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# Floating sensor platform for the monitoring of water quality in urban and white-water environments

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*Abstract* — **In the present paper the project of an embedded solution for the realization of a floating sensor platform for the monitoring of the water and ambient quality in a flowing water environment is described. First results regarding the monitoring of the water conductivity and the ambient noise level under harsh environmental conditions in a karstic river and in the final part of a river going towards the Mediterranean Sea are presented. It is further discussed how this kind of system can be modified in order to serve as urban waterway multisensory platform, adding important features like connectivity, energy harvesting and determination of the platform position.**

**Keywords: water quality, ambient noise, remote sensing, water conductivity, embedded sensor, smart city.**

## I. INTRODUCTION

One of the most important constituents of smart city networks are autonomous sensing solutions. A great variety of nowadays developed sensors are dealing with road traffic and air pollution control. However, another important city ambient, that needs to be monitored, are the urban and suburban water ways and the recreation areas with lakes and rivers. Water quality is one of the most important parameters, that influences the wellness of the urban population. Some first solutions of continuous pollution monitoring based on the use of buoys [1] and also the application of a smart phone for water monitoring [2] have been reported. The realization of an autonomous multisensory buoy with a wide range of sensor functions, including salinity, sea water temperature and turbidity has been reported in literature, however in this case the sensor platform had no space restrictions [3]. This was also the case for an aerial wireless coastal buoy [4]. Here we will show first results of a small, simple and mechanical very stable sensor platform for the monitoring of important water and ambient properties during floating operation on a river and then discuss the needed future developments in order to achieve autonomous operation and connectivity of the sensor platform.

## II. SENSOR PLATFORM REALIZATION

### A. Embedded sensor platform

The described sensor platform has been originally developed for a non-urban application. The initially planned and realized application was the monitoring of a small white-water river in karstic environment with long underground passages without possibility of wireless contact to the sensor platform. One of the main focuses during the development was therefore a very stable mechanical design, which can even survive passages in wild water and over high water-falls.

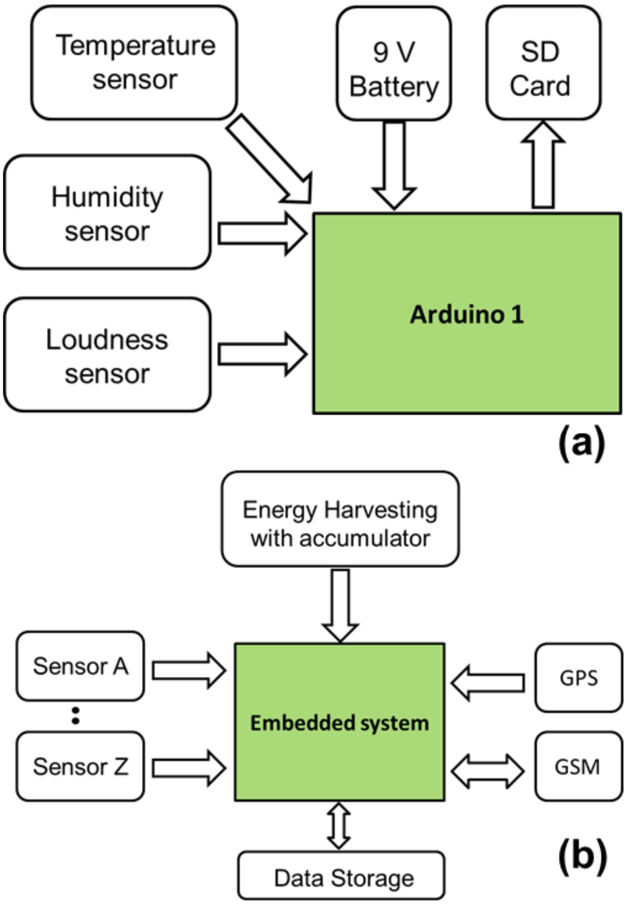

Fig. 1. Block-diagram of the electronic circuits of the a) actually developed and b) of the future design of the floating water sensor platform

The electronics of this first version of the embedded sensing platform is schematically shown in Fig. 1a. The core element is an Arduino1 embedded system with multiple analog inputs and a connected SD card unit for long-term data storage. Arduino based sensor solutions are popular due to the easy to learn programming language. For example, an indoor environmental quality sensing system has been developed, that was based on an Arduino embedded system with VOLTRON software for data handling and analysis [5].

In this first sensor platform version three sensing elements have been used. The measured entities are water temperature, ambient acoustic sound level and water conductivity. The power supply by a simple 9V block battery was sufficient for some hours of data taking.

Regarding the first two sensors, commercial sensor solutions have been used. The water temperature has been measured using a MCP 9701 bandgap reference type electrical temperature sensor glued into the lower part of the plastic case of the sensor and for the ambient acoustic noise measurements, a loudness sensor type “SEED Studio Grove Sound Sensor” has been used. This type of sensor had been added in order to distinguish calm water and turbulent water – including waterfalls and cataracts – during the floating of the sensor platform in the investigated mountain river. In an urban environment the determination of the noise level in recreational area waters could also be of potential interest.

The last type of sensor, a water conductivity sensor, however, has been our own development and will be described more in detail.

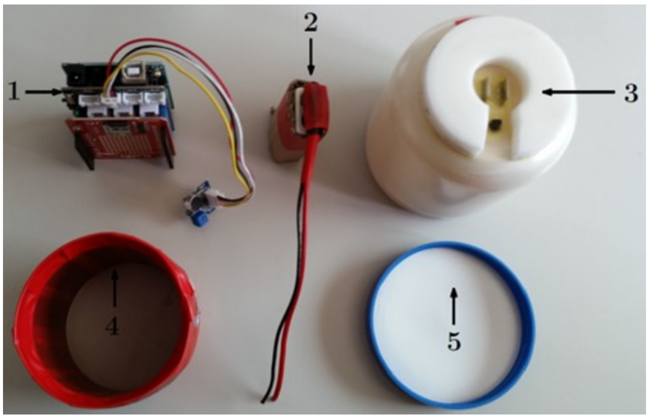

Fig. 2. Main parts of the realized floating water sensor platform, as are:

1. Arduino UNO with sensor shield, SD card unit and attached loudness sensor
2. 9V Block battery
3. Bottom part of the sensor shielding with conductivity sensing electrodes, temperature sensor and protective plastic shielding
4. Metallic ring as weight for ensuring floating operation
5. Upper closure of the sensor shielding

An exploit of the sensor components is shown in Fig. 2, the main electronic board, with the Arduino1, the SD card unit and the sensor connection shield is put within a plastic case with the temperature and the water conductivity sensor integrated into the bottom part of the plastic case. Both sensors are protected by an additional plastic ring in order to withstand even hard falling on rocks within a typical white-water river environment. The efficient floating in the river and the maintaining of an upright position within the water has been obtained by adding a cylindrical metallic ring into the plastic case with a specific weight. After connecting the 9V block battery to the electronics, the case is closed by screwing the top closure tight and the measurements start.

Because in the case of the white water river with under-earth passages no radio-frequency connection has been possible, this first version of the sensor platform has been realized just with a local data storage on a SD card. In this case for the data recovery, the platform has to be physically recovered and opened after the measurement campaign.

In Fig.1b the block diagram of a possible future evolution of the floating type sensor platform is indicated. In addition to the various ambient sensors (e.g. pH-sensor, water $CO_2$ concentration sensor, optical turbidity sensor) a GPS system allows for the determination of the sensor position during data taking and the GPS-unit allows to send the data, which is eventually also locally stored on the platform, in real time for direct feedback. This future version of the platform could also be made completely autonomous by adding an energy harvesting option with electrical energy storage in a rechargeable battery or a supercapacitor. For this option, however, it would be needed to utilize an embedded system with far less power consumption than the Arduino type.

### *B. Conductivity sensor*

Water conductivity is an important parameter, which has to be monitored (see for example [6].) Regarding the conductivity sensor, developed by two of the authors, a more detailed description regarding the geometry, measurement principle and calibration procedure will be given. A variety of techniques have been proposed for water conductivity measurements. For example, a capacitive technique has been reported [7] also optical spectroscopy techniques are often proposed [8].

Due to the geometrical constraints of the small sensor platform dimensions these measurement techniques could not been used in our case and we decided to use conventional metallic contact based measurements. A drawback of this techniques is of course the poor long-term stability due to electrochemical modifications of the used electrodes. In order to minimize these problems, a pulsed voltage signal, generated with the Arduino (shown in Fig. 3b) with a pulse length of only 12 ms and a repetition rate of 1 Hz has been applied to the electrodes, which together with a series calibration resistor forms a voltage divider. The voltage, measured over the measurement electrodes, is then fed into one of the analog input channels of the Arduino with a maximum input voltage amplitude of 5 V.

The sensor has been calibrated using a commercial type “HANNA HI 99300 EC/TDS” conductivity meter as reference instrument and adding successively small amounts of salt to the distilled water (the measurement setup is shown in Fig. 3c). The sensor calibration curve is shown in Fig.3a and it can be seen, that with the chosen resistance value for the series resistor, a large range of conductivity values can be monitored with a good sensitivity in the expected typical conductivity range of river water.

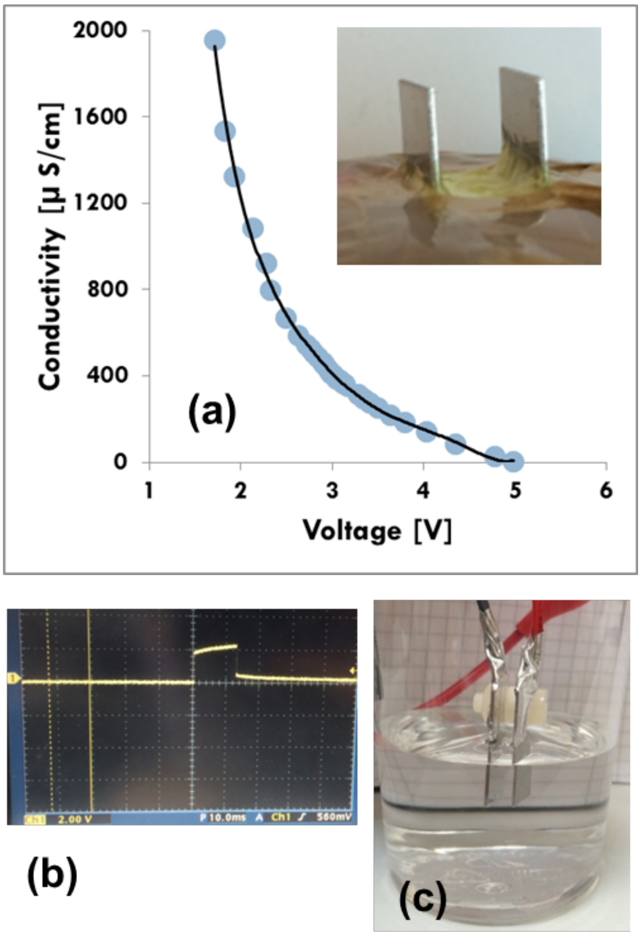

Fig. 3. Conductivity sensing configuration with a) calibration curve (inset: photo of the sensor electrodes), b) the electrical measurement pulse and c) a photo of the experimental setup for the calibration procedure

## *III. Experimental monitoring results*

### *A. Water conductivity monitoring during the floating on the river Irno*

Even if the sensing platform originally has been developed for the characterization of a white-water river in a karstic environment in the Cilento region south of Salerno, we started testing it in the urban environment of Salerno. In particular, we let it float in the last 300 m of the Irno river, ending in the salty Tyrrhenian sea.

Some months before this monitoring test, Salerno University students under guidance of Prof. D. Guida measured the water conductivity at different points on the beach, very close to the final part of the Irno river with a commercial water conductivity meter. In Fig. 4a in the map of the fraction of Salerno, where the Irno is meeting the Tyrrhenian sea is shown.

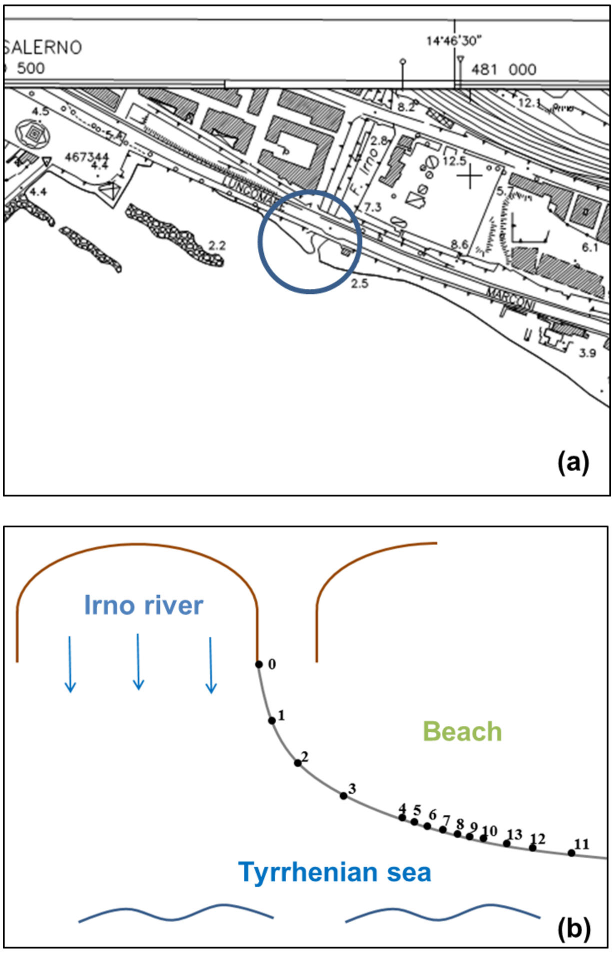

Fig. 4.a) Map of the investigated region with the Irno river (indicated by the blue circle) going to the Tyrrhenian sea near Salerno harbor and b) sketch of the Irno near seaside area with indicated measurement points on the beach.

TABLE I
WATER CONDUCTIVITY VALUES
AT THE INDICATED POSITIONS IN FIG.4

| Point | Conductivity (µS/cm) |
|---|---|
| 0 | 665 |
| 1 | 669 |
| 2 | 670 |
| 3 | 674 |
| 4 | 677 |
| 5 | 700 |
| 6 | 715 |
| 7 | 725 |
| 8 | 715 |
| 9 | 695 |
| 10 | 715 |
| 11 | 42000 |

| | |
|---|---|
| 12 | 42000 |
| 13 | 695 |

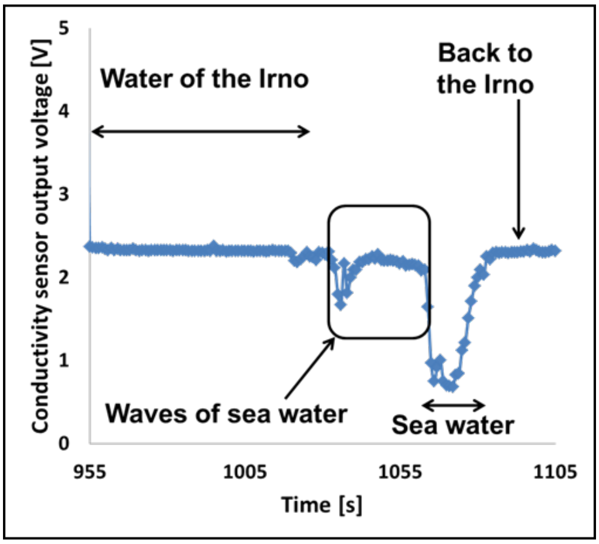

Fig. 5. Conductivity sensor output voltage monitoring during the floating of the sensor platform for the last 300m towards the open sea.

In Fig.4b a schematic drawing of the river and the nearby shoreline is given, where the numbers are indicating the measurement positions, where the students measured the electrical conductivity values, listed in Table 1. We see that rather constant values are measured up to point 10 and only the following 2 measurements show conductivity values typical for the salt concentration as present in the Tyrrhenian sea.

The monitoring results of the conductivity sensor output voltage during the floating of the sensor platform for the last some meters before entering the open sea are demonstrated in Fig.5. It should be reminded, that high output voltages correspond to low electrical conductivity values (see the above shown calibration). It should be mentioned that only some few erroneous data points have been removed for clarity, but that no filtering procedure has been applied to the data.

It can be observed that in the beginning a very smooth trace is observed with a conductivity sensor output voltage value of about 2.33 V. The corresponding electrical conductivity value, obtained by using the calibration curve, shown in Fig.3, agrees very well with the values measured by the students before (see Table 1) in the river near measurement positions. Successively we see a slightly noisier signal with varying conductivity due to the arrival of sea water waves in the river ending and the beginning of mixing of river and sea water. And finally the sensor output voltage drops to much lower values of about 0.65. This is out of the range of the prior done calibration of the conductivity sensor and the salinity most probably reaches values near the sensor close to the open sea values. The sensor platform had been afterwards with the help of an attached cord again teared back inside the Irno river. The sensor signal increases again exactly to the value as in the beginning of the shown monitoring trace. This is an indication for the good reproducibility of the sensor data and for the absence of short term sensor characteristics drift.

### *G. Monitoring of the ambient noise level during the sensor floating in a white-water mountain river*

As another example of successful data taking during sensor platform floating, in Fig.6 the monitoring of the loudness sensor output voltage, which is proportional to the measured sound amplitude, is shown.

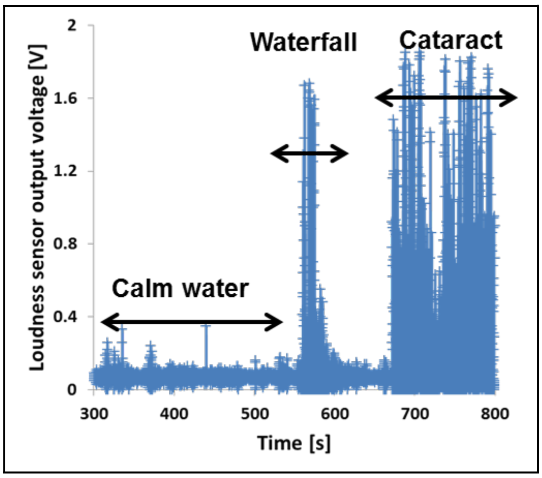

Fig. 6. Loudness sensor output voltage monitoring during the floating of the sensor platform on the Bussento river in the Cileto mountains.

In this case the sensor has been tested under extreme conditions in the Bussento river in the Cilento region south of Salerno. The monitored part of the river was characterized by cataracts and water falls, which presence is clearly evidenced in the monitoring trace seen in Fig.6.

## III. CONCLUSIONS

A compact and robust floating measurement platform for the monitoring of water and ambient parameters has been realized using an Arduino embedded system for the data taking and storage. A water electrical conductivity sensor has been developed, calibrated and tested successfully for the characterization of a river estuary, showing clearly the mixing process of sweet and salt water when the measurement platform was entering the Mediterranean Sea. The results have been compared to measurements done with a commercial water conductivity meter in a separate measurement campaign.

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