Technology based on distributed GIS tools: an approach for sustainable planning

V. Ferrara & C. M. Ottavi
Department of Electronic Engineering,
University of Rome "La Sapienza", Italy

Abstract

An information system such as GIS is the main instrument supporting decisions about complex problems in sustainable development, where geographic, orographic, rural growth, geological, geo-social, etc. data make up recurrent and important elements of planning. Many problems and territorial activities have spread characteristics, so that both analysis and management/control systems should hold in account this distinctive feature by specific design oriented to distributed objects and functions. In order to put in evidence these spread characteristics, we will introduce one example of data measures and links for application in the fields: farm activity support, natural park management and control. In particular we will focus on two systems: the remote multi-detection device and GIS. Collection of sequential data, spread on the territory, determines important choices on: structure of detection device, data transmission, links, communication channels, communication protocols, data consistency, pre/post-elaboration of data, etc. Distributed architecture of Terrapack32M GIS includes: special tools, communication server module and radio-control interfaced by different layers (DCOM, JAVA, .NET). Interoperability extended to linked applications and, in our case study, improved stages of: remote connection, update data servers and data correlations.
Keywords: Geographic Information System, Territorial Information System, sustainable planning, development, interoperability.

1 Introduction

Sustainable planning involves many different areas: social sciences, economics, statistics, environmental science, technological development, industry impact, etc. When one realizes a plan of sustainability, each area lives and adapts itself to obtain a compromise: to achieve maximum development along with good levels of environmental safeguard and social equity. The main priority is to improve life quality in any case. This result, normally of medium-long term, cannot leave environmental protection out of consideration. Much connection and correlation should be considered between different aspects of a specific sustainable planning: the danger is unexpected life degradation or loss of cultural identity, originated from the drift of some parameters of a wrong design. So, e.g., urban transport planning includes implications on trade development, air quality, habitableness of quarters, traffic reduction [1]; large areas conversion from rural to industrial zones determines changes in life rhythms, rural and mountain depopulation, contamination of neighbouring tillable zones, new life perspectives. When we forget or underestimate the weight of even one aspect during the plan organization, it degenerates and produces lessening of life quality levels after all.

Models that cover many research areas (state of health, pollutant condition, brownfield increase, etc.), monitoring social and environmental state, frequently produce indicators [2]. In most cases these indicators supply only qualitative data, because they are generated by means of an abstraction of reality and of reduced correlation analysis among original source data. More important questions are: how indicators must be managed? How to organize an information system that intersects indicators with geo-political, geo-social or simply territorial parameters? These problems rise in particular when indicators are locals, by changing from one zone to other of a territory, when they are not global in a geo-spatial sense, or when they consist of uniform data on a large area of territory where contrary social conditions, human activities or other different elements change considerably.

In our previous paper [3] we defined an information system with the main instrument to support decisions about complex problems in sustainable development. In effect it organizes and correlates inputs, data, models and output. Where the model describes a framework, the data define work conditions of models and the specifications of the regional area state at a specified time, inputs are parameter data introductions or generic questions, as political requests, outputs include indicators and their intersection with geo-political parameters. More important qualities of an information system are the capability to link, to correlate all elements that share in the framework and the visualization of friendly results. The last aspect must not be undervalued because it is fundamental to explain powerfully data outputs, and furthermore because it is a basis for information spreading.

In effect, a modern information system must take care of the interface towards other systems and the external world in general. The quality of interface design is important both for a network of information systems and for the divulgation aim. Analysis results should be spread and should become common knowledge. The aim is to increase the interest, the awareness of many important aspects of development and consequently emancipation of people.

From the point of view of interfaces and links, the information system project falls within the ICT (Information and Communication Technology) area and all aspects; from protocol to hardware configuration and internal structure define up growth level of information system design.

Figure 1 shows a simplified scheme: from the measurement of parameters to final visualization. Data acquisition and data pre-elaboration are realized normally by external and remote modules. An information system, such as the Geographic Information System (GIS) or the more general TIS (Territorial Information System), receives data by means of many different links and protocols: bus, radio link, etc. It correlates data by models, elaborates description parameters, as indicators, and finally realizes images for better visualization of intersecting parameters and basis data.

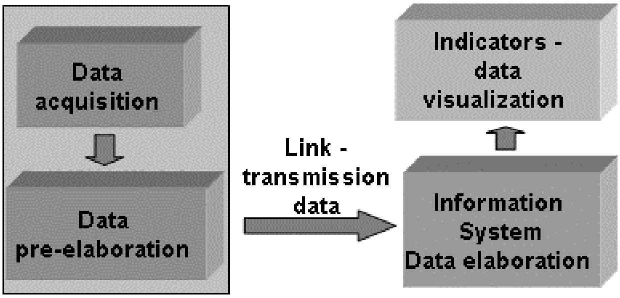

Figure 1: Data measurements are executed in remote places normally. Sometimes they need pre-elaboration before their transmission. Distributed location of acquisition systems orientates to special design of GIS.

In the following paragraphs we will examine that management and control of many problems and territorial activities have distributed characteristics normally and that internal, peripheral structures and interfaces are conditioned by technological development in the communication and information fields.

We will focus on two systems: a remote detection device and GIS; examining a special and exemplificative case: the measurement of environmental/meteorological parameters involved in the management and sustainable development of natural parks.

2 Distributed data input

At first, in order to put in evidence the preferable characteristics of GIS input interfaces, where GIS supports sustainable development analysis, we introduce one design example of data measures and links. This example considers a device prototype used in the following application fields: farm activity support, natural park management and control. More simple software products, different from GIS, could be adopted in farm activity supervision and management when

WIT Transactions on Ecology and the Environment, Vol 84, © 2005 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)

factories have a small extension. Schematic lists and maps of measurement locations are sufficient, organizing a centralized check up system. But versatility, easy reconfiguration (included addition of new input interfaces and of remote links or sensor reposition and redistribution) give a competitive basic GIS product.

Farm activity support and natural park management requires periodic measurements of a discrete number of parameters. Measurements should be repeated in different places, so that the area under observation will be described by nodes of an uneven network. In this paper we aggregate both the application fields because most parameters are in common. But the structure of measurement and survey devices can be different. The more evident difference is: in the farm activity, measurement points are fixed normally, contrary to large size parks which orientate towards mobile instrumentation for survey. In any case very small dimensions and the low power of devices are preferable, to avoid heavy impact and to limit power dissipation. Data can be transmitted on line, memorized into solid state memory or memorized and next transmitted in a delayed way. Very large capacity (GBytes) of new generation memories, joined with a very small size of flash technology e.g., allows for considerable autonomy from the point of view of acquisition data quantity and of measurement duration. Live transmission of data by means of radio-link to a master station is a design request in the case of activity reaching emergency management.

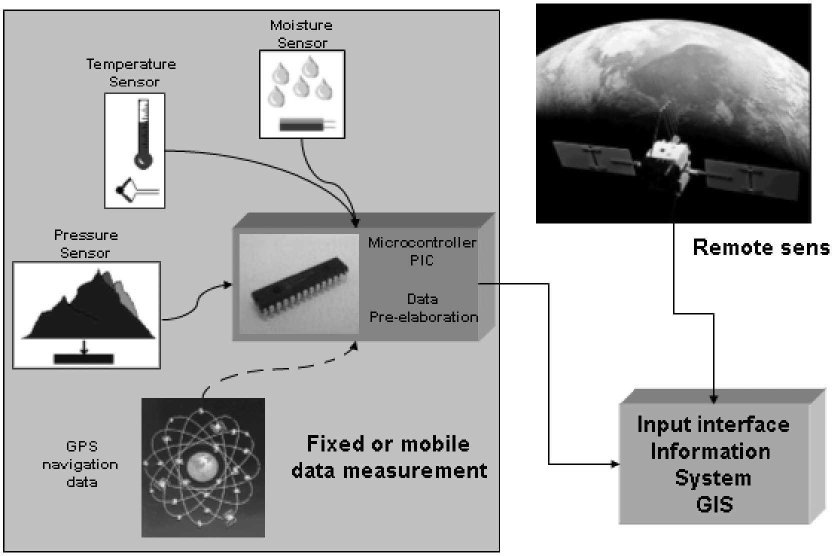

Figure 2: Normally data come from many different locations. Detection systems for fixed or mobile data measurements pre-elaborate and send data to a master station. So that input interfaces of the last one must be designed using distributed and shared criteria.

In any case, when the system architecture adopts many fixed sensor stations, operating in remote places that are far from master stations and from them, radio-link transmission is an economical solution however. It is more competitive than data memorization constraining frequent controls and movements of technicians.

2.1 Detection data device example

In farm activity support and natural park management, the data more frequently wanted are: temperature, relative humidity, atmospheric pressure and, in the case of mobile detection, location survey. Some other parameters can be important to apply special forecasts or to manage the model correctly: chemical analysis, state of plants, parasite attack, snow/ice and dry days' duration, etc. A lot of them need direct observation of experts, because the automation of measurements is very complicated or not profitable. Some measurements can be obtained by analysing global detection by remote sensing.

Figure 2 shows a typical structure of remote detections. Remote sensing and sensors distributed throughout the territory send coarse or pre-elaborated data to the information system GIS. This one must ensure that input interfaces and their structure must be oriented towards distributed organization. The same figures provide that the detection of different parameters is managed by portable devices including: sensors, microcontrollers, solid state memories, wireless modules and output interfaces. However we could have designed on a chip, we built prototypes using COTS (commercial off the shelf) components. Table 1 lists some models that are included.

Table 1: Main COTS components included in the mobile remote station of detection.

Type	Model	Trade mark
Microcontroller	PIC16F876	Microchip
Temperature sensor	LM35	National Semiconductor
Pressure sensor	XFAM-115KPa	Fujikura
EEPROM	24LC16B	Microchip
RS232 interface adapter	Max232	Maxim
Navigation device	GPS module	Garmin

The PIC16F876 microcontroller is the core of the device. It adopts: RISC CPU technology, 32 single word instructions (assembler) to learn, low-power and high-speed CMOS FLASH/EEPROM technology, 10 bit ADC (Analog to Digital Converter), Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I2C™ (Master/Slave) protocols, Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection, Parallel Slave Port (PSP) 8-bits wide and In-Circuit Serial Programming™ (ICPS) and Debugging via two pins by single 5V capability. Consequently one can develop firmware using high level language. Some PIC functions are: to select state (navigation data detection, environmental parameter detection and measurement together with memorization and visualization), to set up sampling time, different for each measurement type, to select a parameter that must be memorized one at the time, etc.

The analog section includes detectors such as LM35 (temperature) and XFAM-115KPa (pressure) sensors. Ranges from -50°C to 150°C of temperature can be measured by LM35 with 10 mV/°C sensitivity, whereas XFAM-115KPa detects pressure in the range 50÷150 kPa, with 10 mV/m sensitivity and 10 meters accuracy.

Normally ADC is included into the PIC microcontroller converting analog data to digital. The last ones are properly processed by PIC, realizing a data format compatible with the transmission section of the system. Internal structure of the PIC limits to five the number of analog inputs; so that a larger number of different detectors constrain to make a different architectural choice: ADC outside the microcontroller. Moreover, the increase of measurements and/or their duration determine a larger capacity of memory. The one inside PIC becomes insufficient and an external memory module must be included.

Obviously, the choice of previous detectors determines better or worse precision of measurements and the limitation of sampling rates, involving a different set up of microcontroller. This concerns modifications and new specifications of software programs put at the head to manage all operations, from received data to processing and transmission.

The basis structure of the detection system is shown in Figure 3, where we put in evidence two special communication buses to PC and GPS. The PC link allows one at first to program the PIC during the construction period, next to check bad working (debugging analysis) and finally to use a friendly interface for visualization.

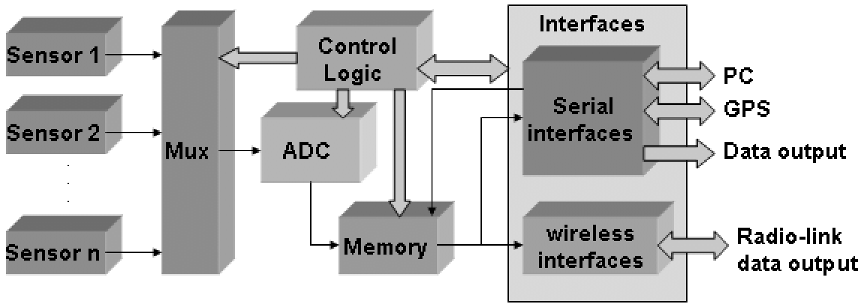

Figure 3: The basic structure of a detection system using a microcontroller. External detectors (analog devices normally) are connected to the processing system one at a time by a multiplexer. Data are converted in digital and properly memorized together with navigation data. Finally they are transmitted by means of a serial bus or by wireless technology as Bluetooth.

A GPS module was canning insert as a generic sensor on the left in Figure 3, but a more complex structure of navigation data leads one to adopt a direct link from GPS to PIC. Our prototype includes a GARMIN GPS product linked to control logic by serial interface RS232.

2.2 Data consistency

Most of data have local validity and, in the case of mobile acquisitions, they are not comparable among them. A value of temperature measurement depends on different set up conditions: altitude, atmospheric stability or instability, shades persistence, etc. In the same way, altitude influences the value of pressure measurement and this is at the basis of operation of solid state pressure sensors in common altimeters. Obviously microclimate conditions as: areas continually in the shade, moist earth, trees with high trunks, undergrowth characteristic, etc. should be classified to correctly explain influences of the data detected. Operators, during their investigation, could attach a descriptive list to measurements. Remote sensing alternatives have advantage of a large zone covering but complex and laborious post-process is needed to extract some important parameters. In any case, two methods can be aggregated by means of the GIS producing maps that are fully described and calibrated by on-site checkpoints.

Again a measurement campaign adopting mobile detection (no fixed on-site monitoring network) suffers no contemporariness of observations that consequently are not directly comparable. So that GIS tools and special software algorithms should be developed and included extending validity of specific parameters to full duration of observation.

3 GIS

In the previous paragraphs we introduced typical characteristics of information data describing the environment which are in common with e.g. geo-social condition, etc.: spatial and time dispersion. Both mobile acquisition and the network of fixed monitor stations evidence these attributes. Detection of physical parameters from distributed locations can be collected and included into a single transmission by means of radio, internet, LAN or different link. The collection must preserve data information allowing the specification of location origin of each measurement. In alternative every monitor station, fixed or mobile, provides for the data transmission to master station. In any case it is more usual to fall in with distributed transmitters. Again, modern structure of management system delocalizes: data sources, function subsystems, data memories, monitoring output, etc. The most obvious architecture for these systems is: distributed [4].

We not only consider distributed systems (different management systems linked among themselves) as host servers, but we include as servers all elements and subsystems that makes up each system. So that data archives as soil-properties, orographic, terrain morphology, meteorological data, etc. are specific data servers. Each system can enter one data server by means of activation procedure and it can read data. The difference between local and server memory consists of shared data of the last one and priority, policy and protocol of data revision: intervention conflict can rise when two or more hosts must change, at the same time, data values included into the same archive.

Distributed organization requires link channels and communication protocols. Hardware channels are simple wires, bus connectors or more present wireless links building physical connections among all server nodes. Many different standard protocols are adopted and adapted to system frameworks. Communication protocols are included in a larger activity which greater software companies are improving: interoperability performance of their software framework. More famous frameworks are: CORBA [5] by OGM (Object Management Group), JAVA [6, 7, 8] by Sun Microsystem, COM/DCOM and .NET [9] by Microsoft.

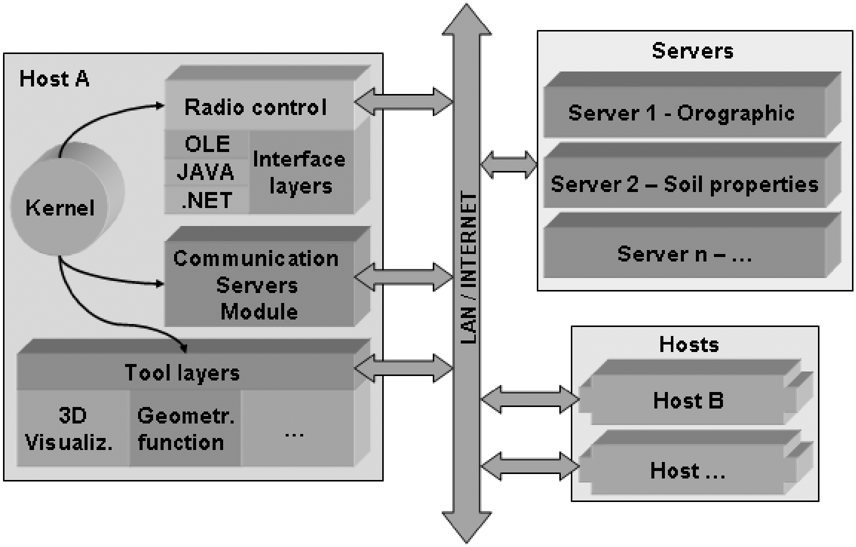

Figure 4: Terrapack32M have distributed structure. It shares databases and different hosts as servers. Links have been realized by means of radio control that uses many interface layers increasing interoperability. Kernel, inside the host, manages special internal tools together with many database servers and other remote systems.

When internet network is adopted, recent frameworks as .NET and JAVA resolve and improve interoperability using XML (eXtensible Mark-up Language) [10] and SOAP (Simple Object Access Protocol) [11] levels instead of binary level. But the concept of interoperability is normally limited to the following case: to write a software program and to run it on supported platforms.

Distributed structure of our management system Terrapack32M is shown in Figure 4. It is organized by different hosts and data memories which are all servers. Host includes resident/local tools as 3D visualization functions, geometrical operation tools, special software simulators (e.g. electromagnetic field tool), etc. Again it counts communication servers and radio control modules. The last one realizes interoperability by using of interface layers as OLE, JAVA and .NET that allows links to multiplatform systems. In this mode, it can extend interoperability definition to linked applications. A software program, which runs in a client or server system, controls (eventually it starts) applications on remote system (different server). Each of them will resolve a specific function (measure, algorithmic evaluation, control data, etc.) and it will return elaborated information to other hosts of the distributed network.

3.1 GIS in the case study

In the case study of natural park management, GIS can be organized by: main host, data servers and remote sensors. Each remote sensor transmits data. The main host receives and elaborates them producing a detailed list of indicators or better visualizing original data and results superimposed to reference maps. Original data are normally sequential list of measures, so that visualization of parameter evolution, at the single instant and in full area, can be obtained by adopting standard variations of physical quantity. This is the case of the daily evolution of temperature, characterized by seasons. A more satisfactory solution is to add another temperature sensor in fixed location, at the centre of area preferably. It should transmit data every sampling time, upgrading main host with temperature evolution in the zone. Extra meteorological data such as: atmospheric stability, temperature profile along altitude detecting inversion layer, can be inserted in the procedure of method refining. Since a transmitted data is GPS location, whose communication protocol is the standard NMEA [12], we collect all information data (navigation and jointed physical parameters) in ASCII file conformable to same standard protocol. Remote measurement devices can include a communication module based on a wireless link such as Bluetooth, an effective short distance communication technology. Data transferred on cellular system, compatible with Bluetooth protocol, can next transmit collected data to the main host by means of another standard protocol e.g. GPRS.

GIS tools elaborate received data interpolating in the time, adding details, etc. For example, when original data does not include the state of measurements such as shade conditions, originating from mountain shadow or covering by tree leaves, tools GIS can deduce these conditions correlating: measurement location, sun position, orographic data, vegetation maps, etc.

4 Conclusions and acknowledgements

We presented the characteristics of a distributed management system supporting sustainable planning. We have considered a special case study: to monitor a natural park by multi-detector devices and GIS oriented to distributed object and applications. Future improving of the measurement device is on-chip integration of a lot of functions. Again new technology based on video-transmission will allow us to add more elaborate data resolving some questions of on-site measurement or quality definition.

Finally, we thank Eng. M. Guerriero, who developed most of the GIS Terrapack32M modules, and Dr. A. Giulianelli who built the prototype of the measurement device.

References

[1] Deakin, E., Sustainable Development and Sustainable Transportation: Strategies for Economic Prosperity, Environmental Quality, and Equity, Working Paper 2001-03, University of California at Berkeley, Institute of Urban and Regional Development, 2001

[2] Meadows, D., Indicator and Information System for Sustainable Development, A report to Balaton Group, Published by Sustainable Institute, PO box 174, Hartland Four Corners VT, Sept. 1998

[3] Ferrara V., Integrated data and utilities to support sustainable planning, Sustainable Planning & Development, Wit Press Southampton, pp. 375-382, 2003

[4] Ferrara V. & Guerriero M., Territorial Information System interoperability: a design improving interaction in an emergency, Risk Analysis IV, Wit Press Southampton, Boston, pp. 475-484, 2004

[5] Chang, Y. S., Wu, R. S., Liang, K. C., Yuan, S. M., Yang, M., CODEX: Content-oriented data exchange model on CORBA, Computer Standards & Interfaces, **25(4)**, pp. 329-343. 2003

[6] SUN Microsystem, java.sun.com/developer/onlineTraining/corba /corba.html

[7] Sharma, R., Stearns, B., Ng, T., *J2EE Connector Architecture and Enterprise Application Integration*, Software Technical Publications, Sun Microsystems, Inc., 2003

[8] Rist, O., Aubrey, D., Connecting with Java web services, InfoWorld, **23**, pp. 48-54,56,58,60, 2003

[9] Troelsen, A., *COM and .NET interoperability*, Apress, 2002

[10] Extensible Mark-up Language (XML) 1.0, *W3C Recommendation*, www.w3.org/TR/1998/REC-xml-199802010

[11] SOAP Version 1.2 specification, www.w3.org/TR/soap12

[12] NMEA protocol, www.nmea.org