Mobile GIS for Surveyors and GIS Professionals Working for Cadastral and Mapping Agencies

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Key words: Mobile GIS, Mapping, GPS, TPS, Laser Distancemeter, Level

SUMMARY

This paper highlights the significance of GNSS (Global Navigation Satellite System) and other sensors (such as TPS (Total Stations), Level, Laser Distancemeter, …) integration within a mobile GIS environment. It provides insight and direction of Leica MobileMatriX as the platform for the integration of surveying in a mobile GIS. Methods, sensors, and graphical representations of measurements and surveyed features can be combined in real-time to allow the most beneficial results. The trends of mobile field systems are dominated by:

- Wireless technology between sensor and TabletPC,
- Move to data acquisition, go away from simply collect X, Y, Z
- Field to Finish solution
- Quality and Completeness control in the field
- Seamless dataflow between office - field - office
- No redundancies in data and workflows
- With the approach of providing the entire geodatabase in the field, field crews can react on changing conditions
- All geographic truth in any map or GIS can be traced to a surveying and mapping process.
- For survey crews the GIS is a “silent” partner – no GIS knowledge is required

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1. INTRODUCTION

Dr. Roger Tomlinson built the first Geographic Information System (GIS) in Canada in the early 1960s. Since that time GIS has emerged from a geek user application to “everybody's” desktop – GIS became a multidisciplinary tool of many professions, including surveying, mapping and cadastre. On the other hand is the long surveying history, with its grown procedures, methodologies and most important: rules. Both professions coalesced in the past years.

Mobile GIS is the natural expansion of the enterprise database into the field as it is part of the whole office system and environment. While wireless technology will increase the usability of mobile GIS in the future, it is not an essential component for the successful operation of mobile GIS today. The field device (TabletPC) as well as the (surveying) sensor is an integral part of the mobile GIS - it must be robust, easily operated in any conditions and based on industry standards (e.g. Bluetooth). Location information is central to the operation of mobile GIS. Reliable location definition ensures the efficient management and use of data - both in the field and office.

The requirement to access information anytime and anywhere has never been stronger and will increase more and more within the next years. Professional users working for mapping and cadastral agencies move towards mobile platforms to increase productivity and quality through efficient information handling, resulting in cost reduction, as well as a well-informed mobile workforces. The expansion of the enterprise GIS into the field is currently taking place, but there is still a lot of misunderstanding and confusion about how to combine the wide spectrum of services, sensors, workflows and technologies that defines a mobile GIS. The work of field crews has changed in the past. Years ago, it took surveyors minutes to define the reliable XY location of a point in the field, with recent survey grade equipment it takes seconds for the surveyor to get reliable X, Y and Z coordinates. This results in a wide variety of new tasks for field crews – the collection of other information beside a “simple coordinate”.

Understanding the need of mobile GIS, it is useful to consider the changes that have occurred within the broad context of GIS. With this understanding, the role and the need of mobile GIS will become clearer and explains that the accessibility of the enterprise database in the field will be the key for future activities.

2. UNDERSTANDING MOBILE GIS

The operation of GIS in its initial years was largely restricted to technically skilled operators. Highly trained GIS professionals did everything from building the database, scanning paper maps, digitizing, through to complex spatial analysis. Operations were generally made on powerful, standalone workstations, with the GIS database managed and maintained as a totally independent monolith within an organization. But nowadays, GIS is a centralized information system – rather than a useful cartographic tool like CAD. GIS is becoming a key component of business systems as a whole. An administrative role still exists, but has been changed in the past:

- Data Model Definition
- Restricting operations to a specialized few within the user organization,
- Defining and allowing access rights
- Managing check in/out processes

In these days, GIS reaches many people within an organization, but the management and operation of GIS is still restricted to those within an office environment! Field workers are still required to return to their office to utilize or modify data that is managed and maintained within the enterprise database. With the streamlined workflow of mobile GIS, survey crews, emergency workers, inspectors, maintenance teams, and many other field workers should have real-time access to the enterprise data they require to do their job. With the current approach, field crews cannot react on changing conditions due to missing information in the field. Jus think of the current field crew equipment – they have survey grade equipment, paper maps, coordinate files – but that's it. What is there possibility to react on changing conditions without having all needed information available in the field - having mature filed crews requires mobile GIS.

Furthermore geographic data isn't only geometry, it is geometry linked with many attribute information. Leica MobileMatriX enhances this model with – the highly important - quality information. Who is these days not interested in the quality and reliability of his data?

The main goal of mobile GIS is to deliver intelligence to the field in ways that improve productivity and provide a competitive edge in the marketplace. To describe in more detail it means:

- Have mature field crews
- Improve scheduling and dispatch
- Improve data records
- Reduces costs and (drive) time
- Eliminate reworks
- Improve Quality and Completeness checks
- Integration of a variety of sensors in one system (incl. Data Storage)
- Eliminate process and data redundancies
- Improve maintenance tasks and workflows
- Bi-directional interface to a wide variety of sensors.

2.1 Is a Multi-Sensor Support Required in a Mobile GIS?

As listed above, one of the key elements of a mobile solution is the interaction with a variety of different sensors. What kind of sensors should be used in order to fulfill customer's needs? The answer to this question is not trivial. Nowadays, mobile GIS must support GPS. But what happens to field crews working in cities or forests where GNSS may not deliver at any time a satisfying result. Then other sensors such as TPS will be used. Is the customer happy with a position accuracy of a few meters? Otherwise he has to use DGPS? Does the mobile GIS allow to configure the sensor in order to work in Real-Time? If yes, then the sensor interface must allow the configuration of the RTK (Real-Time Kinematic) device (Mobile Phone or radio) – working with "simple" NMEA strings is then no sufficient solution. Many organizations work with TPS to avoid the above mentioned problems. The workflow here is that they measure in the field with TPS, using feature codes, and later use an import to get the data into their GIS. Or what happen if you want to simply measure distances between different objects, then the usage of Laser Distancemeter (e.g. Leica DISTO™ A6 with a Bluetooth™ interface) may be the right choice for the user. Here it is required again that the mobile GIS supports the storage and computation of the measurements. Any value the user keyed in in the past, the DISTO™ A6 can now be used to measure it directly and send it– via Bluetooth – to the mobile GIS, without using the stylus. Another useful application – beside feature construction – is the measurement of feature attributes using the DISTO™. For example you can measure the depth of a manhole and send it directly to the Attribute field: Depth. Or even more advanced you may measure indirectly the Height of e.g. Buildings or Trees and then send the computed Height to the attribute field.

Another issue in Mobile GIS is the height modernization for existing – height critical - features. By connecting level and GNSS sensors to the mobile GIS, field crews can measure accurate locations with GNSS and in parallel they can update the less accurate GPS height with a leveled height – this process is called Height Modernization and is easily possible by the Multi-Sensor support in Leica MobileMatriX. The Height Modernization utilizes GNSS (Global Navigation Satellite System) and TPS technology together with level instruments to improve all mapping, surveying, and engineering activities – all within one mobile application.

The following examples show the importance of robust and reliable spatial data:

- Height Modernization benefits mapping of an entire water distribution system: the objective is to know the location of every component of the system at a level of accuracy that will allow to quickly find that component (such as a valve), even if it is under water. In the past GPS, TPS and Level measurements had to be analyzed in different software packages. The combination of various sensors results in lower costs for surveying and mapping throughout the whole workflow and data analysis chain. Furthermore, it enables reliable sharing of spatial information between organizations and reduces unnecessary duplication of data while working with different sensors.

- Height Modernization benefits the determination of accurate elevations, which are absolutely essential for flood hazard mapping. In many cases, elevations must be carried over long distances for determining elevations at a particular project site where flood hazard mapping is needed. The traditional survey techniques for transferring elevations such as optical Levelling are extremely post-processing-intensive and expensive. Especially combining the level and GPS measurements finally in the enterprise GIS requires many steps. This cost and workflow can be greatly reduced by using GPS and digital levels within Leica MobileMatriX with its Height Modernization functionalities.

Conclusion, a mobile GIS has to support also other sensors then GPS and provide algorithms to compute a final location for the measured feature (e.g. Free Station, Traverse, Level Adjustment) – like Leica MobileMatriX does.

2.2 Location is the Key

A Cartesian coordinate system is a grid, with one corner being the arbitrary "false origin" (0,0) and all positions on the grid measured as distances north and east of it. Although coordinates are essential, most people are usually more interested in which house and street to find someone or something. Coordinates are therefore linked to a map showing information that can be interpreted by a user to allow functions such as route planning and querying the user's current location. Staking out locations then turns from staking out a simple coordinate to directly staking out e.g. a corner of a parcel.
Therefore intelligent location information always has played an elementary and central role in GIS, and its importance in mobile GIS is even greater. All mobile GIS applications use location inputs (GPS, TPS, Disto™, Level, Laser Rangefinder, …), with three types of mobile operations in particular benefiting from accurate and timely location information:

- **Accessing feature datasets**: The mobile device's ability to know precisely where it is enables it to automatically retrieve datasets, relating to its current position. For example, a utility technician arriving at the site of a blackout won't have to search through a menu of serial numbers and location information to find the section of the electrical network map relating to the problem, he simply can associate his location information with the feature.
- **Updating enterprise database**: One of the current uses of mobile GIS is to take existing data into the field to update them onsite or survey new information (geometry and attribute). Later the data will be synchronized with the office database.
- **Navigation to a feature:** A technician can't update attributes of a feature if the feature can't be found in the field. Mobile GIS applications provide navigation capabilities to support the field workforces. Navigation capabilities help field crews reach a feature in the field quickly and safely.

As the enterprise expands and mobile GIS, location-enabled devices will become common-place, the incorporation of location into mobile devices enables data to be managed efficiently and seamlessly, resulting in higher productivity, less data handling errors and less redundant data. The efficient expansion of the enterprise GIS to the entire workforce of an organization depends on the seamless integration of location into the applications used by the mobile workforce.

2.3 What Happened in the Last Few Years …

What happened in the last few years – e.g. with Leica MobileMatriX – Surveying and GIS came closer, many huge surveying organizations based their complete office system on an enterprise database. Survey data are now stored in GIS systems in Relational Data Base Management System (RDBMS). Surveyors can even take out the GIS as a silent partner into the field, can manage and update GIS features directly in the field. This model allows surveyors the unique perspective as the holders of accurate data that can impact the system.

Surveyors measure, manage, and create data. The issue has always been that once the data was in the GIS the survey was no longer needed as the GIS features were in no way connected to the survey. There was no link between the survey measurements and the GIS map feature. With the new technology – available in Leica MobileMatriX – survey data is now stored in the database with the GIS layers. Allowing spatial adjustment of GIS features by linking the GIS map feature to the survey point that identifies the feature location and accuracy and then adjusting the feature to the survey point. Surveys and survey data are stored in the database and the database becomes a management tool for the surveyor.

2.4 What is Required Bridging the Gap between GIS and Surveying?

Harmonization of survey and GIS data. In the past entirely different instrument technologies, which were used by certain disciplines - like GIS, government inspection department and surveyors - became increasingly integrated. Think only of the rising importance of mobile computers as well as their connection via wireless communications. Mobile users and surveyors are especially delighted with the concept of visualization and the computer technology that supports this world-view. What is referred to here is that innovation leaders harmonized the concept of a centralized database with a number of other systems of information technology - GIS, GNSS, TPS and applications for remote TabletPC workers. The convergence between the GPS and GIS, i.e. data bases for recording, analysis, and presentation of geographical information, made it possible to model and visualize, in the near future even with live geo-data, the current position of the user.

Some key factors to bridge the gap between surveying and GIS:

|1| GIS must be a silent partner
|2| Surveying rules implemented in GIS

Historically it was required that surveyors are licensed to perform cadastral or engineering work. “Everyone” – no license or exam required - can do GIS work.

|3| GIS must facilitate the surveyor in his daily work – best would be if he can take out the entire GIS into the field – where he can see what he does.

After these fundamental hurdles are passed, then technical issues must be solved:

|1| Synchronization of field database with office database
|2| Implementation of survey layers and survey rules
|3| Sensor interface (not only NMEA, but also full control of the sensors)
|4| Field2Finish solution – complete processing, display and mapping functionality in the field
|5| Quality control – allows the surveyor to do his quality control checks directly on site and not when back in the office.
|6| Advanced Data Collection Methods – support the workflows of surveyors and don’t invent new methods or try to introduce GIS methods.

2.4.1 Present situation

The present situation sees the mobile field device operating its own resident application and working unconnected with the data from the office – as a monolith - that everyone else accesses within the traditional enterprise GIS. As such, mobile GIS does not interact seamlessly within the structure of the network. Because mobile GIS has to be part of the enterprise GIS, the operating system and application software on the field device must be compatible with that used by the enterprise GIS – even more the same data model should be used in field and office. Leica MobileMatriX stands out especially in this aspect from other applications because the field crews directly work in the ESRI geodatabase, without conversion or import/export demands and furthermore using the exact user data model. With the latest technology development in ArcGIS, the mobile GIS user can work with versioned (disconnected editing) database in the field, which will later update the enterprise database – the field crew will be part of the enterprise database.

This than formulates the main question about mobile GIS: how to provide a loss-free and error-free data exchange for collection, update and retrieve of data between the mobile system and large enterprise systems? Is it possible to integrate mobile systems efficient into existing workflow?

2.4.2 Existing functionality

If you compare the functionality of available mobile GIS products you then get the following result:

- In the majority of cases only GPS sensors are supported. In addition there is mostly only a one-way communication possible – the systems can read information from the sensor, but cannot configure anything on the sensor.

- Multi-sensor support (TPS, GPS, Level, Laser Distancemeter, Camera, Laser Rangefinder, …) is mostly missing
- Database connection via ODBC or standard interfaces exists.
- Only limited geodetic computations are supported
- Standard creation of features (e.g. points, lines, polygons) exits.
- Multiple feature editing at the same time is hardly available.
- Standard interface for data exchange exists in the majority of cases.
- Storage of quality information for features is hardly available – missing link between surveying and GIS.
- Hybrid data display (raster and vector data) with Georeferencing is standard.
- Capture and update of thematic data and maps via editors and queries mostly available.
- Coordinate systems and transformation are supported in most products.
- The work with sketches and recompile functions are missing.
- In the majority of cases the Operating System is Windows XP TabletPC Edition or Windows 2000 and the programs uses the standard Windows interface.
- Program interfaces for extensions of functionality and user interfaces are exceptions.
- Most systems do not explicit support TabletPCs – the drawing and writing advantages are not used, as well as most programs are not optimized for pen usage.

2.5 Data Capturing Concepts

The data capturing concepts in a mobile GIS must be specially designed for field crews – both in user interface and functionality:

- GIS as a silent partner – it must be considered that field crews are not as trained as GIS Professionals, therefore usability and intuitive workflows must be ensured. The mobile GIS has to manage all Data Model rules (like Topology, mandatory attribute fields) without bothering the user in the field.
- The mobile GIS must be specially designed for stylus usage.
- The mobile GIS has to work as a data logger for connected sensors, e.g. TPS, GPS.

The data-capturing concept within a mobile GIS requires some mandatory concepts:

- Pending Feature
- Multiple Feature
- Continuous and Repeating Feature
- Feature Attribute Collection

2.5.1 Pending Feature

Pending feature editing allows the user to directly edit already existing feature data (including their attributes). For example, if it is not possible to survey all 4 corners of a building at the same time, the field crew first could survey the visible corners of the building, and finish the feature later. At any time the remaining corners of the building can be surveyed without losing any kind of information.

2.5.2 Multiple Feature

Creating multiple features or interpolation points of features (vertices) with just one measurement ensures economic field practices. A measurement triggered by a sensor either creates one or more new features or extends one or more existing features.

For example, a survey point could have multiple thematic meanings (a survey point could be the vertex of a building, a street and a parcel at the same time). When surveying, directly in the field a feature is created for each real-world object that is surveyed, which then avoids feature coding and additional office work. Such flexibility helps the user to perform complex-surveying actions, with immediate visual feedback for quality and completeness control, quickly and easily with the ability to undo and redo their last actions in the field.

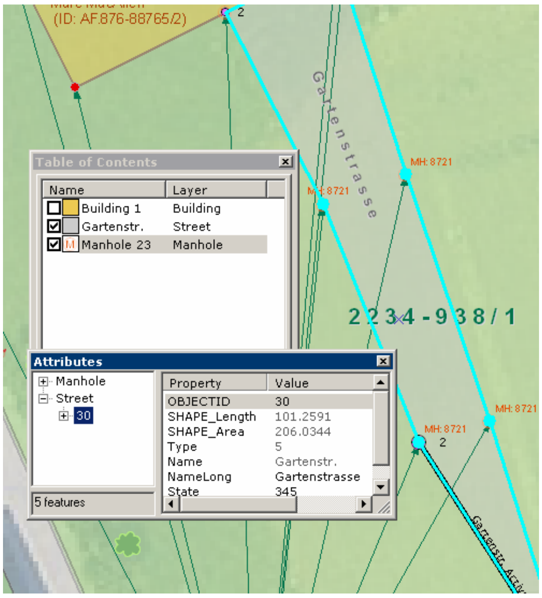

Figure 1: Multiple feature editing of street, building and manhole feature classes.

Creating more than one feature with just one measurement ensures economic field practices whereby one point is measured to extend/create multiple features. For example, imagine that a survey point could have multiple thematic meanings – it could be the vertex of a building, a street and a manhole at the same time.

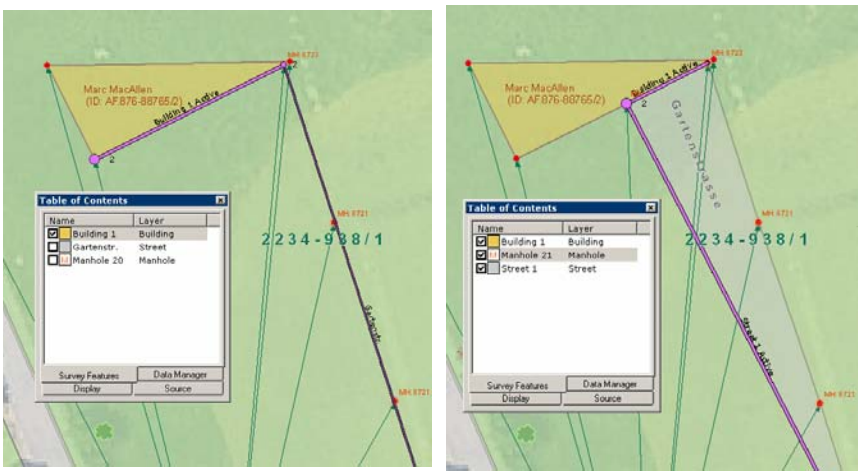

Figure 2: Before (left) and after (right) inserting a vertex into the parcel polygon: The insertion line indicates where the next vertex will be inserted.

Another easy method to survey a new feature is to sketch it and then measure its vertices. Such flexibility assists the user to perform complex-surveying actions, with immediate visual feedback for quality and completeness control, quickly and easily and the ability to undo and redo their last actions in the field. Expensive re-measuring is avoided by immediate quality and completeness control, when traditional evaluation of data reveals insufficient quality of measured data.

2.5.3 Continuous and Repeating Feature

Repeating Feature editing is highly important when surveying feature with same attributes, but different geometry – e.g. a sequence of power poles or manholes. This then allows a high performance data capturing while e.g. recording multiple similar features.

Figure 3: Example – Repeating Feature editing with power poles.

Continuous Feature editing allows the user to map a wide variety of different features simultaneously without having the need to finish first one feature before continuing with a new one. Continuous Feature editing also improves field data collection performance and efficiency resulting in having not the requirement to retrace steps.

2.5.4 Feature Attribute Editing

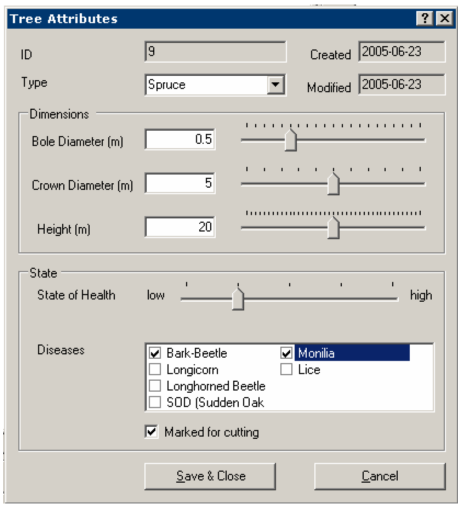

Figure 4: Customized dialog for editing tree attributes.

Leica MobileMatriX enables survey crews to map surveys, collect spatial and feature data, simultaneously anywhere on the globe by integrating GPS/TPS with the power of ESRI ArcObjects mapping and data acquisition abilities. Field crews are able to quickly pick from a list of pre-defined attributes that are associated with a structure to enforce consistent and reliable data standards - combined with user logic based on approved workflows increases both efficiency of fieldwork and quality of captured data.

2.6 Reporting

For mobile GIS in cadastral and mapping agencies it is mandatory that reports of captured survey data are generated. You can generate different reports of survey objects by just selecting an appropriate style that determines the general layout of a report. You are able to further influence the final report by adding your own header and footer and by selecting the attributes of a survey object you are interested in. It is also possible to change font, size, and color of these attributes.

The reporting component is based on XML/HTML. That means the survey objects to be reported are first written to an XML file and afterwards a style sheet (XSL) is used to generate an HTML file. The HTML file can either be saved or printed. There are several pre-installed style sheets available to report survey computations and survey points. These style sheets can be adopted to fulfill the users requirements, regarding layout or additional information.

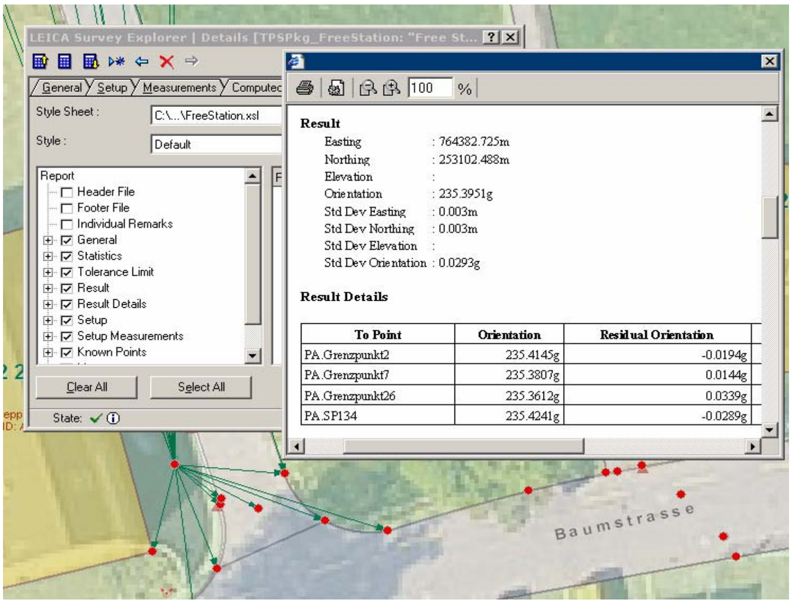

Figure 5: Reporting engine and print preview in Leica MobileMatriX.

Examples of reports include:
- Textual reports on computations
- Point and coordinate tables
- User-defined reports

2.7 Data exchange

For data collected in the field by a surveyor it is normally a long and complex path into a GIS. After data collection, the data is imported to office software to execute the computations for the points. The resultant points are then exported to a CAD system where additional constructions are performed and finally the data is imported into the GIS. If the user detects a problem in his results, by checking the position of the created features in the GIS, he may have to rerun the whole series of events.

With a mobile GIS application for cadastral and mapping agencies, all survey data measured in the field are automatically stored into e.g. the ArcGIS Geodatabase, eliminating the need for data conversion when moving data between field system and ArcGIS. To update the office database, simply use the synchronization mechanism to transfer the data from office to field and vice versa.

E.g. Leica MobileMatriX provides tools for synchronizing the office database with the field database and vice versa. Many mobile users, such as a field survey crew, require similar functionality. They need to work independent from an organization’s infrastructure and database connection, often for a longer period of time. When preparing for a particular work order or project, the relevant data is transferred to a portable device, such as a TabletPC. Afterwards this device will then be disconnected from the network, enabling the user to operate independently.
Mobile users may then continue to work with and modify the data even though they are disconnected from the network. When a connection to the network is re-established, any changes made to the data can be integrated with the data maintained in the central database.
ArcGIS Geodatabase disconnected editing allows organizations to disseminate their spatial data to other departments, associated agencies, or mobile workers and maintain the integrity and actuality of that data. The disconnected editing functionality is provided by ESRI. As with checking out data, the check-in process involves an automated process.

This process begins by selecting all or only a specific set of features from multiple feature classes. All features used for working in the field are checked out from the Enterprise Geodatabase (ArcSDE) into a Personal Geodatabase represented by a Microsoft Access database file running on the field system (e.g. a TabletPC). Data capturing and feature editing in the field is performed in disconnected mode and completely offline: All changes are stored to the Personal Geodatabase. Afterwards fieldwork data has to be synchronized with the master database in the office. Special tools help to detect the changes of the data in the field and only check-in the differences between Personal and Enterprise Geodatabase.

The process of check-in/check-out is based on the Geodatabase versioning concept. Checking out a part of the Geodatabase creates a new version in the master database. A copy of this version, a Personal Geodatabase, is used for working in the field. When checking back in, changes are directly transferred to the corresponding version in the Enterprise Geodatabase: there is no version reconciliation at this point with the check-out version living in the

Enterprise Geodatabase. If the check-out version for working in the field has been modified since the data was checked out, these changes are overwritten when checking in. The standard process of checking in allows to reconcile and post all changes of the check-out version with its parent version. It is up to the user to perform reconcile and post immediately or after some post-processing. After successful reconcile/post to the parent version all associated check-out information (e.g. list of datasets checked out) is removed both from the master database and the check-out database. Any versions created in the Enterprise Geodatabase are also removed. However, deleting the copy of the Personal Geodatabase that was checked out or any residual copies of the data once checked-in remains choice of the user or data administrator.

E.g. Leica MobileMatriX Professional Edition includes disconnected editing of features. That means features can be checked out from an ArcSDE database to a Personal Geodatabase and edited while the field worker is disconnected, using the tools provided by Leica MobileMatriX. Later the new and edited features can be checked in and reconciled with the master database. This process applies for features but not for survey objects, because they do not participate in the check-in/check-out process at the moment. That means the user is able to modify features in the check-out database, based on the links established between the features and the survey points, but while the features will be synchronized with the master database during check-in, survey objects will not. This does not mean that the link information or the survey information is lost, but it will not be visible in the master database. In order to maintain link information later the user has to check out the features to the local database used in the field. Since this database still contains the original survey objects, the link information will be available again and the user can start using it in order to modify the features.

To ensure maximum compatibility with all systems, a mobile GIS should allow the user to interact with data from different sources, such as CAD files, shapefiles and raster data.

3. CONCLUSION

As the enterprise GIS goes mobile, location-enabled devices will become commonplace, the incorporation of locations into mobile devices enables data to be managed efficiently and seamlessly, resulting in higher productivity, less data handling errors and less redundant data. The efficient expansion of the enterprise GIS to the entire workforce of an organization depends on the seamless integration of locations into the applications used by the mobile workforces.

Mobile GIS expands the enterprise to the entire workforce. Knowledge enables all decision makers where and whenever needed – as their colleagues in the office - and ensures all data is current, reliable and relevant. The expansion of the enterprise allows the field crews n to access data and processing tools directly on site. This ability results in speeding up the dissemination and distribution of information, allowing the mobile workforce to remain independent and flexible, which results in less down time and faster and more reliable results.

Mobile GIS removes the need for intermediary paper-based recording. It is not unknown within organizations for modifications made on paper maps to never make it into a digital format, which means many changes to the real world are never reflected correctly within the enterprise. With mobile GIS, data is always in a digital format, making it easy and efficient to transfer from the field to the office without introducing interpretive errors. Quality and Completeness checks are still required, of course, but many of these can be automated and directly visualized in the map so those carrying out the checks can focus on the real errors without the drudgery of filtering through large quantities of flat tables (nowadays often all measurements and collected feature are still stored in flat tables without having the possibility to get visualized while being in the field). With mobile GIS, data is always digital, making it easy and efficient to transfer from the field to the office without introducing interpretive errors, redundant data and workflow cycles.

Viewed from a technological perspective then, we can easily connect the mobile field application into the existing structure of the enterprise GIS. There is still the enterprise GIS that resides on a powerful, centralized server, carrying out the main data management role and providing the underlying application development software for spatial analysis and queries. The enterprise GIS feeds data into the organizational network for all with access to the enterprise and the mobile field application simply connects to the enterprise to access the same data. However, mobile GIS is not interacting seamlessly within the context of the network, but must take a version only of the data that everyone else sees and operate it's own resident application to process or use the data – most probably done nowadays through the disconnected editing technology provided by ESRI.

Moving forward, the seamless interaction of the mobile field device as part of the enterprise network itself will eventuate through the utilization of wireless technology. Finally, the mobile GIS operates as a web-browser, where it's interface and analysis is carried out on the GIS Server. But that's a long way off. A more useful mid-term approach would be that the field device only interacts with enterprise when data is updated or when new data is required to be viewed or queried. Wireless technology, however, isn't quite there yet, and in fact seems to have slowed down with the associated economic slow-down; therefore I believe that the process will be done anyhow via disconnected editing as it is done nowadays.

Whether wireless or not though the ability for the field application and device to be aware of its location is a significant factor in the ultimate success and acceptance of mobile GIS for operational efficiency. While the technology is becoming increasing by robust, there are business reasons to encourage the expansion of the enterprise to the mobile workforce.

To summarize, there are three main points I'd like to leave you with:

|1| Mobile GIS is an extension of the enterprise. It's part of a system, and in fact is dependant on a system for its success. It's not an island unto itself. It's useful to note that while wireless will be very useful for mobile GIS in the future, it's not essential for successful operation.

|2| The field device (the combination of TabletPC, GPS, TPS, or other sensors) is an integral component of the mobile GIS system. It needs to be robust, easy to handle and based on industry standards. When considering the right device to use, don't forget to think about how valuable the data that remains on it is.

|3| Finally, location is central to the operation of mobile GIS – even more so than to your office-based GIS – as location will ensure the efficient management and use of data on your field device and between the field and the office - both now and even more so into the wireless future.

Mobile GIS means "GIS-enabling the field crews to work with data they need where and when needed."

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