4. Conclusions

A software-hardware partitioning proposal for designing an embedded digital system for fingerprint identification has been presented. The paper describes the most important stages involved in the minutiae extraction of a fingerprint image. The algorithm has been executed obtaining a profiler that allows the most critical parts with higher computational cost to be detected. Hardware is recommended to implement these stages and software to implement the others.

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Submarine Mapping using Multibeam Bathymetry and and Acoustic Backscatter: Illuminating the Seafloor

More than 70% of the surface of the Earth is covered by the oceans and its submarine topography is still poorly known, and as a consequence, oceanographers have constantly tried to improve their knowledge on the morphology and nature of the seafloor. Acoustic mapping systems have undergone a revolution during the last thirty years. From single-beam echo-sounders to the more sophisticated multibeam echo-sounders, seafloor mapping techniques and characterization has grown impressively. Multibeam echo-sounders are based on the principle of acoustic wave transmission and reception in the water. They represent the most significant advance in mapping large areas rapidly and accurately, and are essential for the study of geomorphology and seafloor facies. Combined with detailed positioning information (acquired through modern GPS navigation systems) and advanced computer graphics, multibeam systems provide us with a whole new view of the seafloor.

Multibeam echo-sounders: Overview

At first, multibeam echo-sounders consisted of an extension of single-beam echo-sounders. Arrays of sonar projectors produce soundings not only along the track, but also for significant distance across to the ship track.

Instead of lines of single soundings, new multibeam systems produce a swath of soundings (Fig. 1). In modern deep-water systems, the swath covered on the seafloor can be up to 7 times the water depth. This means that if we are working in an area of 3000 m water depth, the maximum width swept is of 21 km. To obtain a complete cartography of the seafloor, the vessel scans adjacent swaths at a speed of 8 to 12 knots, drawing up a mosaic of seafloor topography. Therefore, in «deep water» (> 3000 m), a zone of 400 km by 20 km (8000 km^2) could be surveyed in less than a day.

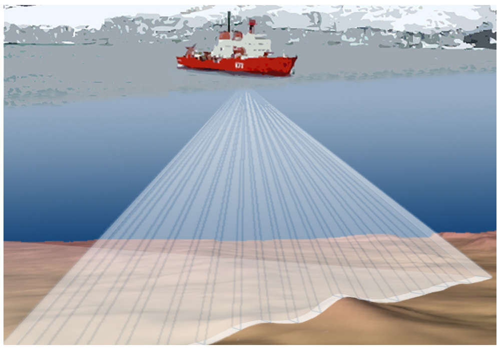


Fig.1. Sketch of how a multibeam echo-sounder surveys the seafloor.

Multibeam echo-sounders provide us with two types of complementary information, essential to understand the relief and nature of the seafloor:

- **Swath-bathymetry** represents the submarine relief usually in metres (m). It is calculated based on the time taken by an acoustic wave to propagate in seawater (i.e. sound propagation speed in water is about 1500 m/s). Swath bathymetry mainly gives information on the morphology of the seafloor, which on continental margins is dominated by sedimentary, erosive and tectonic processes.

- **Sonar imagery** records the reflectivity of the acoustic signal returned by the seafloor in decibels (dB). Reflectivity varies according to the angle of incidence, seabottom local topography and nature of the seafloor (Blondel and Murton, 1997). Thus, in a flat area, different values of acoustic backscatter must be related to different seabed facies. For instance, hard acoustic returns are indicative of hard rock or coarse grainsizes (gravel, sands) while softer returns are indicative of thinner grainsize (silts or clays).

Multibeam echo-sounders are composed of the following elements: transmission and reception arrays, transmission electronics, reception unit, user interface (with system control options and real-time processing results) and ancillary systems, such as a positioning system, attitude sensor unit (giving roll, pitch, heave and the heading values), and sound velocity profiles (SVP). The main characteristics of multibeam echo-sounders are acoustic frequency, maximum angular aperture, number of beams, beam spacing, length of emission and cadence of the emission. The resolution of systems increases with frequency, but so does the attenuation in the water, so higher frequency systems will have shallower depth limitations than lower frequency systems. Therefore, acoustic frequency determines several types of systems (Lurton, 2002): *deepwater systems* (50–12000 m) that work at 12 kHz for the deep ocean and at 30 kHz for continental shelves; *shallow-water systems* (5–1000 m), work at 100-200 kHz and are designed for mapping continental shelves, and *high-resolution systems* (few meters) work at 300-500 kHz and are used for local studies (e.g. ports, bays, etc). The frequency also determines the subbottom penetration: the lower the frequency the more it penetrates into soft sediments. The maximum angular aperture determines the swath width. Typical values are from 90º to 150º and beam spacing can be equidistant or equiangular. The number of beams changes depending on the echo-sounder. The signals commonly used on the acoustic emission are referred to as «pings», portions of sinusoidal signals restricted to a length. The more the pulse lasts the higher the resolution is (typically between 1ms in shallow waters and 15 ms in deep waters). The length between two successive emissions of the sounder is referred to as the cadence of the emission and, at least, it is longer than the duration of the return trajectory of the more external beams.

Acquiring new data: The multibeam echo-sounders of the R/V Hespérides

The UTM (Marine Technology Unit) of CSIC (*Consejo Superior de Investigaciones Científicas*) in Barcelona is responsible for the maintenance of the scientific equipment of our oceanographic vessels, such as the R/V Hespérides, and provides the necessary technical support during research cruises, mainly funded by the Spanish Ministry of Education and Science (MEC). **The R/V Hespérides is the largest scientific vessel available to the national scientific community, and is equipped with two different multibeam echo sounders:**

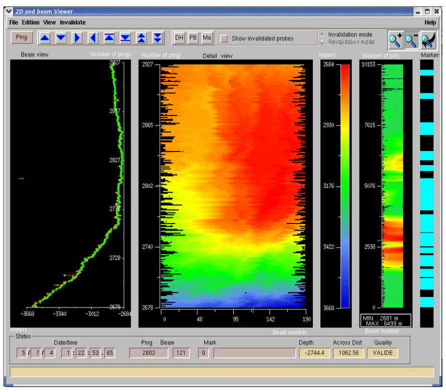
The Simrad **EM120 swath-bathymetry system** is a full water depth (50-11000 meters) echo-sounder that works at 12 kHz with 191 beams, covering up to 150 degrees. Beam spacing can be equidistant or equiangular. Transducers are linear arrays in a «mills cross» configuration with separate units for transmission and reception. All necessary sensor interfaces, data displays for quality control and sensor calibration, seabed visualization and data logging are a standard part of the system. A combination of phase and amplitude detection is used, resulting in a measurement accuracy in the order of 50 cm or 0.2% of depth RMS (Root Mean Square), whatever is greater, practically independent of beam pointing angle. The Simrad **EM1002S echo-sounder is the shallow-water system (2–1000 meters) that works at 95 kHz with 111 beams covering up to 150 degrees.** Both sounders share the same acquisition system, the SIS (Seabed Information System) now operated in a PC under MS Windows, as well as the attitude sensor, stabilizing the transmitted beams for the ship's roll, pitch and heave movements.

Processing the data: Obtention of bathymetric charts and backscatter mosaics

A multibeam mapping system acquires a large amount of raw data containing the bathymetric and sonar imagery data. Once processed, bathymetric data is normally represented as an iso-depth (isobaths) map. Imagery data is represented as a mosaic. It is also possible to merge both data on a single combined document, overlaying imagery on top of the bathymetry. In the UTM-CSIC we have implemented a new service addressed to the national scientific community to provide them with the necessary software, hardware and technical support for processing data acquired with multibeam echo-sounders. We are specialized in the CARAIBES™ system (Fig. 2), a complete submarine mapping software developed by IFREMER (*French Research Institute for Exploitation of the Sea*) to process data from multibeam echo-sounders (bathymetry and imagery) and deep-towed sidescan sonars. Next, we summarize the main steps to follow during processing of swath-bathymetric and acoustic backscatter data.

Swath-Bathymetry processing

The first step is to import the raw data into CARAIBES software in order to get navigation (date, time, and geographic coordinates) and depth data (date, time, beam number, two-way travel time). After navigation post-processing, which mainly consists of an automatic filtering of anomalous values, smoothing and interpolation, the two types of data are merged and a georeferenced sounding file (x, y, z) is generated. A Digital Terrain Model (DTM), a binary grid, is first interpolated from raw soundings to search for errors, such as the effect of tide (for shallow waters), variations in water column sound velocity, and motions of the vessel (roll, pitch and heave) (Bourillet et al., 1996). Once these corrections are introduced, data are filtered and cleaned up using different methods, such as raw data automatic cleaning by comparison with a reference DTM (using a band-pass filter), and raw data manually cleaning with the ping graphical editor to get more accuracy on the depth data control (Fig. 2). After filtering, bathymetric data is interpolated at nodes of a regular-spacing grid in order to get a final DTM. The choice of the spacing of the grid nodes takes into account the density of the soundings, quality of the data and finally, the scale of the final document. The software allows many operations on the DTMs such as spline or numeric filter smoothing, interpolation or mosaic of several DTMs. The final DTM can be displayed under different cartographic views such as slope gradient representation, bathymetric cross sections along a specific path, shaded relief maps and, 2D and 3D visualizations (Fig. 3).



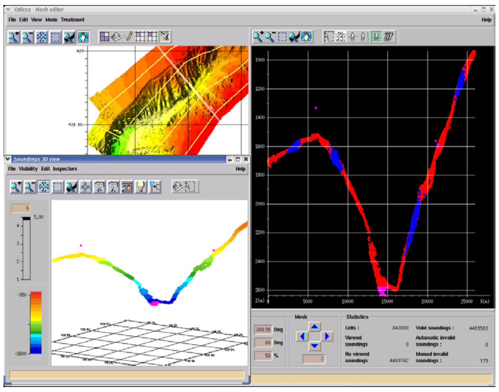
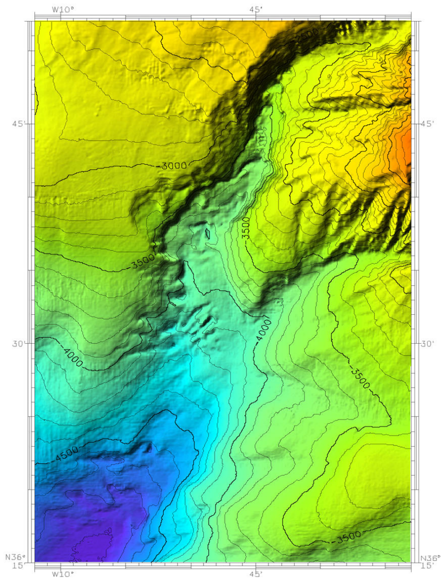


Fig. 2. Snapshot windows showing different stages of swath bathymetric processing with Caraibes. Left: Ping and beam editing. Right: Soundings editing across a defined path.



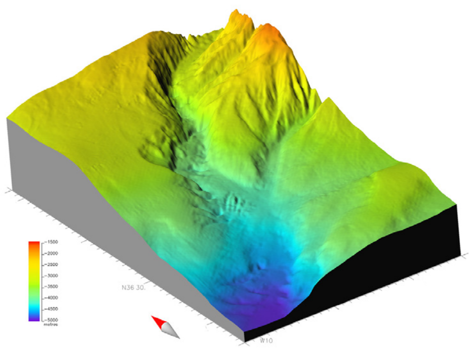
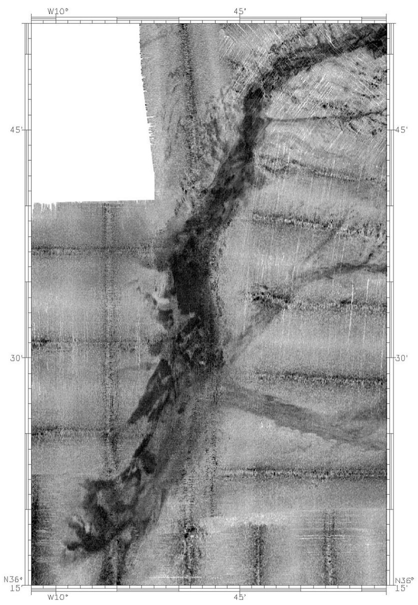


Fig. 3. Results of swath bathymetric processing. Left: Processed data depicted in a colour shaded relief map. Isobath contour: 100 m. DTM grid: 100 m. Right: 3D map of the same area, corresponding to the Sao Vicente Canyon in the SW Iberian Margin. Data acquired during PARSIFAL-

Imagery processing

The main goal of the imagery processing is to obtain a digital image mosaic generated from the seabed backscattered strength measured in dB (Fig. 4). After data importation and raw data corrections (time correction, antenna gain correction, etc.) the mosaic is prepared including these geometric corrections, as well as bathymetric and navigation values to accurately position the imagery pixels (Augustin et al., 1994). The mosaic can then be created in different projections (i.e. Mercator, Lambert, UTM, Polar stereographic) with a given pixel resolution and with specification of inter-profile overlapping processing method (above, below or mixed). Other computations that can be carried out are interpolation (along a fixed direction or following the ship navigation), filtering, cartographic extraction, etc. CARAIBES software offers also an image analysis module, enabling us to visualize the image mosaics (typically in grey levels) and to interactively correct them by enhancing the contrast according to the image histogram. The final mosaic can also be visualized under a large variety of views in 2D and 3Ds, merged with bathymetric data (Fig. 4).



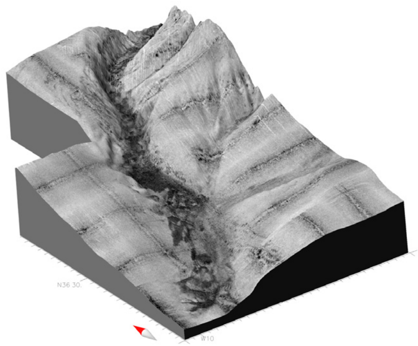


Fig. 4. Results of acoustic backscatter processing. Left: Imagery mosaic. Right: Acoustic imagery overlaid on top of the 3D bathymetry of the Sao Vicente Canyon. Dark colours correspond to high backscatter and light colours to low backscatter. Regularly spaced thick lines correspond to ship track.

Why do we map the seafloor? Scientific applications of the multibeam echo-sounders

Swath-bathymetry and acoustic backscatter data allow us to identify the main morphologies and structures of the seafloor and determine its nature based on the acoustic facies. The seafloor is an active domain where many processes interact. For instance, in the sediment-starved mid-ocean ridges, accretionary processes (tectonic, magmatic and hydrothermal) take place with establishment of extreme ecosystems associated. Detailed mapping of oceanic ridges is essential for understanding the genesis of new oceanic crust, as well as information of its axial segmentation and morphostructure (e.g. Parson et al., 2000). Acoustic backscatter gives information of the faulting distribution and magmato-tectonic activity along a segment, with the identification of different types and relative age of the submarine lavas. In continental margins, detailed cartographies have allowed identification of submarine depositional systems sources of hydrocarbons, discovery of mud volcanoes, fluid escape areas and gas hydrates. Mapping and studying active faults and associated structures (i.e. large submarine landslides) in continental margins, such as the Sao Vicente Canyon and Fault that we present in Figures 3 and 4, has implications in the assessment of seismic and tsunami hazards in the SW Iberian Margin (Gràcia et al., 2003). Submarine faults represent a risk for neighbouring coastal countries (Spain, Portugal and Morocco) as large destructive events have already occurred in recent times, such as the 1755 Lisbon earthquake and tsunami (e.g. Mendes Victor et al., 1991; Baptista et al., 1998). Following the same type of approach, a high-resolution multibeam survey has just been carried out in Sumatra (Indonesia) to explore the rupture area and possible submarine landslides resulting from the 26th December 2004 magnitude 9 earthquake, which caused the consequent tsunami and its devastating effects. In summary, high-resolution bathymetry and backscatter data acquired through new generation of submarine mapping systems provides us with high quality and essential information of geological and geomorphic processes, and thus a better understanding about seafloor formation and evolution and, therefore, on how the Earth system works.

Acknowledgements

We thank the captain, crew, technicians and scientific party of the HITS 2001 cruise on board the BIO Hespérides, during which the data presented in this article was acquired. We thank funding from the *Ministerio de Educación y Ciencia* (previous MCyT) through projects ESF EuroMargins SWIM (REN2002-11234-E-MAR) and PN IMPULS (REN2003-05996MAR).

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SCRIED TCP-IP technologies applied to distributed data acquisition systems in the Hesperides vessel

In this paper we present an integration of hardware/ software technologies in systems and networks based on TCP-IP protocol. In order to implement distributed data acquisition systems, a TCP and UDP Humidity and Temperature server was designed. This work is part of the LabVir project, devoted to implementing distributed measurements in marine technologies

Ideally a data acquisition system has to offer:

1. Real time access to data which are generated in different nodes of the network
2. Scalability. New node, application and data type incorporation facilities. Data and application portability.
3. Interoperability. Collaboration between nodes. Active data exchange
4. Remote control of all the system application, integration of the acquisition network in other user networks (local area networks, Corporative networks and internet).
5. Robust and low cost hardware platforms (processors and sensors).

The complete acquisition system is modeled with UML (Unified Modeling Language). Originally created to model and document orientated object applications, UML is a powerful tool to analyze any kind of system in which we can identify its components, expressed as entities or classes, and the logical relationship between them. Using UML it is possible to describe all parts of the distributed system no matter their nature (PC, workstation, intelligent sensor, electronics, …) and the implementation language