gvSIG Mobile on Openmoko: Ubiquitous Spatial Data at Oxford Archaeology

This presentation will outline the current use of GIS within a large commercial archaeology practitioner, the theory behind gvSIG mobile on the Openmoko platform and some of the results of the implementation so far. The combination of gvSIG mobile and the Openmoko platform has the opportunity to revolutionise not only archaeological practice, but also any discipline or industry that utilises, or even potentially utilises, spatial data infrastructures. Practitioners in the field are all too often separated from the technology and work flows utilised by office based workers with computers; this presentation demonstrates that by utilising Open soft- and hardware we can engage a new category of user with spatial data.

Keywords: Spatial Data Infrastructure, Openmoko, gvSIG mobile

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1: Introduction:

Oxford Archaeology is Europe's largest independent archaeological service provider and a major contributor of applied archaeological research. We employ over 400 members of staff on projects located from the north of Britain to the south of France, and often further afield. We are actively researching and developing hard- and software solutions that enable all members of staff to centre their work around access to spatial data. Our desk based operations are adopting a work flow centred upon gvSIG and we aim to provide the same tools to our field staff.

At Oxford Archaeology, a team of specialists with skills in hardware, GIS, databases and web application development work full-time towards creating a complete computing infrastructure for archaeologists. Our philosophy of "free IT everywhere" comprises digital field data capture, 3D site modelling and post excavation analysis. For us as a company and major employment provider, open source development means to struggle free of the unpredictability of vendors' licensing and pricing schemes, avoid product-specific lock-ins and build long-term, sustainable software and data infrastructures as well as transferable staff skills. But there are other, equally important factors in our decision to advocate and support free software usage and development.

Free software allows for the use of traditional “desktop” tools in new and innovative environments. Oxford Archaeology have chosen the Openmoko platform, a Linux based mobile phone, to be the digital recording tool for all of our on-site site; this paper will outline the use of gvSIG within a large commercial archaeology contractor and will discuss the theory behind, and the results of, porting gvSIG mobile to Openmoko.

2: GIS Development

GIS remain the most powerful spatial technology available and therefore quite naturally provide the backbone for excavation and survey data management, processing and visualization, at Oxford Archaeology just like countless other institutions. Archaeologists traditionally use GIS applications for the storage, interpretation, visualisation, and dissemination of spatial data. This data is drawn from a range of existing data sets, primary collected data, such as on-site surveying with GPS or Total Station devices and newly digitized sources, such as historic materials. Within traditional usage models, GIS data is exported to clients, usually in a CAD format, or is passed onto the graphics department who prepare it for printed publication. At all stages data takes the form of file formats.

What may be different about our case, however, is that as a company with now more than 400 employees we need to find another paradigm for our software infrastructure than a small research group or single excavation project. In our environment, interoperability, i.e. being able to pass data efficiently from one software and hardware component of the in-house workflow to another and to archive it in standard-compliant formats, is more important than feature richness of a single application. In such a setting, applications that do not integrate well into the global workflow and attempt to lock the user into vendor-specific file formats and protocols, cannot be part of a long-term solution and represent dead-end investments.

Whether due to a lack of transferable software and IT skills or just of general interest in the overarching concepts behind GIS technology -- archaeologists tend to adopt application-centric workflows based on very few products. Indeed, sometimes the term "GIS" itself seems to be used as a synonym for ESRI's ArcGIS product line (more precisely, the ArcView component of it). But this perception is dangerously narrow, as it threatens to limit the view on the wider, far more interesting and diversified GIS world.

In fact, today's GIS market is (fortunately) not dominated by a single vendor or product and there is much room for individual developments that cater for specific application needs. To make sure that they all tie together, the Open Geospatial Consortium (OGC; www.opengeospatial.org) provides open, durable standards for geodata file formats, web service and database protocols, and much more. As a result, the GIS world is open and integrative and puts much emphasis on interoperability and team work, allowing users to freely choose individual components and connect them together to get a job done instead of having to rely on complex, monolithic applications.

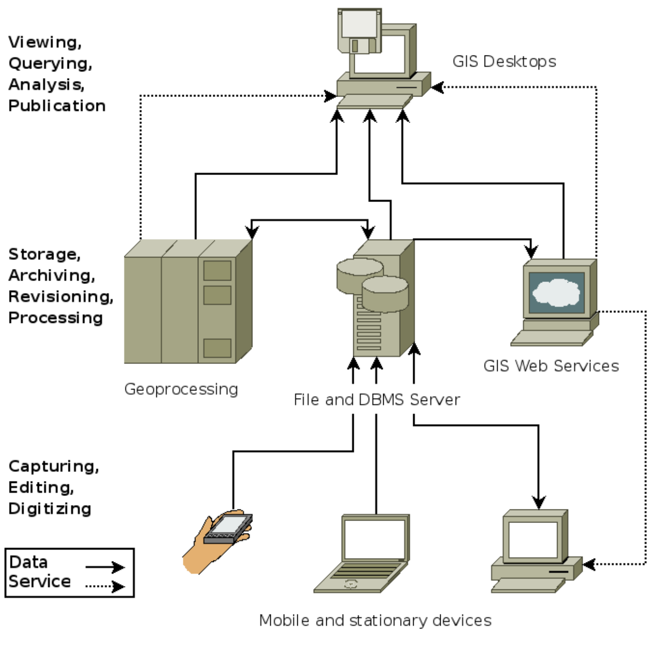

Figure 1: A spatial data infrastructure (SDI) for a complex workflow. Note that some data

and service paths and directions have been omitted in order to keep the picture simple.

3: Spatial Data Infrastructures

GIS applications are traditionally, and roughly, divided into desktop, workstation and web service types. Used in combination within a *spatial data infrastructure* (SDI), they cover an application range beyond the scope of any single GIS application (Fig. 1). The development of gvSIG mobile and its use within an appropriate SDI allow us to add a forth category to this list:

1. A minimal GIS workflow usually includes a desktop type GIS for interactive work such as geo-referencing, map editing, querying and layout. User-friendly graphical interfaces, Windows compatibility and good support for weakly structured, file-based workflows are among the most commonly demanded features of these applications. MapInfo, ArcView and Manifold are all well-known examples.

2. Workstation GIS, on the other hand, focus on non-interactive modelling, mass data management and batch processing. Popular examples of this GIS class are IDRISI, ArcInfo and the open source GRASS GIS (www.grass.itc.it). These applications offer powerful geo-processing capabilities that can easily be automated to provide efficient mass data manipulation and analysis.

3. Web service GIS can be deployed to offer mapping and analysis services on the internet or intranet. Users can request maps and perform simple querying and editing operations via a browser-based interface without needing to install software or worry about where and how the spatial data is stored. In addition, selected web-based geo-processing services can be used to provide more advanced analytical and data manipulation functions.

4. Mobile GIS applications allow users to both contribute raw data to the SDI and to query the results. Within archaeological contexts this allows all users to conduct their work whilst being aware of, and informed by, the spatial data that is usually produced as a distinct process to their own activities. GvSIG mobile obviously existed before Oxford Archaeology began undertaking research into the software, but our approach differs from traditional implementations because of our investment in an SDI and our desire to empower a wide range of staff often ignored within archaeological practice.

A major challenge in spatial data management is the difference between GIS and relational database models, the two most commonly employed by archaeologists (Fig. 2). GIS build complexity by overlaying geographic information. Relational Database Systems (such as Microsoft Access, MySQL or PostgreSQL), build complexity by linking fields in a table to fields in another table. Although the GIS vector model includes the concept of an attribute table, this represents only a 1:1 correspondence between a GIS layer and a DBMS table, and -- perhaps even more limiting -- between GIS map objects (*features*) and data rows in the attribute table. Information linked in via foreign keys in the DBMS model will be hard to manage. Common *1:n* or *m:n* relations, e.g. between features and artefacts or features and photographic documentation, can not be handled elegantly in the GIS front-end. In addition, the links between features and database records tend to be fragile. Changes in the database front-end may be hard to keep consistent with editing in the GIS. GIS with more flexible database support do exist (e.g. GRASS GIS is capable of linking a vector map to any number of database tables), but they are either still not flexible enough or have never left the world of academia and research labs.

The most effective remedy is to ``re-unite" features and attribute data by storing both in the same database table using a spatially enabled DBMS as core part of the SDI (Fig. 1). As an additional bonus, this also cures many other illnesses of file-based workflows by introducing proper team work practices such as revisions, flexible permissions management, concurrent access and a consistent, safe central data repository.

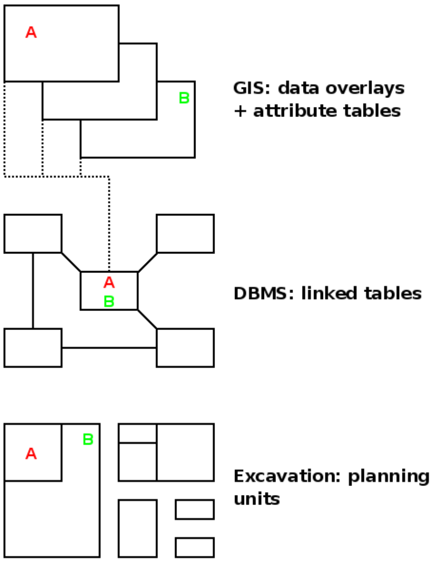

Figure 2: Two pieces of information (A,B) and their association with each other within different data structures.

ESRI's "Personal Geodatabase" is one option that comes to mind, but it suffers from the poor performance and limitations of a file-based database (most notably, a 2GB size limit) and missing interoperability necessitated by the vendor's licensing strategy. Other closed-source solutions such as ArcSDE and Oracle Spatial are mostly out of the question simply due to prohibitive licensing costs. A far more capable, free alternative is the open source PostgreSQL DBMS (www.postgresql.org) in combination with PostGIS (postgis.refractions.net), an extension that enables storage and querying of spatial data inside regular database tables. This solution stores GIS feature data as human-readable WKT format strings, making it easy to tightly integrate GIS and database back-ends. PostGIS is the *de facto* standard of spatial databases in the open source GIS world and integration with closed source GIS is making good progress, as well (e.g. see the zigGIS connector for ESRI ArcGIS: www.obtusesoft.com).

At Oxford Archaeology, we are currently establishing a fully OGC standards compliant SDI according to the design above, which will include all of our open and closed source spatial information components.

4: Ubiquitous Computing

A crucial element within the GIS workflow developed at Oxford Archaeology is the notion that data should be created digitally, and remain usable, by all members of staff in the field. This approach has previously gone under the moniker of "One Laptop Per Archaeologist" (OLPA - a nod towards the educational laptop programme with a similar name), and has been loosely described as an attempt to remove all pens and paper from Oxford Archaeology excavations. One element of this project is the planned replacement of all paper based context recording sheets with digital counterparts. Another key concept is the integration of ubiquitous site survey tools and GIS applications in the field with traditional recording techniques and synchronous communication from the excavation to the data storage centre.

Archaeologists primarily record the excavation they undertake on paper “context sheets”; these records are entered into a context database by a member of staff in the office. This process of replicating data entry introduces the opportunity for error and increased cost, whilst dramatically limiting the potentials for useful data transfer from the field, to specialists in the office and back to the workers at the excavation's edge. The OLPA project initially intended to provide a direct connection between the context database and the field based excavator by means of a wireless handheld device to be provided to every member of staff. It quickly became apparent, however, that we should be combing such tools with our SDI to improve the experience for our fieldstaff and to enrich our spatial information.

Such tools have long been promised to archaeologists, yet have often failed to meet expectations. However, we hope to finally succeed in providing ubiquitous computing tools by employing recent technological developments and our abstraction of the notion of a “computing device”. We began by considering the specifications a device meant for every member of staff should meet; it must be cheap enough to provide to hundreds of staff, it must be robust enough to survive out-door conditions, it must allow data entry and a form of wireless communication; most importantly, it must run a completely Open Source software stack in order to provide a sustainable platform. The One Laptop Per Child (OLPC) Foundation's XO laptop initially seemed to be a strong candidate for the position, but it soon became clear that we did not want to provide members of staff with a compacted or reduced computer; we aimed to provide our staff with an archaeological tool. Rather than aim for another consumer laptop design, we just wanted to provide a tool that could be used outside whilst engaging with digital data. There are plenty of devices that do this already; mobile phones, handheld GPS receivers, portable audio players, portable gaming devices. Such technology shows great usage possibilities and should make us curious as to whether it can guide our own thinking about the form factor of our tool (http://blogs.thehumanjourney.net/finds/entry/1).

We decided upon the FreeRunner mobile device from Openmoko (www.openmoko.com) as the base component of our digital recording toolset (Fig. 5). This is a mobile telephone, built on open hardware and running a GNU/Linux operating system (www.linux.org); FreeRunner is the name of the particular piece of hardware, whereas Openmoko refers to both the company manufacturing and selling the devices and is also the name of the operating system it runs. The phone, in actuality a handheld pc with cellular modem, includes high speed mobile Internet connectivity, a GPS receiver, WiFi, Bluetooth, a 400 MHz processor, 3D accelerometers, USB host mode and a 480 x 640 pixels touch-screen display. The device has a retail price of US $400 and will be available to archaeological contractors through Oxford Archaeology for a reduced price. On site, the FreeRunner shall be used in conjunction with a roll-up USB keyboard to complete remediated context sheets which are entered directly into the context database. Likewise, data can be returned the other way, providing the excavator with reference material as they request it. The ability to communicate with every member of staff will also bring great benefits to Oxford Archaeology. We are a company that regularly undertakes within a region a thousand miles long and we will now be able to communicate effectively; we can email staff as they dig and allow them to create their own social network experience. This is distinct from many popular web 2.0 approaches that offer little more than a “Facebook group for an excavation”, instead we allow all staff to become social members of the company and empower them with archaeological and spatial data.

Figure 5: The OpenMoko FreeRunner device and some applications running on it (Total Open Station, tangoGPS and gvSIG Mobile).

By adopting such hardware we are able to draw upon some of the benefits provided by the digital devices mentioned above; no longer does a laptop need additional, expensive hardware to make it function like other pieces of equipment. The effects of this are most pronounced when considering the GIS, surveying and visualisation potentials of the FreeRunner device.

5: gvSIG Mobile on Openmoko

gvSIG Mobile originally appeared packaged for handheld devices running Microsoft's Windows Mobile operating system. This platform was undesirable for a number of reasons: At the time of release, the hardware running Windows Mobile devices was much less desirable than that of the Openmoko FreeRunner; it was not possible to buy a device with the same screen resolution as the FreeRunner and those available with similar specifications in other areas were often much more costly. Too costly, in fact, to be provided to every member of staff. Windows Mobile, as a closed source piece of software, was also very undesirable; whilst gvSIG remains open source and flexible to our requirements, we would not have been afforded the same luxuries by our operating system. As previously stated, we did not want to provide staff with a cut down computer, as such there was no intention to provide a “Windows in your hand” experience, and a closed source operating system would not have given software developers the flexibility we desired.

As a Java application, gvSIG mobile required a Java stack on the Openmoko to function and some interface changes to cater for the increased screen size. Porting gvSIG mobile to Openmoko was undertaken by Juan Lucas Domínguez Rubio of Prodevelop SL and was achieved using the Jalimo (https://wiki.evolvis.org/jalimo/index.php/Main_Page) “Java-like” stack. Jalimo provides the CacaoJVM, GNU Classpath and Classpath-GTK libraries for devices compatible with the OpenEmbedded (http://wiki.openembedded.net/index.php/Main_Page) cross-compile environment. With Cacao and a complete Classpath installation, any device compatible with OpenEmbedded can run gvSIG mobile. There are a number of software distributions available for Openmoko (see http://wiki.openmoko.org/wiki/Distributions for a complete list), and Oxford Archaeology intends to release distributions specific to our needs, or the needs of our clients; in every instance, however, gvSIG mobile will work in a predictable manner, both on Openmoko hardware and a range of other devices.

GvSIG mobile on Openmoko is in a continuing state of development; its features are, as yet, not finalised and there are choices to be made in the future concerning what it should do. At present, gvSIG mobile on Openmoko serves as a viewer of GIS data. It is possible to add shape files, WMS layers, Yahoo! satellite imagery and OpenStreetMap map tiles; these can all be layered and queried in the same manner as they would be on a desktop GIS system. The FreeRunner's GPS can be used to project the user's location on top of the displayed data, or can be used to retrieve relevant data from appropriate sources. At present gvSIG on Openmoko displays shp files that have been transmitted to the phone and saved locally; future integration with a SDI via the device's mobile internet connection would allow for the movement of data as depicted in Figure 1. Simple data editing tolls could be added allowing the user to create or manipulate data using either the touch-screen or the GPS to enter the details of features that existed where they stood. GIS data is something that specialists within archaeology often guard very closely, and rightly so given the easy opportunity non-specialists have to damage their hard work. A properly managed SDI with provisions for access control and Quality Assurance (QA) procedures could allow field based users the freedom to do what they liked with the data without the potential of damaging another practitioner's efforts. Likewise a trained or trusted member of field staff could be an invaluable asset for office based GIS professionals.

The archaeological opportunities presented by gvSIG mobile on Openmoko, supported by a SDI, are hard to exaggerate. Field workers and those working with GIS tools in our offices are almost always too divorced from each other; surveyors often have little understanding of the GIS procedures that will follow as a result of the data they have produced, whereas those conducting GIS work often have little contact with surveyors and suffer a similar lack of insight into field processes. Staff such as excavators suffer the same problems on an even larger scale. The FreeRunner is a device that can be used by all members of staff and that is powerful enough to bridge the gap between those in the field and those in the office. I envision a situation within which an excavating archaeologist can remove her phone from her pocket and be provided with all the survey data relevant to the location she's in, as well as access to the existing data sets and newly digitised data that has already been produced elsewhere. The relatively simple act of placing oneself within a geo-referenced historic map would enable the excavator to have an understanding of the work they were conducting in a way that very few members of field staff currently have the opportunity to do. Applications would not have to be limited to these instances of visual presentation of spatial data; archaeological data dealt with via the FreeRunner, such as primary data in the form of context sheets or interpretive data produced elsewhere can also become spatially enabled and presented to the user. The inclusion of temporal data within this GIS would also be a very powerful tool; archaeological data is already provided with a great amount of temporal information and presenting this to the user in an appropriate manner would allow them to engage with representations of their physical location in a variety of periods. One may select, for example, to view the Bronze Age archaeology of their trench before scrolling through to the Iron Age and on to the modern day.

At Oxford Archaeology we're confident that such approaches to remote interaction with spatial data will be valuable to many more industries than simply archaeology. We have formed a digital consultancy business, OA Digital (http://oadigital.net), to provide similar services to anyone that requires them. Potential clients are easy to imagine; logistics, emergency response and tourism are just three examples of industries that rely upon remote users having access to spatial resources. The potential for user generated content in all three examples is also either of enormous benefit, or mandatory for the intended role.

6: Enhancing survey capabilities with gvSIG on Openmoko

The FreeRunner contains a GPS that outputs standard NMEA sentences via an internal serial port. Therefore, at a most basic level, we will be able to provide a rough latitude and longitude reference for every context, photograph, section or drawing point produced on the site. These can be sent straight to the SDI data centre and used for both internal reference and instant dissemination via web mapping services or GeoRSS. Software produced by Oxford Archaeology allows archaeologists to geo-reference photographs with GPS data as they are taken. GPS data can also be used to download and display relevant spatial data for users in the field. We developing the GPS capabilities of the FreeRunner, however, to enable a higher resolution of GPS results and to further enrich data produced in the field.

We are currently working on a combined A- and DGPS implementation that will rival the results produced by the expensive equipment and services currently utilised by our survey department. Assisted GPS (A-GPS) is used to reduce the *time to first fix* (TTFF) for a GPS receiver and works over standard TCP/IP using the FreeRunner's mobile Internet connection. It works using a simple client/server model: The FreeRunner is programmed before leaving the office with a rough (within 1000 kilometres, for example) latitude and longitude positioning. This data is passed to the A-GPS server which sends back details of the satellites the receiver should be able to read from. By concentrating on these satellites rather than ones it will not be able to deal with, the GPS receiver experiences a TTFF of less than 30 seconds, as opposed to the usual 5 minutes. The benefits of this are largely related to battery life and usage experience, but are made possible only by the open hardware and software employed by the FreeRunner.

Differential GPS (DGPS) is of much greater interest to the archaeological community and really provides us with the opportunity to alleviate the current dependence upon costly and proprietary third party products and services. Differential GPS is another client/server implementation that is used to transmit known information about sources of GPS inaccuracy to the client so that they may be removed and a greater degree of accuracy achieved. It is estimated that we will be able to provide all members of staff with a device capable of recording its position with an accuracy of +/- 5 centimetres, although we are currently working to reduce this to +/- 1 cm. DGPS works by providing clients with data concerning factors such as the nature of the Earth's Ionosphere, multipath signals received by the client and jitter information. Oxford Archaeology will run a wide area DGPS server to provide information to on-site servers that in turn communicate with clients via short range links such as Bluetooth or WiFi. Such a system will bring great cost benefits to our survey operations; they are not intended to replace current survey techniques completely, but shall at least provide every member of staff with the opportunity to undertake high quality survey work almost for free.

Improved GPS recording techniques can also be combined with the FreeRunner's built-in 3D accelerometers to produce real world sketches of features. The FreeRunner knows where it is in the world with an accuracy of up to 5 cm and it also tracks how it is being moved in 3D space with much greater precision. Based on this, we are developing a system that allows the archaeologist to run the device around the extent of a feature and have it produce a geo-referenced sketch plan. With such a system, 3D surveying becomes not only very cheap, but also quick and intuitive.

Finally, the FreeRunner allows members of staff to download data from a Total Station and have it sent to the data centre whilst remaining in the field. Total Open Station (totalopenstation.sharesource.org) is a piece of software written by Stefano Costa and Luca Bianconi to allow downloading data from a Total Station without any proprietary software. It is a Perl (www.perl.org) application that works on the FreeRunner without any modifications. Members of staff can simply connect their FreeRunner to a digital theodolite using a USB host connection and a supplied cable and send their survey data straight to the data centre. From there it can manipulated by staff in the office. Such rapid data transfer is going to have a positive effect on the archaeological process; we do not need to place members of staff on site for a more reflexive archaeological experience, instead we replace the cables that they would usually use with a wireless device and give them the tools required for unbridled levels of communication and creativity.

The results of these applications can all be fed directly into gvSIG mobile, or into a supporting SDI; by demanding a completely open stack for both our infrastructure and mobile devices we are able to work with spatial data in ways that would previously not be possible and provide opportunities to both our members of staff and those in other disciplines or industries.

7: Conclusions

Typically, archaeological contractors and field workers operate under high economic and time constraints. In such environments, even the best software tools can only be used productively if they can be integrated into an economic, efficient and, above all, sustainable digital workflow. Such a workflow must be data-oriented rather than application-centric and it has to be ensured that all components can communicate using open file formats and protocols. Proprietary file formats and other forms of "vendor lock-ins" have to be avoided as they introduce unpredictable risks to any long-term data management, archiving, business and research practice. Open source GIS and spatial DBMS allow us to design open and sustainable spatial data infrastructures; we have outlined the principal components involved.

We believe that sustained progress in archaeological computing is best fostered by a combination of hardware, software and creative workflows all playing together in the framework of a flexible and open SDI. We need to make sure that, when the devices to create the data we want become available cheaply and in large numbers, our software tools will have the right data models and processing functions in place to deal with them. In a closed source, commercial environment, this amounts to an expensive gamble on vendors' internal development and licensing plans. Using open source software and open hardware, however, we can put ourselves in control of the entire development process and make sure that we meet our critical targets.

GvSIG mobile on Openmoko allow us to enable our staff to produce better archaeology. Results, data and information flow freely between the excavation and all members of staff. The concept of the “specialist” in the office is becoming less important as the borders between desktop and field research start disappearing with ubiquitous computing tools and all staff have the opportunity to communicate their knowledge with others freely. Oxford Archaeology is a geographically dispersed company, but is becoming increasingly communicative, with the latest in communication technology drawing us closer together and removing the traditional boundaries of archaeological practice.

Our research demonstrates not only that an Open Archaeology approach is vital to the development of our discipline and the records it produces, but also that it enriches archaeological practice and adds value to our cultural heritage. The fruits of our research efforts are to be shared with the wider archaeological community; hard- and software developments produced at Oxford Archaeology will be made available to any practitioner that requires them. In this way we hope to contribute to the development of better digital field work practices and more useful digital outputs.