

# Innovation Technologies and Applications for Coastal Archaeological sites



**ITACA** project is coordinated by Planetek Hellas E.P.E. (GR) and includes the following institutes and companies: ALMA Sistemi Sas (IT), ANESTI Ltd (UK), CODEVINTEC Italiana Srl (IT), DHI GRAS (DK), FFCUL (PT), I.EN.A.E (GR), Kell Srl (IT), NAIS Srl (IT), Regione Sicilia (IT), SME4SPACE VZW (BE)

## www.itaca-fp7.eu

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# Coastal heritage landscapes under marine spatial planning policy: a "forgotten layer"

Through Strategy Framework the Marine Directive (DIRECTIVE 2008/56/EC) European Union aims to achieve a Good Environmental Status (GES) for marine water, implemented by all member states by 2020. The European marine region of Mediterranean Sea adheres the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean adopted in 1995, with Cyprus being one of the 22 Contracting Parties. Amongst the Convention's main objectives is to protect the cultural heritage (both in land and in water), while one of the Mediterranean Action Plan (MAP) key priorities for the coming decade is to intensify integrated planning of coastal areas.

Traditionally, marine space has been predominantly regulated within individual economic sectors such as shipping channels and aquaculture sites, and there has been little consideration of the effects of potential conflicts across sectors on other human activities or the marine environment. During the past decade, the traditional sectorial approach to natural resources and environmental management has been recognized to be insufficient to address the cumulative effects of human activities on the marine environment and has shifted to a more holistic "ecosystem approach" that calls for comprehensive analysis of all dimensions of environmental problems. Such problems have been also highlighted in the land, including of course coastal heritage sites, where both natural and anthropogenic hazards are visible. Indeed, as presented in this study several threats have been mapped for the Paphos district using solely remote sensing data from various sources (Landsat series; MODIS products; QuikcBird images etc).

According to UNESCO, Marine Spatial Planning (MSP) is not limited to just a conservation planning. While a network of marine protected areas might be one outcome of MSP, it further seeks to balance economic development and environmental conservation, and does not focus exclusively on the goals of conservation or protection. Therefore, MSP can play a key role for future prevention and protection of cultural heritage both in land (coastal zones) as well in the sea (underwater heritage). During the MSP implementation, a strategic regional assessment of conservation values as well as current and emerging pressures on the marine environment is performed.

As already demonstrated in this event, a variety of remote sensing datasets and algorithms can be used as a tool to support MSP implementation. Indeed, remote sensing technology may be used so as to monitor through time the changes of an archaeolandscape of a site, or even used for the detection of buried archaeological features. By now ready products from earth observation sensors can provided calibrated and global parameters for monitoring sea and oceans around the world.

In this paper the MSP application in Cyprus, using Geographical Information Systems (GIS) is presented, in order to identify the current and future pressures on cultural heritage sites and monuments located in the coastal zone of the island. In addition, the paper aims to demonstrate the importance of implementing MSP programs for the (future) management of Cultural Heritage sites, for the reduction of future conflicts and minimize any potential pressure in the surroundings of these archaeological sites and monuments. MSP may be used and exploited by the stakeholders as tool for protection and preservation of Cultural Heritage either located in the coastal zone or in the sea.

## Floriana Agneto, Giacoma Brancato, Salvatore Emma

Regione Siciliana, Soprintendenza del Mare (Sopmare)

## Test case Egadi Islands – The ITACA experience

Soprintendenza del Mare was involved in ITACA project as archaeological end-user, cooperating in development of a management system for underwater archaeological sites.

The technologies and the applications developed in the frame of the project have been validated by traditional technological survey, through a demonstration campaign carried out in the Egadi Islands and addressing different typologies of underwater sites.

The survey campaign was focused on three underwater wrecks, different for age, depth and characteristics.

The first one is Cala Minnola, an archaeological site including several Roman age amphorae. This site, deep between 27 and 30m, is located in the bay that has the same name, on the south-eastern coast of the small island of Levanzo.

The second one is the "Carmelo Lo Porto", a merchant vessel of 294t, 43.96m long, 7.45m wide, sank in 1941 near Favignana Island, lying at a depth between 12 and 18m. This ship carried salt rocks on the route from Sicily to other Mediterranean or European harbours.

The third one is the "Elphis I", a merchant vessel carrying a cargo of smuggled cigarettes sailing to the Egadi Islands. The wreck is located near the small desert island of Maraona at a depth between 10 and 17m.

The scuba diving research conducted during this test campaign provided digital images, data and 3D reconstructions, in order to verify/validate SAR radar data as well as multispectral data and to build up the 3D scenario for the WebGIS management tool.

During the test case Regione Sicilia, as WP leader, performed scientific and archaeological supervision interacting with CODEVINTEC that has conducted the technical survey using multi-beam echo sounder.

## Stelios **Bollanos**

Planetek Hellas E.P.E.

## ITACA – Technological and collaborative challenges

ITACA (Innovation Technologies and Applications for Coastal Archaeological sites), is a collaborative project funded by the Research Executive Agency of the European Commission in the framework of the 7<sup>th</sup> Framework Program for Research, under the theme SPA.2013.3.1-01, call SME space technology research and technology transfer. The project main goal was to test a management system for underwater archaeological sites in coastal regions. The discovering and monitoring service uses innovative satellite remote sensing techniques combined with image processing algorithms and WebGIS technologies. The project develops a set of applications integrated in a system that pursue the following objectives:

- Search and location of ship wrecks with archeological interest
- Monitoring of submerged ruins and historical artefacts
- Integration of resulting search and monitoring data with onsite data into a management tool for underwater sites
- Demonstration of the system's suitability for a service

The ITACA project consortium is combined by 12 partners, from 5 different European countries, with different but complementary background. Greece, Italy, Denmark, Portugal and UK constitute the map of the countries that have representatives in the project.

## Silvia Ciccarelli, Rosario Pavone

SME4SPACE

## Earth observation satellite data for coastal archaeological sites

The ITACA service is based basically on the use of two kinds of satellite data:

- high resolution synthetic aperture radar (SAR), based on radar technology;
- multispectral satellite data, based on optical technology.

The radar images were obtained by two national satellite constellations operating on X-band: Cosmo SkyMed, Italian constellation made up of 4 satellites, owned by the Italian Space Agency (ASI) and the Italian Ministry of National Defence, for dual uses and TerraSAR X, a joint venture being carried out under a public-private-partnership between the German Aerospace Center (DLR) and EADS Astrium.

Images taken from radar satellites do not have any limitations in terms of weather (clouds) and have always acquisition capabilities (day and night). They have very short interval between the acceptance of the user request acquisition and the release of the remote sensing product (System Response Time) and high image quality (e.g. spatial and radiometric resolution).

During the ITACA 11 products from Cosmo SkyMed and 2 products from TerraSar X have been acquired.

Radar images are complementary to optical ones, that have very high-resolution but have limitations in terms of weather conditions and light.

In ITACA we acquired 5 optical images from Digital Globe (Worldview 2 and WorldView3).

Furthermore, in the framework of ITACA the new Sentinel data have been also tested, and more specifically Sentinel 1 (radar technology) and Sentinel 2 (optical technology).

These satellite images have been acquired using several channels:

- Cosmo SkyMed data: archive data are available at favourable conditions for Italian public institutions. There are also an open call for national and international research centers/universities as well as for Italian SMEs. During the ITACA project Cosmo SkyMed data have been acquired through Regione Sicilia.
- TerraSar X data: we applied to an open call issued by DLR for the use of TerraSar X data for scientific purposes.
- Worldview 2/3: images bought directly from Digital Globe.
- Copernicus Space Component Data Access (CSCDA): based on the Datawarehouse requirements issued by the European Commission, ESA organises the procurement of Earth Observation data from a series of Copernicus Contributing Missions and publishes the resulting data offer into the Data Access Portfolio (DAP). Itaca partners could access

satellite data through CSCDA as participants to a research project financed under the EU research programmes.

• Sentinel data are open and free and are available on Sentinel Scientific Data Hub, the web platform made available by the European Commission for the exploitation of Sentinel data, i.e. the satellites that are part of the Copernicus mission.

## Alessio **Di Iorio**, Roberto **Filippone**

Alma Sistemi sas

## Advancement on shape detection algorithms for underwater archaeology

Finding a shape into a big size image is a challenge for the next years image processing science. Finding a shape into a sea image is a stronger path: an object lying under the sea surface assumes different color and - often - a different form, due to depth, sun light and water turbidity. Huge extension images like those provided by satellites require powerful and precise processing software.

Several known algorithm have been considered and a work of analysis of possible improvement has been done. The scope is to tune, refine the algorithms to work with marine images having few contrast and few colors occurrences. This allow the use of such techniques in the field of sub-marine archeological science. The selected algorithm have a common capability to identify a shape with a combination of color and shape edge, both participating with different weight.

- HU's moments algorithm derives six absolute orthogonal invariants and one skew orthogonal invariant based upon algebraic invariants, which are not only independent of position, size and orientation but also independent of parallel projection.
- The log polar algorithm uses the Fourier domain approach to match images that are translated, rotated, and scaled with respect to one another.
- A detection operator based on the derivative of the double exponential (DODE) is developed to detect two-dimensional shapes.

Algorithms shows both advantages and disadvantages. The limit of all algorithms is mainly due to resolution and size of the searched shape: a significant amount of color pixel is required to build a shape characteristic histogram. Marine images provide many similar color spots, so the number of false positives is generally very high, though the algorithms detects a well edge defined shape in 70% of cases. Results of the test performed are illustrated in the presentation.

Lars Boye Hansen

DHI-GRAS

## Satellite derived bathymetry from very high resolution optical data

What's under the sea surface? To a large degree we still have no detailed information about bathymetry and bottom characteristics for a large part of the coastal zone. Using optical very high resolution multispectral satellite data it is possible to map the bathymetry down to 20 - 30 m depth depending on the physical characteristics of a given area.

Three different use cases have been performed under the ITACA project in order to test the possibilities of using this technology for archaeological purposes. This includes:

- an ancient submerged settlement in Greece,
- a modern ship wreck near Sicily, and
- the ancient harbour of Lechaion near Corinth.

The three use cases will be presented along with conclusions and findings from the test executions.

## Dimitrios Ioannidis

Planetek Hellas E.P.E.

# Management & Monitoring of underwater archaeological sites: An innovative approach

European Mediterranean countries are characterized by two elements: extensive coastlines and large number of ancient settlements. The aforementioned characteristics conclude to the existence of submerged sites or artifacts that present important archaeological value. Many of these sites or shipwrecks have not been located yet and the known ones need continuous monitoring. Furthermore, underwater archaeological sites are threatened by alteration of shorelines, seabeds and currents due to natural phenomena as well as human intervention; the activity of sediment and pollutants; and the abuse and exploitation of natural resources. Thus, the capability of locating and monitoring underwater areas of archaeological interest is a vital asset for the improvement of the historic heritage's conservation. Organizations and international institutions involved in the protection and conservation need reliable and systematic techniques in order to accomplish their mission. In recent years, these entities have developed and tested new methods that exploit non-invasive technologies such as satellite images and GIS systems. The development of specific tools based on the processing of Earth Observation satellite data makes possible the production of systematic survey of wide coastal areas. In this context, ITACA project introduces a combination of innovative tools, aiming the improvement of the capabilities to locate and monitor coastal underwater archaeological sites as well as the development of a web management system. The aforementioned objectives are accomplished by two available services: Location & Monitoring Service and Management & Operation Service. These two services provide a cost effective solution to entities in charge of underwater cultural heritage preservation and mark a substantial progress in the definition of best practices for the specific activities.

## Bjørn Lovén

Saxo Institute, University of Copenhagen

## Eyes in the sky above Lechaion – Ancient Corinth's main harbour

In ancient times as today, the sea helped cultures connect with a wider world through trade, colonization, and military conquest. Perhaps nowhere was the sea used more effectively than in the ancient Greek world, which saw the rise and fall of maritime empires long before the Roman, Byzantine, Venetian and Ottoman Empires.

Among the most economically and militarily powerful, and enduring, was Corinth, which for centuries competed with a host of other economic centres. The city lay astride an isthmus that facilitated land travel between northern and southern Greece and travel by sea between the western and eastern Mediterranean. Corinth, which lay some three kilometres from the sea, built on this natural advantage by constructing two harbour towns, the main harbour Lechaion on the Corinthian Gulf to the west, and Kenchreai on the Aegean to the east. According to ancient sources, most of the city's wealth derived from the maritime trade that passed through her two harbours, eventually earning her the nickname "Wealthy Corinth." The wharves and warehouses of Lechaion, the city's main harbour town, saw vibrant maritime activity for over a thousand years, from the 6th century BC to the 6th century AD. Ships and fleets departed from here laden with cargoes, colonists and marines destined for ports all over the Mediterranean and Black Sea. This seaborne Hellenization of the Mediterranean region was, in effect, the beginning of Europe, as we know it.

This lecture will primarily focus on how satellite technology is used to document, analyse and monitor the ancient harbour structures at Lechaion and the surrounding landscape.

The Lechaion Harbour Project is a collaboration between the Ephorate of Underwater Antiquities under the Greek Ministry of Culture and Sports, the SAXO-Institute, the University of Copenhagen, and the Danish Institute at Athens under the Danish Ministry of Education. It is directed by Dr. Dimitris Kourkoumelis of the Ephorate of Underwater Antiquities and Dr. Bjørn Lovén. The Augustinus Foundation and the Carlsberg Foundation finances the project.

## Lorenzo **Minno**

Codevintec Italiana srl

## High definition technologies to investigate the seafloor. An application in archaeology

The contribution is about the most recent oceanographic methodologies and the marine instruments used in the Egadi islands during the ITACA test survey. The purpose of the survey was to determine, with a high degree of accuracy and resolution, the morphological characteristics of the seafloor and of any object laying on its surface.

The contribution will describe technical features, applications and uses, advantages and distinctive benefit of the various instruments used in the Project: Multibeam Echosounder, Sound Velocity Probe, Inertial Measurement Unit, GPS and hydrographic software.

The survey procedure is explained, including equipment installation, calibration and reasons of the technical decisions.

The results of the survey is exhibited, with processed images of wrecks detected in Elphis, Carmelo Lo Porto and Cala Minnola.

## Antonio **Monteleone**

NAIS srl

## Supporting coastal archaeological sites management on the web: the ITACA service web portal

Archaeologists and managers of coastal archaeological heritage are called to perform complex tasks (e.g. archaeological investigations, diagnostic and monitoring, safeguard and risk management, site documentation and site management) in their daily operations.

ITACA, a service on the web dedicated to coastal archaeological heritage, arises as a support tool to institutions, organisations and scientists involved in the operations of coastal archaeological sites. Specifically, the ITACA web portal, reachable at <u>https://services.project.itaca-fp7.eu/itaca/</u>, is intended to provide its users with services such as: (i) Location and Monitoring Service, (ii) Management and Operation Service.

The *ITACA Location and Monitoring Service* provides archaeologists with software tools to search for wrecks or other underwater cultural assets by the semi-automatic analysis of digital bathymetry maps according to a Software-as-a-Service approach.

The *ITACA Management and Operation Service* provides its users with a web collaborative platform integrating both content management and cartographic views of sites elements, threats and surveys, enabling, in this way, the collaborative management and sharing of geospatial information about underwater archaeological sites in coastal regions. Thanks to the ITACA Management and Operation Service, site managers and archaeologists from all over the world can benefit of a single point of access to geospatial information about ITACA managed sites. In this way, it will be potentially possible to (i) avoid any transfer of data among stakeholders of the sites and (ii) reduce the use of expensive desktop solutions when managing sites information.

### Nikos **Papadopoulos**

Laboratory of Geophysical-Remote Sensing & Archaeoenvironment, Institute for Mediterranean Studies (IMS), Foundation for Research & Technology Hellas (FORTH)

## Mapping the cultural dynamics of littoral archaeological sites through geoinformatics: Examples from Crete, Greece

Geoinformation technologies like Global Positioning Systems (GPS), low altitude aerial imagery with Remotely Piloted Aerial Systems (RPAS) and geophysical prospection have been extensively used in mapping onshore buried antiquities in a non-destructive manner, thus contributing in the management and promotion of the cultural heritage. Despite the relative frequent employment of these imaging approaches in the recovery of archaeological relics (e.g. shipwrecks), in deep marine environments, the specific technologies have minimal contribution towards the understanding of the past dynamics in littoral and shallow off-shore environments. The efficiency of these technologies in coastal and shallow marine archaeological sites will be presented through two successful case studies in Agioi Theodoroi and Elounda in Crete, thus signifying their future potential in the documentation of archaeological sites in similar environmental regimes.

# George **Papatheodorou**, Maria **Geraga**, Elias **Fakiris**, Dimitris **Christodoulou**, Nikos **Georgiou**, Xenophon **Dimas**

Laboratory of Marine Geology and Physical Oceanography, Department of Geology, University of Patras (LMGPO)

## Marine remote sensing techniques and underwater archaeology: Case studies from Greece and the Eastern Mediterranean

Studies using marine geophysical techniques in the surveying and management of underwater cultural heritage sites in eastern Mediterranean Sea, conducted by the Laboratory of Marine Geology and Physical Oceanography (LMGPO) Department of Geology, University of Patras, will be presented. Emphasis will be given in the survey conducted nearshore off the southwestern coast of Pagasetikos Gulf in 2015, in collaboration with the Hellenic Institute of Marine Archaeology (H.I.M.A.). Underwater discoveries included ruins of ancient shipwreck cargos and submerged settlements of the Bronze Age (Bay of Nies) attest to the archaeological importance of the area. The survey utilized a multibeam echosounder system (MBES) for the acquisition of the bathymetric data. A high resolution Chirp sub-bottom profiling system was used for the examination of the seafloor stratigraphy focused on the evaluation of the coastal zone evolution and the detection of possible buried archaeological findings. Side scan sonar data acquired by a dual frequency (100 and 500kHz) system in order to examine the seafloor geomorphology, to map the previous detected underwater cultural sites in high resolution and to detect potential sites of archaeological interest. All the acquired data sets were georeferenced. The aim of that study was to localize and map all the known and potential underwater archaeological sites and to evaluate the costal paleogeography model of the area thus to construct a geo data base for the current and future archaeological research.

## Antonio Salvati

KELL srl

## Bathymetry estimation using satellite-based SAR observations

The work package analyzed the possibility of estimating the bathymetry and detecting underwater sites by means of High resolution Synthetic Aperture Radar (SAR) in coastal regions of the Mediterranean sea. A physical model which relates radar cross-section modulations with sea-current variations over bottom topography and which provides the state-of-the-art methodology for bathymetry measurement by SAR has been implemented. The resulting algorithm was applied to the areas of interest for the ITACA project, which are the Egadi islands, Metohi and the Messina strait due to the presence of archeological remains and ship wrecks. The applied methodology is already well established in oceanic contexts, such as the North Sea, where it is known there are occurrences of the right environmental conditions for the application of the model. However these conditions are generally rare and, as a consequence, it was challenging to employ this methodology in the Mediterranean environment. Furthermore, a data assimilation algorithm was implemented with the purpose of evaluating the possibility of integrating bathymetries from different sources by using different interpolation techniques. The results of this research will be presented and discussed.

## Massimiliano Secci, Giorgio Pier Spanu

Dipartimento di Storia, Scienze dell'Uomo e della Formazione Università degli Studi di Sassari, Italy

## The underwater archaeological world in three dimensions. Some theoretical and conceptual considerations

The considerations presented spring from the PhD Dissertation of the author (Secci) as part of a larger research program attempting to connect a coastal and underwater landscape archaeological approach, with technological experimentation and a strong commitment to public archaeology. In this frame, contemporary archaeology confronts many issues relating to broader societal challenges. Information and Communication Technologies (ICTs) play a relevant role within this confrontation. Understanding the role and effects of ICTs in society is still in the process and so is for archaeology. The relation between archaeological thought and computer technologies has witnessed a preliminary and strong commitment of archaeologist to computer's potentials as part of the positivistic strand of the New Archaeology, going through to the acquisition of the GIS and virtual reality potentials since the 1980s. The data enriching environment of post- processual archaeology and the increasing development in computers power and means, have brought to the fore issues of data archiving, management, retrieval, sharing and access. The digital environment requires an ever increasing amount of space for the ever increasing amount of digitally-born data to be preserved and shared.

The present paper aims to analyze the digital world of archaeology and, particularly, photogrammetry applied to the survey and recording of underwater cultural heritage, with an eye on theoretical and methodological aspects that affect the way photogrammetry and 3D models enter the process of archaeological interpretation. Photogrammetry and the resulting threedimensional models are useful in the interpretation process as part of a larger digital framework for the analysis of spatial data in underwater archaeology. Issues of image perception and cognition enter the analysis and interpretation of underwater archaeological sites as part of a larger framework which relates to visual representation.

The present paper proposes a series of considerations that are deemed of value when approaching visual digital technologies in the archaeological interpretive process.

## Elias Spondylis, Myrto Michalis, Christos Agouridis

Hellenic Institute of Marine Archaeology (I.EN.A.E.)

## ITACA's Test Case Greece: The Pagasetikos Underwater Archaeological Research at Metohi and Glaros

Within the framework of the ITACA project, the Hellenic Institute of Marine Archaeology (I.EN.A.E.) conducted an underwater archaeological research at Nies Bay, in the west coast of southern Pagasetikos Gulf and through an extensive demonstration campaign on selected test sites had to apply both intrusive and non-intrusive methodological techniques; excavation and survey, in order to collect all required data and contribute successfully to the ITACA's objectives.

The results of the excavation project would be included in the ITACA's management and operation tool, whereas a systematic survey on the selected sites would provide data in order to verify/validate the SAR radar data as well as multispectral data and build up the 3D scenario for the WebGIS management tool. As a result, the archaeologist/end-user will be able to acquire a set of services that will support his/hers research and will contribute to the successful monitoring of sites under investigation.

Research during 2014 and 2015 field seasons included:

- Review of the selected test sites and trade-off analysis
- Acquisition of existing data and information on the selected test sites at Nies Bay
- Test campaign planning
- Test campaign execution: a) Survey/Excavation, documentation and study of the Metohi submerged prehistoric settlement, b) Survey, documentation and study of the shipwrecks located at Cape Glaros
- Geophysical mapping campaign on boat using a multi-beam echo sounder
- Production of the 3D scenario
- Data processing and preliminary analysis of the results

## Chris Stewart

Tor Vergata University of Rome

## Submerged Palaeolandscape Monitoring with Sentinel-1

Shallow water regions in the European continental shelf contain some of the best preserved palaeolandscapes. These have been left largely undeveloped by humankind since they were submerged by rising sea levels as a consequence of global warming following the last glacial maximum. However, very little is known of these palaeolandscapes, partly due to their inaccessibility, and partly due to the immense size of the areas. Activities such as mineral extraction, construction and commercial trawling are contributing to them becoming increasingly under threat. Mapping and monitoring of submerged palaeolandscapes is important to understand and preserve the underwater heritage. While depth maps alone may not be sufficient to provide the full picture of past landscapes, due for instance to deposition or erosion induced they nonetheless can support palaeolandscape analysis changes, conjunction with other techniques, such as seismic survey and coring. The systematic and guaranteed long term availability of high resolution Synthetic Aperture Radar (SAR) data acquired by Sentinel-1 could potentially support cost effective, regular monitoring of bathymetric features in extensive areas.

This presentation shows the application of a recently developed bathymetric retrieval algorithm on Sentinel-1 data over the North Sea. While a scientific validation of the results has not been carried out, a comparison of the output has been made with freely available bathymetry data from the EMODnet portal. Results show general agreement between the two datasets. Limitations exist in the ability of the algorithm to measure only one dimensional depth variations in range; in the need to remove the influence on the SAR backscatter of all effects not due to bathymetry, and the seeming underestimation of the depth of deep trenches.

To assess the support that Sentinel-1 derived bathymetry can provide to the analysis of submerged palaeolandscapes, the results of the retrieval have been compared with the palaeolandscape map of the same area produced in the framework of the North Sea Palaeolandscapes Project (NSPP). Results show a clear correspondence between some topographic structures identified in the Sentinel-1 depth map and features interpreted by the NSPP as Early Holocene rivers other NSPP lakes. and landscape topography. There are palaeolandscape objects which are not visible on the Sentinel-1 map, possibly since they lack a topographic signature, or perhaps due to insufficient conditions for bathymetry retrieval. There are also structures on the Sentinel-1 bathymetric chart which do not correspond with NSPP features: These may be modern topographic structures, or artifacts not due to seabed topography.

## Eutimio **Tiliacos**

ANESTI Ltd

## The market perspective of the ITACA project

As stipulated in the Description of Work, ITACA had to center around two objectives:

- A. the provision of a location & monitoring service plus
- B. software tools for managing underwater sites and guiding underwater operations

both of which have a specific application on Underwater Cultural Heritages (UCH) search and monitoring. Variety of service models were examined and discussed in D 5.1.

To evolve to Market Potential Assessment and High level Business Plan however the following elements were taken into consideration:

- a) Preliminary evaluation had been carried to find if the service models under investigation were clearly stating the project goals
- b) Further: if the likely achievements pertaining single specific aspects were or not each supported by consistent preliminary considerations
- c) Whether each main consideration in turn was or not supported by accurate and specific pieces of information providing cross references about actual achievement possibility
- d) If specific pieces of information regarding market penetration could be already verified in real situations and on technical literature
- e) If Intellectual Property Rights (IPR) ownership could be assessed as real and implementable resulting outcome
- f) Whether validation materials had come into the picture and if it was or not sufficiently close to the expected achievement goals
- g) If further checks had been carried on actual impact by way of information from personal experience or data from sources other than the reading materials
- h) Whether there was a clear indication of the capacity building process to make the most of the impact and speed up the time to market
- i) Whether the barrier to entry were clearly stated

Filters so introduced have been instrumental to better identify appropriate service model and prepare a High Level Business Plan. As result a preemptive service discriminating conditions that make search and monitoring data reliable has been paid consideration to and quantified in terms of costs, in order to minimize risks of low accuracy and other shortcomings of the system as a whole.

Discovery and monitoring of underwater cultural heritages (UCH) is in fact something more challenging and difficult than just locating an object by track and tracing its movements along a man made transport infrastructure. Spatial Data assessment applied to object discovery and monitoring is in fact the result of several highly complex adaptive systems (CAS) in constant evolution and for such reason characterized by 1) unpredictability, 2) nonlinearity and 3) different sensitivity to initial and evolving conditions induced by natural events or by human activity.

A detailed cost analysis has been carried to prove the economic benefits of the solution envisaged and a similarly accurate SWOT analysis has in addition been provided.

## João Vieira, Manuel J. Fonseca

Faculdade de Ciências da Universidade de Lisboa (FFCUL)

## A fuzzy approach for shape detection in complex images

Automatic detection of archaeological objects in satellite images is an asset that can save a lot of work and time to archaeologists and money to organizations involved. Such a solution can reduce the size of the areas to explore and the number of exploration campaigns to be made, my helping archaeologists to better select the locations to explore.

Here we describe an approach for shape detection in complex images, based on the Generalized Hough Transform (GHT) algorithm, which combines fuzzy logic and a spatial neighborhood vote grouping to improve the voting process, and introduces a filling ratio to control the completeness of the detected shapes.

Experimental results show that our improved version of the GHT presents a much better accuracy than the original GHT, being able to detect arbitrary shapes in complex images (like archeological images), making it suitable to detect shipwrecks and other archeological artifacts in bathymetry images.

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