A novel DPV as a holistic platform for real-time physiological status assesment of divers

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EXTENDED ABSTRACT

I. INTRODUCTION

Underwater archaeological sites are inevitably challenging to explore in a limited time by humans. Diving equipment is used by underwater divers to make diving activities possible, more natural, safer and/or more comfortable. The fundamental item of diving equipment used by divers is an underwater breathing apparatus, such as scuba equipment, and surface supplied diving equipment. Still, there are other essential pieces of equipment that make diving safer, more convenient or more efficient. The underwater breathing apparatus and the human physiology limit the time the archaeologists could explore the sunken areas and analyze the points of interest. One emerging technology providing safe and unmanned access to underwater sites for surveying is the ROVs (Remotely Operated Vehicles). Still, for the underwater archaeology and the management of marine protected areas, there is a critical requirement to dive with operators and work underwater with vehicles at the same time. Some diving modalities like professional, scientific, and recreational diving expose divers to greater risks while they cannot benefit of a "buddy system" safety of the conventional recreational diving. International scientific studies report that one of the significant health risks underwater is fatigue. Addressing this need, DiveSafe project, co-funded by the EMFF programme of EU through the EASME and DG MARE call, integrates SoTA technologies, in order to deliver to the diving market (primarily professional/scientific and secondarily recreational) an innovative smart vehicle that will allow divers to safely and efficiently conduct underwater surveys for accomplishing tasks related to visual census, photographic and photogrammetric documentation, exploration of unknown areas, search and recovery, touristic visit of wide underwater sites, etc.

DiveSafe will provide a solution by equipping divers with a novel Diver Propulsion Vehicles (aka DPV, aka "scooter") able to data-gathering to hugely improve both the amount of data collected in a single mission and the management of time and human resources at disposal. The DVP will be equipped with an Android tablet, a docking station like the one developed in the Lab4Dive project [3] and a capability to communicate with surface and with a safety wearable sensor network equipped into the diver's suit. The professional diver could use an underwater tablet equipped with environmental sensors, like high-resolution cameras and an acoustic localization system, where a dedicated data gathering system is accessible through its application, communicates with the surface and monitors its physiological status.

The overall system is represented in Figure 1 where the DPV apparatus and the diver wearable system has been depicted. The paper describes the design and validation of the wearable sensors to real-time monitor the diver's medical status.

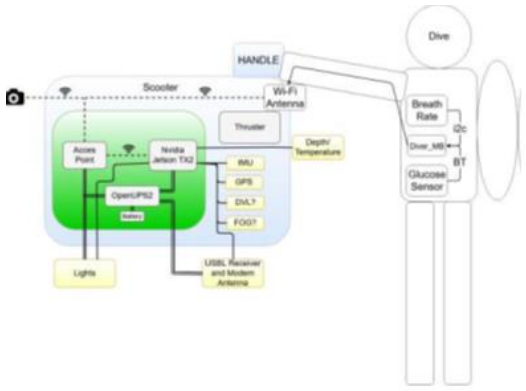

Figure 1. Underwater architecture.

II. SPECS FOR THE "SENSORIAL INFRASTRUCTURE"

The scuba diver has been equipped with a mainboard able to collect data from the wearable sensors and communicate with the scooter mainboard. The wearable sensors developed and tested are:

- glycemia sensor, able to communicate through Bluetooth or radiofrequency over the suit;
- sensor for breathing/heartbeat that warns of regulator malfunctioning, able to communicate through I2C or UART.

A. Wearable Sensor for Breathing Monitor

Breathing is the key health parameter for a diver. It is previously demonstrated that monitoring the breathing rate of the divers is possible by measuring the intermediate pressure of 1st stage regulator. Every time diver inhales from the 2nd stage, the intermediate pressure of 1st stage regulator drops and by this way breathing of diver can be monitored. This is a dual pressure sensor (one for ambient pressure, the other for intermediate pressure of 1st stage) system is placed between on BC inflator hose of and send data to DPV. Monitoring the breathing rate also enables heart rate estimation.

The requirements of the developed breathing monitor module are given below:

- External housing depth rating 100 m
- Dual pressure sensor (absolute, 0-25 Bar)
- Wireless/wired data transfer to tablet
- Rechargeable power supply

Pressure data processing has been embedded on the DPV's docking station side and will has been performed using the proprietary algorithm developed. The system is able to provide warnings for leading indicators of degraded respiratory conditions such as:

- No breathing for 30 seconds
- Breathing rate faster than 30 /min for more than 30 seconds
- Intermediate pressure too low or too high.

B. Glucose sensor

In order to take care of the glucose parameter, a glucose monitor has been designed starting from G4 Plantinum glucose sensor (Dexcom Inc., San Diego, CA, USA). The sensor has been completed with an electronics board that serving as a transmitter, based on the open-source RF transmitter/receiver board.

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