The Concept, Principles and Benefits of Integrating Internet, Intranet and Mobile GIS for Maximum Utilization of Geospatial Data

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ABSTRACT:

Geospatial Data are essential for sustainable development. They need to be collected and updated by new technology. For dissemination of the data computer systems and the Internet offer new possibilities. For the efficient use of the technical possibilities of the Internet high speed transmission computer networks are required, which are in the process of realization. Wireless network connections offer a less effective alternative. Geodata servers, DGPS developments, and mobile mapping offer new tools which need to be integrated for efficient practical uses of this future oriented technology.

1. Introduction

The African Association of Remote Sensing of the Environment celebrates its 10^{th} anniversary. It is a regional member of the International Society for Photogrammetry and Remote Sensing founded in 1910, which has tracked the remote sensing achievements since their early beginning.

There has probably been no decade in the 92 years of ISPRS history, in which technological changes have been so rapid as now. Traditionally ISPRS has been concerned to image a part of the earth's surface by means of photographs in order to create a model of the natural and socio-economic environment in form of maps according to which sustainable development may be planned and monitored. It took revolutionary tools such as the airplane in the early 10^{th} century and the satellites in the late 20^{th} century to extend the success of the mapping task to the developing continents.
Efficient tools of data acquisition are now globally available, but it needs the revolutionary tools of computer development and communications to make the use of geospatial data more effective. In this context it is very appropriate for AARSE to discuss the concept, the principles and the benefits of integrating Internet, Intranet, and Mobile GIS for maximum utilization of geospatial data, the topic of this paper.

2. Geospatial Data

Topographic and Thematic Mapping had its early roots in exploration and in military strategic and tactical planning. It has been recognized in the last century that they are an indispensable part of national and global planning strategies forming the base data for a spatial data infrastructure.
The United Nations Secretariat has monitored the progress in mapping throughout the UN Regional Cartographic Conferences. The last summary published in 1993 reflects the situation for the different scale ranges for the continents of the globe, shown in fig. 1:

Continent / Scale range	Africa	Asia	Australia & Oceania	Europe	former USSR	North America	South America	World
1:200 000	89.1 %	100 %	100 %	90.9 %	100 %	99.2 %	84.4 %	90.2 %
1:100 000	21.7 %	66.4 %	54.4 %	87.5 %	100 %	37.3 %	57.9 %	58.9 %
1: 50 000	41.1 %	84 %	24.3 %	96.2 %	100 %	77.7 %	33 %	56.1 %
1:25 000	2.9 %	15.2 %	18.3 %	86.9 %	100 %	45.1 %	7 %	33.3 %

Fig. 1: Status of Topographic Mapping

While parts of this coverage may still be in form of analog maps, these can, however, easily be raster scanned and reproduced on CD-ROMs or by other digital media. GIS analysis with links to attributes, however, requires that these map data are converted into vector data. Most countries have already converted their map data into vector form, or are in the process of doing so.

Thus a near global coverage at the scale 1:200 000 is available for global needs and about 2/3 of the land area of the world has a 1:50 000 coverage for national needs.

A bottleneck, however, exists in updating the map content, particularly in the developing countries. Fig. 2 lists the update rates for the global topographic map coverage during the 1980-1987 period.

Continent / Scale range	Africa	Asia	Australia & Oceania	Europe	former USSR	North America	South America	World
1:200 000	10.9 %	15.4 %	2.2 %	59.9 %	-	51.9 %	2.2 %	3.4 %
1:100 000	28.8 %	0.2 %	0 %	55.9 %	-	0.2 %	0	0.7 %
1: 50 000	18.4 %	21.4 %	6.1 %	45.9 %	-	21.4 %	6.1 %	2.3 %
1:25 000	14.0 %	32.2 %	0 %	52.5 %	-	32.2 %	0	5.0 %

Fig. 2: Update Rates 1980 to 1987 of Global Topographic Map Coverage

The annual world updating is shown in the last column. This shows, that even the 1:200 000 coverage is about 30 years old, and the existing 1:50 000 coverage is about 43 years old. Thus the technology of satellite mapping is indispensable to complete the map updating process within a reasonable time frame.

The topographic base permits to link thematic coverages, which nowadays can best be obtained via satellites as far as land cover, forest stands, hydrology, and geology are concerned. Transportation networks or special features are best collected terrestrially using GPS.

The data acquisition via satellites, of course, depends on the resolution of the satellite as compared to the desired scale range. Landsat TM data with 15 m panchromatic and 30 m multispectral resolution are at best suitable for the 1:200 000 global scale range, while Spot 5 with 2.5 m panchromatic and 5 m multispectral resolution is suitable for the national 1:50 000 scale. Ikonos 2 (1 m panchromatic and 4 m multispectral resolution) and Quickbird (0.6 m panchromatic resolution and 2 m multispectral resolution) images are suitable for the local 1:10 000 scale.

Obviously mapping needs to be controlled to a geodetic reference. The isolated national reference systems (fundamental point and azimuth, reference ellipsoid, projection chosen) are in the process of being related to the International Terrestrial Reference Frame ITRF with a global (not a local) reference ellipsoid related to the GPS satellite positioning system WGS 84. This referencing has been completed in Europe (EUREF), North America and Latin America (SIRGAS), and awaits initiatives in other continents (AFREF).

With the existence of such systems DGPS may be successfully utilized. While the more inexpensive GPS-code receivers can do the referencing with 5 to 15 m accuracy, the more expensive GPS-phase receivers can do relative positioning within the dm-range, even in a kinematic mode.

Another part of geospatial base data is the digital elevation model. The recent NASA/NIMA Space Shuttle Topographic Radar Mission with a radar interferometer is capable to deliver global digital elevation model with 15 m accuracy. Of course, existing contour maps can be used to derive DEM’s at higher accuracies except in areas of change (volcanic activity, erosion, and sedimentation, construction).

3. Dissemination of Geospatial Data

The use of geospatial data in paper form is subject to a great number of handicaps. Maps need to be printed. This printing process often covers a period of up to 3 years between data acquisition and publication of the map. The map needs to be available through an established distribution system, either at a governmental location, or ordered by mail. While national mapping agencies take the trouble to establish such a distribution system many owners of valuable thematic data do not. For this reason such information is hidden or useless to the one who needs it. The situation arises, where not even related authorities know of the existence of such data, and costly duplication of effort is going on. Hence the Multidonor Advisory Committee for Environment Information Systems in Subsaharan Africa, the newly incorporated EIS Africa, as early as 1990 recommended the establishment of national committees with all relevant partners to inform each other and to regulate procurement of relevant environmental data.

The next stage is the dissemination of the information by more efficient means. These have become possible through Computer Technology leading to the Internet and to Mobile Communication.

4. Computer Technology

Computer technology has made possible the establishment of a GIS. Today a GIS has a great number of input possibilities, efficient processing and storage capability, and various output facilities.

Among the raster input devices are scanners of photographic images (50 lp/mm corresponding to 12.5 µm pixels or better) or of maps (300 DPI or better). Vector digitisation can, of course, be done on digitising tables to 0.2 mm, but it is usually more efficient (if possible) to do vectorization automatically from raster scanned maps. The input possibilities must also provide for images of digital sensors (full frames, linear array scanners), coordinate and survey data from total stations, GPS receivers, and photogrammetric work stations. The processing task must be done by the CPU of the computer, which executes the programmed commands at speeds better than 300 MHz within a 32 or 64 bit data format. The arithmetic unit of the computer performs the arithmetic and logical operations. The control unit arranges for data transfer between arithmetic unit and main memory, which should be greater than 4 GB. The RAM of $>$ 128 kb administers machine programs and data in short access time. The computer is connected to the input/output devices by an 1/0 controller for hardware posts and for software drivers. The connections are realized by a bus system. Graphic cards help to speed up the output.

Standard external storage devices are diskettes of 1.44 Mb, zip tapes of 100 Mb capacity, and hard disks greater than 30 GB, which allow a 10 msec access for the data. Jukeboxes of several TB permit to store large amounts of data. The most common computers in use are PC's with 1 to several Intel processors for use with Windows operating systems. However, also more powerful workstations may be utilized, such as HP RISC, Sun SPARC, IBM RISC, Dec $\propto$ and SGI MIPS.

5. Computer Networks

Computers may be interconnected in a client-server arrangement by LAN's (local area networks), in which the server administers the data and the application programs. Clients are usually PC's as user terminals. The user interface is a CRT, in which the cursor is controlled by a mouse or the keyboard. LAN-performance is governed by hard wired connections, preferably by Ethernet cables permitting to transfer data at speeds of 2 Mbps.

Wide area networks (WAN's) permit to interconnect distant computes or distant LAN's. In a WAN the computers or LAN's are networked together in general also by hard wired connections. The fastest connections at several 100 Mb/sec are glass fibre cables. The connection is made by modems. Ethernet cables may also be used for shorter distances. As a rule wired telephone services may be used for the transmission of data. Standard analog telephone lines, depending on the country of service, permit data transfer at 9 Kb/s to 18 Kb/s. ISDN digital telephone connections offer 64 Kb/s.

Wireless telephone connections are offered by the mobile telephone industry networks. These require a dense network of fixed receiving stations of about 700 m distance in cities to about 35 km in rural areas. However, the current GSM network providers (Global System for Mobile Communications) only permit transmission at analog telephone rates (9.6 Kb/s in compressed mode). Local improvements are possible by GPRS (general packet radio service) and HSCSD (high speed circuit switched data) up to 56 Kb/s. But an overall improvement in mobile communications is expected by UMTS (Universal Mobile Telecommunication System), for which the antenna network still needs to be established in urban and in rural areas with the aim to reach connection speeds at 384 Kb/s in general and in hotspots at 2 Mb/s. The establishment of UMTS networks is in preparation and is a cost question.

The U.S. Department of Defence (DISA) permits use of satellite communication using Iridium satellites in the form of Enhanced Mobile Satellite Services (EMSS) for worldwide telephone and data transmission at only 2 Kb/s.

France Telecom offers similar services by the Thuraya Satellite network covering Europe, North and Central Africa, the Middle East, Central Asia and the Indian Subcontinent. The Thuraya network uses a geostationary satellite above Somalia with the data transfer rate at 64 Kb/s and a phone rate at 2.4 Kb/s.

6. The Internet

The Internet is a software linked network of physically connected computes. Its effectiveness depends entirely on the transmission speeds between computers connected worldwide in subnets. The transfer of data is regulated by the ISO standard protocol TCP/IP.

Within the Internet the following services are available:

- E-mail between different computers identified by a URL (Uniform Resource Locator). It contains an approved user name followed by the symbol @ and the name of the domain server. E-mail programs are contained in Windows operating systems or in the usual browsers (Netscape Communicator, Internet Explorer).
- Usenet as a forum between usegroups via a news-server, addressed by browser of an Internet Provider (A-Online, Compuserve etc.).
- FTP (protocol for file transfer) for data transmission of large data files from an FTP server to the user.
- The World Wide Web (WWW), which is a multimedia information system in the Internet. It is addressed by a “home page”, which is programmed in HTML (Hypertext markup language) and which can be viewed by a browser (Netscape, Internet Explorer).

Imbedded applets or plugins (Internet transmitted Java programs in the browser or software offering new functions for added hardware) permit to operate in multimedia use loud speakers, microphones or digital cameras.

Internet access is usually made possible by an Internet Provider (A-Online, Compuserve etc.) who charges for Internet access I addition to the telecommunication access (telephone company). Scientific and educational institutions provide telecommunication and Internet access free of charge to the user, since these costs are absorbed by the sponsoring government.

The popularity of the Internet and the www as a source of knowledge in North America, Europe, Australia, and parts of Asia is due to the fact, that these areas are blessed with high speed network connections and efficient and relatively inexpensive telephone services (e.g. ISDN). These conditions permit browsing for information.

In parts of Africa, Latin America and Asia these infrastructure conditions sofar do not exist to the same extent. Thus the use of the Internet is often limited to the communication by e-mail. But even in North America, Europe, Australia, and parts of Asia use of the Internet and the WWW can still be greatly improved to utilize the Web’s capability for

- music and radio transmission
- DVD transmission, video viewing and TV channel reception
- telephone services via Internet, which are very cost saving for intercontinental calls
- video telephone services via Internet, which are already a reality
- Internet shopping and e-business [Reiss]
- Internet banking, for which special encrypted transmissions are required.

The use of the Internet can, of course, be restricted to a limited number of users, e.g. those who have paid access, or those who represent certain governmental organizations with special access rights. In this case the Internet capabilities can be used as "Intranet".

7. Internet, Intranet, and Geospatial Data

The transmission of geospatial data through the Internet poses a number of special problems in addition to those concerning the access speed provided by the infrastructure of the network.

GIS data of an urban area, a district, a country or a continent can consist of a great volume of d ta. While vector data and their attributes in (object-)relational data bases usually are favourable with respect to storage needs, raster data (scanned maps and in particular images such as orthophotos) have high storage requirements, even if the data can be compressed into gif, jpg or wavelet formats. This has led to the use of geodata servers, which can be accessed either from an Intranet at no charge, or from the Internet at a data retrieval cost. To do that the geospatial data must be properly structured in the geodata server. One example is the Terramapserver by Z/I Imaging, which can be used for decentralized photogrammetric processing in a mapping enterprise [Rosengarten], [Greening], [Meyer]. Another example is the Swedish image data server from which digital orthophotos or satellite im ges of a certain area may be ordered via credit card through the Internet. In certain countries (Germany, United Arab Emirates) the knowledge of owners of land parcels is considered confidential by law, therefore access to the full attribute data is only possible to user who has received authorization of his privileges.

At the University of Strasbourg a web based photogrammetry system has been designed, which permits to use scanner photographic data available from geoservers for local stereo-processing in the "Arpenteur"-System. To permit web based HTML formatting restrictions programming has been done in the XML language, which extends the formatting capabilities of HTML [Grussenmeyer]. Most GIS vendors, such as ESRI, Intergraph, Map Info, Smallworld and others have provided access programs to their GIS-software packages. ESRI's Arc View IMS and Map Objects IMS; Intergraph's GeoMedia WebMap; Map Info's Map Xtreme; Smallworld Web, runs on Internet map servers.

With these possibilities a great number of experimental projects have been carried out worldwide. In Korea borehole data records have been interfaced with map data on servers [Y. Chang et al.]. In the Canadian Arctic projects have been carried out to merge map data with geoscientific and marine data [M. Wojnarowska & B. Ady], [D. Michalak]. In Canada a web based system for the quality control of GIS data production has been developed [S. Li & D. Coleman]. In Ireland a web-based land management system has been created for the Irish Department of Agriculture [M. Bertoletto et al.]. In Germany a bicycle routing system has been developed [M. Ehlers et al.]. At the U.S. Geological Survey the Earth Explorer provides seamless data sets for DEM's, land cover, geographic names and transportation [J. Faundeen et al.]

Then Internet services are to be provided by mobile telephones access is provided by special WAP (wireless application protocol)-phones. These are linked to PDA's (personal digital assistants) by HP, Journada, Nokia 7110, Palm, Psion, Smartphones (Hitachi) or laptops (Sony, Vaio, C1XD). Implementation is only practical on a limited basis because of the lack of reliable base map data, road and street address information, the limitations of wireless transmission of data and the limited wireless coverage [T. Tarle]. Web based services using mobile telephone communications have nevertheless experimentally been put into place in a number of research projects in North America, Europe and Asia. One of them is the Nexus project at the University of Stuttgart. To provide sufficient interoperability a local data transmission network has been established for this purpose, and a sufficient amount of 3D urban data has been collected for the demonstration (3D city model, subway stations, schedule of trains and fares, hotels). The system is integrated with a DGPS receiver [D. Fritsch].

8. GPS and DGPS

The use of mobile mapping systems is unthinkable without the advances in GPS and DGPS positioning technology. To determine a 3D position on the earth centered WGS 84 ellipsoid by GPS requires reception of signals from at least 4 of the 24 operating satellites. Code receivers permit to do this with 15 m accuracy based on orbital data supplied by the satellite. Relative positioning with respect to a map based location may be possible within 5 m accuracy. The more expensive phase receivers permit differential positioning to higher accuracies.

The principal error sources in GPS signals are ionospheric disturbances. These can be overcome by networked reception stations, which have previously been tied to ITRF. Their real time position observations with networked correction processing permit to reach cm-accuracy in position in RTK mode when the reception stations are at a distance of about 50 km. Such a system of reception stations has been built up in Germany under the name of SAPOS. The real time corrections are transmitted via WAP-phones to the GPS phase receivers operating in RTK mode.
A Europe wide DGPS correction service has been installed by the Federal Mapping & Geodesy Institute BKG in Frankfurt, operating a permanently recording GPS station. The correction is transmitted by long wave radio over the continent. It permits to achieve positioning of points 1000 km away to 1 m accuracy free of charge. Competing with this technology all over the globe are correction models transmitted from satellites (FUGRO), permitting absolute positioning in the 5 m range at relatively high cost. These positions can be integrated into mobile mapping systems.

9. Mobile Phone Location Based Services

In areas, where dense mobile phone networks are in operation, there is yet another possibility to determine the position of point in relation to the known positions of the mobile telephone antennas passing on the phone signals. Such a mobile phone location based service is of interest in emergency situations for first aid, security and vehicle location. Signal propagation is, of course, severely affected by local reflections, but within a particular cell identified by its transmission frequencies the timing delay of signals arriving at the nearest 3 cell antennas may be used by intersection of the 3 distance to these antennas. Tests in Hannover, where urban antennas 35 km apart have resulted in positioning accuracies between 70 m in open fields and 200 m in urban canyons.

The advantage is that mobile phone signals do not need direct line of sight to GPS satellites. The positioning therefore also works in buildings and for moving vehicles.

10. Mobile Mapping

Mobile Mapping systems are an attempt to integrate changing situations into an otherwise static GIS. This, on the one hand, can be utilized to rapidly survey multimedia information by new means, which would classically not be possible in time and cost.

In Hannover a company is active with a mobile van to survey facades and road details (street signs etc.) of a city. The van is equipped by 12 video-cameras, which can be operated by the driver. The vehicle is equipped by DGPS receivers and for interpolation of the GPS data in urban canyons with gyroscopic systems, guaranteeing positional accuracies of 3 m of vehicle and imaged object. The images may be draped onto house-facades in city models. To survey a city of 520 000 inhabitants and 62.000 buildings only 130 hrs survey and 250 h post processing time is required. The information may be integrated into car navigation systems in a multimedia mode.

These are just a few of the future oriented technologies of mobile mapping, which are under development.

Practical use of these systems will orient itself according to actual demands for which overall economic savings will result. Development of these uses is not a quick time solution, but a long term evolution process, which we all in different parts of the globe must follow.

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