special Interest Group) was founded by Nokia, Ericsson, IBM, Intel, and Toshiba (see http://www.bluetooth.com). Bluetooth works with devices in close proximity (it has a range of about ten meters) with data rates of up to 1 Mbps (http://www.gsmworld.com/technology/bluetooth/index.shtml).

Figure 15 – An Example of a Bluetooth-Enabled PDA (courtesy of DELL – http://www.dell.com)

Many mobile phones and PDAs (e.g., HP iPAQ) now come with Bluetooth built in, and a large range of adapters is also available to make PDAs, handhelds, and laptops Bluetooth-compatible—e.g., the Belkin Bluetooth device that plugs into a USB port. The major benefit of Bluetooth over IR is that the devices do not have to be aligned for the connection to work and the devices remain connected even if there are walls or screens separating them. Furthermore, Bluetooth-enabled pointing devices, for example, Microsoft's Bluetooth Mouse (http://www.microsoft.com/hardware/ mouseandkeyboard/productdetails.aspx?pid=001) makes using a mouse more practical in the field because of the lack of wires and need to align devices.

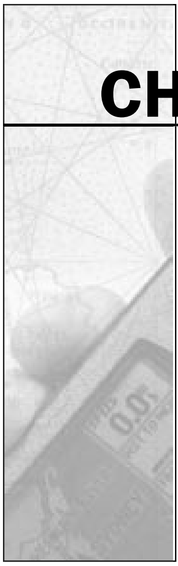
- Wireless Networking

  A further type of wireless networking is the IEEE 802.11b and 802.11g standards. The 802.11b operates at 11 Mbps, while the 802.11g can operate at up to 54 Mbps. This type of wireless networking is generally used within homes and offices, eliminating the need for cables between computers. However, wireless hubs have recently been set up in airports (e.g. throughout Ireland, Belgium etc.), cafés, and some universities (e.g., the University of Aberdeen) that allow mobile computers equipped with wireless adapters to connect to a network and to the Internet. This type of wireless device has a greater range than Bluetooth does. Nevertheless, Bluetooth was designed specifically to be light and to provide short-range communications, which is ideal for mobile fieldwork.

- Hybrids and SIM/PC-Card

  Hybrid handheld devices also exist that combine a PDA with a mobile phone, therefore removing the need for any type of connection device. A good example of such a device is 02's Xda and the more recent Xda II (http://www.02.com).

  PC-Cards are also available by which an Subscriber Identity Module (SIM) card can be plugged into a laptop, allowing the computer to connect to the Internet, and also be used to send and receive SMS text messages (e.g., Vodafone™ Mobile Connect — http://www.vodafone.com). Network providers charge a monthly fee for this service and will also charge extra for any data that is sent and received.



CHAPTER 7

REMOTE DATA ACCESS

Access to remote data sources has been facilitated by two developments, image compression and Image Web Servers and online GIS or Internet Map Servers.

Image Compression and Image Web Servers

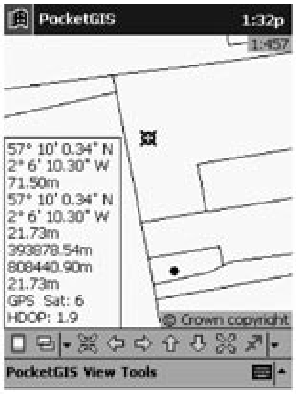
ER Mapper (http://www.ermapper.com) and LizardTech™ (http://www.lizardtech.com) have both developed image compression software that allows a digital raster image, such as a digital aerial photograph or satellite image, to be compressed in size from gigabytes (Gb) to megabytes (Mb). Thus, imagery is more easily transferred onto mobile computing devices (with less memory and storage capacity than desktop PCs) and also across the Internet. The ER Mapper technology, called Enhanced Compressed Wavelet (ECW), is delivered on the Internet using ER Mapper's Image Web Server (IWS). LizardTech also has a compression technology called GeoExpress (the next generation of its MrSID Geospatial Encoder). Imagery compressed using this software can be served on the Internet using LizardTech's Express Server (formerly Content Server).

Many GIS software products are capable of reading both ECW (.ecw) format and GeoExpress/MrSID (.sid) format imagery. For example, ESRI's GIS products can read MrSID imagery natively, while ER Mapper provides a range of software plug-ins that can be installed for different GIS software allowing them to read ECW image files. ECW imagery can also be viewed on the Internet using a browser plug-in, and because the imagery is compressed, it can be transmitted relatively quickly and easily to mobile computers and PDAs. Likewise, MrSID imagery may also be viewed using a browser plug-in. LizardTech's Express/Content Server also allows the compressed imagery stored as MrSID files on a server to be sent to a Web browser as JPEG files. Both ECW and MrSID imagery can be viewed with a degree of end-user interaction, including zooming and panning. Earth Resource Mapping (ER_Mapper) has also made a free ESRI ArcPad v6.0 ECW Plug-in v1.0 to allow users of PDAs to view ECW and remote ECW images (ECWP) using ArcPad v6.0. (http://www.directionsmag.com/pressreleases.php?press_id=5672).

The benefit of data compression technology is that large images, e.g., scanned aerial photographs, can easily be remotely accessed using a mobile phone and PDA in the field. Integrated with other geographical data, they can be displayed, analyzed, and interpreted whilst on location. Using software, the imagery can be annotated and may even be uploaded to a remote database on a server. The relatively small compressed image files still provide sufficient information to be useful to the fieldworker while offering rapid access and display.

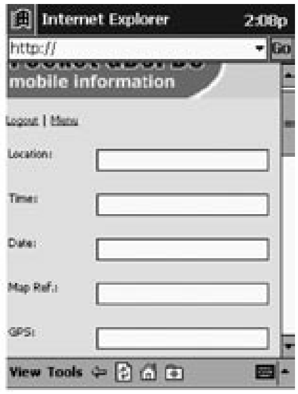
Internet Map Servers

Internet Map Server technology has advanced markedly over the past five years. Today, map server software offers a great deal of the functionality normally associated with desktop GIS software packages via a Web-based interface (e.g., zoom, pan, measure, identify, search, query, buffer). Most of the major GIS vendors now provide a map server software package, either as part of the desktop GIS, an extension, or a separate product. These include ESRI's ArcIMS, MapInfo's Map Extreme, Intergraph's GeoMedia®, CARIS® Internet Server, and Autodesk's MapGuide. A number of others are available at less cost, such as the University of Minnesota's MapServer (http://mapserver.gis.umn.edu/). Most map server software delivers a map via a Web page as either a raster image or streams the vector data to the client using a Java-based viewer. PDAs equipped with an Internet browser are capable of viewing maps delivered as raster images via the Web. Although the data is displayed as a raster, map server software usually allows the data attributes to be displayed as well. Using ESRI's ArcPad mobile GIS software, it is possible to connect to an ESRI ArcIMS map service and use remote data held on a server as a background map during data collection (Figure 16). If a GPS is connected to the PDA, the map data from the ArcIMS server will automatically update to the user's location, as the user moves around. Remote access to data in this way is advantageous, because a user in the field can access data and maps that may not have been stored locally on the PDA. The main disadvantages at present to remote data access are the data transfer speeds that are relatively slow and the financial cost of remaining connected to a mobile phone network for long periods of time.

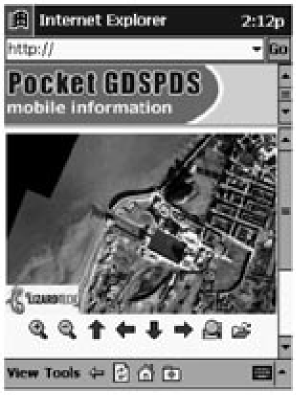


Using Pocket GIS on a PDA connected to a GPS system to collect data in the field

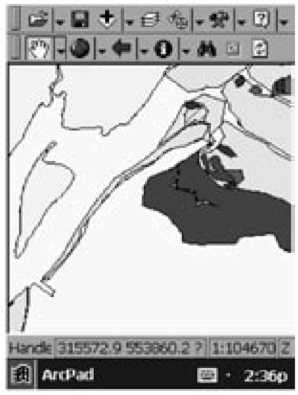
(Map data Crown Copyright Ordnance Survey. An EDINA Digimap/JISC supplied service).



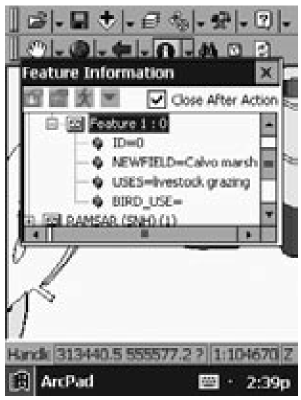
Using a web-based form to submit data from the field to a remote database. (Author)



Viewing colour aerial photography on a PDA connected to the Internet using a mobile phone. (Aerial photography Copyright English Nature 1997).

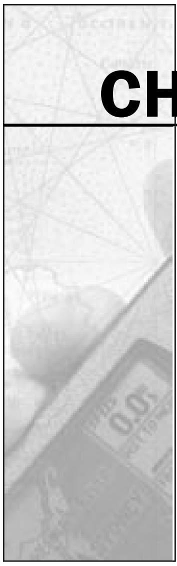


Using ESRI®'s ArcPad™ on a PDA to connect to an ArcIMS map service and view map data in the field. (Author)



Reviewing attribute information using ArcPad™ (Author)

Figure 16



CHAPTER 8

PHOTOGRAPHY AND DIGITAL IMAGES

Other valuable field data collection technologies are the digital still camera (e.g., Olympus) and the digital video camera (e.g., Sony). Cameras and video cameras can be used to take snapshots of the environment at a specific time and place. This is useful information to help describe to others what the environment looks like, and can also be used to monitor environmental changes over time. Digital imagery has many potential uses as the basis for collecting data, calibration, and recording digital transects/quadrants. While such photography is usually taken at ground level, oblique or near vertical pictures can also be taken from a light aircraft and even from kites (Aber et al. 2002), balloons (http://www.southernballoonworks.com/index.htm; http://modelballoon.com/aerial.html), model fixed-wing aircraft (Green et al. 1998), and helicopters (http://www.hicam.com.au/links.htm) (to be discussed in Chapter 9). These provide low-cost ways of acquiring aerial photography (panchromatic, color, and color infrared (CIR)) as the basis for environmental data collection. For example, Green et al. (1998) successfully used a model aircraft to gather multitemporal information about estuarine macroalgal weedmats. Aerial photographs taken with a 35 mm SLR camera can easily be scanned, geocorrected, and mosaicked using digital image processing (DIP) and/or GIS software (e.g., Erdas Imagine®, ER-Mapper, ENVI, PCI, Pixoneer's PG-STEAMER; Idrisi Kilimanjaro; ESRI ArcView/ArcGIS/ArcInfo™), and input to a desktop or mobile GIS for on-screen digitizing or interpretation to create maps.

Digital photographs can easily be enhanced using image-processing software, e.g., JASC's Paint Shop™ Pro® (http://www.jasc.com), mosaicked together using Adobe® Photoshop® (http://www.adobe.com), or stitched into 180- or 360-degree panoramic images, e.g., PhotoVista (http://www.iseemedia.com/) that can either be printed out or displayed as rotating 360-degree images on an Internet Web site using viewing software such as Apple's Quick Time (http://www.apple.com) (Figure 17). Although digital still cameras of just a few years ago could only capture images with a resolution of 640 x 480 or 800 x 600 pixels, most current digital cameras provide much

Figure 17 – A series of Digital Photographs Stitched Together to form a 360° panoramic image using PhotoVista (http://www.iseemedia.com/) (The Ythan Estuary, North East Scotland) (courtesy of the Author)

higher resolutions, enabling the capture and storage of much sharper and higher-quality images.

Digital cameras, which are also getting much smaller, come in a wide variety of different sizes, ranging from the thin penlike cameras to the camera accessories now available for PDAs, as well as built-in cameras or attachments for mobile phones, and digital voice recorders or dictation machines e.g. the Olympus W-10 (http://www.olympusamerica.com/). Images captured using a digital camera or a video camera can be stored as attribute data within a mobile GIS, and then be mapped to a location on a map using a hot link. Mobile phones with integrated or attached cameras also are now capable of sending photographs as attachments via e-mail, or from phone to phone using the new MMS offered by a number of service providers, e.g., Orange™ (http://www.orange.com), O2 (http://www.o2.co.uk), and Vodafone (http://www.vodafone.com). MMS can combine text, pictures, photographs, animations, speech, and audio into a multimedia message consisting of a drawing, photograph, or picture postcard annotated with text and/or an audio clip (a synchronized playback of audio, text, photo), or in the near future a video emulating a free-running presentation or video clip (http://www.ericsson.com). Although most of the images captured with these devices are currently not at a very high resolution, they nevertheless provide a useful photographic record that can easily be e-mailed or sent by MMS. This type of technology has considerable potential in situations where field information needs to be sent back to the office quickly for decisions to be made, e.g., in a search-and-rescue operation.

CHAPTER 9

MODEL AIRBORNE PLATFORMS

Using model aircraft to acquire aerial photography is not new. The literature reveals that a wide range of different aerial platforms have been successfully used over the years as a means to acquire aerial photography and video of varying types and formats for many different applications. Over the past 25 years, numerous studies and applications have been reported citing the use of small-scale aircraft for field and environmental research where remotely sensed data needs to be collected. A great deal of commercial interest also exists with many small companies making use of a wide range of small-scale platforms to acquire low-altitude aerial photography, e.g., in the United Kingdom, High-Spy (http://www.highspy.co.uk).

Small-scale aircraft fall into two distinct categories: the “fixed wing” and the ”rotary wing” or helicopters. Fixed-wing platforms can also be subdivided into “high-wing monoplanes” or “biplanes,” “powered,” and “power/powerless” categories or “gliders.” Kites (http://www.arch.ced.berkeley.edu/kap/kaptoc.html) (Figure 18) and balloons (http://www.skyeyephotography.com/ and http://modelballoon.com/aerial.html) in particular have been found to offer low-cost image data–acquisition platforms.

In practice, fixed-wing, small-scale aircraft have been more popular for applications than have rotary-wing. Monoplanes offer good stability and a slow-flying capability. Biplanes, although more complicated to construct and more susceptible to damage, offer increased wing areas and therefore increased capacities to carry camera or video equipment and to fly slowly.

Figure 18 – A Model Airborne Platform and a 35mm Aerial Photographic Print Captured with a 35mm SLR Camera (courtesy of the Author)

Helicopters have been less popular because they are more costly to purchase, are far more difficult to fly, experience vibration, can be unstable, have a low payload capacity, and, if they suffer from engine failure, they can plummet from the sky, inevitably losing both the platform and the camera equipment. Today, however, a surprising number of commercial Web sites reveal companies using model helicopters for aerial work, for example, High Spy (http://www.highspy.co.uk/), Hi Cam (http://www.hicam.com.au/), Airborne Video Services (http://www.airbornevideo.net/), and Cloud Hopper (http://www.cloudhopper.com/). The benefits usually cited are the ability to hover and the availability of different photographic perspectives. The problems of vibration from the main rotor, tail rotor, and engine have been diminished by using damping systems (http://www.hicam.co.au./heli.htm). Seldom mentioned in the literature, gliders can be used where there is a need for quiet operation, e.g., wildlife monitoring and habitat surveys, but they generally offer a less practical solution than does a powered plane.

Besides aircraft and helicopters, numerous other airborne platforms are suitable for remotely sensed data capture, such as airfoils, balloons, kites, and model rockets. Each platform can be used to acquire environmental data with the aid of a traditional or digital camera, with its suitability determined by the nature of the application and the available budget.

These platforms offer a number of practical advantages over the more conventional light aircraft, autogyros, and microlights most often used for acquiring small-format aerial photography. A key advantage in the context of field-data acquisition is that the photography can be acquired at virtually any time, except under very extreme weather conditions. The availability of a small, easily transported aerial platform provides relative freedom for image acquisition; no booking is needed for flying time, reducing the risk of flight cancellation because of poor weather conditions on the proposed day of flight when a light aircraft is likely to be grounded. Flying regulations also prevent low altitude flying (< 200 meters) of light aircraft and thus prevent the acquisition of large-scale photography, something that is easily achievable with a small-scale aircraft (see, e.g., http://www.members.home.net). Furthermore, when special types of photography taken at one or more specific times of the day/year are needed, the model-aircraft platform is ideal for it allows almost complete flexibility. One additional advantage noted by Hi Cam is that taking photography at a lower altitude reduces the effects of atmospheric haze and enhances the clarity of the imagery.

Another advantage is the relatively low cost of acquiring the photography. Beyond the cost of the model plane, the only additional finance needed is to cover the costs of the engine fuel, aircraft spares and maintenance, and films and processing. Cost is a particularly significant factor for many small-area studies, for aerial photography can be very expensive to obtain, especially when multitemporal photography is required. Although 9 x 9-inch contact prints can be purchased relatively inexpensively— the cost in the UK is approximately $50 for a true color print—the total cost soon mounts up if more than one date or a large aerial coverage is desirable. Furthermore, if special one-time flights have to be made, additional expense is usually incurred.

Some of the environmental applications using model aircraft to obtain aerial photography are shown in Table 3.

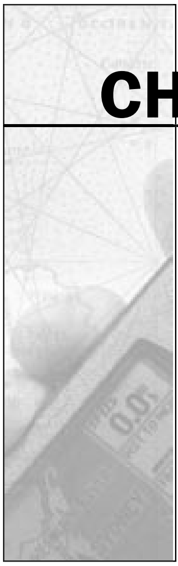
Table 3 – A Range of Environmental Applications (Wedler 1980)

Monitoring ice conditions
Observing coastal erosion and deposition features
Recording ports and harbor sites
Monitoring flood conditions at river ice jam sites
Measuring storm-induced beach erosion/deposition
Recording engineering structures and facilities
Detecting underground utilities
Determining the quality of rural highway decks
Inspecting older dam sites and river embankment protections
Mapping preliminary sites
Observing domesticated farm animals and their environs
Watching over tree nurseries and experimental agricultural farms
Identifying tree species and tracking tree spacing
Observing snowmelt behavior
Determining field-drainage patterns

Small commercial operations have also used various platforms for both scientific and nonscientific applications (Table 4).

Table 4 – Commercial Applications of Model Airborne Platforms

Commercial sites
Real estate
Site survey
Company presentation
Advertising, brochures
Local government municipal projects
Mining
Local trades
Legal work and law enforcement
Construction industry
Private properties
Golf courses
Plane to plane
Insurance companies, accident sites
Landscaping companies
Mortgage companies
Appraisal companies
Land management
Environmental impact studies
Gifts (framed pictures, business cards, greeting cards, composite displays), presentations, Web sites, awards



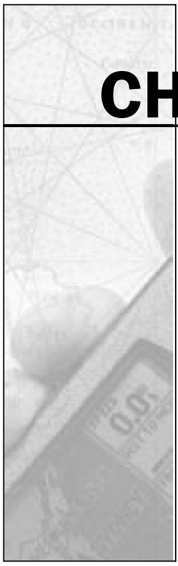
CHAPTER 10

INTEGRATION

The trend towards the growing use of mobile geospatial technologies in environmental applications, while largely driven by the physical size and power of the microprocessor and the associated technologies, is also being driven by the practical benefits of being able to integrate data and information in a seamless way in a mobile environment.

While integration of data has nearly always been necessary, geospatial technologies have greatly enhanced the practical possibilities and ease of integrating spatial data sets and information from many disparate sources into a single "window" or "environment." In addition, they have made it easier to undertake data exploration, analysis, modeling, visualization, and communication of information. One scenario, for example, is that it is now easy to download a digital image (e.g., an aerial photograph or satellite image) from a remote server via a mobile phone connection, store it on a memory stick or similar device, open it on a PDA with an image-processing suite of software (including image compression), interpret the image, overlay a map data layer, and then collect new geospatial data with the aid of a GPS, annotate the imagery from information gathered at the ground level in the field, and upload it via the WAP-enabled phone back to a server or via e-mail to another PDA using a phone link. It is even possible to utilize voice-activated GIS software with the aid of a mobile phone connection (e.g., VoiceInsight (http://www.voice-insight.com/) has developed a speech-recognition interface to ArcView using the VQL™ (Voice Query Language)).

For example, in a coastal management application requiring field mapping, a GPS can be connected to a PDA and mobile GIS software such as ArcPad for collecting line-feature data. A fieldworker can then either walk the shoreline and capture data points automatically at set intervals or collect the points manually. This is one way of mapping the current shoreline to determine shoreline movement over time. Data collected may be compared to archival maps or even aerial photography, or to data collected at an earlier date. This is particularly useful for short stretches of coast that may experience rapid change because of storm activity. The mapping can be complemented by photographs (single frame and panoramic) and video clips to provide a visual record of the study area. In ArcView, for example, hot links can be made between a theme (point, line, or area) and images, providing additional descriptive information about a location.



CHAPTER 11

EXAMPLES OF APPLICATIONS

As the technologies described have become more affordable, reliable, powerful, standardized, and easier to use, so have the applications grown. The briefly described examples that follow—available in more detail via the Web links provided—are only some of the many possibilities that now exist for using off-the-shelf commercial hardware and software. Many other examples could be cited.

Education

With the introduction in many countries of GIS courses in primary and secondary schools, and in further and higher education institutions (see Green 2002), it is inevitable that a range of mobile technologies will be mentioned or even used as the basis for illustrative examples and practical fieldwork in up-to-date courses. Children are becoming increasingly aware of, familiar with, and proficient in using many of the new mobile technologies—ranging from computers to mobile phones, GPS, and PDAs—and also in using the Internet. Many of these children will also go on to further and higher education and will likely utilize such technologies in their studies in geography and in many other disciplines, as well as on their jobs. Raising awareness of the role that such technologies play in the workplace and exposure to practical applications are, therefore, very important.

In the summer of 2002, at the University of Aberdeen, students were introduced to a practical GIS project over a one-week period. The project consisted of introductory lectures in the geospatial technologies with an emphasis on cartography/digital mapping, GIS, remote sensing, GPS, mobile mapping and the Internet, laboratory-based work, fieldwork, a 30-minute group presentation using Microsoft PowerPoint, and the preparation of an A0 laminated poster summarizing the project work.

The class theme was to study GIS in an environmental application, in this case coastal zone management (CZM). The course objective was to provide students with a basic amount of GIS background, theory, and concepts (fundamentals) and then to expose them to geographical problem solving using a geographical data-handling toolbox. For this stage, the students worked as a team using the ESRI ArcView GIS 3.2 software package, ESRI's Map Manager 6.1, and the ERDAS Imagine version 8.4 digital image processing (DIP) suite to process map data (Ordnance Survey vector data in National Transfer Format (NTF) and Shapefile (.shp) format) and 80 cm resolution thermal infrared (TIR) image data supplied by Infoterra (http://www.infoterra.com) and Aberdeen City Council (AAC). Field-based GIS mapping was also undertaken to map the location of some geographical features, for example, harbor cranes using a combination of a PDA, PocketGIS software, and a GPS with the help of a local Aberdeen company, Positioning Resources (http://www.posres.com). The data acquired and processed was subsequently uploaded to a Web site, but could just have easily formed the basis for developing a virtual field course on mobile GIS using WebCT (Figure 19).

Coastal Search and Rescue

In coastal search and rescue operations, access to geographical data and information is vital. Such information may be required during both the search and the rescue stages (Green and King 2002). While some relevant data and information may already be available, in the form of paper and digital maps and hydrographic charts, much of the baseline data and information required is currently not available at a scale that is useful to an operation, and therefore it must be collected in the field. The acquisition of local geographical knowledge and information, for example, requires fieldwork, often carried out on the move, with the aid of a range of mobile geospatial technologies. Field-data acquisition can include field sketches or detailed mapping of an access footpath to a beach; Short Message Service (SMS); sonar, radar, digital images, and video; laser direction and distance finder; Radio Technical Commission for Maritime Applications (RTCM); radio receiver Direct Access Radar Channel (DARC) service; sound, voice, fax, text, and MMS. Advantage can also be taken of the terrestrial GSM network or GLOBALSTAR (satellite telecommunications) for transmission. Integration of this data can provide a framework for an Internet-based decision-support system. One fieldwork scenario might be to use a PDA and mobile phone to upload a datafile to an online GIS, e.g., ESRI ArcIMS; an on-board PC with wireless access to the Internet accessing the ArcIMS-based online decision-support system; a digital camera that sends photographs by e-mail on a mobile phone, e.g., a picture of the coast from the seaward side to the local Coast Guard either on board a ship or to a rescue team on the cliff top; sonar information that can be uploaded to an ArcIMS system and combined with an Ordnance Survey digital coastline; a video clip, panoramic photograph, or field sketch (Figure 20) of a section of the cliffline that can be zipped and sent as an attachment by e-mail.

Figure 19 – Students and George Ritchie of Positioning Resources (http://www.posres.com) from the University of Aberdeen Summer School Geography Masterclass (http://www.abdn.ac.uk/cmczm/masterclass/index.htm) Using a Portable Computer, a GPS, and PocketGIS Software for a mapping exercise at Aberdeen Harbor

Coastal Zone Management

A Geo-Information Decision Support Processing and Dissemination System (GDSPDS) was developed as part of a research project undertaken by the Center for Marine and Coastal Zone Management (CMCZM) in the Department of Geography and Environment, University of Aberdeen. The objective was to develop an online Decision Support System (DSS) to aid in Integrated Coastal Zone Management (ICZM), a component of which incorporated mobile field-data collection and access to information in the field. The project sought to make greater use of remote sensing data, geographic information systems, and the Internet to deliver information that coastal zone managers

Figure 20 – A field sketch of a section of coastline (courtesy of Joanna McDonald, MRI, Scotland, UK)

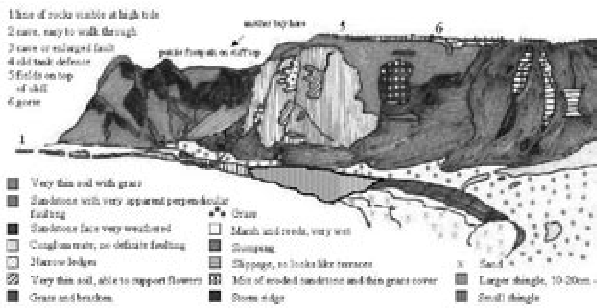
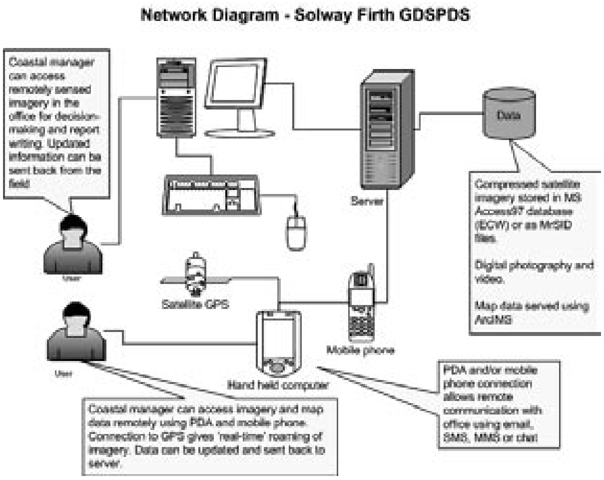


Figure 21 – The GDSPDS Internet-Based System Developed at the University of Aberdeen



need to make their day-to-day decisions. The system was developed for the Solway Firth on the border of Scotland and England. Figure 21 shows a diagram for the GDSPDS system and some images taken of field-data collection and access to information using a Compaq Aero 2160, a Garmin GPS, a WAP-enabled mobile phone, and ESRI's ArcPad.

Fire

Bower (2001) describes the application of a PDA using ESRI's ArcPad GIS and GPS by the Bureau of Land Management in El Centro, California, for "on-the-fly" mapping of fire areas during aerial over-flights. The benefit of using the GIS on a PDA is the ease with which it facilitates mapping in the field and sharing the map data using the IR-enabled ports on the hardware. In the future it is hoped that the wireless technology will enable on-site access to relevant map and image data (http://gis.esri.com/library/userconf/proc01/professional/abstracts/a1075.html).

Another similar firefighting application using GIS on pocket-sized hardware platforms is detailed by Johnson (2001). During any emergency, access to multiple sources of information is needed. Traditional maps do not allow for easy integration and comparison of data from different sources, and are not easy to use in the field or for sharing information. Portable computers and associated hardware running GIS software, while applied in recent years as a solution, are considered cumbersome in a helicopter or truck where there is limited space to operate. An alternative was to provide firefighters with a handheld PC, ArcPad mapping software, and a GPS receiver to map the location and perimeter defining the spread of a fire. The addition of wireless capabilities will later allow communicating the information to others from the aerial mission (http://www.esri.com/news/arcuser/0401/viejas.html).

Utilities

Utility companies (water, electricity, gas) increasingly must deliver information in the field to their workforces. Their aim is to provide customers with better service through more effective delivery of information to repair crews via mobile devices that can link to a wide range of database information while these fieldworkers are out of the office. Ultimately, such access to information enhances work efficiency and customer service (http://www.infowave.com/solutions/utilities.html). The role of the mobile technologies can also be extended to provide tools for tracking tasks, time sheets, inventory, packages, dispatch, and location-based services (http://www.nextel.com/about/enterprise/wbs/packaged_apps_utility.shtml).

Products such as DISYS (Digital Intelligence Systems) MyWorkforce (http://www.mymobileworkforce.com/news_nextel.html) allow information to be accessed via a mobile phone or a PDA, and with the addition of GPS tracking and a digital map can provide an office manager with information about the proximity of a fieldworker to a customer. Many other examples of similar combinations of geospatial technology utilize GPS and mobile phones and digital maps for location and route planning, for example, fleet management, delivery services, and job dispatching.

Local Authorities (Street Furniture, Maintenance, Tree Inventory)

Mobile geospatial technology has been an ideal development for inventories. Many local authorities and other organizations have rapidly migrated from portable computers to a combination of a PDA (or similar device), a GPS, GIS software for pocket PCs, and other peripherals such as digital cameras. This combination is extremely useful for recording the location of street furniture (e.g., lampposts), urban tree inventory, and maintenance records. Positioning Resources (http://www.posres.com) has used such a combination for a number of applications where the locations of objects are required, complete with records of their conditions. PocketGIS, for example, can be customized to provide specialized attribute record interfaces to facilitate ease of recording in the field including symbolization and digital photographs. Similar types of applications have been reported in the United States for road-sign inventory using ESRI's ArcPad (http://www.esri.com/news/arcnews/winter0102articles/boulder-cnty.html). In addition to providing cost-effective solutions to tasks that previously required a lot of effort and paperwork, mobile technology has provided up-to-date maps for personnel, improved the portability of information, updated capability and access to information, and increased organizational benefits.

Another novel application using ArcPad has been developed in California where mobile GIS has been employed for weed management to reduce fire and health hazards (http://www.esri.com/news/arcnews/summer02articles/city-of-riverside.html). In this example, ArcPad was customized to help the end user with the software for the application. GPS provided locational data that allowed the user to interact with a land-parcel map to check for compliance. In this application, the resulting information was uploaded to a desktop GIS and ultimately into ArcIMS for the Web.

Precision Agriculture and Viticulture

The capability to map agricultural or horticultural crops, to monitor their status, and to store this information is very important for cost-effective application of fertilizers, pesticides, or water to fields, especially when crops have high economic values such as fruit, e.g., grapes. GIS, GPS, and remote sensing have successfully been applied to field-data collection, processing, analysis, and visualization for agricultural and horticultural crops.

While many such applications have considered using desktop computers, portable computers, PDAs, and GPS offer a new suite of tools for mapping the fields or vineyards together with the potential to capture attribute data that can then form the basis for input to databases for management and analysis. Data can be gathered in the field directly or can be downloaded from on-site data-logging equipment. For example, fieldworkers can now easily record the number of buds per vine, the crop damage following a hailstorm, or the distribution of beneficial insects on a PDA, information that they previously had to record by hand onto a form attached to a clipboard. Data collected in the field can then be placed into a database on a desktop computer in the office. Palm PDAs with GPS are also being used to precisely match vineyard locations with their corresponding attribute data. This can help to identify differences in environmental conditions across a vineyard and also productivity over blocks of vines. An example from California cites the use of a Compaq iPAQ 3650 and a Trimble AgGPS 132 GPS and the HGIS software. Mapping field boundaries and changes in elevation and recording soil-sample data are also some of the ways to provide information to assist in vineyard management. Multitemporal layers of information can be created, overlaid, and correlated to assist in making management decisions that include knowing where to add fertilizers or to irrigate, and subsequently to provide the basis for even more informed management decisions (Pierce 2000; Stern 2004).

Botanical Garden Mapping

Garden Notepad is part of the BG-Mapping suite of software products including BG-BASE and GreVid (http://www.bg-map.com/), and provides a software tool running on a PDA for capturing plant information that can then be stored on BG-BASE and viewed using GreVid. Attribute information on plant condition, diameter at breast height (DBH), number of trunks, sex, reproductive status, spread, and height can be recorded, together with additional information, in the form of notes. Botanical gardens, arboretums, and plantations are now using this product to keep an inventory of their plant collections.

Location-Based Services

Location-based services are gradually being provided to more mobile users either through PDAs or mobile phones. They provide Positions, Events, Distributions (e.g., demographics), Assets, Service Points, Routes, Context (Overview), Directories, Transactions, and Sites (http://www.jlocationservices.com/). Some examples are shown in Table 5. At present, many applications largely consist of drawing users' attention to different types of services offered at particular locations. Typical examples are: restaurants, shops, weather stations, houses, nursing homes, and Automatic Teller Machines (ATMs) (Figure 22). Such services may provide information on the proximity to a geographical location or may devulge an address to a site or service, or may determine routing information such as a precise description of a route, either on foot or by car. Some of the applications also may deliver map information, often through the Internet, to mobile phones and/or to PDAs (http://gis.esri.com/library/userconf/proc01/professional/abstracts/a1015.html). Other information delivery may take the form of geographic and spatial searches using geocoding and reverse geocoding (The process of assigning geographic locations to attribute data — www.pasda.psu.edu/outreach/glossary.shtml).

Figure 22 – A Screen Grab of VISA ATM Location-Based Services (courtesy of http://www.jlocationservices.com/showcase/lbs_services.html)

Today, in their relatively early stages of development, many of these applications are affected by the display limitations of mobile devices, that is, by the amount of information that can be viewed at any one time, and by the need to navigate the information using small keyboard buttons. These limitations currently make many of the services quite difficult to use for the end user (Kewney 2004). Furthermore, while many location-based services are operational, the almost endless succession of new models of mobile devices with new screens and resolutions, and the use of new image formats makes it difficult for the end user to keep pace with the technology, even if each new generation of mobile devices offers additional functionality.

Besides offering regular services, mobile location-based services can provide end users with the capability to access databases while the users are on the move. Information can be accessed on a portable computer, using products such as ESRI's ArcFM Viewer, providing access to up-to-date information using the latest analytical and display tools. Other information that can be provided to mobile users via the Web includes personalized weather and driving information, e.g., RouteWAP™ (using RouteMAP IMS, a product of RTSe) gives road directions to drivers via mobile phones.

A wide range of other location-based services are described at http://www.jlocationservices.com/.

Table 5 – Types of Location-Based Information and Location Services

Types of Location Information	Location Services		
	Consumer	Business	Government
Positions	•Where am I (map, address, place)? •Where is (person, business, place,...)?	•Contact nearest field service personnel. •Where is this business located?	•Location-sensitive reporting. •What's your 20?
Events	•Car broken down ... need help. •Medical alert!	•Local training announcements. •Traffic alert!	•Local public announcements. •Accident alert!
Distributions	•House hunting in low-density area. •Vacationing near highest concentration of....	•High growth trend? •Sales patterns?	•Growth patterns? •Per-capita greenspace?
Assets	•Where is my car? •Lowest insurance rates?	•Where are my dispatched repair trucks? •Status of my holdings?	•Where are the snowplows? •Road maintenance.
Service Points	•Tell me when I'm near where I'm going. •Where are the sales?	•Where are my customers, given target profile? •Targeted advertising.	•Economic development areas? •New zoning.
Routes	•How do I get there (address, place)? •Fastest route (given traffic situation)?	•Best delivery route (given shipping manifest, traffic, and weather)? •Taxi dispatch.	•Traffic patterns? •Emergency dispatch.
Context (Overview)	•Nearest visible landmark? •Show me the nearest___ (business, place,...)	•What's near the hotel? •Show me car rentals near the airport.	•Collaborative economic planning. •Local commerce.
Directories	•Looking for nearest___ (specialist,...) •Where can I buy (product, service)?	•Best supplier within next two hours? •Nearest repair services?	•Public services. •Outsourcing?
Transactions	•Lowest shipping rates? •Must purchase in specific location.	•Low-cost distribution services? •Location-sensitive quickdial.	•Tax revenues. •Location-sensitive tolls.
Sites	•Candidate properties to build my house? •Places to visit?	•Candidate store sites? •Optimum cell- tower locations?	•New schools? •Environmental monitoring stations?

(Source: http://www.jlocationservices.com/education/what_lbs.htm)

Medical

Medical and environmental health applications of the mobile technologies are relatively recent. Schmidt and Dunkler (2004), for example, describe using mobile technologies to monitor patient health in Germany. While patient monitoring is not new, advances in information and communication technologies, such as miniaturization, now provide significant opportunities to improve the way in which this can be accomplished and the flexibility using wireless connections and mobile devices. Wireless devices can be used to measure parameters such as temperature, pulse, and blood-oxygen saturation. The information logged or recorded then can be retrieved using standard PCs, notebooks, PDAs, or mobile phones. Requirements for reliable transmission of sensitive and confidential information are met by using automatic encryption. The concept of a wireless Body Area Network (BAN) linking wireless connections to medical sensors can assist in patient care and rapid response of a medical team in an emergency. Telemedicine has many applications, ranging from emergency services to home care and even to physical-exercise training. Additional benefits can include a reduction in the duration of patient stays in the hospital, the costs of examinations, and even claims for medical insurance.

Others such as Elgethun et al. (2003) have used a GPS tracking system contained in a vest to record the movement of young children for exposure assessment studies in a wide range of environments ranging from a vehicle to inside a house or school building. The information is then transferred to a desktop GIS for map overlay, visualization, and tabular analysis.

Similar ideas have been proposed as the basis for monitoring the relationship between personal incidence of asthma and environmental variables such as air pressure, wind, and pollution.

Forestry and Woodland

An increasing number of forest-management companies now require both rapid and timely forest and tree inventories. The Woodland Stewardship Company, for example, has used the PocketGIS (http://www.pocketsystems.co.uk) field-data capture software and laser rangefinders to capture data and to produce maps. Using Ordnance Survey data downloaded onto a Husky palm-top, an OmniSTAR DGPS, and a laser rangefinder, data on tree heights, diameters, and crown spreads can be recorded using PocketGIS and uploaded to a desktop GIS for analysis.

ForestPad™ (http://www.gisnetsf.com/forestpad_en.php) is another example of a PDA-based system designed for forest inventorying and mapping applications (Figure 22). This product is one of the GISnet Spatial Framework™ (GNSF) products consisting of client applications using server services where the client can be a mobile device such as a PDA or mobile phone that provides fieldworkers with the capability to remotely access databases as well as to update spatial information on the move. It combines a system for field survey and mapping. As with any other PDA GIS application, it is possible to digitize points and areas on screen. ForestPad is based on MapLT®, the Java map component of GISnet that includes basic GIS functions such as zoom, pan, layer control, query, and an information tool necessary for mobile mapping applications. Although ForestPad is currently available for use on the Husky Fex21, it can also be adjusted to run on other mobile devices by using the Java runtime environment for the PDA device. In addition, raster images can be used as base maps.

Biological

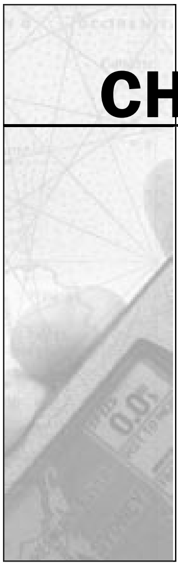
Researchers in the Oxford Forestry Institute, Department of Plant Sciences at Oxford University, are currently using PocketGIS (http://www.pocketsystems.co.uk) in the collaborative project FLAXIGEN. FLAXIGEN is a European project that aims to develop practical seed-collection strategies for the genetic resources of ash species. Part of the project involves temporal mapping of flowering trees in woodland areas to build up a picture of gene flow and mating patterns. PocketGIS data-capture software has replaced traditional mapping work usually undertaken with a tape measure and a handheld compass, manual recording of the data, and subsequent production of a map by traditional or computer-based means. Ordnance Survey map data, downloaded to a Husky handheld computer using the PocketGIS software, was used together with distance and bearing data recorded using a laser rangefinder and digital compass to map the spatial location of each tree. The locations, together with attributes, such as maturity, canopy exposure, and DBH, were placed in the PocketGIS database. Information gathered in the field was subsequently uploaded to a desktop GIS for analysis and mapping (Positioning Resources Application Sheet, 2004a).

Transport

Translink from Northern Ireland is using PocketGIS and differential GPS to collect data and images and to map all bus stops and shelters making up its transport network. A database of information is compiled that details the attributes of each bus stop. Digital images are taken of each bus stop and are linked to the main GIS database. Subsequently, this information is being input to the corporate GIS. Some of the data collected is also being used in BusTrak, a bus Real Time Information Project in Belfast. PocketGIS is also being used to store digital imagery and information about the positioning of directional and information signage along roadways for all Translink bus and rail stations. Ultimately, this will all form part of a digitally georeferenced infrastructural assets register (Positioning Resources Application Sheet, 2004b).

Homeland Security

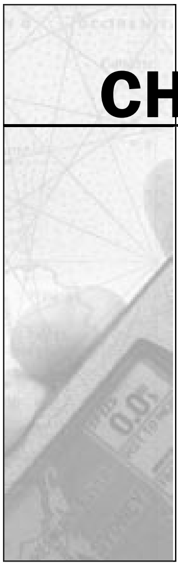
Following September 11, 2001, it became apparent just how important access to data and information is in the context of decision making in emergency situations. Homeland security requires rapid access to geospatial information and the capability to visualize it on the move. Such information can be used for detection, preparedness, prevention, protection, and response and recovery (Federal Geographic Data Committee (FGDC) — http://www.fgdc.gov/publications/homeland.html). Autodesk has developed a Homeland Security Initiative (http://www.autodesk.com/his) to deliver design and mapping applications for public safety and emergency management. Software produced by Autodesk has been designed to run on a tablet PC with wireless connectivity for mobile access to geographical data and information. Further related developments include the Location-Based Services (LBS) that are promoted for homeland security as described by Niedzwiadek (http://www.jlocationservices.com/Newsletter/Oct.02/Location-Based Services for Homeland Security.pdf). These utilize wireless networks, PDAs, and the Internet. The advantage of LBS is the wireless support for mobile platforms facilitating the exchange of vital geographical information between end users in the field with the aid of electronic maps and images. According to Niedzwiadek, these have potential for public safety and emergency response, public health, and critical infrastructure protection, as well as other security applications. An important issue for the exchange of information using mobile technology is standards such as those required to facilitate discovery and retrieval of distributed data and information via Web services. These are being pursued through the OpenLS Initiative (http://www.opengeospatial.org/functional/?page=ols) and the OpenGIS Consortium (OGC) (now renamed Open Geospatial Consortium — http://www.opengeospatial.org/).



CHAPTER 12

SOME LIMITATIONS

Unfortunately, all these emerging technologies also have a number of practical and operational limitations. Much of the mobile technology, for example, is still at a relatively early stage in its development and a number of areas exist in which problems can arise. These include, for example, battery-power life that is still not adequate for prolonged use of computer-based equipment in the field. Not all areas of the world can be covered reliably yet with mobile communications or GPS receivers, and in some locations, poor reception may provide only an intermittent service or a poor "view" of the required number of satellites to provide a locational fix. Mobile data communication networks are also still quite slow and this prohibits rapid communication of large data sets from a mobile unit to a remote server and vice versa. Unfortunately, current mobile links via WAP-enabled phones still rely on relatively old technology, and reception is not always good, frequently leading to loss of the link. Using portable computers and PDAs in the field can also be quite difficult, and restrictive as not all are lightweight and rugged; some have limited memory and data storage capacity, while others have small screens, no keyboard (Krogstie 2003), poor screen illumination (in sunlight), and small window or viewport dimensions that are incompatible with the practical use and display of graphics, imagery, and Web site pages.



CHAPTER 13

FUTURE

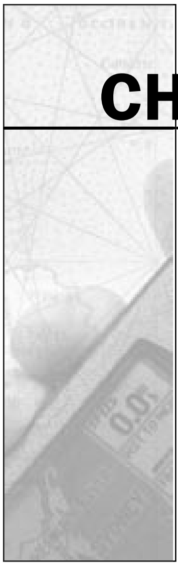
Despite these limitations and problems, it also must be remembered that the geospatial technologies are still developing at a very fast pace and many of these limitations are already being addressed. For example, the limitations of the small screen sizes on PDAs are being overcome using software solutions, as are improvements in the transmission times of large image data sets using data-compression techniques. Already, Condat's Skyware (ESRI, 2002), integrated within ESRI's Geography Network, is providing the means for "clients" to access GIS content with any mobile device, e.g., Smartphone, wireless PDA, or laptop, dynamically optimizing the content to match their device capabilities—display size, menu structure, navigation, color depth, resolution, layout, and available memory.

Wireless technology (e.g., Bluetooth) is also greatly improving the opportunities for linking mobile hardware such as phones and PDAs. Some cars now have plug-in facilities for using PDAs. The new BMW Mini, for example, offers as one of its options a PDA integration kit for the Compaq iPAQ, which includes a central unit with charge electronics, a bracket for memory extension cards, and the specific Mini PDA software (Figure 23) (BMW Group, 2002).

Mobile phone technology is also developing very quickly. Second-generation GSM networks already

Figure 23 – Bluetooth-enabled PDA in the BMW Mini (courtesy of BMW – http://www.bmw.com)

deliver mobile voice and data services such as SMS/text messaging. The GPRS-enabled networks provide services such as color Internet browsing, e-mail on the move, powerful visual communications, multimedia messages, and location-based services. The third-generation (3GSM) products will provide mobile multimedia services focusing on visual communication. Enhancements in data-handling capability will be provided with EDGE-delivering mobile services, such as video clip and music download, full multimedia messaging, high-speed color Internet access, and e-mail on the move. All these developments will greatly enhance the possibilities for accessing data and information at any time and anywhere (http://www.gsmworld.com/technology/edge/index.shtml).



CHAPTER 14

SUMMARY AND CONCLUSIONS

As with the mobile phone, so too, has the PDA become a staple of daily life. These devices are complemented by the slightly larger platforms such as laptops and tablet PCs. Their affordability, portability, and usability—together with their functionality and convenience factor—have largely been responsible for driving a market demand that has grown very rapidly with time. As the technology has developed, such devices have become more integrated, providing multiple functionality in a single handheld device. For example, many of the new generation of mobile phones also serve dual functions as PDAs. The wider adoption of these particular devices has really only been limited by their bulk, which makes them less convenient than many of the smaller mobile phones. As yet, no single device has really successfully served both purposes, although some, such as the O2 Xda, have come quite close. Besides size, factors such as cost, screen size, design, functionality, usability, speed, and storage and memory capacity have all limited their general appeal to the masses. Often the devices provided by different manufacturers vary only by the degree to which they compromise between these different factors. In most cases, the higher the price, the more powerful and flexible the hardware is, though not always sufficient to justify purchase.

While each new model of a mobile phone or a PDA on the market has generally become physically smaller, more powerful, and more complete, with more on-board 'gimmicks' and 'gadgets', such as a higher-definition camera, ultimately the small physical size of the device itself limits practicality in the field, and the ease with which the end user can work with the device. In some cases, with the smaller screens, some compensation has been made with higher-definition displays and smaller text. With smaller keyboards, however, it is necessary to possess both the skill to use the device and the nimble fingers to access the device! Although the market for new devices is often initially quite small, especially because of their cost, longer-term adoption of such devices can also be quite slow, especially if the device does not find mass appeal because of the physical size, weight, screen, processor speed, usability, and competition provided by other manufacturers. There is also the problem of new models constantly appearing on the market. Each new model usually benefits from having a more powerful processor and more functionality, new software, and a more user-friendly interface. However, as soon as one model is released, another one, potentially better, is usually on its way—such is the speed with which this technology is now developing. One thing, however, that has perhaps not improved very much to date is the plug-and-play nature of much of the hardware. While Bluetooth has helped to minimize the need for cables and setup, configuring mobile phones and PDAs is still not always as simple or as straightforward as suggested in the promotional literature, as can be seen by the detailed manuals that still frequently accompany most mobile devices. This usually means reference is necessary to other documents, which are most often found on the Internet. However, relatively new products such as Blackberry (http://www.blackberry.com/ provide new opportunities for easy access to email and the web on the move.

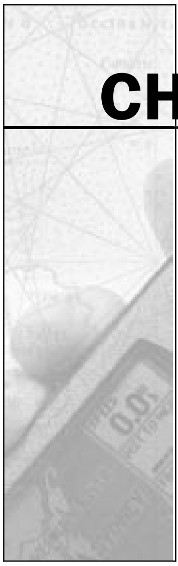
Nevertheless, new processors, larger memory and storage capacity, and larger and more compact storage media have considerably aided the potential role and practical use of mobile computing technology. Hardware and software applications are continually evolving, and nearly every day, new examples are more powerful, easier to use, offer more plug-and-play, are smaller and more mobile, cost less, and are even more functional than they have been in the past. PDAs, GPS, mobile phones, smaller printers, digital still and video cameras, and mapping tools are just some of the examples considered.

As awareness and demand for the capability to both gather and process geospatial data (often in real time) grows, so the products, which only a few years ago were very expensive and limited by the technology, are now becoming all-pervasive in the workplace. The development of mobile geospatial technologies, together with vastly improved communications networks, are providing us with the capability to gather data anywhere and anytime, to process it "on the fly," to download and upload it remotely, and to produce updated maps and visualizations en route. Furthermore, we are increasingly able to move closer towards a paperless environment, with the benefit of the direct-to-digital approach, thus minimizing sources of error, and expanding the ability to synchronize data in the office with that in the field.

Although the technology is getting much easier to use, however, we still need knowledge and understanding to allow us to make the best use of the technology, as and when it is appropriate. As noted by Maguire (2001, 6), *a mobile GIS is not a conventional GIS modified to operate on a smaller computer, but a system built using a fundamentally new paradigm.* It is important, therefore, to be aware of the technologies available, the theory, their potential applications, and how to use them.

The different technologies available to us now are gradually becoming more integrated, making it easier to put data together and to process it, as well as to generate a more complete picture of the environment. Mobile GIS is now a reality and we are in the era of "smart decisions." Such technology cannot and must not be ignored. While the technology is not yet perfect, we should nevertheless seek to embrace this technology for what it is, an exciting development that offers a significant breakthrough in providing a powerful suite of tools to help us gather data and process it into information.

We also must be able to gather data using a wide variety of different scales and, moreover, to be able to turn this data into information that we can use to help us make decisions. As noted by Harrington (2003), these "go-anywhere gadgets" allow us to do more wherever we are because we have more information at our fingertips all of the time. Already, in terms of productivity and timeliness, mobile GIS devices are considered a huge success. Geographical data collection, processing, analysis, and visualization are becoming increasingly flexible and offer individuals an exciting suite of tools. The future of geographical data collection lies with these technologies. As Green and King (2004) recently noted, *pencils are out, the stylus is in!*



CHAPTER 15

REFERENCES

Bower, R. 2001. Fires, and plants, and lizards, oh my! ArcPad™ GIS. Proceedings of the ESRI® User Conference 2001. September 2004, http://gis.esri.com/library/userconf/proc01/professional/abstracts/a1075.html.

Chivers, M. 2003. Differential GPS explained. ArcUser 6(1): 40-41.

Elgethun, K., R. A. Fenske, M. G. Yost, and G. J. Palcisko. 2003. Time-location analysis for exposure assessment studies of children using a novel global positioning system instrument. Environmental Health Perspectives 111(1): 115-22.

Engelhardt, J.. 2003. Tablet PCs for mobile GIS. September 2004, http://www.geospatial-online.com/geospatialsolutions/article/articleDetail.jsp?id=45442, 3 p.

FGDC. Homeland security and geographic information systems. How GIS and mapping technology can save lives and protect property in post-September 11th America. December 2004, http://www.fgdc.gov/publications/homeland.html.

Green, D. R., and S. D. King. 2003. Pencil out, stylus in: geospatial technologies give fieldwork a new dimension. Geography 89(1): 58-70.

Green, D. R., S. D. King, and D. C. Morton. 1998. Small-scale airborne data acquisition systems to monitor and map the coastal environment. D. C. Morton and S. D. King, Paper/Poster Paper for the Marine and Coastal Environments Conference, San Diego, October 1998. Proceedings 1: 439-49.

Harrington, A. 2003. Mobile GIS. Increase productivity with timely data. September 2004, http://www.geoplace.com/gw/2003/0302/0302mgis.asp.

Johnson, R. 2001. Firefighters pioneer pocket-sized GIS collection. ArcUser (April-June 2001), September 2004, http://www.esri.com/news/arcuser/040/viejas.html.

Kay, A. 2004. September 2004, http://www.honco.net/os/kay.html.

Kewney, G. 2004. Location, location, location… Personal Computer World (September): 37.

Krogstie, J. 2003. Applications and service platforms for the mobile user—introduction. ERCIM News 54(July): 8-9.

Maguire, D. 2001. Mobile geographic services come of age: ESRI® dives into wireless markets. GeoInformatics (March): 6-9.

Niedzwiadek, H. Location-based services for homeland security. December 2004, http://www.jlocationservices.com/Newsletter/Oct.02/Location-Based Services for Homeland Security.pdf, 4 p.

Pierce, F. J. 2000. Precision agriculture in grape production. 2000 Meeting Washington Grape Society, http://www.grapesociety.org/2000meetingproceedings/precisionagriculture.html.

Positioning Resources Factsheet. 2004. September, http://www.posres.co.uk.

Positioning Resources Application Sheet. 2004a. September, http://www.posres.co.uk.

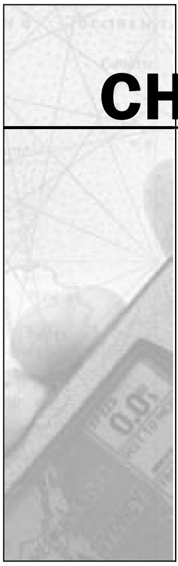
Positioning Resources Application Sheet. 2004b. September, http://www.posres.co.uk.

Roberts, A. 2001. Notewriting goes digital. Handheld computers help you better manage data, boost efficiencies in the field. The Grower, Vance Publishing, September 2004, http://www.growermagazine.com/home/2001_PDAs09.htm.

Schmidt, J., and R. Dunkler. 2004. Medicine on the move in Germany: mobile monitoring sensor technology for health. GeoInformatics 7(July/August): 18-19.

Stern, R. 2004. A world of data in your palm—handheld computers help free you from paper, boosting efficiency and productivity. The Grower, Vance Publishing, September, http://www.growermagazine.com/home/03-04MarPDA.html.

Thales. 2004. MobileMapper CE Factsheet. September, http://www.thalesnavigation.com



CHAPTER 16

FURTHER READING

Aber, J. S., S. W. Aber, and F. Pavri. 2002. Unmanned small-format aerial photography from kites for acquiring large-scale, high-resolution, multi-view-angle imagery. Pecora 15/Land Satellite Information IV/ISPRS Commission I/FIEOS 2002 Conference Proceedings, 6 p.

BMW Group. 2002. Mini Accessories. Booklet. Munich, Germany.

Corbley, K. P. 2003. Mobile GIS improves data collection. ArcUser Online (January-March): 4 p., September 2004, http://www.esri.com/news/arcuser/0103/elephants1of2.html.

Compaq. 2002. Compaq Tablet PC TC1000 Specifications.

ESRI®. 2000. ArcPad™: mobile mapping and GIS. ESRI® White Paper, 7 p.

ESRI®. 2002. Condat provides mobile device support for ESRI®'s geography network. ESRI® press release, September 2004, http://www.esri.com/news/releases/02_1qtr/condat.html, 2 p.

Green, D. R. 1995. Preserving a fragile environment: integrating technology to study the Ythan Estuary. Mapping Awareness 9(3, April 1995): 28-30.

Green, D. R., and S. D. King. 2002. interactive Search and Rescue System—iSARS. Unpublished research proposal. Center for Marine and Coastal Zone Management, University of Aberdeen, Aberdeen, Scotland, UK.

Green, D. R., S. D. King, and M. Carlisle. 2002. A geospatial toolkit to support coastal zone management. Paper presented at the British Cartographic Society's 39th Annual Symposium and Map Curators' Group Workshop, September 2002. The University of Portsmouth, UK, 8 p.

Green, D. R., S. D. King, and D. C. Morton. 1998. Small-scale airborne data acquisition systems to monitor and map the coastal environment. D. C. Morton and S. D. King, Paper/Poster Paper for the Marine and Coastal Environments Conference, San Diego, October 1998. Proceedings 1: 439-49.

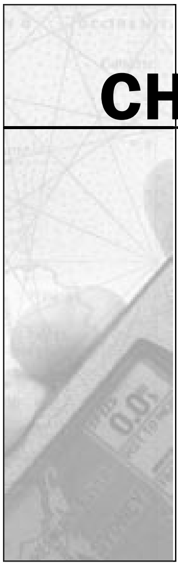
Green, D. R., and D. C. Morton. 1994. Acquiring environmental remotely sensed data for input to geographic information systems. Proceedings of the AGI 1994 Conference: Broadening Your Horizons, Birmingham, UK, November 1994, 15.3.1-15.3.27.

Martin, M. 2003. Be mobile and connected. GIM International (February 2003): 62-63.

Udani, P. M., and U. K. Goel. 2002. GPS-enabled mobile GIS services. GIS development. Map India

2002, September 2004, http://www.gisdevelopment.net/technology/gps/techgp0021.htm.

Wedler, E. 1984. Experience with radio-controlled aircraft in remote sensing applications. Proceedings 1984 ASP-ARSM Convention, Washington, D.C., March 1984, 44-54.



CHAPTER 17

INTERNET ADDRESSES

http://amstrad.cpc.free.fr/index_e.html (Amstrad)

http://ermapper.com/press_view.aspx?PRESS_RELEASE_ID=314 (ERMapper)

http://extranet.mapinfo.com/products/Overview.cfm?productid=1661 (Mapinfo)

http://gis.esri.com/library/userconf/proc01/professional/abstracts/a1015.html (ESRI®)

http://gis.esri.com/library/userconf/proc01/professional/abstracts/a1075.html (ESRI®)

http://gis.esri.com/library/userconf/proc01/professional/papers/pap402/p402.htm (ESRI®)

http://gislounge.com/ll/mobilegis.shtml (GIS Lounge, Mobile and Field GIS)

http://global.acer.com (ACER)

http://lenewa.netsync.net/public/CP0297.htm (Thomas H. Obourn, Precision Viticulture)

http://map.sdsu.edu/mobilegis/ (Integrated Mobile GIS and Wireless Internet Image Servers for Environmental Monitoring and Management)

http://mobile.eric-poncet.com/frames.html (Mobile.EricPoncet.Com)

http://pda.toshiba.com (Toshiba)

http://winebusiness.com/html/MonthlyArticle.cfm?AId=55216&issueId=55195 (PDAs Budding in the Wine Industry, Zillah Bahar, Wine Business Online, June 15, 2002)

http://www.abc.net.au/rn/science/buzz/stories/s403123.htm (Precision Agriculture Monday, October 29, 2001)

http://www.aut (Autodesk)

http://www.bg-map.com/ (BGMAP)

http://www.bluetooth.com (Bluetooth®)

http://www.dell.com (Dell™)\

http://www.directionsmag.com/pressreleases.php?press_id=5672 (Directions Magazine, Earth Resource Mapping Releases ArcPad™®, v6.0 ECW Plug-in v1.0, October 2, 2002)

http://www.esri.com (ESRI®)

http://www.esri.com/news/arcnews/fall00articles/arcpad501.html (ESRI®)

http://www.esri.com/news/arcnews/summer02articles/albany-airport.html (ESRI®)

http://www.esri.com/news/arcnews/summer02articles/city-of-riverside.html (ESRI®)

http://www.esri.com/news/arcnews/winter0001articles/gisextended.html (ESRI®)

http://www.esri.com/news/arcnews/winter0102articles/boulder-cnty.html (ESRI®)

http://www.esri.com/news/arcuser/0103/

elephants1of2.html (ESRI®)

http://www.esri.com/news/arcuser/0401/bunchls.html (ESRI®)

http://www.esri.com/news/arcuser/0401/viejas.html (ESRI®)

http://www.fieldworker.com/prod_enterprise.html (FieldWorker)

http://www.geobasemap.com/products/gbm_mobile.htm/

http://www.geoconcept.com (GeoConcept)

http://www.geoinsight.com (GeoInsight International)

http://www.geoplace.com/gw/2003/0305/0305gint.asp (geoplace.com, Greg Pendleton, GIS Data Collection vs. Mobile GIS, GPS/GIS INTEGRATION)

http://www.gisdevelopment.net/proceedings/gita/2000/mobile/mobile008pf.htm (Mobile Geospatial Applications: A New GIS Paradigm, Tadeo H. Schultz, GITA 2000)

http://www.gisnetsf.com/forestpad_en.php (ForestPad)

http://www.grapesociety.org/2000meetingproceedings/precisionagriculture.html (F. J. Pierce, 2000 Meeting Washington Grape Society, Precision Agriculture in Grape Production)

http://www.growermagazine.com/home/03-04Mar-PDA.html (Renee Stern, 2004. A world of data in your palm—handheld computers help free you from paper, boosting efficiency and productivity. The Grower. Vance Publishing)

http://www.growermagazine.com/home/2001_PDAs09.htm (Amy Roberts, 2001. Notewriting goes digital. Handheld computers help you better manage data, boost efficiencies in the field. The Grower. Vance Publishing)

http://www.gsmworld.com/technology/bluetooth/index.shtml (GSM™ World)

http://www.handandgo.com (Handandgo)

http://www.handspring.com (Handspring)

http://www.handygis.com (HandyGIS)

http://www.hicam.com.au (HICAM)

http://www.honco.net/os/kay.html (The book and the computer—the Dynabook revisited, a conversation with Alan Kay)

http://www.hp.com (HP)

http://www.ibilttechnologies.com/gis_in.shtml (iBilt)

http://www.intergraph.com (Intergraph)

http://www.itronix.com (Itronix)

http://www.macromedia.com (Macromedia)

http://www.mapinfo.com

http://www.microsoft.com/windowsmobile/products/pocketpc/default.mspx (Microsoft®)

http://www.mindfusion.org/pocketchart.html (PocketChart)

http://www.mitac.com (MITAC)

http://www.packardbell.co.uk (Packard Bell)

http://www.palmone.com (Palm)

http://www.palmsource.com (Palm)

http://www.pocket.co.uk (PocketGIS)

http://www.pocketpc.com (Pocket PC)

http://www.posres.com (Positioning Resources)

http://www.posres.co.uk (Positioning Resources)

http://www.sonystyle.com (Sony®)

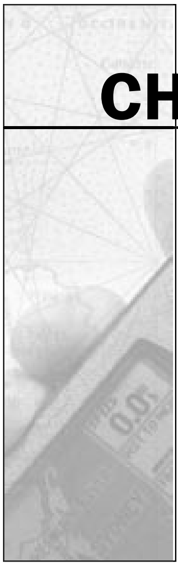
http://starpal.com/ (Starpal Handheld GIS)

http://www.surveysupplies.co.uk (Survey Supplies) http://www.thecore.nus.edu/writing/ccwp10/james/pda_history.html (PDA History, James Chew, National University of Singapore, 2000)

http://www.viewsonic.com/products/mobilewireless/ (ViewSonic)

http://www.wirelessfuturemagazine.com/ (wirelessfuturemagazine)

http://www.yakumo.com (Yakumo)



CHAPTER 18

ABOUT THE AUTHOR

David R. Green is Director of the Centre for Marine and Coastal Zone Management (CMCZM) and the Marine Resource Management (MRM) Program at the University of Aberdeen, Scotland,UK. He is also associated with the Aberdeen Institute for Coastal Science and Management (AICSM), and the Centre for Remote Sensing and Mapping Science (CRSMS). David is involved in a number of European funded projects, Nature-GIS, COASTWATCH, CORE-POINT, and CoPraNET. As well as being President of the EUCC-The Coastal Union, he is a past Chairman of the Association for Geographic Information. David is currently involved in the organization of CoastGIS 2005 to be held in Aberdeen, Scotland.