BLUEMED

Activity 3.6
Design and implementation of the augmented diving service for Underwater Museums

Deliverable 3.6.2
Modification and integration of the autonomous surface monitoring platform

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Deliverable Team: UNIZG, UNICAL

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Summary

1. Introduction

The autonomous surface vehicle Pladypos (named after its initial purpose as a dynamic positioning platform), shown in Figure 1, carries the international flag marking underwater activity. The vehicle is equipped with four thrusters in the "X" configuration allowing omnidirectional motion, i.e free motion in the horizontal plane under any orientation. Such vessel configuration is convenient for research purposes due to easy deployment procedure, robustness in real environmental conditions, and low power consumption. Omnidirectional motion makes it agile and thus applicable in tracking underwater agents capable of quick change of direction such as human divers. Pladypos prototype was developed in 2012 (Figure 1.a) and was tested and validated in different scenario, among which the diver tracking scenario in (Misković, 2015) is of biggest impact in the BLUEMED context. During 2016 the second version was designed, and the prototype built, see Figure 1.b. Starting with 2017 this version is production ready and two vehicles are projected to be assembled for the BLUEMED project purposes as part of the augmented diving service.

(a)

(b)

Figure 1. (a) the first prototype developed in 2012 and (b) the second, production ready, version finanlized in 2017.

Pladypos is equipped with a control computer (isolated from environmental disturbances within the platform hull) in charge of performing navigation, guidance and control (NGC) and other data processing. Depending on processing requirements, extra room is reserved for a second backseat computer, usually dedicated for image processing or high-rate data acquisition. Pladypos is approximately 0.35m high, 0.7m wide and long, and weighs up to 25kg depending on payload and battery type. Basic vehicle payload consists of:

- Emlid Reach RTK GPS
- MPU9250 MEMS Inertial Measurement Unit
- Ubiquiti 2.4GHz wireless communication
- BlueRobotics T100 thrusters
- 12V VRLA battery

1.1 Functionalities required for BLUEMED project

During the kick-off meeting, two functionalities were identified for the autonomous surface monitoring platform: a) diver localization aiding and b) acoustic bathymetry.

The main technical objective of this deliverable is to combine existing and custom underwater acoustic localization solution with an autonomous surface vehicle (ASV). Performance of different solutions will be compared during the preparatory stage and a final solution for diver localization provided.

Two acoustic systems will be mounted: 1) Seatrac USBL, 2) SBL system developed by UNICAL. The Seatrac Ultra-Short BaseLine (USBL) system is a commercial product for centralized acoustic localization and provides a comparison baseline. The interrogation node is mounted on the ASV and underwater modems should be mounted on divers. The modem interfaces with the underwater tablet via RS232-Bluetooth dongle (Misković, 2015). During interrogation, each underwater tablet is first localized by the surface platform and the position returned to the tablet. This is done sequentially for each underwater tablet. The main drawback is that the update rate decreases proportionally with the number of underwater tablets. On average the interrogation for each node is 1.5 s. Localizing five divers limits the update rate for each diver to once every 8 s. The potential advantage is that all tablet positions are known directly on the ASV and diver tracking is possible. The Short BaseLine (SBL) system is a modification of a classical Long BaseLine (LBL) system to fit on the ASV. The goal of D3.6.1 is to provide modifications to avoid the USBL interrogation strategy. The SBL will broadcast localization signals for underwater tablets. Based on triangulation, each underwater tablet can calculate their own position. The main benefit is that the localization update rate is unaffected by the number of divers, thus enabling scaling to more divers. However, due to calculation sensitivity special attention is required during mechanical design and measurement synchronizations.

The second technical objective is to provide acoustic imaging of pilot sites. Opto-acoustic imaging is required to enable 3D reconstruction and visualization of pilot sites in Knowledge Awareness Centres and underwater tablets. The acoustic part of the imaging procedure provides a baseline point-cloud for the underwater site, with optical imaging providing detail and texture. Therefore, a bathymetry sonar will be acquired and mounted on the ASV to provide autonomous 2.5D acoustic data acquisition and georeferencing.

2. Hardware modifications

Achieving required functionalities involves hardware additions and modifications to the autonomous surface monitoring platform. The core ASV system, described earlier, remains constant but, depending on the application, different mounting elements must be developed.

2.1 USBL and SBL mountings

The SeaTrac USBL device, Figure 2.a, finished development within CADDY (CADDY-FP7, 2016), improving underwater localization and communication between vehicles and the diver. The devices allow flexible acoustic payload transmission and simultaneous localization of a single agent under 2s. The data transmission bandwidth is 100 bps with very low failure rate. Range resolution is +/- 0.1 m and angular resolution is +/- 3 degrees. Underwater localization precision of +/- 1.5 meter was obtained during trials. Within the BLUEMED project, scaling is important, but this is hard to achieve using USBL devices that require individual interrogation. Therefore, the system will be used as benchmark for localization precision were a similar precision is desired by the SBL system described in deliverable D3.6.1. The SBL system will offer a scalable alternative to USBL localization.

(a) (b)

Figure 2. (a) the Seatrac USBL and (b) the SBL transducer as proposed by UNICAL.

The USBL device mounting already exists and will be reused for the assembled BLUEMED monitoring platforms. Four SBL transducers must be mounted beneath the vehicle thrusters while maintaining a required baseline. The proposed mounting, shown in Figure 3, was designed in Solidworks based on the transducer model, and with the assumption that transducer electronics will be embedded in the vehicle hull.

The SBL mount is detachable with a rotational click mechanism and should allow for easier deployment and recovery by divers. Once detached, the SBL cross construction can be positioned on top of the vehicle to minimize the risk of hitting the SBL transducers during recovery. Orientation of the cross relative to thrusters should be investigated for best signal to noise ratio.

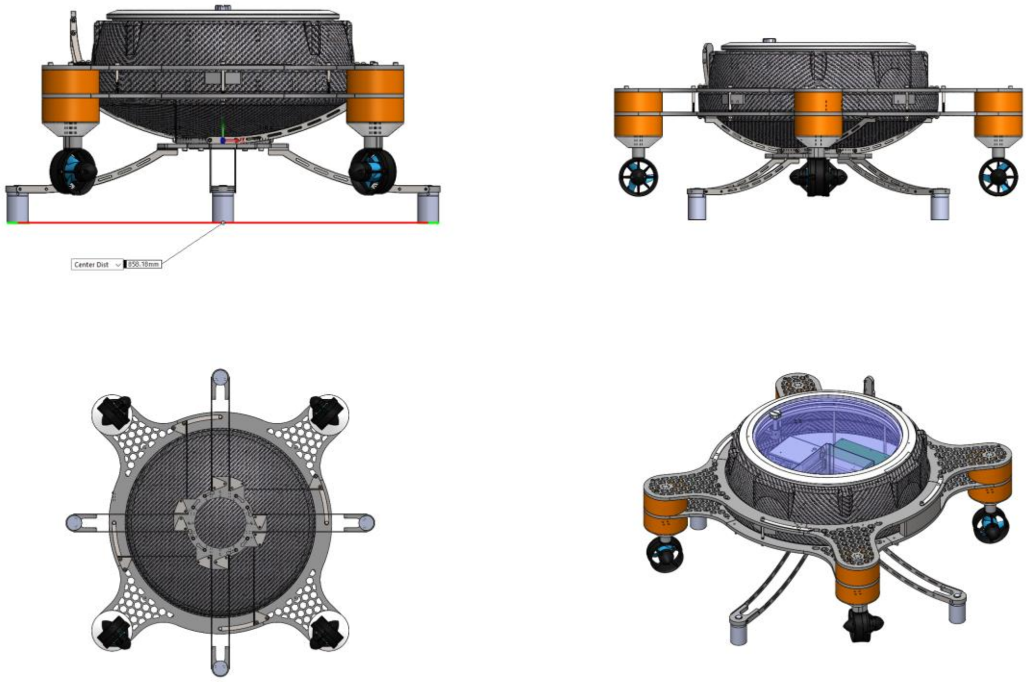


Figure 3. Removable cross carrying the SBL transducers.

2.2 Sonar mounting and ASV modifications

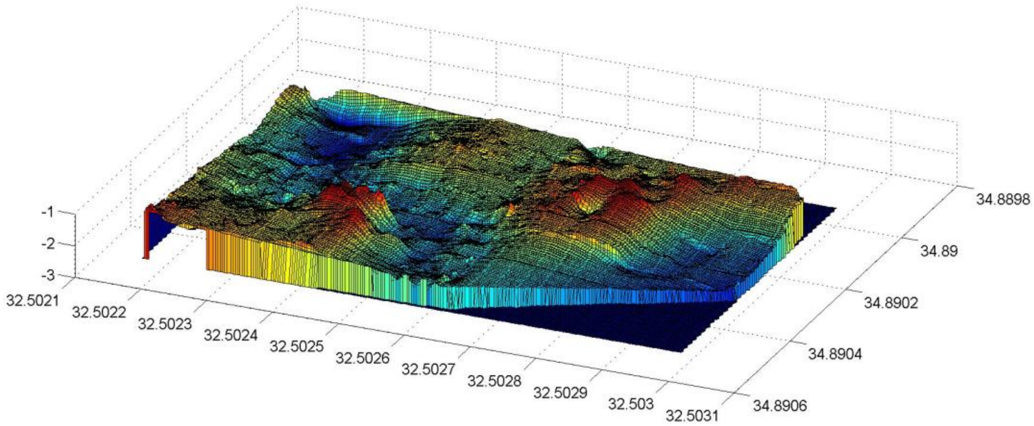
For acoustic bathymetry, sonars must be mounted on the platform rigidly to allow precise compensation of attitude. Bathymetry using two sonars will be investigated in preliminary testing and based on results used for mapping of pilot sites. High-resolution sonar ARIS 3000, Figure 4.a, is designed as an imaging sonar. The large along-track beamwidth can be lowered to 4 degrees using a specialized acoustical lense. Considering the sonar operating range under 15m, the narrowed along track angle is useful for short-range bathymetry. This is applicable on two pilot sites which are at maximum 10 m depth. The proposed sonar mounting is shown in Figure 5. A prototype was already developed and tests with the ARIS 3000 forward looking sonar in a bathymetry formation were performed. The mounting is based on a similar principle to the SBL mounts and allows removal of the sonar before recovery. The mounting provides a classical (vertical) position for the bathymetry sensor but allows selection of arbitrary sonar rotation between 0-90 degrees. This allows acquisition of acoustic imaging data for the shallow sites that can be used for creating acoustic mosaics (Persistent autonomy, 2017).

(a) (b)

Figure 4. (a) the ARIS multibeam sonar and (b) the proposed Norbit multibeam sonar.

Figure 5. Proposed mounting for the ARIS sonar as a backup solution for the proposed Norbit bathzmetry sonar.

The bathymetry results on a shallow archeological site in Caesarea, Israel are shown in Figure 6. The recorded data provides details about the pillar and wall locations in the bay but lacks smaller detail. The georeferencing is achieved using the Emlid Reach RTK sensor. While the data is adequate as a base for optical imaging reconstruction, the small depths of less than 3 m are below expected depths in BLUEMED pilot sites.



(a)

(b)

Figure 6. (a) the 2.5D reconstruction of the seafloor and (b) the georeferenced bathymetry.

To provide improved results on all pilot sites, shallow and deeper, a classical small-scale bathymetry sonar will be purchased and mounted on the platform together with the required INS system. The higher frequency (~700 kHz) sonar should provide along-track angles less than 1 degree for improved accuracy on larger depths. The recommended Norbit sonar, Figure 2.3b, fulfills the requirements and a public procurement is arranged by Q2 2017 wih payment in Q3 2017 upon system delivering and cominssioning. The sonar is integrated with a RTK GNSS-INS to provide high-grade georeferenced images as is required for achieving BLUEMED objectives. The high swath angle of 150 degrees, compared to the ARIS swath of 30 degrees, will allow covering pilot sites more efficiently and potentially including larger areas around the sites.

Due to its shape and design the sonar requires only an adaptor plate to be attached to the mechanism that will be developed for the SBL. However, the larger size and weight require modification of the vehicle floating mechanism. Therefore, additional floats, shown in Figure 7, will be mounted on the vehicle and positioned to convert the vehicle to a small catamaran like vessel. The omnidirectional thruster configuration will be maintained to provide smoother tracking during data acquisition. Since the basis of the diver monitoring platform is maintained, a vehicle developed for diver monitoring can be repurposed for bathymetry within a single day. These vehicle configurations will be used during pilot site mapping and data acquisition, while the standard SBL configuration will be used during experiments with divers.

First tests with the vehicle and Norbit sensor (before potential purchase) are shown in Figure 8. The experiments were carried out with an older version of the Norbit sonar at 400 kHz. The tested sonar was provided by partners from other projects free of charge to evaluate the potential increase in bathymetry quality. The preliminary experiments were carried out in La Ciotat, France during April 2017. The results show a shipyard floor at depths of 8 meters.

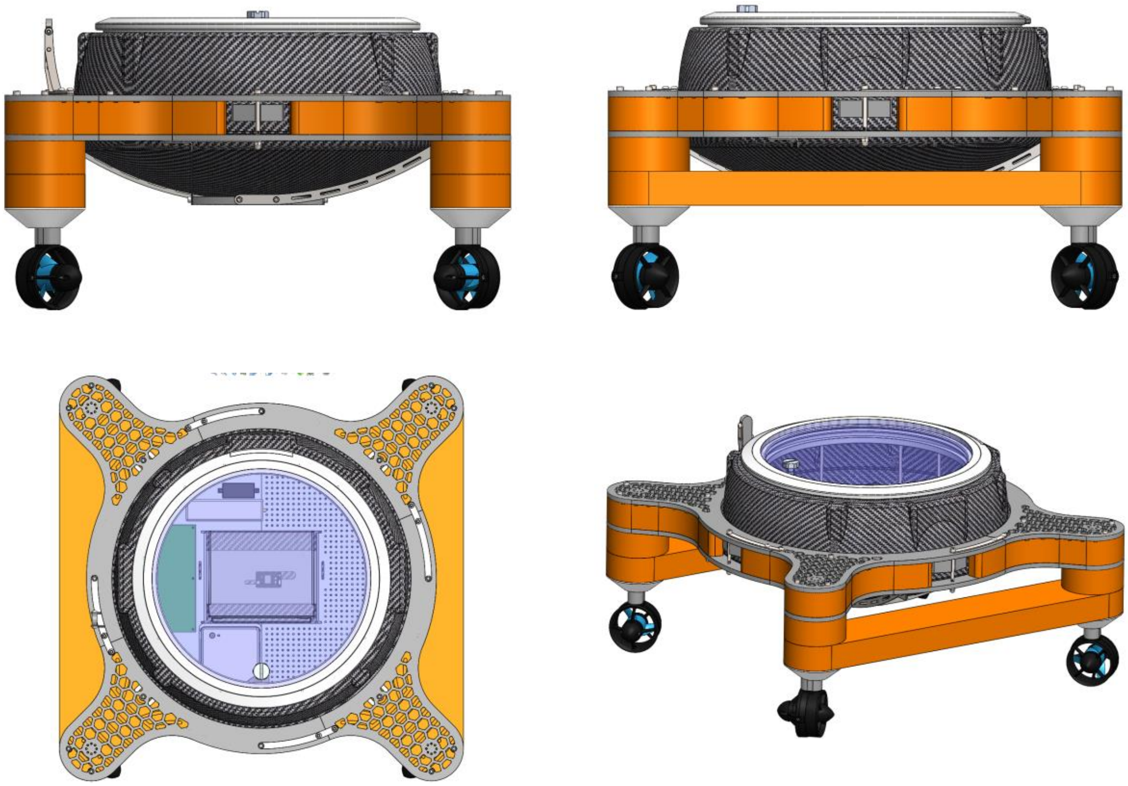
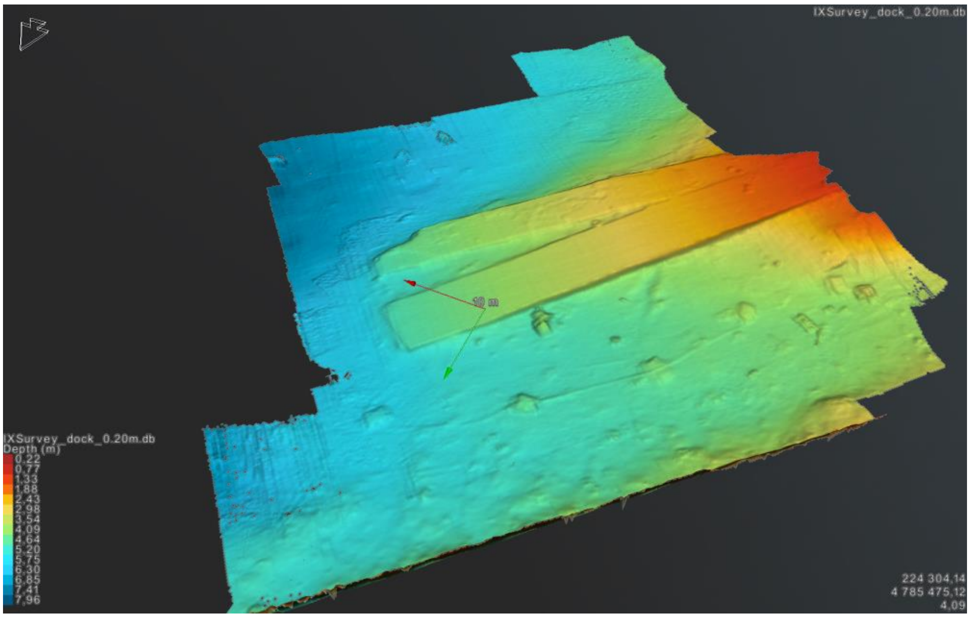


Figure 7. Modifications for the bathymetry sonar mounting.

2.3 Internal mountings for third-party electronics

The surface monitoring platform electronics occupies only half of the available payload space. Therefore, the SBL electronics can be mounted inside the platform reducing overall size and cost of transducers. Minor hardware changes are required for mounting the electronics. Additional wiring is prepared for AHRS, GPS and PPS signal exchange between onboard sensors and the SBL main board.



(a)

(b)

Figure 8. (a) the 2.5D reconstruction of the seaflor and (b) the georeferenced bathymetry.

3. Software modifications

In addition to hardware modifications, software modifications are required to provide interfacing different sensors and allow automated positioning, tracking and bathymetry.

The existing navigation, guidance and control framework will be configured for the surface monitoring platform functionalities (LABUST GitHub, 2017). Sensor drivers for ARIS, Seatrac USBL have been developed. Additional INS sensor driver will be developed as part of final integration. The bathymetry sonar software will operate on a second CPU to avoid additional software modifications and reduce integration time.

3.1 SBL software intergation

Two physical interfaces are available on the main control computer: ethernet and RS232. The recommended connection and inclusion of the SBL computer into the vehicle network is via ethernet. GPS timestamped vehicle attitude and position will be made available over UDP connection. Attitude data, Table 1, contains filtered Euler angles in addition to raw gyro, acceleration and magnetic measurements. GNSS data, Table 2, contains relative local RTK coordinates and standard latitude and longitude coordinates for absolute positioning.

Table 1. Recommended structure of the IMU UDP packet

Element	Type	Units	Description
Seq #	int8	-	Indicates the packet number
Timestamp	double	s	Fractional seconds in GPS time
Gyro	double[3]	deg/s	Raw gyro measurements
Acceleration	double[3]	m/s^2	Raw acceleration
Magnetometer	double[3]	mG	Magnetometer
RPY	double[3]	deg	Filtered roll, pitch and yaw

Table 2. Recommended structure of the GNSS UDP packet.

Element	Type	Units	Description
Seq #	int8	-	Indicates the packet number
Timestamp	double	s	Fractional seconds in GPS time
Latitude	double	deg	Geodetic coordinate
Longitude	double	deg	Geodetic coordinate
Altitude	double	m	Altitude over ellipsoid
North	double	m	Local coordinate in the tangent plane
East	double	m	Local coordinate in the tangent plane

Time synchronization will be achieved using Pulse Per Second (PPS) connection with absolute time provided by the GNSS sensor. The SBL computer should provide a PPS pin and software elements to connect detected pulses with absolute time. Time synchronization accuracy is required since all attitude and position data will be timestamped to allow estimation of SBL transducer positions for accurate diver positioning.

To enable diver tracking the SBL system should send the diver position in absolute or relative coordinates at minimum 0.25 Hz. For applications where tracking is not required slower updates rates are possible. The vehicle will maintain position near diver locations instead of performing direct tracking. The data should be sent through UDP, Table 3, in an ascii or binary format depending on convenience. The payload requires at minimum horizontal North-East positions relative to the vehicle. Diver orientation, depth and similar info, while optional, provides improved estimation of the diver location and future movement. Other optional payloads for improved diver monitoring include diver SMS (6 bit/character) or predefined diver messages (1 bit/message). However, for multiple divers the payload could increase uncontrollably, affecting positioning quality and introducing delay.

Table 3. Recommended structure of the Diver UDP packet.

Element	Type	Units	Description
Seq #	int8	-	Indicates the packet number
Timestamp	double	s	Fractional seconds in UTC time
North	double	m	Diver coordinates relative to USV
East	double	m	Diver coordinates relative to USV
Heading	double	deg	Diver heading estimated by tablet
Depth	double	m	Diver measured depth
Predefined message	int8	-	Number of the predefined message
SMS	char[]	-	Variable character array

4. Conclusion

The report analysed the required modificiation to the autonomous surface vehicle and work, procurement and develpment on most recommended modification is starting in Q2 2017 and will end in Q2 2018 ready for WP4 activities. Initial BLUEMED agreement considered only one autonomous surface vehicle that would move between sites. However, with increased production readiness we estimate that two vehicles can be provided as small-scale investment. One vehicle will also be utilized for bathymetry during data collection and then refurbished back for diver navigaiton aiding. The two vehicles will remain on two pilot sites selected by the BLUEMED committee.

5. References

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