UPGRADE and IMODELASER: Tools and Best Practice for 3D Data Acquisition and Processing for CH in Different Environments
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Tools and Best Practice for 3D Data Acquisition and Processing for CH in Different Environments

Acquisition and processing of 3D data for CH documentation

3D models as a mean for visualization and presentation of artefacts, but also:
- a form of digital preservation
- a basis for archaeological and/or architectural analysis.

NEW TOols Needed: IMODELASER and UPGRADE practices and tools for efficient data gathering and 3D documentation.

**IMODELASER**: optimization of terrestrial image-based 3D modelling by means of integrating laser scan data with close-range photogrammetry: from data capture to outlier filtering to edge-preserving 3D models

**UPGRADE**: towards widely automated underwater archaeological surveys: integration of optical, acoustical and navigation data
Combining photogrammetry and terrestrial laser scanning for high quality 3D modelling

ETH Zurich - Chair of Photogrammetry & Remote Sensing
A. Gruen, S. Sotoodeh, D. Novak, M. Sauerbier

Goal:
Combine the advantages of laser scanning (high point density) and close range photogrammetry (high accuracy edge modelling) to overcome the specific weaknesses of both technologies

Case Study: ETH Sternwarte by G. Semper (Observatory), 1861 – 1864
Field equipment

**Imaging:**
Camera
- Nikon D2XS, 12 MP, 5.5 um pixel size
- Average distance to object = 15m
- Lens focal distance = 18mm
- Expected RMSE in object space = 2.75 mm

**Laser scanning**
Scanner
- Faro, Laser Scanner LS
- Distance: 70m
- Linearity Error: 3 mm at 10 m
- Vertical Field of View: 320°
- Horizontal Field of View: 360°
- 10 scanning positions, Point space in object space = 3 mm
HOD (Hierarchical Outlier Detection)

Clusters a point cloud and detects outlier clusters using proximity graphs (EMST, Gabriel Graph) in two phases:
- the first phase copes with large scale outliers
- the second phase tackles small scale outliers
- the final result is the cleaned point cloud out of outliers, also clustered
- Inputs: 3D point clouds (XYZ)
- Output: Clustered/cleaned point cloud
HOD (Hierarchical Outlier Detection)

Original point cloud

Clean point cloud
Orientation of images with respect to a point cloud system

Precisely oriented images allow for special processing of point clouds:
- Edge constraint triangulation
- Blunder detection and removal
- Precise parameters for texture mapping

This leads to an overall improved representation of the 3D model.
An iterative, semi-automatic work flow is suggested.

Check PC, I.O. & E.O. and improve if necessary

Register point cloud to image coordinate system

Back project points into images

Perform visibility analysis

Match back projected points

Run Bundle Adjustment and obtain new E.O.
Work flow

**Back projection**
Projection of 3D points back into the images

**Visibility analysis**
Removal of occluded points to decrease mismatch, computation

**Matching**
Match homologous, back projected points in images

**Bundle adjustment**
To acquire refined orientation parameters

**Iterate until satisfactory**

- Check PC, I.O. & E.O. and improve if necessary
- Register point cloud to image coordinate system
- Back project points into images
- Perform visibility analysis
- Match back projected points
- Run Bundle Adjustment and obtain new E.O.

Iterate until satisfactory
Results – Visibility Analysis and Matching
Results – Bundle adjustments
3D Surface Reconstruction tool

*Constructs a 3D surface out of a point cloud*

- Using proximity graphs (EMST, Gabriel Graph, KNN)
- 3D Delaunay triangulation followed by sculpturing
- Inputs: 3D point clouds (XYZ)
- Output: surface triangles in OFF format
3D Edge-Constrained Surface Reconstruction tool

**Constructs a 3D surface out of a point cloud and includes edge information**

- Using proximity graphs (EMST, Gabriel Graph, KNN) while respecting the defined 3D edges
- 3D edge-constrained Delaunay triangulation followed by constrained sculpturing
- Inputs: 3D point clouds (XYZ) + 3D edge file (OFF format)
- Output: surface triangles in OFF format
Influence of edge constraints in the surface reconstruction

Before using the edge constraint (the edges is just overlaid)

After using the edge constraint

Green line is an edge constraint
### Availability and contacts

**Services:**
- “How-To” instructions for data acquisition, required data formats and introduction into the methodology in our labs.
- Processing of data by our staff and partly by clients (e.g. point measurements, image orientation) or by clients themselves.

**Series of Tools** (surface reconstruction, hole filling) which run under Linux, available as Open Source; Point Measurement has to be performed using external software (e.g. Photomodeler (commercial) or others (OS))

**Data Formats:**
- *Import*: Point Clouds (XYZ, OFF), others possible after conversion
- *Export*: VRML, COLLADA

**Contact:** Martin Sauerbier, Institute of Geodesy and Photogrammetry
Wolfgang-Pauli-Strasse 15  CH-8093 Zurich
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Equipments and data management tools for underwater archaeology

Underwater PhotoGRAMmetry and Archaeological Data Enhancement - UPGRADE

Partnership

Ciencia Viva, PORTUGAL
CNRS - UMR 694 - MAP GAMSAU, Ecole d’Architecture de Marseille, FRANCE
DRASSM – Département des Recherches Archéologiques Subaquatiques et Sous-Marines, FRANCE
IST - Instituto Superior Técnico, PORTUGAL
ISME - Interuniversity Ctr. Integrated Systems for the Marine Environment, ITALY
SIMVIS - University of Hull – Simulation and Visualization Research Group, Hull, UK
UIBK - Institute of Geodesy, University of Innsbruck, Innsbruck, AUSTRIA
Objectives

Development of a software suite, together with a set of best practice recommendations, for the integration and fusion of acoustical, optical and platform navigation data in the exploration and mapping of underwater archaeological sites.

Automatization of the data fusion process

Construction of integrated, geo-referenced, large-to-medium 3-D scale maps of underwater archaeological areas from optical and acoustic data.

*Bring the data collection process in the underwater field closer to the standards already reached by land archaeology*
<table>
<thead>
<tr>
<th>Specific items</th>
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<tr>
<td>- accurate navigation of underwater platforms with affordable sensors;</td>
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<td>- underwater images automated photogrammetry with environmental disturbances;</td>
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<td>- estimation of camera parameters and adaptation of standard calibration software to the underwater case;</td>
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<td>- integration of Digital Terrain Models (DTM) at different resolution scale with 3-D information from photogrammetric data;</td>
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<td>- compatibility of DTM+photogrammetry with archaeologically oriented metadata;</td>
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<tr>
<td>- compatibility of DTM+photogrammetry with 3-D Virtual/Augmented reality systems, with particular attention to requirements in the education and learning sector and to standards supported or indicated within EPOCH.</td>
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### Data format and data flow

- **Definition of EXIF and XML formats to describe navigation data and camera parameters**

- **Software tools and a specific protocol to associate (in EXIF/XML format) navigation data to images taken by digital cameras or videocameras mounted on underwater vehicles**

- **Automatic data conversion from EXIF/XML to XML, and/or X3D, employing the software Arpenteur, a photogrammetric model and a Photomodeler project**

- **Software tools to generate automatically a 3D VRML script to show the camera position and the projection of photographs onto an approximated model of the seabed**

- **Techniques for constructing realistic immersive visualizations of underwater sites, using state-of-the-art computer graphics facilities, have been investigated, starting from the analysis of available material (pictures, videos)**
ROV-generated integrated data

Video Stream

Optical Image (JPEG)

Seabed image

Telemetry DATA (EXIF area)

x = UTM32 east coordinate (meter) of ROV position
y = UTM32 north coordinate (meter) of ROV position
dist = seabed distance (meter) from ROV position
z = depth (meter) of ROV
yaw, pitch, roll = yaw, pitch and roll angle (degree) of ROV
RPS = thrusters RPS related to the ROV
sonar ping = sonar data
z scout = depth (meter) computed by the usbl related to ROV position
scout data = full data scout related to ROV position
Acoustic-based underwater map construction

A set of terrain map generation tools for archaeological surveys

Hardware: test of mechanically scanned pencil beam sonar (shallow water) and single beam echosounders, to be installed on autonomous vehicles or on manned surface vehicles

Acoustic data integrated with navigation: GPS with RTK, attitude reference unit

Software for data acquisition and processing (including outlier detection and geo-referencing) and map construction.
Terrain-map generation: a case study

Coastal area map

From tools to Terrain Map
Terrain-based navigation

Development of algorithms and software for terrain-based navigation systems that can exploit the availability of existing digital terrain maps to accurately position a platform underwater. Algorithms were assessed in simulation.

Using terrain information as a Navigation Aid
PUT: a portable underwater tracker

Nikon D200
Optical high quality image acquisition

Sonardyne USBL
DIVER position measurement

Data acquisition, processing and archiving

- Realtime Clock
- Magnetic Compass
- Flash Light Sensor
- Acceleration Sensor

Generic Outputs

Portable Interface Unit and Tablet PC
Snake Mosaicking using SIFT

Development of “quick-and-dirty”, almost real-time, photomosaicking software tool from camera and video survey in the field. It relies on the EXIF data format previously defined.
Experiments have been carried on in the framework of 4 missions:

- **Pointe de la Voile, Marseille (France):** preliminary study.
- **San Nicola Island, Tremiti Archipelago (Italy):** test of calibration procedure, software testing and data gathering.
- **Barco da Telha, Sesimbra (Portugal) (UPGRADE partially supported):** photomosaicing with divers and testing of tracking tools and procedure.
- **Elba Island, Tuscany Archipelago (Italy) (UPGRADE partially supported):** test of photomosaicing with divers and testing of tracking tools and procedure.
Pointe de la Voile, Marseille (France)
Year 2006 (-100m)

San Nicola Island
Tremiti Archipelago (Italy)
May 2007 (-60m)

http://www.marlintremiti.it/labsub.html
Barco da Telha
Sesimbra (Portugal)
October 2007 (-58m)

Elba Island
Tuscany Archipelago (Italy)
November 2007 (-63m)

http://www.marcianamarina.toscana.it/italiano/STAMPA/Comunicato_Nasuto_07.html
ROV and Sensory Apparatus

- PXI - FPGA
  - Navigation, Instruments management, Data acquisition, processing and archiving

- Communication and Power Supply

- Umbilical cable

- 68K/ColdFire
  - RISC MicroController
  - Low Layer systems synchronization, Data fusion

- 4 Thrusters
  - 2 Horizontal act
  - 2 Vertical act

- Compass, IMU, depth

- Navigation data acquisition

- ROV position measurement

- Sonardyne USBL

- Phantom S2
  - Deep Ocean Engineering

- Nikon D200
  - Optical high quality image acquisition

- Kongsberg Sonar
  - Bathymetric data acquisition

- Sony HDR_HC7E
  - Optical high quality video image acquisition
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Mission Preparation and Design

Video and photo camera calibration

NCG parameters setting
Georeferenced data acquisition

GPS signal

Umbilical cable

Acoustic links
Availability and contacts

*Software tools:*
open source from the sites of the different partners, linked from EPOCH web site

*Hardware Tools:*
drawings of tools available from the sites of the different partners, linked from EPOCH web site, for non commercial use

*UPGRADE coordinator:*
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