ESMAC, A NORDIC RESEARCH PROGRAMME FOR ENVIRONMENTAL MAPPING AND CARTERIZATION OF THE SEAFLOOR.

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Introduction.

While the technology for mapping the seabed topology has improved immensely over the last decade, with swath mapping systems being constantly improved and taken into use, the technology for seabed characterization has not improved to the same extent. Still the assessment of seabed characteristics is mainly based upon manual interpretation of sidescan sonar recordings, combined with analysis of material being sampled from the seafloor.

Throughout the world ever increasing demand is being made on the coastal and marine environment as an exploitable resource. The growing interest on the coastal and marine environment has resulted in a greater frequency of conflicts between the different modes of exploitation and preservation. Important economic activity is seen within fisheries, fish farming, and exploitation of oil and minerals reserves. Typical user groups that need to know more about the seabed than its shape, are offshore oil contractors, cable- and pipeline contractors, environmental organizations, and geologists.

The demand for more systematic coordination and basic marine information has therefore increased. One of the most important bases for the planning of the development of coastal and offshore waters is the marine geological maps.

On this background an initiative was taken in early 1992, to form the research program "Environmental Seafloor Mapping and Characterization" (ESMAC). The project participant include qualified users, 3 research groups with different qualifications, and industry. The aim of the 2-year program is to develop technology for seabed investigations, which within short time can be further developed into industrial products. Only when the industrial products are put to the market, will the user community be able to benefit from the improved solutions.

Project financing, organisation, reference group.

The ESMAC project is funded by the Nordic Industrial Fund, Swedish National Board for Industrialand Technical Development (NUTEK), Royal Norwegian Council for Scientific and Industrial Research (NTNF) as well a by the participants during the two year project periode. The contribution from the participants will mainly consist of manpower, shiptime, equipmentime and computertime.

The ESMAC project had its formal kick-off in June 1992, and the period from June 1992 to June 1993 is called phase 1. Correspondingly the period June 1993 to June 1994 is called phase 2.

The formal organisation of the project is that it is headed by a steering committe with one representative from each participating organisation. The project has appointed a project cordinator that together with the task managers is responsible for the following up of each task. The technical and financial responsibility for each task lies with the appointed task manager.

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A reference group has been established, with participants from Sweden, Norway, Denmark, Finland, UK, Canada and Germany. The reference group is composed by participants from research organisations, industry and potential future users of the developments under the project. Their task is to monitor the progress, the results and the plans of the project and to give useful feedack and input to the project. In the reference group, we will in particular mention the participation of Heriot Watt University, University of New Brunswick and Kiel University.

Project participants, resources, competence.

ESMAC is a Nordic project with active participants from Sweden and Norway.

The Swedish participants are Chalmers University of Technology (CTH) in Gothenburg, Geological Survey of Sweden, the Swedish Fishery Authorities (FV), represented by the Institute of Marine Research in Lysekil and ContextVision A.B. The Norwegian participants are the Norwegian Computing Central and Simrad Subsea A.S. The project is headed by Simrad Subsea.

Marine Technology has been taught for over a century in Gothenburg at what is now Chalmers University of Technology, in view of the importance of shipping and shipbuilding for Sweden. Special courses in Underwater Technology began in 1969, together with research into diving technology. More recently there has been a growing interest in ocean resources, underwater survey, and hydroacoustics. In 1985, Chalmers joined forces with the Fishery Research Laboratory in Lysekil and other institutes to procure and operate a "Sea-Owl", at that time the most advanced of SUTEK ROV products. Thus began the interest in seabed monitoring using both sonar and video-camera sensors, subsequently pursued in a close collaboration with the Geological - Palaeontological Institute in Kiel. The Chalmers participation in ESMAC, as well as in ODER, a second Environmental Monitoring Program involving Keil University, follows naturally from these earlier interests.

The Geological Survey of Sweden (SGU), established in 1858, is a central governmental agency responsible for the investigation of the geology of Sweden. Its main tasks are to prepare and issue geological maps and to provide geological, geophysical, geochemical and sedimentological data prognoses and information regarding resources such as groundwater, sand and gravel, ores and minerals.

Since 1969 SGU has been conducting a marine geological survey of the Swedish continental shelf areas. At the outset the aim of the survey was to find and map deposits suitable for sand and gravel extraction. In order to produce not only maps showing the positions and thicknesses of sand and gravel deposits, but also a basis for estimates of risk for permanent damage to the marine environment by possible extraction operations, the survey very soon was given the form of a regional mapping of marine Quaternary deposits. In 1979 the marine geological mapping project was included in SGU's government funded program for mapping the Quaternary deposits of Sweden. In 1982 it was given status of a separate mapping program.

The Lysekil Istitute of Marine Research belongs to the Swedish National Board of Fisheries and is its center for marine fisheries research. The primary aim of the Institute is to provide data that can ensure rational exploitation of our marine fish and shellfish resources on long term basis.
The activities of the institute are to a a large extent based on cruise data obtained by the research vessels ARGOS and ANCYLUS. These data and samples from commercial catches provides the base for stock assessment on the most important commercial species. During recent years the field of activity has extended to cover monitoring of the distribution of fish and shellfish diseases, the environmental effects on fish and fisheries and evaluation of the biological effects of fishing gears and methods.

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ContextVision was formed in October 1983 by professor Gösta Granlund at Linköping's Insitute of Technology. Professor Gösta Granlund and his colleagues had then for several years been working on new technology leading towards the development of vision computers based on the new image processing technology.

Norwegian Computing Central (NR) carries out commissioned research, and is active in the fields of applied research in information technology and statistical modeling.

NR is a national centre of excellence, and is internationally recognized for its contributions in image analysis, environmental and nature resource evaluation, and information systems in public administration.
NR has worked since 1982 with:

- analysis and interpretation of remote sensing data, and
- statistical methods for processing spatial information.

NR has participated since 1990 in a project for mapping of the sea floor, commissioned by Simrad A/S. NR's work has been concentrated on the extraction of features and statistical classification of sonar data.

Simrad Subsea A.S. has for more than 40 years been a recognized supplier world wide of under water acoustic and computer based instruments and systems for naval, offshore, scientific and fish finding applications.
We have, in cooperation with various research organizations, since 1959 developed echo sounders for scientific purposes. In 1986, Simrad launched the EM 100, their first multibeam echo sounder. The acquisition of data to produce 3-D detailed, high resolution, seabed maps. The development has continued with new a new generation of multibeam echo sounders, for shallow and deep waters, bringing technology further and combining bathymetric mapping with acoustical imaging. Tools for data decoding and data processing play a central role in Simrad's ongoing development.

The resources of the project are vessels and data acquisition equipment operated by the participants, as well as computer equipment, laboratory facilities and human resources.

R/V "Ocean Surveyor" is operated by SGU. The vessel is equipped with a wide range of scientific equipment, but during the ESMAC project it will mainly be the 50, 100 and 500 kHz sidescan sonars and sediment echosounder with datalogging that will be utilized, together with equipment for taking bottom samples, and the vessels laboratoty facilities.

The ROV "Sea Owl" is equipped with a TV camera and a scanning sonar.

The vessel of the Institute of Marine Research, R/V "Ancylus" is mainly used as the mothership of the ROV "Sea Owl" in addition to taking bottom samples.

R/V "Simrad" is mainly used as Simrad Subsea's test platform for new equipment. In the ESMAC project, the vessel will perform surveys with the EM 1000 shallow water multibeam (95 kHz) and the EA 500 singlebeam echosounder (18, 38, 200 kHz).

During the project a GOP image processing computer has been supplied by ContextVision. This computer is used for the development under the mosaicking task at CTH. NR has a wide range of workstations that are utilised for the classification task.

Classification.

The goal for this task is to develop and test scientific methods and the corresponding computer algorithms/software that will classify seabed geology and biology into a number of pre-defined classes. Input to the computer programs will be data from various hydroacoustic sensors,

and the results will be verified against ground thruth and bottom samples. Segmentation of the seabed data into areas with homogenous properties will be one activity under this task.

For the principal design of the prototype classification system, please see figure (A).

The Norwegian Computing Central, with their expertise on statistical classification methods, remote sensing and pathernrecognition has together with researchers from Industrial Research (SI) who are experts on neural networks been the main contributors within this task. Simrad Subsea with their expertise on hydroacoustic instrumentation and data produced by hydroacoustic sensors is also doing work under this task. The task is headed by Simrad Subsea.

The methods and algorithms will be developed and "trained" on data from multibeam echosounders as well as data from single beam echosounders and sidescan sonars.

Four papers held during this conference are produced under the classification activity in the ESMAC project,
please see reference (3), (4), (5) and (6).

Mapping and Mosaicking

In its simplest form, sonar mapping is the generation of a paper strip-chart from side-scan echoes, recording successive echoes to form a 2-dimensional picture. Manual "cut and paste" techniques can then be used to combine these strips into a mosaic aligned with grid coordinates. Digital versions of such processing have been used for some time, for example to handle GLORIA imagery (1). However, the mapping system ESMAC should first be regarded as an operational database to support the seabed classification experiments, rather than a black box for producing seabed charts. Figure (B) illustrates the input/output data which the system should accommodate, and shows clearly that it must be regarded as a Geographic Information System. Hence the working name GISMO (GIS + Mosaicking). The range of operational decisions which GISMO should support becomes clearer as the Project proceeds. At the present stage of field survey, these include the selection of survey lines,the
selection of areas for ground truthing, and charting of survey overviews. In the next stage it will involve the selection of training data for classification, and the generation of thematic maps. There will also be requirements to compare side-scan mosaic, obtained with Multibeam and Klein 50, 100 and 500 kHz, with each other and with the classified data. Sub-bottom data must also be taken into account.

The experimental version of GISMO is not required to generate "production quality" annotated charts. For SGU, this will be done via an interface to the Intergraph equipment on "Ocean Surveyor".

Like most GIS systems, GISMO must support rapid data selection. However, raw hydroacoustic data volumes are particularly large, and this raw data must be preserved for some time in order to test alternative classification algorithms. Note also that the raw data is in a different coordinate system from the rectified mosaic. GISMO also needs to support specific sonar processing operations for the Klein data, including artefact removal, slant-range correction, TVG correction and geometric warping, all of which are computationally intensive. The hardware used is a network of Sun-Sparc Workstations, one of which hosts a ContexVision GOP300 for sonar image processing. The GOP300 is designed to carry out very high speed convolution/correlation signal and image processing operations. A number of side-scan and sub-bottom processing operations are already available to exploit the GOP architecture. The User Interface for GISMO being developed by Chalmers in conjunction with Contex Vision, based on "X-windows". The GISMO design is discussed in more detail in the companion paper (2) which also indicated its current development status.

For the future, GISMO must have the capability, not just to handle one or two survey data sets, but surveys carried out at regular intervals to monitor the state of the seabed.

It can be seen as the marine sciences equivalent of the seismic workstation, in routine used to support geological interpretation.

This could fit well with SGU's operational policy of using "Ocean Surveyor" as a floating data processing laboratory, and not just a platform for hydroacoustic instruments.

ROV Strip-charts

Optical instruments are fundamental to high resolution underwater inspection. A wide range of cameras has been developed for this purpose.

In turbid coastal waters, visual range is frequently less than 1 meter, so individual

frames provide little information in isolation. A strip chart offers the opportunity to consider the whole sequence together, but requires precise position and altitude information for the ROV. The basic idea of the strip charting is not new, and Hasselblad cameras were used to make strip-charts of the moon's surface in the Appollo project. In the crudest form, ROV strip-charts can be generated by mapping a few scan lines of successive video frames, depending on the scroll velocity of the region of interest. Precise matching of successive scan lines, as well as rectification, is carried out by cross-correlating the position of significant features on successive frames. ROV attitude information is currently superposed on each video-frame, and extracted by OCR techniques.

Such strip-charts will integrated into the GISMO system provide additional ground-truth for the hydroacoustic classification experiments. In principle these strip-charts can be mosaicked in the same manners as side-scan records.

Use of ROV in biological investigations

The Institute of Marine Research in Lysekil investigates the biological and mechanical effect on benthos and sediment on bottoms with different fishing activities. The fishing with bottom trawls in the Skagerrak and Kattegat has changed and increased in recent years. Similar observations have also been made in many other important fishing areas. New multi-rig trawls are used and the Norway lobster (Nephrops norvegicus) has more and more become a target species. As the Nephrops live in burrows, figure (C), in soft clay/silt bottoms they are not catchable by trawls when they are hiding in the burrows. Thus the conventional trawling methods for examination of the distribution and density of Nephrops are not as accurate and useful as for fish.

To proceed in this work it is necessary to find a method for classification of different bottom types and to estimate the area they cover.

The use of a ROV has, in spite of a very consuming video analysis, become an important complement to shellfish trawl survey. The main task for the Institute of Marine Research in the ESMAC project is to collect and analyze video sequences at ground truth stations. The field data will be used in the work for development of GISMO at Chalmers University of Technology as shown in figure (B).
New procedures are needed to document the effect of the increasing fishing pressure and environmental changes (oxygen deficiency in the bottom water) on the distribution and density of Nephrops stocks. Field data with different biological, environmental, and physical conditions have been collected in the ESMAC-project.

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ROV instrumentation.

One of the resourses in the project is the ROV "Sea Owl", and we will during the project continue the development of the ROV's instrumentation system, partly through experience gained in the operation of the vehicle.

The development will in phase 1 consist of new and better sensors (TV cameras, sidescan sonars), improvments in the positioning of the ROV and user procedures for the operation of the ROV and the "mother ship" when doin ground thruthing tasks in connection with seabed classification.

In phase 2, we will besides the sensors look at the ROV-platform itself, integration of the ROV acquired data with the data acquired by the surface vessels as well as data integration in a marine real time GIS.

The ROV task is headed by CTH with contribution from FV, SGU and Simrad Subsea.

Field surveys.

The main purpose of this task is to utilise the vessels available for the project for both surface and sub surface (ROV) acquisition of data that will be used in the other tasks of the project. Other important activities under this task are the selection of suitable areas for data acquisition, survey planning and coordination and data quality control and re-formatting. Based on their wide experience in geological surveying, SGU is in charge of this task.

During 1992 one area in the Oslofjord and three areas on the Swedish west coast has been surveyed. The areas have been carefully selected to cover different classes of seabed.

Instrument development.

This activity belongs to phase 2 of the project. We will study the instrumentation used for data acquisition in phase 1, together with the requirements to the data that are input to the classisfication and mosaicking systems. Based on these studies, proposals for improvements of the existng instrumentation as well as new developments will be made.

Status, results and future schedule.

As per today the project is progressing according to the initial schedule. The time schedule for the project is presented in figure (D) below.

The results under the classification task are beeing presented in the other ESMAC papers during the conference, ref. (3), (4), (5) and (6).

The GIS task in the project is presented in a poster session during this conference, reference (7).

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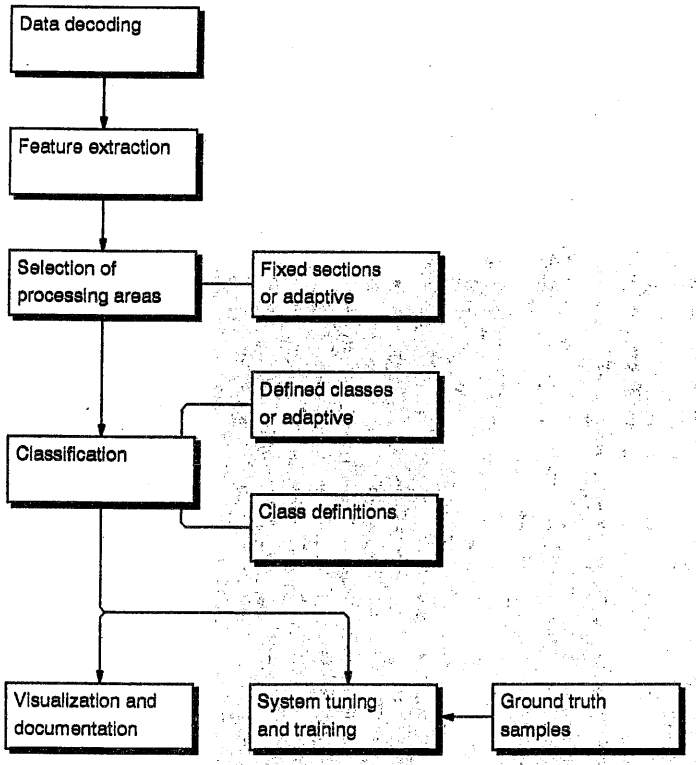

Figure (A) Principal block diagram for acoustic seabed classification prototype system.

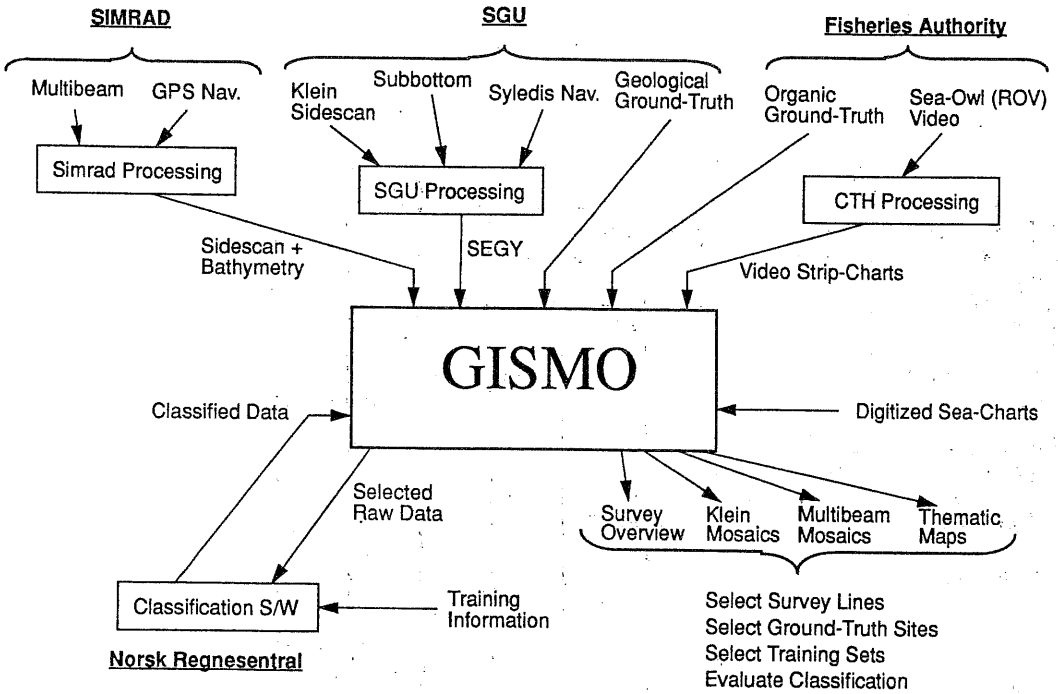

Figure (B) GISMO Environment

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Figure (C) Nephrops norvegicus burrow.

	1/6 92		1/1 93		1/6 93		1/1 94		1/6 94
Plan., Experiment	==		====	=====					
Field Surveys	====	==		=====	====				
Classification									
- Multibeam methods	====	=====	====	=====					
- Single beam, methods			====	=====	====				
- Prototype system					====	====	====		
- Evaluation							==	====	
"Mosaicking"									
- Tool development	====	=====	====						
- GOP installation	====								
- Sonar algoritm.		=====	====	=====	====				
- Video algoritm.			====	=====	====	====	====	====	
- Integration				=====	====	====	====	====	
Instrument analysis									
- 92/93	==								
- 93/94			====	=====	====	====			
- Phase 2						====	====	====	
GIS, specification						====	====	====	
ROV instrumentation									
- Ground trouth	====	==		=====	====				

Figure (D) ESMAC time schedule.

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References

(1) "Computer rectification and mosaicking of side-looking sonar images", Pauluzzi, P.R. et al, OTC 4018 (May 1981) pp 103-115.

(2) "Design of a Marine GIS for Seabed Mapping and Classification", Shippey, G.A., Vikgren, K.J., Elhammer, A., Finndin, R.

(3) "Seabed classification from backscatter sonar data using statistical methods", R.B. Huseby, O. Milvang, A. Solberg, K. Weisteen (Norwegian Computing Central)

(4) "Seabed classification from sonar images using neural networks", T. Kavli, M. Carlin (Industrial Research), R. Madsen (Norwegian Computing Central)

(5) "Feature extraction from backscatter sonar data", O. Milvang, R.B. Huseby, A. Solberg, K. Weisteen (Norwegian Computing Central)

(6) "Sediment classification by means of multibeam echosounders", T.H. Eggen (Simrad Subsea A.S., Norway)

(7) "Design of a marine GIS for seabed mapping and classification", G. Shippey, K. Vikgren, R. Findin (Chalmers University of Technology, Sweden), A. Elhammer (Geological Survey of Sweden).