Automation and Robotics in Construction XVI © 1999 by UC3M

INTEGRATED MONITORING SYSTEM FOR MADRID UNDERGROUND

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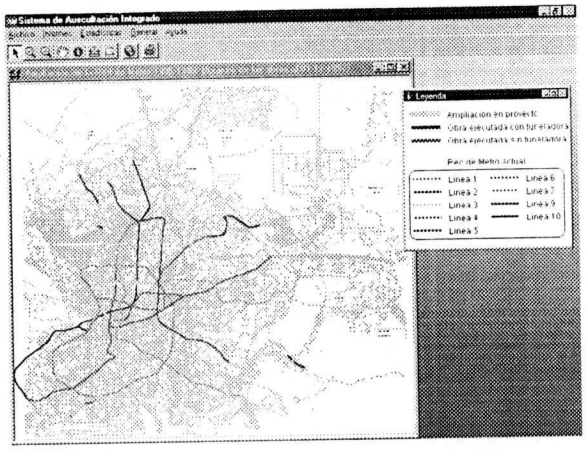
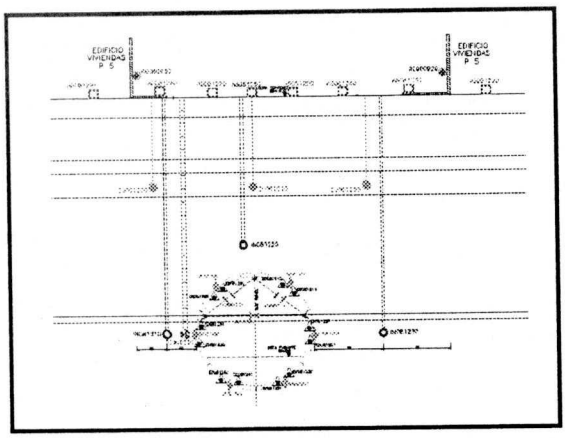
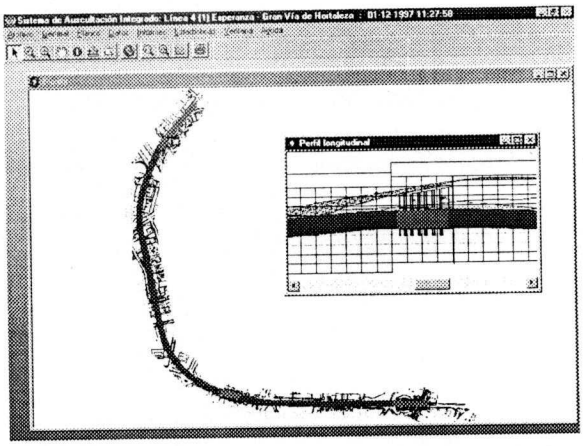
The Madrid Underground Extension, within the period 1995-1999, has been extended by 37.5 new kilometres of urban tunnels in soft ground and 35 new stations. This absolutely stunning amount of work – the greatest ongoing extension in the world -, being executed simultaneously, required a huge effort of control. This control was achieved with the installation of more than 7.500 measuring instruments in the vicinity of the work sites. The main target was to raise to the maximum level the safety of the works, both for the workers of the extension and the surrounding areas. Another objective is taking advantage of all the data obtained to improve the knowledge about underground excavations and therefore enlarge the quality of the design for future works.







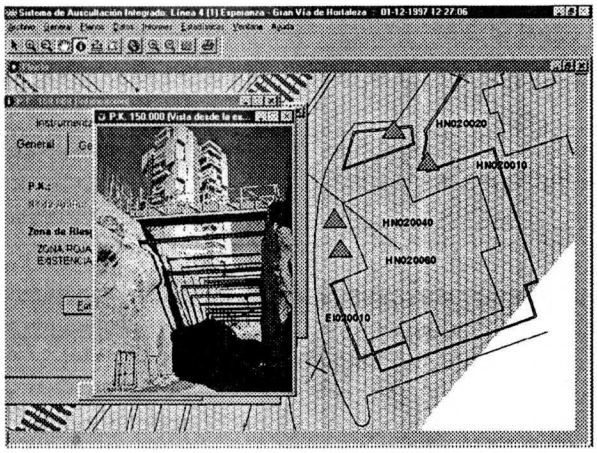
For all these reasons the Autonomous Community of Madrid, through their Dirección General de Infraestructuras de la Consejería de Obras Públicas, Urbanismo y Transportes, created, at the beggining of the Extension, a control centre of all this instrumentation, know as Monitoring and Control Unit.

One of the main problems arising to the Unit was the complexity of the handling of the data –that amounted to more than 50 million data to the end of the works- provided daily by each of the contracts. For this task a powerful relational database manager was required., allowing quick access to the data and complex queries with an easy graphic user interface as the system is being used by the geotechnical engineers. In the

beginning, the possibility of using a Geographic Information System (GIS) connected to a database via ODBC was considered, but this solution was rejected to avoid the limitations of the development tools provided by the GIS in the field of the complex queries.

The software development team, made up of by computer engineers from GEOCISA, finally decided the use of a development environment oriented to the managing of relational databases, able to integrate the geographic information. Microsoft Visual Foxpro v5 was the choice (visual development tool with a good performance object oriented programming), that includes a very fast relational database manager, using at the same time the ActiveX MapObjects of ESRI for the display and handling of the geographic information of the system.

This system allows the storage and fast access to practically any kind of information that might be imagined, such as numerical data, project drawings, geotechnical information, photographs, technical data of the buildings nearby the tunnels, and so on, using both typical relational databases queries and spatial queries characteristic of a GIS.



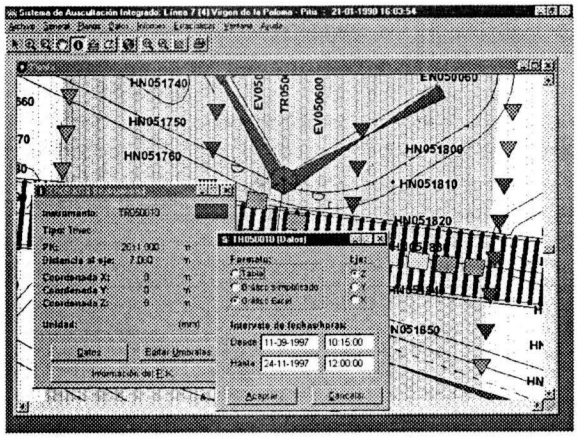
Using the original construction design drawings of the different metro lines as a base (plan, longitudinal, and transverse section drawings), the system enables a continuous zoom to be implemented in order to reach the level of detail required. The system also contains a displacement tool which enables one to move rapidly along a given line. It is also capable of measuring areas and distances on the drawing. Basically the system optimises all the possibilities of MapObjects as far as the management of geographical information is concerned.

If the scale of the drawing is increased enough, each ring of tunnel lining segments placed during the construction of the tunnel can be identified in is actual position. If one clicks the mouse cursor, access is obtained to the information registered by 64 sensors, minute by minute during the execution of each of the tunnels.

Each 1.5 m ring, of which there are approximately 20.000, has all the information relative to itself associated to it. This information is for example the ground predominantly encountered during excavation of the section of the tunnel, its geographic co-ordinates, as well as additional information in the form of photographs of the area, drawings, documents, reports, etc...

The different instruments located in the ground or on buildings can also be identified, and can be selected in the same manner as described above. The information obtained from each of these instruments can be accessed in the form of tables (exportable to the commonest file types), or graphs with different level of detail. The instruments include a small dialogue box giving data such as its code, the type of instrument and the co-ordinates of its exact location.

One of the main aspects for the security control is the fact that the symbols representing each instrument change colour automatically depending on the reading registered at that time, thus enabling the user to rapidly check the state of the instruments.



The system is not limited only to giving information stored in the database, but also has tools which permit taking maximum advantage of this information. Statistics of the progression of the tunnels, joint analysis of all the readings of instruments in one same section of the tunnel, prediction of ground movement in areas not yet built and a multitude of other engineering applications can all be obtained.

It is interesting to point out that the flexibility of the system has enabled some of the tools described above to be developed by non specialist computer users by means of other software of wider use (spreadsheets for example), thanks to the possibilities offered the Windows OLE characteristics.

The updating of the information contained within the system is continuous from each of the sites within the metro extension and undertaken by telephone. The central server of the Monitoring Unit constitutes an Infovia node and is connected to the telephone network via a Frame Relay line. Also the system is able to transmit data to remote users via Infovia with the connection made each time the user wishes to do so.

This software allowed the control of the works to the the client's total satisfaction of, facilitating the decision making before the problems arise and achieving costs of 37 million dollars per kilometre, instead of more than 100 million dollars that were spent in other projects of this type around the world.