MICROVEGA (MICRO VESSEL FOR GEODETICS APPLICATION): A MARINE DRONE FOR THE ACQUISITION OF BATHYMETRIC DATA FOR GIS APPLICATIONS

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The MicroVeGA drone is an Open Project of an Autonomous Unmanned Surface Vessel (AUSV) conceived, designed and built to operate in the coastal areas (0-20 meters of depth), where a traditional boat is poorly manoeuvrable. It is an open project prototype designed to test the procedures and methods of morpho-bathymetric surveys execution in critical areas. This project has been realized within the project PRIN 2010/11 of which Professor Raffaele Santamaria is scientific responsible, at national level.
Characteristics of MicroVeGA

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Length</td>
<td>135 cm</td>
</tr>
<tr>
<td>Width</td>
<td>85 cm</td>
</tr>
<tr>
<td>Weight in navigation trim</td>
<td>14 kg</td>
</tr>
<tr>
<td>Motors</td>
<td>2 brushless 750Kv / 140W</td>
</tr>
<tr>
<td>Operating speed</td>
<td>0.5 - 2 m / s</td>
</tr>
<tr>
<td>Power Autonomy</td>
<td>2 - 4 hours</td>
</tr>
</tbody>
</table>
MicroVeGA is a low technology risk project. The spiral model of project management is divided into smaller sections, as shown in figure.

MicroVeGa is an evolving open project, and for this reason, we have been capable of realizing surveys already in the early stage of development.
Drone assembling

Microvega is equipped with a set of sensors for acquiring morpho-bathymetric high-precision data.

During the survey

In the Lab
Drone assembling

A MICROVEGA DEVELOPMENT PHASE
The architecture of the data acquisition system is structured in three blocks:

1. **Base station**, which manages the mission data by means of the TrackStar software, managed by an operator which defines the navigation routes;

2. **On board computerized system** that acquires and organizes the GPS, echo sounder, inertial platform, obstacle detection sensor data;

3. **Communication system via data link**, to connect the AUVS with the base station, allowing the mission progresses monitoring by the operator.
On board instrumentations

1. Data acquisition and transmission software (TrakStar);
2. Data transmission system;
3. On-board electronics;
4. Differential GPS system;
5. Single-beam echo sounder;
6. Integrated system to 9 axes for attitude control.
7. Video acquisition system (both above and below sea level)
8. Anti-collision system (SIROS1)
The data transmission, is based on two distinct wireless networks:

1. The first transmits telemetry data (position, depth, structure, atmospheric temperature, obstacle detection) from the vessel to the Trackstar software.

2. The second one transmits the videos of the two on board cameras to the base station. This information is managed by a specific App, for viewing the images on tablet in real time.
Onboard electronics

A microcomputer OLinuXino, with Linux operating system is dedicated to mission management, data recording and transmission to the base station over wifi.

The Arduino microcontroller is dedicated to controlling the drone motors, to temperature measurement and management of the anti-collision ultrasound systems.
GPS TrimbleDSM232 (for marine applications)

The GPS receiver, installed on board of MicroVeGA, is the Trimble DSM™ 232 (24-channel L1 / L2), a possible solution for dynamic positioning tasks in marine environment. The device configurations allow the user for different accuracy levels, including SBAS (Satellite Based Augmentation System), Beacon, OmniSTAR-VBS/XP/HP, and RTK (Real-Time Kinematic) differential correction sources.
The SonarLite (Omex) is the single-beam echo sounder installed on-board. It is optimized for the bathymetric survey in coastal waters, and its transducer is vertically positioned above the GPS receiver in order to remove same off-set.

**Features:**

- **TRANSDUCER FREQUENCY** - 230KHz
- **BEAM SPREAD** - 8 to 10 Degrees
- **DEPTH RANGE** - 0.30m to 80.0m (s/ware limited)
- **ACCURACY** - +/-0.025m (RMS)
- **SOUND VELOCITY RANGE** - 1400-1600m/second
- **PULSE FREQUENCY** - 0.5Hz
Inertial platform XSense – Serie G

The inertial platform used on board of MicroVeGA is XSense MTi series G, a reliable device for the measurement of balance and direction (Attitude and Heading Reference System). The G series is characterized by its lightness and reliability and it represents a standard for marine and air drone applications.

**Specifications**

- Static accuracy (roll/pitch) < 0.5 deg
- Power Consumption 350 mW
- Gyro Bias Stability 20 deg/h
- Timing accuracy 10 ppm

Static accuracy (heading) < 1 deg

- Dynamic accuracy 2 deg RMS
- Angular resolution 0.05 deg
Two GO PRO HERO 3 cameras are installed on board, one emerged and submerged another. The cameras make a video recording during the whole survey, allowing the operator to check for the environmental conditions and to control in real-time the obstacles presence.

Go-Pro Hero3: risoluzione WVGA, 720p 60fps, 960p e 1080p a 30 fps, foto da 5 megapixel, raffiche da 3 fps, modalità time lapse con intervalli da 0.5, 2, 5, 10, 30 e 60 secondi. Impermeabile fino a -50m, Wi-Fi integrato
Anti-collision system

The anti-collision system is equipped with an ultrasonic sensor and an Arduino Mega microcomputer.

The system checks for potential emerged obstacles, in a range from 5 centimetres to 4 meters from the drone bow. SIROS1 is an experimental system that allows to detect with good accuracy the presence of emerged obstacles, using some components common in robotic field.
Anti-collision system

The System is based on: an Arduino controller; an ultrasonic sensor; a servomechanism; an electronic component; a software application.

The obstacle detection system scans a prow sector of about 160 degrees, using a servomechanism.
In case of critical alarm, the software stops the motors automatically. This feature, along with the camera's surface, is very useful in the presence of not marked on the cartography obstacles, like rocks scattered. It was also implemented a control system that decreases the false alarms problems.
Anti-collision system

**SIROS 1 Ultrasonic sensor module Description**

- **Working Voltage**: 5V(DC)
- **Static current**: Less than 2mA.
- **Output signal**: Electric frequency signal, high level 5V, low level 0V
- **Sensor angle**: Not more than 15 degrees.
- **Detection distance**: 2cm-450cm.
- **High precision**: Up to 0.2cm
- **Input trigger signal**: 10us TTL impulse
- **Echo signal**: output TTL PWL signal
- **Mode of connection**:
  1. VCC  2. trig(T)  3. echo(R)  4. OUT  5. GND

**Use method**: Supply module with 5V, the output will be 5V while obstacle in range, or 0V if not. The out pin of this module is used as a switching output when anti-theft module, and without the feet when ranging modules.

<table>
<thead>
<tr>
<th>V1 (20°C)</th>
<th>T (°C)</th>
<th>V2 (T)</th>
<th>Time (s)</th>
<th>D1 (cm)</th>
<th>D2 (cm)</th>
<th>dD (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>343,4</td>
<td>5</td>
<td>334,3</td>
<td>0,010</td>
<td>171,7</td>
<td>167,2</td>
<td>4,5</td>
</tr>
<tr>
<td>343,4</td>
<td>10</td>
<td>337,4</td>
<td>0,010</td>
<td>171,7</td>
<td>168,7</td>
<td>3,0</td>
</tr>
<tr>
<td>343,4</td>
<td>20</td>
<td>343,4</td>
<td>0,010</td>
<td>171,7</td>
<td>171,7</td>
<td>0,0</td>
</tr>
<tr>
<td>343,4</td>
<td>30</td>
<td>349,5</td>
<td>0,010</td>
<td>171,7</td>
<td>174,7</td>
<td>-3,0</td>
</tr>
</tbody>
</table>

**COMPARISON TABLE** between the distance measurement at the standard temperature of 20 °C (*columns V1 and D1*), and the distance measure at the actual temperature (*columns V2 (t) and D2*).
The TrackStar application manages data acquisition (position, depth and balance). The software captures and calculates in real time:

- the measured depth and GPS location;
- the route followed;
- the route to follow to get to the endpoint of the navigation line;
- the deviation in meters of the vessel from the line planned;
- the supposed time of arrival at the end of line.
The first application of this new technology has been carried out during a geo-archaeological survey made in Sorrento Marina Grande (Naples, Italy), to study the evolution of the coastline over the last 2000 years.
In this site, a bathymetric survey (Jones, 1999) through Micro VEGA drone has been realized, integrating it with direct measures by means of graduated stadia.

Direct measurements by means of graduated stadia have been carried out both in correspondence of the submerged finds, to calibrate the indirect measurements made by the echo sounder installed on the drone.
MicroVeGA has been designed in order to interact with the GIS systems in all survey phases: the planning, the data processing, and the production of the final output.

OPTIMAL MANAGEMENT OF MORPHO-BATHYIMETRIC SURVEY
Planning phase

The GIS layers created in this phase were:

- cartography of the area (Marina Grande in Sorrento), with appropriate coordinate system (UTM - WGS84);
- layer of navigation lines, spaced two meters;
- layer of the base station position, located on the bathhouse wooden structure (Bagni Salvatore);
- layers of the interesting environmental information, such as the position of the finds submerged identified from aerial photos.
Post-processing phase

The post-processing phase permits to analyse in detail the survey data within a single GIS project. In this phase the correction (respect to the tidal level and atmospheric pressure) of bathymetric measurements has been realized. The GIS layers were:

- Layer of GPS navigation data, to control the areal coverage percentage;
- Layer of bathymetric data (corrected respect to the tidal level and atmospheric pressure), to detect and remove all failed measures (spike), by means of the profiles analysis along the bathymetric lines;
- Link to the area photos;
- Link to video.
Elaboration phase

The elaboration phase provides, in the first instance, the interpolation of bathymetric data through special instruments, in order to transform the point measurements into continuous measurements. The outputs were:

1. isolines of equal depth (isobaths) - typical processing used to produce a bathymetric map of the area;
Elaboration phase

2. seabed DTM - to reconstruct the seabed morphology;

3. points measurement of archaeological remains submersion.

If necessary, additional processing, to perform specific environmental studies, may be carried out as the calculation of the slope for the evaluation of the risk of coastal erosion.
Correction of bathymetric measurements

In order to perform the depth corrections of the bathymetric data and archaeological findings (amount of submersion) the methodology described by (LEONI and DAIPRA, 1997) was applied.

\[ q = Q + h_i + \Delta h_p \]

where \( q \) = correct depth compared to the average sea level (m)

\( Q \) = survey measure (SBES or graduated stadia) (m)

\( h_i \) = tidal level at the time of measure (m)

\( \Delta h_p \) = barometric correction (m)

In particular, the tidal height \( h_i \) is calculated by mean of a linear interpolation between the tidal height values of the two ports nearest to the site in question, in function of the relative distances.
Results and Discussion

The use of the drone in our study area is a typical case in which this marine technology permits to realize a bathymetric survey also in presence of natural and anthropic obstacles, as the outcropping rocks or cliffs and piers.

<table>
<thead>
<tr>
<th>ID</th>
<th>Time</th>
<th>Marker</th>
<th>SBES Corrected Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11:28</td>
<td>quay A</td>
<td>-0.9</td>
</tr>
<tr>
<td>2</td>
<td>11:33</td>
<td>quay B</td>
<td>-1.04</td>
</tr>
<tr>
<td>3</td>
<td>11:34</td>
<td>pier C</td>
<td>-1.01</td>
</tr>
<tr>
<td>4</td>
<td>11:35</td>
<td>quay D</td>
<td>-1.02</td>
</tr>
<tr>
<td>9</td>
<td>12:14</td>
<td>quay F</td>
<td>-0.6</td>
</tr>
<tr>
<td>10</td>
<td>12:14</td>
<td>quay H</td>
<td>-0.77</td>
</tr>
<tr>
<td>11</td>
<td>12:16</td>
<td>quay G</td>
<td>-0.77</td>
</tr>
<tr>
<td>12</td>
<td>12:17</td>
<td>quay I</td>
<td>-0.79</td>
</tr>
<tr>
<td>13</td>
<td>12:40</td>
<td>fishponds</td>
<td>-0.74</td>
</tr>
</tbody>
</table>
Results and Discussion

The main results of processing data were:
• Bathymetric map of the area;
• DEM of seabed;
• Topographic profile topographic along the lines of navigation;
Operational research field

MicroVEGA is an Open Prototype platform made to experiment some methods of morpho-bathymetric survey in coastal areas difficult to be accessed by boat, as well as to test the performance of individual components installed on board.

The operational areas of this project are manifold:
1. Realizing bathymetric surveys in critical areas;
2. Testing of satellite methods in order to extract the bathymetry from multispectral data;
3. Performing 3D spatial analysis in order to study the coastal erosion or other environmental hazards, such as the monitoring of riverbeds in order to prevent flooding;
4. Realizing underwater archaeological surveys in order to study the evolution of the coastal landscape.
in the Future

Project of industrial mock up in fiberglass

MICROVEGA PRO
Conclusions

In conclusion MicroVeGA permits to perform integrated surveys in high-criticality coastal areas, and also to assess the state of submerged environment, creating a geodatabase of all mopho-bathymetric data, useful for monitoring the evolution of sensitive areas.

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Many thanks for your attention and goodbye.