THE MIRAMON MAP READER, A NEW TOOL FOR THE DISTRIBUTION AND EXPLORATION OF GEOGRAPHICAL INFORMATION THROUGH INTERNET OR ON CD

Xavier Pons[2,1] and Joan Masó[1]
[1] Center for Ecological Research and Forestry Applications
[2] Department of Geography. Autonomous University of Barcelona
x.pons@uab.es , joan.maso@uab.es

Working Group VI/4

KEY WORDS: GIS, Maps, Cartography, Internet, Data compression, Spatial Data Sharing, MMZ.

ABSTRACT

This paper shows the main aspects of technology in which the MiraMon Map Reader, a program of free diffusion for the distribution and exploration of geographical information through Internet or on CD, is based. The information can be raster (1 to 32 bits per pixel) or vector with topology, and is distributed using the most advanced algorithms of data compression. The information provided by the MiraMon Map Reader neither is a small part of the initial data nor a screen dump, but it supplies all the graphic, alphanumerical and documentary information of any type related to each map to be distributed. Data are certified to guarantee its integrity and the authorship of the distributor. The technology of the Reader is already working in two web servers and an important amount of geomatic data is distributed from them.

1 INTRODUCTION

Geographical Information Systems (GIS) and, in general, digital cartography, have experienced an increasing popularization in many fields in the last few years due to its natural concern to a wide range of disciplines and the use of the computer as a usual tool totally transverse to the different fields of work. The continuous improvements in the hardware with only a slight increment of the cost, and the practically complete implantation of the 32-bit operating systems, which allow to treat in the appropriate way the important amount of data existing in digital cartographic bases, have been playing a main role in this expansion (Gould 1998).

However, it is evident that this popularization would not be complete if we did not take into account some substantial improvements in the systems of storage and diffusion of data. Undoubtedly, two means have contributed in a decisive and very important way to this panorama: the popularization of the CD-ROM and Internet. In fact, the typically available 650 Mbyte in a compact disc at a extraordinarily low record price, both if it is decided to edit a CD one by one (using a duplicating system on blank discs) or if it is decided to edit it massively in a professional way (generating a master copy, etc.), have produced radical changes in the prospects of the diffusion of digital cartographic data. A good proof of the excellent acceptance and service of this format is the difficulty to implant the new DVD format, which tries to gain ground to a format in many cases satisfactory in itself such as the conventional CD. For example, on a single CD it is possible to distribute the whole topographic cartography 1:50000 of Catalonia edited by the *Institut Cartogràfic de Catalunya* (ICC) or the topographic base 1:200000 of Spain edited by the *Instituto Geográfico Nacional* (IGN), what was unthinkable few years ago.

On the other hand, Internet has also meant in the world of cartography, and for those institutions who have had the will to that, the possibility of giving out bases and offering related services (Archer and Croswell 1989). An extraordinary example in this sense has been the United States Geological Survey (USGS), with its laudable task of free of charge data diffusion. However, Internet is not a suitable solution for those collectives or countries where the access to Internet is still carried out through conventional telephony; in these cases, and while we wait for new technological solutions for the massive data diffusion, the CD can still be the best media choice (LUCC 1998a, Maso et al. 1998).

2 SOME OF THE EXISTING ALTERNATIVES

Although we run the risk of an excessive simplification, we could say that there are essentially two main tendencies under the objective of the diffusion of geographical data: Offering the possibility of consulting the database of a server and that this prepares a sight to be sent to the client, or giving the data in a considered standard format and allowing the user to manage with it. We will consider these alternatives briefly.

2.1 **A server receives the request and generates a bitmap every time.**

The idea of this option is that data reside in the server and a specific application complies with the requests of the client, also from the server, generating a static answer based on hypertexts and bitmaps. This solution, which usually uses CGI technologies or Java servlets, has in favor the possibility of generating sights *à la carte* and being an appropriate mean in very simple consulting systems, such as a city street map. However, users of such a service may have detected some of its problems for more complex uses:

- Required data need two waiting times: the first one depending on the processing time the server destines to each request of the client (with the additional limitations of systems that can only comply with a small number of clients simultaneously), and the second one depending on the net speed (more critical if a conventional modem is used). This latter time always means a problem if a fast answer is required because a bitmap must be transmitted to each request.
- Sometimes the latter point carries with it important slowness, specially when successive requests are sent: zoom level changes, lateral movements (*pan*), etc.
- These systems usually choose very little screen areas in order not to affect the client with even longer waitings (it must be said that a 'x' enlargement of the XY screen size means a x^2 enlargement of the file to be generated and transferred). Nevertheless, small sizes are very often inappropriate for users requiring synoptic views of a territory, or that simply want to have a bigger screen area for the map in order to place many elements on it.
- Elements are not individualized (they are not "detached"). In other words, every geographical object has lost its individuality because the whole sight has been converted into a screen dump. This problem prevents the user from easily separating a road from the administrative area where it is, and creates difficulties in the queries by location, because consulting the same screen pixel may lose the reference about how many and what elements there are on it.
- The georeference is non-existent or poor, so it is not easy to provide alternative coordinate systems, which are often the ones the user requires. A typical example is wishing coordinates in degrees, minutes and seconds of longitude and latitude when we consult a dataset projected in Mercator system, usually used in coastal and sea GIS.
- The eventual printing of the maps or its inclusion in other documents has a very low quality because it usually has screen resolution (about 72 dpi) and, as we have already pointed out, only a small image is transferred in order not to slow the system so much.
- The combination or analysis between information sources coming from other origins is not possible.
- It is practically impossible to enrich the server system with some new data coming from the users feedback because the user works with a too small and degraded part of the original bases.

2.2 Data transference in a supposedly standard format

This option is useful when we wish to prevent most of the former problems. Moreover, we can point out some important advantages, such as the possibility of reading the original data without neither restrictions produced by the screen resolution or the visualization window, nor by zoom level limitations or by the geographical extent. The data distributor assumes that the user has the necessary software for the visualization of the information. However, this method has also its problems:

- If the data are offered in its original format, the transference will be much slower, because algorithms of data compression are not usually used in the GIS programs. If data compression algorithms are used, the import capability is usually smaller from other softwares different from the one that generated it in the server (less "standard" formats), and if more common data compression formats are used (PKZIP, ARJ, etc.), it is not possible a direct visualization of the data once downloaded, but it is necessary decompress them previously and to indicate the appropriate software for viewing the data.
- When data are imported, the special characteristics of visualization are very often lost (color, patterns, etc.).
- Nowadays there is still a lack of real standards for the distribution of geographical information. In fact, in the case of raster formats, these are very often distributed in very inefficient formats (ASCII), or in formats inappropriate in cartography, either because of its degrading compression technology (in the case of the JPEG, inappropriate when used for remote sensing data) or because they do not offer minimum guaranties of georeferencing (in the case of BMP), or uncompleted (in the case of the usual GeoTIFF and subtle aspects of georeferencing). In the vector case, CAD program formats are usually considered standard, but they are inappropriate for a GIS because they are not topological, they do not have a natural link with databases, etc. It seems particularly strange that explicit polygon formats (with all the edges described twice) thrive again, when at the beginning of the 80's decade the scientific community discussed and concluded that the arc-node model was the appropriate one to store, control and support big vector bases of polygons.
- Besides the aforementioned disadvantages for the user when he has to download them, decompress them, import them and adapt them (eventual reconstructions of topology, etc) before opening them, the data distributor must not forget any of the related files in the dataset or the reading of the distributed data will be incomplete. We must point out that we may not only want to distribute the basic geographical and alphanumerical data, but also we may probably want to distribute associated tables (thesauruses, external tables) or even other related documents (texts, worksheets, etc.). To be on track of all the documents related to a certain cartographic base can be an impossible task in its entirety if we do not have a specific program.
- "Standard" formats are usually very poor in metadata, so the increasing standardization requirements in these fields are badly covered (Sheth and Klas 1998, Devogele et al 1998).
- "Standard" formats are usually also very limited to take up hyperlinks, so the documentary access offered to the user is very often poor, although many times the related documents can be as or even more important than the dataset that is distributed (for example, legal or technical texts individually referred to the different areas or elements of the map, such as the ones regarding different protected areas, new traffic infrastructure projects, etc.).
- If detailed data about a very wide area are offered, the files can become too big to be transferred in a reasonable way, so the area must be divided in zones following administrative units, standard cartographic sheets, etc.
- It requires training, experience and patience because it is necessary very often to know the many details it has. It is not suitable for general public.

The solution to the problem of GIS cartography distribution through Internet or on CD is, in our opinion, a compromise between the two former approaches. It consists of a free of charge distribution tool, easy to use and with high performances, as well as an appropriate and automatic preparation of the data in information packets easy to download. It is not surprising the appearance of some tools exploiting this idea from different points of view, such as the MiraMon Map Reader. In our case, we have eliminated problems such as the previous downloading and the manual decompression/opening. Besides, we have minimized (zipped) the file size and we have maximized the integration with the client operating system and Internet tools.

3 THE MIRAMON MAP READER AND THE COMPRESSED MAP

The **MiraMon Map Reader** is a program of free diffusion that permits the visualisation, query and printing of maps published in Internet or on CD-ROM. The maps must have been generated with the **MiraMon** Geographical Information System and Remote Sensing software (Pons 2000a) endowed with an specific license called MiraMon Internet Map Publisher. With the MiraMon Map Reader we can prevent the main part of the formerly commented problems for other techniques of geographical data distribution.

In the MiraMon Map Reader, the information distributed through Internet or on CD-ROM has a basic element called **MMZ file**, a compressed format containing MiraMon Maps or other kind of electronic documents. Here, the concept 'map' is much wider than the one referred to a conventional paper map. In fact, a map becomes a whole of **digital layers of territorial information**, georeferenced**,** which can be queried by location (by clicking at any point we will be told what is there) or by attributes (we can ask the map to find us a specific element, such as a meteorological station, or a specific phenomenon, such as the meteorological stations with a January medium temperature below 5ºC), and that may have **any other associated information**: textual documents, worksheets, images, diagrams, sounds, HTML pages, Internet addresses, or even other maps linked in its turn to other information microcosmos (Figure 1).

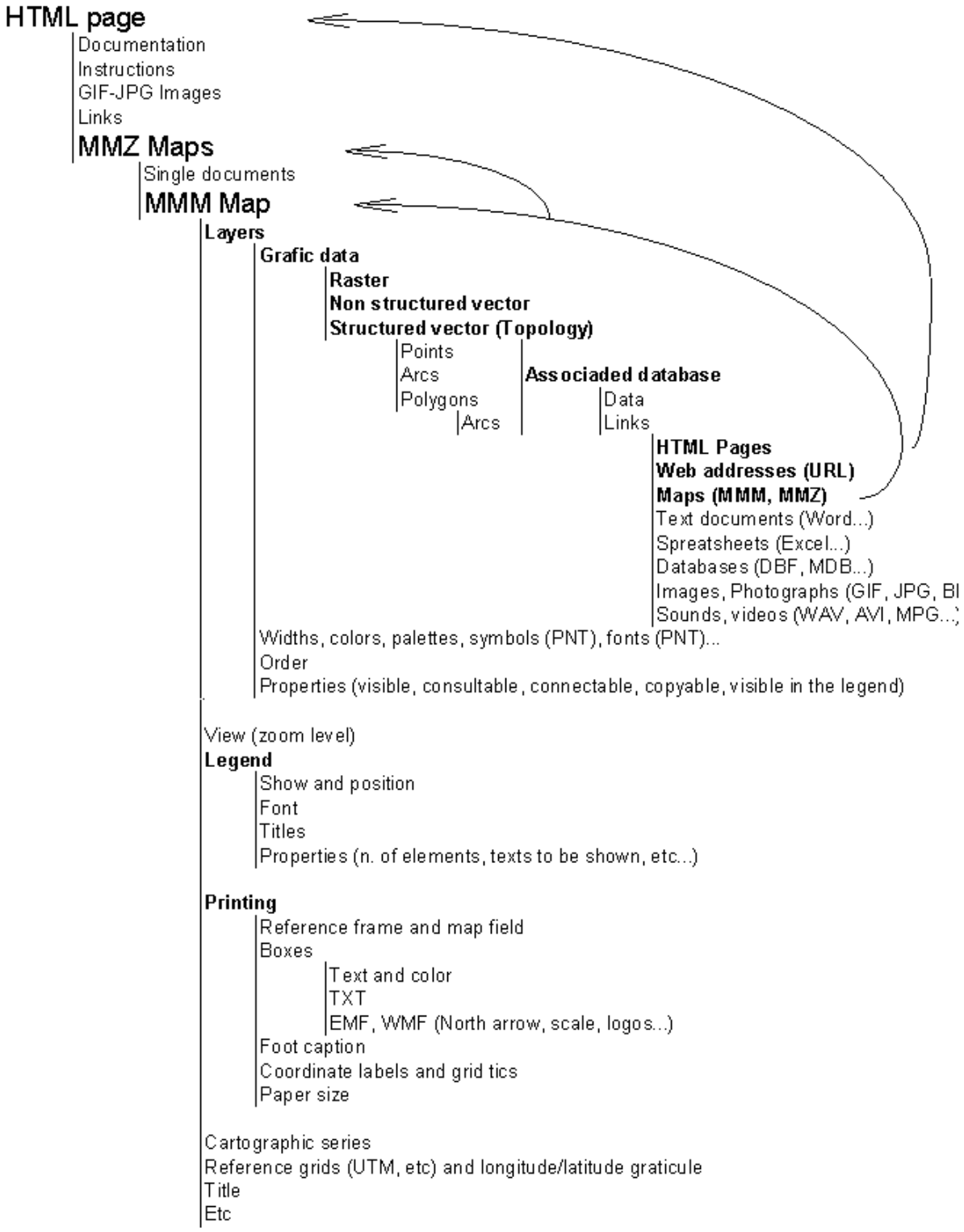

Figure 1: Composition of a map stored in its entirety in an MMZ file.

When an MMZ file is generated to be distributed through Internet, both the direct content of the MiraMon Map and all the files linked to it will be included in the compressed map in order the users use them. If links to URL addresses (Internet) are concerned, they are not "included", but the system is prepared in a way that, when the user requires that information, the Reader will open the navigator and will take the user automatically to the appropriate HTML page. The MMZ file also includes the characteristics and parameters that determine the way in which data are visualised, queried and printed.

The basic contents of a map can include raster or vector data, database tables or a combination of these elements. In the **raster** case we can distribute images, such as air photographs or satellite images, data regarding the relief, such as digital terrain models or digital slope models, raster thematic cartography, etc. In the **vector** case we can include point type elements (such as sampling stations or geodetic heights), line or arc-node type entities (such as contour lines or hydrographic or communication networks), or polygon type entities (such as areas of administrative boundaries). In the case of **database tables** we will have information related to the entities or to the spatial positions, such as censuses, statistics, other tables, links to a new information, etc. As we have already said, we can include here **any type of electronic document** or **URL address** (Internet) and we can open it with a single click, no matter where it is on the local computer, the Local Area Network (LAN) or the Internet. It is simply necessary that the operating system itself knows with what application a document or an URL address must be managed, and the MiraMon Map Reader will know too.

Obviously, it is possible to distribute environmental information but also any information directly or indirectly concerned with the territory. We must point out that any information, although not strictly cartographic, can benefit from this philosophy if it has a territorial representation. Good examples are legal texts and other text documents related to a protected space.

An aspect to be taken into account is that data offered through a MMZ file server could be the basis for later works. This provides coherence and makes easy the comparisons and studies made from other disciplines. Inconsistency problems and other mistakes are also avoided, for example the ones produced when users must reintroduce data, either cartographic or alphanumeric, into the computer again: as you give the data itself, no retyping nor digitizing is required. At the same time, the synergy between data increases because the information of a map can be combined with the information of any other map.

4 PHILOSOPHY OF THE SYSTEM

The philosophy of the MiraMon Map Reader does not lie in giving a simple screen dump or a small data selection, but in offering the **access to data themselves**, so that the user could consult and exploit them as thorough and as many times as he or she wants. As we said before, data are distributed in a totally professional format, that can be queried and, if desired, it can be clonic to the one of the original information.

Moreover, since data are provided as a whole, the user can make the queries, if he or she wants, **disconnected from Internet**, saving traffic problems in the net and at a lower price. Thus, in cases in which a team formed by several people (professionals, school students) wants to work on the same data, it is not necessary that all they connect themselves to Internet. It is possible to make a single connection, to copy the information on a local net server and to work on the copy.

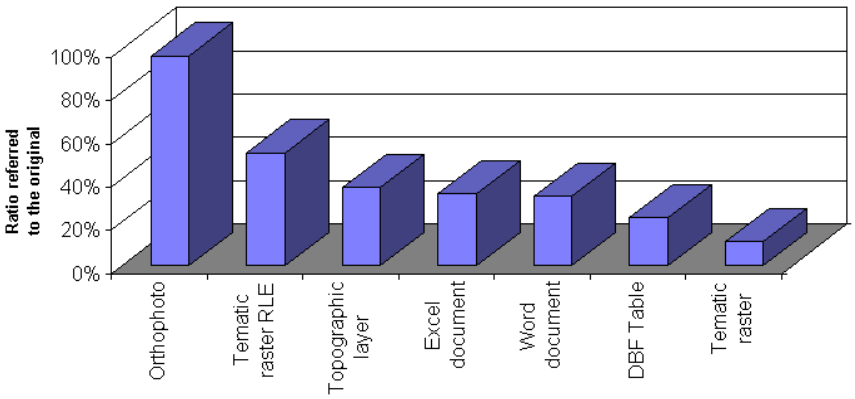

Figure 2: Data compression ratio depending on the type of file

The generation and transference of information is obtained by means of the **most advanced compression algorithms**. It implies a saving in time and money, both in the download time (which is a benefit for the user) and in the server availability (which is a benefit for the user and for the data server as well). The data compression level depends on the type of files, and it is very important in the case of thematic raster files or database tables, and important in the case of vector files. The file compression of the web of the Department of the Environment (DMA) of the Autonomous Government of Catalonia, for example, implies nowadays a size reduction to the 37% of the original size.

Although this philosophy can seem not feasible because of the large quantity of information to be transferred, it is not really like this. With other systems, it is necessary to wait the answer of the server to each query, the generation of screen dumps of tens or hundreds of Kbytes and its transference, to finish up by obtaining a simple sight of the information without a true individualisation of the elements and without georeferencing. Instead, the MiraMon system prepares a packet with the data that allows to transfer smaller files or, at least, a much richer and more versatile information, opened to interrogation. A simple consultation to the DMA web (DMA 2000) or to the Miombo web (LUCC 1998b) will give clear proof of that. It is evident that in this web, big files can be found too, but none of them is not downloading with the most modest present telecommunication systems; if, besides, we have fast Internet accesses we will have at hand the whole relief of Catalonia (32000 km^2) on a 1:250000 scale in less than a minute, with the precision and richness of the digital topographic cartography, not like a drawing. We must point out too that the capability of the current disks allows to include practically any information in a server, even if it is organised in different thematic or territorial fields.

On the other hand, and concerning other present strategies based on graphic formats that must be downloaded, decompressed, converted/imported and adapted before being visualised, the MiraMon Map Reader gives us all the information with a simple click from the web browser and allows us, in a **continuum**, to go directly from the navigator to the Reader, to the territorial zooms, to the queries, to the layer combination, to the opening of documents of any type and, again, to Internet if we want to, offering a coherent and intuitive environment but not simplistic and based in a high performance product such as MiraMon (Figure 3).

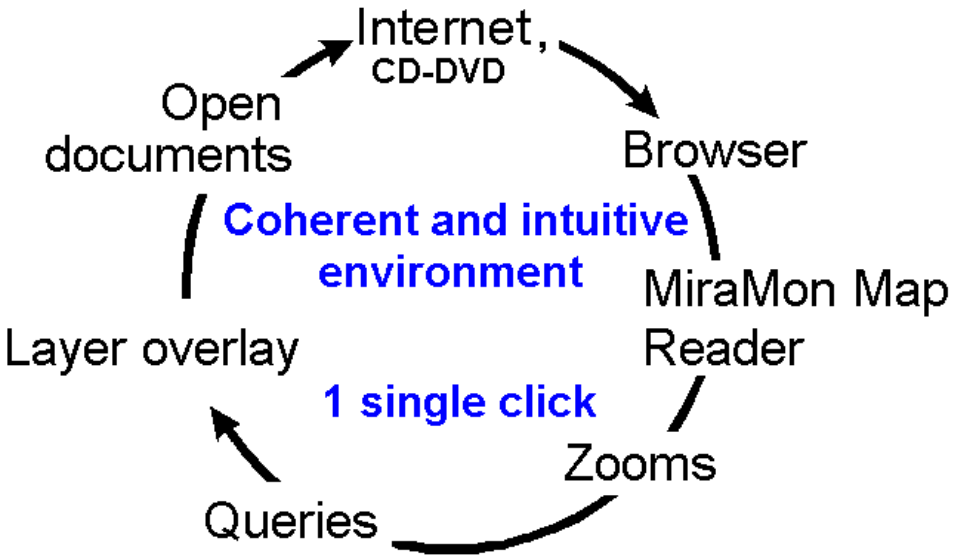

Figure 3: Information flow with the MiraMon Map Reader

The philosophy of really distributing the GIS data poses the problem of its integrity and authorship. That is the reason why when a MMZ file is prepared for Internet, a specific **certificate** for that file, which has an effect on all the layers and databases it contains, is included. Since the MiraMon Map Reader verifies the integrity of this certificate before showing the data, the data is offered to the user with **guaranteed integrity and known authorship**.

As we have already said, the transference of a compressed MMZ file **simplifies to a single click** the use of the data by the user: the file is downloaded, the constitutive elements of the map and the linked associated documents are decompressed, the map is opened and visualised, all this in an automatic way. From the moment in which the MiraMon Map Reader is opened and the decompression starts we can already disconnect of Internet if we want.

Although the system replicates in a temporary directory the hierarchical structure needed to reproduce in a appropriate way the needs of data structure in origin, the user does not need to erase none of the files once consulted, but it is the MiraMon Map Reader which erases everything at the end. The elimination of the MMZ file transferred by the

navigation software and delivered to the Reader is managed by the personal configuration of the user's navigator, as in any automatic downloading in Internet.

Although the simplified use we have explained, advanced users, or the less sporadic ones can store on their hard disk the MMZ transferring and keeping them in personal directories of their computers by the usual methods (right button, etc.). Once on our hard disk, a double click from the file explorer will permit us to open them again without connection to Internet. If we want to generate new maps by combining different layers and/or to change the visualisation coordinates, it is convenient to decompress the MMZ file from the same browser using the contextual menu of the right button of the mouse. If we select this option, we will be able to open directly the decompressed MiraMon Maps (MMM files), which we will find in the directory where they have been decompressed or in a subdirectory.

5 GENERATION OF MAPS TO BE DISTRIBUTED

The generation of maps to be distributed (MMZ files) is made directly from the Maps the complete SIG MiraMon works with (MMM files). Thus, the person who prepares a map to be distributed through Internet only has to indicate that he or she wants to transform the **MMM** into a **MMZ**, **without the need of preparations or additional format changes**; this philosophy is specially appropriate for habitual users of MiraMon, for whom publishing their maps in Internet is very simple. On transforming the MMM into a MMZ there is an added interest: the fact that it is automatically prepared to transfer, not only the basic information but also the characteristics and parameters that determine the way in which data, associated linked files, etc., are visualised, consulted and printed.

Since MiraMon reads in a transparent way or imports formats such as BMP, TIFF, GIS-LAN, IMG, VEC, DXF, E00 or DBF, it is possible to prepare a MMZ file including data originally coming from **other GIS** and **database management systems**, such as ERDAS®, Idrisi, AutoCad®, MicroStation®, Arc/Info®, ArcView®, dBASE®, MS-Access®, Oracle®, etc. The cartographic layers and the databases included in a MMZ will be showed directly by the MiraMon Map Reader. The capability for reading other types of linked files (worksheets, sounds, etc.) will depend on the software installed in each client computer, but thanks to the *de facto* standardisation of some formats that practically any Windows installed can read, it is not usually a problem.

The compression process of a MMM into a MMZ has been thought and programmed with some important characteristics:

- It generates the maps to be distributed (MMZ) **independently of the disk or network units** where the different elements are placed (raster or vector layers, databases, documents of any type spatially related, logos, etc.). It is not necessary to have all the elements on the same disk or directory, but they can be on any physical unit (C:\, F:\, \\SERVER\MAPS) or a unit relative to the map (..\..\...\Data\Climate\, ...\Data\Climate).
- The program of MMZ files generation **searches automatically for** all the documents related to the MiraMon Map and includes them automatically into the MMZ to be distributed.
- Moreover, it **also searches for and include all the related documents mentioned into the databases** (for example, if at a point of an information layer a reference to an Excel document is made, it is also included in the MMZ file to be distributed). The person who prepares a MMZ can consult at any moment the file list that it contents before its definitive publication in Internet.

The MMZ files are placed into the server, linked from HTML pages in the conventional way in the Internet. **Exactly the same technology can** be used to distribute information in intranets or on **CD-ROM**. In fact, if we have a web with compressed maps and we want to generate a CD, we only have to record the content of the server to the CD (generating an autorun file if it may be considered appropriate).

6 THE PROGRAM

The MiraMon Map Reader (Pons 2000b) is a very small application (less than 1 Mbyte the EXE file and about 2 Mbyte as minimum disc requirements), very fast, able to work with big files in size and complexity (2 Gbyte per file). Since it is totally programmed in C language it allows us to obtain a code of the highest efficiency that does not require a hardware of high performances; in fact, with only 8 Mbyte RAM any conventional topographic sheet can be visualised without difficulties. The program is available in three languages, English, Spanish and Catalan, and encloses a vast manual and helps of about 200 pages.

The MiraMon Map Reader is a native 32-bit application that can run on 3.1x, 95, 98, NT and 2000 Windows in Intel platforms or compatible (Cyrix, AMD, etc.). In the case of the 3.1x Windows, the Win32s extensor, free of charge in the Microsoft website, is needed. To take the highest advantage of the characteristics of the program and maps, satellite

images, etc., that the program can show, the graphic card of the computer must be configured for a minimum of 32.000 colours.

To install the application a single 1.5 Mbyte executable file must be transferred. The installation does not need any library external to the standard Windows itself, because it is integrally based on the Windows 32 bit API. This means that neither the content of the folder nor the one of any other directory is modified with the exception of the folder where the user has decided to make the installation. Neither the folders of the navigator are modified because it is not any plug-in but an autonomous application coordinated with the navigator when it is necessary, but that can be used locally in an independent way. The only installation interactions with Windows are some changes in the register to give more flexibility and performance to the work with the MiraMon files.

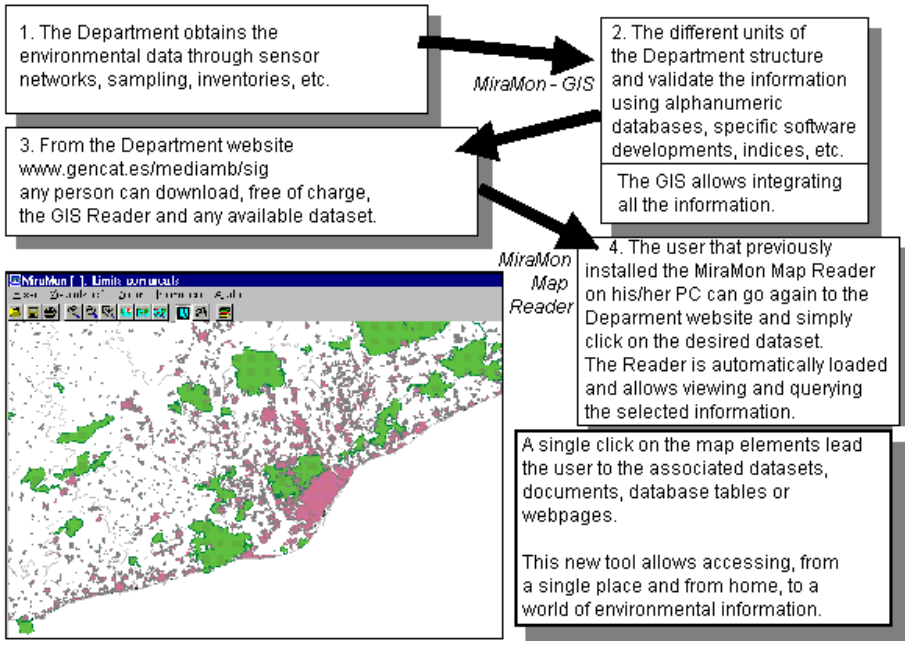

Figure 4: Table summary of the system operation. Source: Website of the Department of the Environment of the Generalitat de Catalunya (DMA 2000).

The MiraMon Map Reader works with certified MMZ files and, among other capabilities, allows:

- **Query** by location (to identify what is at any point) or by attributes (to find where an element or phenomenon can be found) both on **raster** layer (1, 8, 16, 24 and 32 bits, extra-compressed or not) and on **vector** layers. Vector layers have true topology. The most usual **statistics** about the queries can also be obtained.
- **Automatic overlay** of layers thanks to the fact that it works with georreferenced information (in double precision).
- Automatic **geographical synchronisation** of different windows in order that, if we want, we could see the same area in some of the Reader sessions opened each time a zoom, a pan, etc., is made.
- **Zooms** by different criteria. Lateral movements (pan).
- A wide variety of possibilities of **visualisation and symbols**.
- Visualisation of **database tables** (MiraDades) with functionalities of sort and search.
- Creation of **professional compositions** to make **high quality printings** at any paper size. Easy incorporation, through the clipboard (***copy and paste***) and with its original quality, in office applications (Microsoft Word or Powerpoint, CorelDraw, FreeHand, etc.). Enhanced metafiles (EMF) or high resolution Windows bitmaps (BMP) can be generated alternatively.
- Control of the visualisation scale; knowledge of the position: map (UTM, etc) and geographical coordinates.

- A simple access to the information, based on menus of different complexity level, and a button bar for the most characteristic functionalities (zoom, layer reorder, search, etc.). The basic utilisation can be learned in a few minutes.
- Access to the metadata of each layer, following the CEN and FGDC specifications (Arctur et al 1998, FGDC 2000, CEN 2000). This aspect is precisely under development at the moment.

The MiraMon Map Reader is based on the **MiraMon** Geographical Information System and Remote Sensing software, a program developed by Xavier Pons and his co-workers that has at the moment (March 2000) more than 1000 users registered in 14 countries in the world and that is used annually by hundreds of students in degree or PhD courses in different universities.

The DMA website of distribution of GIS data, based on the technology of the MiraMon Map Reader, won in October 1999 the Möbius award to the best multimedia scientific-technical application (Spain and Portugal edition). This page distributes at the moment about 150 cartographic environmental datasets as well as reference conventional topographic maps.

ACKNOWLEDGEMENTS

In different times of its development, MiraMon has relied on the support of the Department of Agriculture (DARP) and the Department of the Environment (DMA) of the Generalitat de Catalunya. The MiraMon Map Reader development has been decidedly supported by the DMA.

REFERENCES

Archer, H., Croswell, P.L., 1989 Public access to geographic information systems: an emerging legal issue. Photogrammetric Engineering and Remote Sensing, 55:1575-1581.

Arctur, D., Hair, D., Timson, G. Martin, E.P., Fegers, R., 1998 Issues and prospects for the next generation of the spatial data transfer standards (SDTS). International Journal of Geographic Information Science, 12(4): 403-425.

CEN, 2000. CEN – The European Committee for Standardization. http://www.cenorm.be/.

Devogele, T., Parent, C., Spaccapietra, S, 1998 On spatial database integration. International Journal of Geographic Information Science, 12(4): 335-352.

DMA, 2000. Sistema d'Informació Geogràfica del Departament de Medi Ambient de la Generalitat de Catalunya. http://www.gencat.es/mediamb/sig (first website distributing maps in MMZ format)

FGDC, 2000. Federal Geographic Data Committee Metadata. http://www.fgdc.gov/metadata/.

Gould, M., 1998. Innovación en Sistemas de Información Geográfica. *in* Alegre, P. (ed.) "Tecnología Geográfica para el siglo XXI". Servicio de Publicaciones de la UAB, Bellaterra. p. 41-59 (397 p.)

LUCC 1998a. LUCC CD-ROM Series. Nr. 1: Miombo. Land Use and Cover Change International Office. Barcelona. 1 CD-ROM. (DL:B-3674-98)

LUCC, 1998b. LUCC CD-ROM Series. Nº1: Miombo Internet release (mirror). http://www.creaf.uab.es/miramon/mmr/examples/miombo/docs/index.htm

Maso, J., Desanker, P.V., Augé, J.I , Baulies, X., Pons, X. 1998 Miombo CD-ROM Databases. CD-ROM Proceedings of the International Conference and Exhibition on Geographical Information Systems, GIS PlaNET'98, Paper Nr. 72. Lisboa.

Pons, X., 2000a. MiraMon: Geographic Information System and Remote Sensing software. http://www.creaf.uab.es/miramon

Pons, X., 2000b. Lector de Mapas de MiraMon. Introducción. http://www.creaf.uab.es/miramon/mmr

Sheth, A., Klas, W., (eds) 1998. Multimedia and Data Management: Using Metadata to Integrate and Apply Digital Media, McGraw-Hill.