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The Electronic Elaboration of Images: A Rapidly Developping Field

Remote sensing, as one of the computer sciences applications, gives the necessary correct and balanced evaluation within the whole cycle of data processing.

In fact, during the input phase, we need to operate on equipments which can make it possible to acquire information by analogical supports (transparents, maps, photos), and digital supports (cd-rom, tapes, cartridges) in different formats, where format indicates the type of package used in the file creation.

In the processing phase, we have to take into account the need of working on large amounts of data. Then, we need hard disks which are able to contain many gigabytes of information and cpu with such a speed as to minimize the stand-by time between a processing phase and the next one.

Here, too, while choosing the processing software, we have to take into account many aspects, such as the availability of suitable tools for manipulation and image processing execution speed, which does not only depend on the hardware possibilities of the computer, but also on the correct design of the processing software.

The acquisition of software and format which are widely used can be advantageous for a more flexible cooperation within the same work group and between different research organizations. Many of the above considerations are also valid for the output phase. We need to have the possibility to plot, print and memorize the processed products on different supports according to the product we want to produce and this has to be done in such a way as to make it possible to export it to any other computer.

It may serve well to in detail the three phases: input, processing and output. It is difficult to establish the order of importance of the output main devices which contribute to a larger flexibility of data acquisition.

Scanner is a kind of photocopying machine able to read the colours of a picture or a film through digital selection filters and to transform them into figures by scanning its tone and number of colours.

Most suitable scanners for these purposes usually work in the 24 bit true colour mode (that is 16 million colours). Regulation parameters have to allow scaning the image up to the resolution of 1200 dpi supplying files in the most common format. During this operation, one has to keep in mind the final target. If we want to screen the image digital copy, in the original image's size, it is enough to acquire a 72 dpi resolution, that is the resolution of the processor monitor. If we need to print the image or the results of its processing, it is necessary to acquire data at least with a 150/200 dpi resolution for average/low quality printers, as laser or ink-jet. If we want to obtain photographic-quality products with thermal or sublimation full colour printers, we have to acquire data with 400/600 dpi resolution.

It is interesting to see that, increasing scanning resolution, it is possible to obtain on the screen images much more detailed than the original ones. The image acquired at a high resolution will appear larger than the coefficient depending on the quality of the supplies to be digited, as the film characteristics on the file space in the memory.

By acquiring this image at high resolution and visualizing it according to monitor resolution, we have a zoom effect before we apply any kind of processing. During the acquisition phase, it is possible to interact both on the resolution and the parameters which are in charge of brightness and contrast. Furthermore, very important device is the cd-rom reader. It became a standard memorizing system for many companies and organizations who use it in order to distribute their data.

Cd-rom can only be read and this characteristic may appear disadvantageous, but at the same time it guarantees the non-deformability of data. Furthermore, it owns the considerable capacity of about 600 megabytes. Such spaces are necessary, if we consider that memory space of SPOT or TM satellite images can be about 40 megabytes large for each band of the same scene. The seven images of the TM shot bands can then cover more than 300 megabytes equivalent to the available space on the whole disk of a small pc. Magnetic tapes, too, offer a similar availability; and in addition they are rewritable and therefore they are useful tools for memorizing and data exchange.

There exist also rewritable cartridges, back-ups, external hard disks and many other supports. The difference between them is mainly in the different access time to information and in the eventual possibility to rewrite the support itself. We recommend the use of cd-rom for final storage and cartridges or tapes for exporting or temporary storage.

One has to underline that networks are vey useful as further vehicles for data exchange, both in local (lan) and in the remote (wan) environment. Connections between different processors, personal computers or work stations make information exchange possible between units located in the same laboratory or building and also in different countries.

In the first case, this can give us the possibility to carry out work, where data are acquired, processed and produced distributing specific tasks and responsibilities among the value units of the group or work groups.

In the second case, network communication creates immediate comparison and cooperation between research centres located in different countries, promoting a mutual growth. At a local level, there are many solutions which are feasible by exploiting a software, peculiarities of which range from the simple file transfer to the complete visibility of the connected equipment's features.

In contrast' for a connection at remote level, we need international networks. The most significant one, today, is Internet, whose potential is considerable. At present, it represents a virtual space shared by several millions of users. Internet connects local networks located all over the world.

The update evaluation is of 3 million connected processors and 30 million users. It is difficult to imagine what Internet really is just by giving a simple definition; it would be just like saying that a book is a set of words.

Let us say that Internet consists of a community of individuals in continuous evolution, searching for information, sending messages, supplying data, exchanging ideas, carrying out commercial transactions and so on. Particularly interesting, in Turin, is the project, which is now being carried out, of a town-network via Internet. This idea is the fruit of the cooperation between public and private bodies. The purpose is the distribution of information in a comprehensive way and the re-establishment of a contact between citizens and public administration.

The data, processed in our field, are mainly consisting of large images. The processing phase, therefore, requires fast computers and suitable software. Personal computers have not the sufficient power for responding to our demand. Even by using 486 processors or pentium, we find ourselves in long stand-by times, that is several minutes, for a simple visualization of 50/100 megabyte images. Stand-by times may become considerably longer when particular 'processings' are applied.

Dos is probably the most widespread operative system in the world. It represents a very good standard example, but it has some limitations which derive from the very first design and today evident. According to the different needs and work phases, the choice of computers, operative system and packages is important.

To process a small image (10/20 megabytes) it is enough to use a pc featured as follows: 20 megabytes RAM, 486 processors or more, 1 megabyte hard disk, a true colour video card.

A work station is more suitable for the elaboration of large images. Someone said that a work station is a computer with a big screen, a mouse and a keyboard. If so, a pc might be considered in the same way, but a fan of Unix would not agree. On the contrary, we think that a computer with the Unix operative system is a work station, indeed, like Sun, Digital or, better, Silicon Graphics.

The Unix operative system performed a great evolution in the last 20 years. At the moment, there are many kinds of Unix which share several characteristics but, at the same time, present a few differences in the release that creates obstacles even to the experts. Fortunately, although this system is not a friendly one, many environments similar to MS-Windows have interfaces in their metaphor but not in their philosophy.

Data processing speed depends also on their storage site. RAM is where operations are executed. Access to RAM is at least 10 or 20 times faster than the access to the hard disk. Therefore, the larger the file portion in RAM, the faster the process. If the size of the data to be processed is larger than RAM, data are divided in small blocks which can be contained in RAM. Obviously, the smaller the space at our disposal, the larger the number of blocks transferred from hard disk to RAM. This operation is called SWAP. SWAP operation takes time and makes the execution of image operations slow down. Visualization time can be considerable, too, especially with true colour video cards. Then, we need to have graphic cards connected to fast communication bases.

It is evident that processing speed is not the only responsible for the performance increase, other factors contribute to it: memory availability, access time to hard disk, RAM, graphic cards, data transmission speed between the system units, the system architecture itself. This architecture varies considerably from computer to computer, but differences become much more relevant between a computer and a work station.

Written application for pc and work station are designed in a different way. Some routines, in particular those for memory management, or swap are optimized in the case of the Unix system. The same application written to MS-DOS, MS-Windows, Windows-NT, Unix, etc., can have the same interfaces, although the working engine has a completely different nature.

In remote sensing we have many softwares ranging from applications oriented also to GIS functionalities as Ilwis or Macroimage, up to many others, lacking in features, linked to the data base management, but with the support of more detailed processing tools, as PCI, Er Mapper, or Erdas.

Erdas is the tool we work with: this choice is due to the same fundamental features that a software should have to be suitable for remote sensing in archaeological environment.

Geometric registration allows us to correct the landscape distortions on satellite images or geometric distortions on aerial photographs, due to unintentional variations of the aircraft route during the shot.

Georeference allows us to attribute to each point of the image a couple of coordinates belonging to a projection system (utm, kilometric).

This operation is useful, as it gives us the possibility of having the real position of the ground object within the required reference system. It enables us to find the visible element on the image but not on the ground, or, on the contrary, to search in the image certain patterns as a result of checking on the ground.

Depending on the work phase or on the target we want to achieve at that precise moment, we will have a different approach. Georeference is an important operation to check if interpretation is correct. Furthermore, the site has to be put on a topographic map, that is why we have to know its exact position on the image in the required reference system, especially in those areas where the anthropic action is dynamic. A clear example is the experience in Jordan.

Software has to be equipped with a complete set of tools which can enable operations as filtering, geometric elements emphasizing, spectral analysis, radiometric analysis.

Image processing, which should not be confused with computer graphics, varies according to the application field. Advertisement, medicine, remote sensing and others use different processing tools. Then, within each discipline, there can be many research fields: as far as remote sensing is concerned, for meteorology, geology, environmental protection, archaeology. For example, the execution of processes, as automatic classification, does not seem so useful in the archaeological field, as it is usually in other fields.

Remote sensing can be defined as an euristic science, where, because of the high variability level of analysed situations, the observer's experience plays a fundamental role.

Then, it is necessary to read images identifying the eventual areas of interest having in mind their morphology, the different kind of vegetation, the geometric data, the elements spatial disposition according to the site history.

The interdisciplinary grade related to this application is evident. Remote sensing, when used by the archaeologist, involves a synergy between different professional identities.

Archaeologists supply ideas and indications about characteristics of the elements in the area. Processing and interpretation produce, as a result, the best indication about the objects on the ground.

This data has to be read again and interpreted by 'the eye' of the archaeologist himself, who, within this armonic cooperation, can free himself from the intrinsic meaning of concepts as pixel or byte.

In any case, we have to briefly explain the pixel concept. Image processing through computer involves a passage from the analogous world (real) to the digital world (image representation in the computer). Cinema represents an example of a passage from real to imaginary. The human eye is satisfied with a perception of about 28 photograms per second to have a full motion vision. This means that, by choosing only 28 photograms, we are able to reconstruct, or better, to have the illusion of reconstructing, an infinite number of photograms in that second. It is just like trying to represent a function describing only a few values. If we look at the scene in the slow-motion, that is, if we try to see what is happening between photograms, we notice we need more than 28 photograms. Let us say that cinema samples reality.

We carry out a similar operation when making the passage from analogous images to digital images. We sample the real image by choosing to represent a certain number of points per inch. The larger the number of points, the better the image definition; so, as a consequence, information loss in this analogous-digital passage is less.

Every point of the image is represented by a pixel. Pixel consists of three integer values (x,y,i) where 'x' and 'y' represent the spatial coordinates of the point in the image and 'i' represents the value of the point brightness intensity.

Pixel is the fundamental element of image. A TM scene, about 180 km large, is represented by a set of 7000 lines which are themselves of about 7000 pixels. In this case every pixel represents an area 30 m x 30 m large, equal to 900 sq. m. The information contained in a pixel is not easily retrievable. Anyway, it is possible to obtain interesting information, if the element contained in those 900 sq. m is sufficiently reflecting so as to influence the near pixels. Every kind of images represents reality with a resolution which can range from the TM 30 m to the SPOT 20 m, to the panchromatic 20 m and so as on up to resolutions of a few centimetres in low altitude shots.

The concept of 'infinite' is an abstraction that comes very useful in mathematics. Unfortunately, within a computer we are tied up in finite spaces and quantities. This gives rise to some limitations in the representation of images. The most evident one is the space they occupy in the memory. An image in grey scale (256 tones) needs 256 different representations per pixel. Then we must be able to attribute one of those 256 available colours, chosen in an infinite set of colours, to every pixel of the image.

To be able to represent different combinations of 'n' with exponent 'm', we need 'n' objects to be permuted in 'm' different positions. In the binary system, adopted by computers, we have at our disposal 2 objects: 0 and 1.

Then, we need 3 positions to obtain 256 combinations. This means that an image consisting of 512 lines and 512 columns in grey scale occupies 512 x 512 x 8 bit = 2 w.e. 9 x 2 w.e. 9 bytes = 2 w.e. 8 x 2 w.e. 10 bytes = 256 kbytes.

A TM scene has a size of about 7000 lines x 7000 columns and therefore is 50 Mbytes large for each of the 7 bands. Any additive synthesis will be about 150 Mbytes large and the 7 bands all together will be about 350 Mbytes large. Any processing on each band costs at least 7000 x 7000 = 14 million operations.

If we apply a filter with 3 x 3 kernel to an additive synthesis, we will have about 756 million operations. Such an amount of data and operations can be managed only by particular softwares and hardwares.

If the computer is able to carry out a million operations per second, this simple processing costs about 12 minutes. By using a work station, this working time is reduced to about one minute with a processing power of about 20 million operations per second.

A further necessary characteristic for a software is the possibility of vectorializing the available digital data. Vectorialization of raster images is an old problem. There are softwares designed exclusively for this problem, which has not been definitively solved, yet. It is very useful to supply vectorial data in the output phase. Then, they can be processed by softwares as Autocad or also plotted in order to obtain maps, the reading of which is interesting if compared or overlaid to raster prints.

Many of the considerations made about input are valid for output, too. It is useful to be able to produce both paper and digital results in a large number of formats.

We recommend sublimation full colour printers or printers that can contain the information loss in the lesser possible extent during the digital-analogical passage (opposite to the previous one). It is also useful to produce prints in grey scale only if these have a photographic quality obtained with a thermal printer. For the production of large prints we can use raster or vectorial plotters.

Unfortunately, the cost of this equipment is rather high but often, when equipping a laboratory, we are obliged to make very definite choices. External rewritable units and tape readers are indispensable for digital output. The possibility to export with different support and format makes exchange and information storage flexible.

It is clear that, today, space and time concepts should be reinterpreted. Computer science proposes solutions and work methodologies, which although they do not escape from the above mentioned bounds, they themselves influence these bounds. The above represents an evolution of the communication.