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SCADA FOR UNDERWATER VEHICLES

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Abstract: *Many of the underwater missions require highly trained specialists and involve an assumption of dangers that can be appeared during the missions. This is one of the main reasons because many of the research centers across the world try to develop certain robots for a specific missions or robots that can be equipped for certain needs/modular robots. Our goal is to build a robot that can perform a variety of tasks from 3D cartography to evaluate the temperature of the environment, photo and video data acquisitions. Also another goal is to design an easy to program and add another facilities or hardware equipments.*

Key words: *AUV, Autonomous underwater vehicle, robot design, ROV, remote operate vehicle, robotics, Mobile SCADA; Android; Web Api.*

1. INTRODUCTION

The hull of the robot has five thrusters M1, M2, M3, M4 and M5 that create a high maneuverability of the robot (Figure 1.).
In three dimensions, the six DOF-s of a rigid body are sometimes described using these nautical names:
1. Moving up and down (*heaving*);
2. Moving left and right (*swaying*);
3. Moving forward and backward (*surging*);
4. Tilting forward and backward (*pitching*);
5. Turning left and right (*yawing*);
6. Tilting side to side (*rolling*)

The robot has only 5 degrees of freedom: heaving, surging, pitching, yawing and rolling.

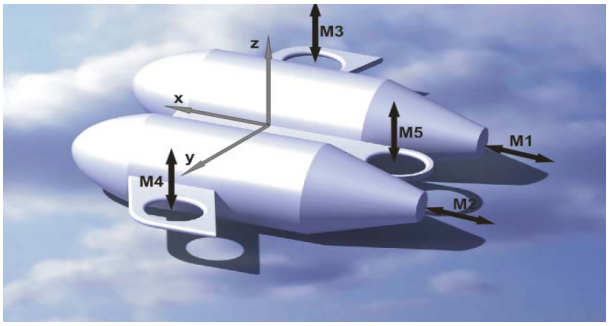

Fig. 1. Hull of the robot with the five thrusters (M1, M2, M3, M4, M5)

The *heaving* is provided by the M3, M4 and M5 started simultaneously with the same direction of rotation, the *swaying* is suppressed, *surging* is provided by motors M1 and M2 with the opposite direction of rotation because the thrusters has opposite blades to provide more stability for moving forward or backward, also by the same direction of the motors M1 and M2 we provide the *yawing* motion; the *roll* of the robot is provided by the thrusters M3 and M4 started in opposite direction of rotation; *pitching* is provided by the motors M3 and M4 in a direction and M5 in opposite direction of rotation.

The two torpedo profile offer a better stability for the robot, also provide a space between the two profile for other equipments that can be easily attached due the flat zone between. The robot has neutral buy on dance.

2. ELECTRICAL EQUIPMENT

The electrical equipment is designed for a large adaptability of the vehicle, with a large possibility to add and control future equipment.

1) Controllers:

The two mbed microcontrollers has an ARM Cortex-M3 Core with a frequency of 96MHz, 32KB of RAM and a flash of 512 KB and a lots of extension for quickly implement other functions on Ethernet, USB Host and Device, CAN, SPI, I2C, ADC, DAC, PWM and other I/O interfaces. [1]

One of the microcontrollers is designed to provide the processing needs for the onboard sensor and the other one to control the five thrusters. It is logically to be distributed like this because the sonar or other sensor did not use continuously oppositely the thrusters is used to maintain the position.

Also the two microcontrollers are connected through an USB cable to the embedded pc that provide the general interface to the human operator from the surface, save data and compute trajectories for autonomous missions, process images from the camera.

Due the high inertial forces in water, there is no needs for real time OS.

The embedded pc has the possibility to install on it Linux or windows based operational systems. Also it has a lot of capability to use plug and play devices for robot. It is communicate to surface with a LAN cable in remote operated missions providing to the operator from the surface a quick and secure data transmission.

2) Sensors

Depth sensor: connected trough analog input of the *mbed* provides the depth of diving for the system trough pressure data acquisition. The model of the depth sensor is an ASDX series sensor.

Temperature sensor is a P48 from Markus automatic connected also to analog input from the *mbed* board provide the inside of the hull temperature. This is needed because in case of a higher temperature that the presented maximum value denotes a problem with equipment or battery, and the robot enter into the warning of error state.

Due the risk of water intrusion, a simple analog water intrusion sensor is connected to the Analog input of the mbed microcontroller to shutdown the equipment in case of hull breach and surface with a emergency system.

3D Gyroscope Module provides the yaw, pitch and roll angles for the robot. The module is INVENSENSE - ITG-3200 – IC, supply voltage range: 2.1V to 3.6V, operating temperature range: -40°C to +85°C. [2]

The battery meter provide to the user in remote operated missions the remaining battery, also trough the connector (SubConn® Combined Power Ethernet Cable [3]) with is equipped the robot is there the possibility to supply with external power. This monitor provide in autonomic mode to the system the capacity to monitor the remaining power and surface or end the missions if the battery is lower than 20% of the charge.

Logitech HD Pro Webcam C910 provide an enough resolution (1920 x 1080) for almost all missions, and the images can stored local or at the surface control unit for future processing's.

The 3D accelerometer provide the information for the accelerations, data that help to adjust the navigation and verify the 3D gyroscope provided data for better accuracy of navigation.

The Digital Compass Sensor magnetically indicates the four Cardinal (N. E, S. W) directions, and the four intermediate (NE, NW, SE, SW) directions.

The Compass Sensor is compatible with the C StampTM microcomputer's supplies and signal levels. Acquiring a direction from the sensor is made easy with A-WIT's supplied software command COMPASSIN. This simple one command interface is all that is required to interrogate the Compass. [4]

Humminbird® 778c HD provides the sonar functions. The choice for this model was determined by the needs for plug and play connections for most of the components. This module is capable Dual Beam PLUS™ with selectable 20° and 60° dual beams, 200 kHz / 20° @ -10db 83 kHz / 60° @ -10db, depth: 1500 ft. includes water temperature readout. It can output navigations data collected trough Humminbird® PC Connection Cable. [5]

The five encoders from motors provide the direction and the number of RPM for the navigation system of robot.

ASDXyyyG2 pressure sensor provide the pressure and the system can know the depth of navigation for underwater robot. Also an alarm signal is set for the remote operated mode to warn the user for approach the maximum depth

and block the surge if the sensor detects the maximum operating depth was reached. [6]

The GPS sensor in autonomous mode provide when the robot surface, a correction for the trajectory. GlobalSat EM 406 GPS module offers the enough precision for the mission requirements.

3. THE MISSIONS INTEDED TO BE IMPLEMENTED IN AUTONOMOUS MODE

The main two mode of the robot will be:

1. The remote operated mode – the human operator control the robot with a joystick from the surface, the robot communication will be trough the network cable.
2. The autonomous mode: in this mode a few missions will be available for robot:
   a) *Cartography mode – this missions input are the shape of the lake and the system will make the 3D map trough the sonar system.*
   b) *Photo/video data acquisition mode: the operator will introduce trough a simple interface the direction for the robot and the distance and the robot will record with web camera the trajectory.*
   c) *Cable following mode – this mode detects the color of the cable (yellow) and follow it to the end.*

4. SYSTEM ARHITECTURE

The SCADA system architecture is described in figure 4. The two mbed has a separate role for motor and sensor data acquisition because of the possible interferences and to increase the possibility of future development by provide more than enough processing power. Also to avoid interferences and insufficient power delivery the system has separate battery one for the sensors and another for the thrusters

The sensors send navigation data to one of mbed, and the mbed locally process data for a human readable format (pressure signal will be transformed in cm of depth, compass signal will be provided by mbed in degrees on each axis, temperature will be provided in Celsius degrees, the accelerometer provide accelerations on each axes in Newton, etc). This data will be sent to the embedded pc. The embedded pc based on this data control the five thruster of robot trough the dedicated mbed2 receiving the feedback from encoders of thrusters trough mbed1.

Due the flexibility of change the embedded pc has USB connection with sonar unit and the camera. This approach provides a quick add or replace possibility for the equipments and different approach for data processing on embedded pc. The local storage unit attached to the embedded pc can be upgraded for a larger amount of storage or lower power consumption solutions than, the actually, s-ata storage drive is. Due the multiple operating system supported by the embedded pc it has a lot of possibility for future new functionality and developments.

The possibility to transmit online data trough the surface command unit need an optimized data management. For this approach we work also to implement a SCADA system to optimize collected data and to reduce the bandwidth needed for transmission of data.

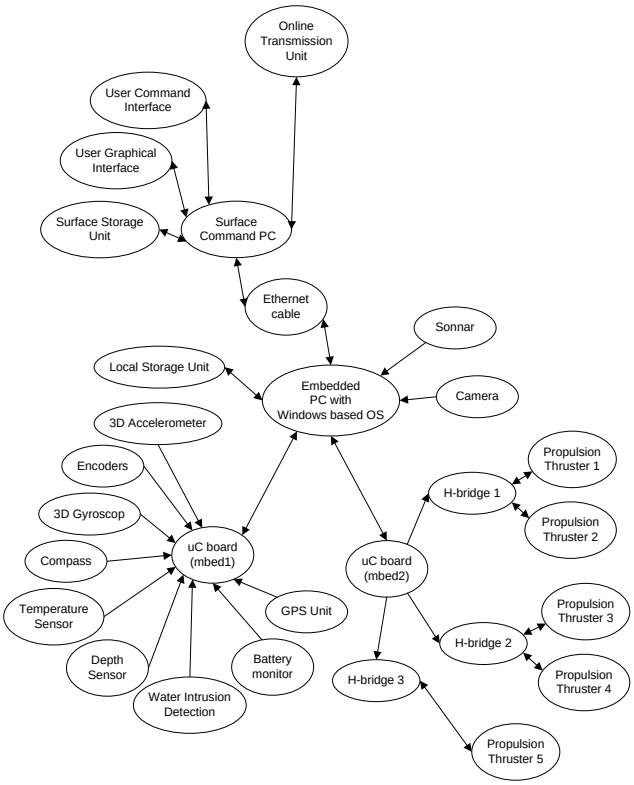

Fig. 2. SCADA architecture for AUV/ROV

5. MOBILE SCADA IN ANDROID

The submersible through its micro-controller and its sensing mechanisms it's a continuous source of information. The functional information is represented by the specific objective monitoring data and by the navigation data through which can be determined real-time the optimum working parameters for the underwater instrument. The inappropriate use of a submersible in the context in which the robot it's in a permanent contact with the water could generate an irreversible alteration of its main components.

The 8 bits ARM Cortex-M3 processor with its programmable Flash memory permits the storage and management of data. To optimize the underwater robot the data kept and handled on the machine should be kept to a minimum and instead should be used a controller computer to which the measurements and synchronization data are sent.

For a permanent acquisition and an accurate control, a relatively inexpensive and versatile Mobile SCADA system based on Android could be used.

SCADA is used to describe a system where both data acquisition and supervisory control are performed, Mobile Supervisory Control and Data Acquisition (referred to as Mobile SCADA) is the use of SCADA with the mobile phone network being used as the underlying communication medium [7], [8].

A. Mobile SCADA's Data Control in Android

When using the Android OS as an underlying tool the data control capability of a SCADA system has a wide variety of options, first of all the data collected by the submersibles sensors could only be further analyzed and stored on the device but for our modern society where connectivity is the key issue this may seem insufficient and also an under-use of the Android's abilities. To transport data to the extraneous world the Android SDK provides a diversity of options:

-*Broadcast Hub* for SMS (Short Message Service) processing by using the Broadcast Receiver class – the main advantage for using such a system for data spreading is that the only device that needs to have the Android platform installed is the sender device, the receivers could use any kind of smart or not smart phones.

-*NXT Remote Control* by making use of the Bluetooth capability – the application can be transformed into a remote control for other intelligent robots.

-*Web APIs* – a development in Web services which are methods of communication between two electronic devices over the web, the emphasis has been transiting from simple access based protocol (SOAP) based services towards representational state transfer (REST) based communications because they do not require XML, SOAP, or WSDL service-API definitions. Web API is typically a defined set of Hypertext Transfer Protocol (HTTP) request messages along with the response message structure definition which is more often expressed in an Extensible Markup Language (XML) or JavaScript Object Notation (JSON) format. Android provides through the java.net.HttlURLConnection package a powerful set of Java-standard network APIs that can be easily called in an asynchronous mode using the java.util.concurrent package thus providing the possibility to perform adjacent tasks while possibly a time consuming service communication is conducted. Web APIs can be used for bidirectional communication, data can also be acquired not only sent making it a very powerful data acquisition tool.

B. Mobile SCADA's Data Storage in Android

Data persistence is a key item not only to SCADA systems, underwater robots but also to most of the real world applications, an Android application can store data using different techniques depending on the data size, lifetime, structure and its share level. For storing small stand-alone bits of information that go with the program the preferences API can be used, the instance state data living in a Bundle class on Android's application stack.

For storing more than just a few bits on the device, as an alternative can be used the Internal File System. Because Android runs Linux under the cover as a result it has a real file system mounted, all of the usual Java methods from the java.io package are available with the disadvantage that the application process has limited permissions and this is due to Android's strict security that prevents an application to disrupt another. Because the internal memory is limited the amount of data to be stored this way is also limited, the general recommendation is to be kept around one or two megabytes with careful control on the I/O errors to avoid running out of space.

When there is a need to store a larger amount of data the solution could be SD (Secure Digital) cards which are flash memory devices plugged in a slot of the mobile phone. They can store multi-megabytes of data with the downfall that every application can have access to this section.

The information that can be stored using the techniques mentioned above is small or one type (picture or audio file), when more complex and structured information needs to be stored a relational database is needed. Luckily Android has embedded SQLLite which is tiny yet powerful database engine and probably one of the most widely deployed engines on the market (can be found in the Apple iPhone, Symbian phones, Mozilla Firefox, Skype, PHP, Solaris and many others) due to the following reasons: it is free; it is small, just one file of around 150KB that can be taken moved around or even copied to another system without causing any errors; requires no setup or administration because there is no server, no configuration file and no need for database administration.

6. SECURITY IN AN ADROID BASED SCADA SYSTEM

In such a system two points essentially present vulnerabilities and they are the data storage and the data transmission. The data storage security is partially taken care of Android that as a platform in an effort to sever one from another it's application uses a resource stamping mechanism which means that each application running in the system is provided with an unique application id identifier and it's dependencies have this id assigned to them so that an application can only access its own belonging elements. When SQLLite is used the data security is essentially manipulated by this server but as an additional precaution the stored data could be encrypted using mechanisms and keys unique to the application so that if the database would fall in wrong hands data retrieval would be a difficult task.

Data transmission is sensitive only when web apis are used, to ensure a higher level of security several methods could be applied. First of all the problem of consuming third party services that may seem insufficiently secured could be solved by creating and publishing an additional service that use the public ones and add security. To ensure WS-Security (web service security), when consuming services the messages used in the communication can be signed which also ensure non-repudiation, encrypted or have attached a security token to ascertain the sender's identity. There is a variety of signature formats, encryption algorithms and multiple trust domains open to various securities token models, such as: X.509 certificates, Kerberos tickets, user ID/Password credentials, SAML Assertions and custom-defined tokens. Key management; trust bootstrapping, federation and agreement on the technical details (ciphers, formats, and algorithms) are essential items that ensure that the message protection system is secure. Some commonly used methods to ensure security are:

- *Transport Layer Security - a communication is done between trusted peers (using HTTPS) reducing complexity and improving performance.*
- *End-to-end security – when a less or not trusted SOAP intermediary is required, the messages are signed and optionally encrypted.*
- *Non-Repudiation – transactions are usually written to an audit trail that is subject to specific security safeguards with optionally added digital signatures.*
- *Alternative transport bindings - SOAP services usually implement HTTP bindings but other bindings such as JMS or SMTP*

are also be used in combination with requiring end-to-end security.

- *Reverse proxy/common security token - Even when https is used it might be required for the service to know about the end user if it is relayed by a reverse proxy. WSS header is used to convey the end user's token, vouched for by the reverse proxy.*

7. CONCLUSION

When utilized in combination with the Android OS, the Mobile SCADA systems on a submersible opens the system to a set of opportunities like never before: the submersible can be used as a data collector of sensor readings and the Android system can then be utilized as a storage device and most importantly as a communication device through methods like the very popular SMSs or WEB APIs for bidirectional data exchange.

The Android Mobile SCADA creates bridges of communication between the industrial world and the real world making a possibility the ability of industrial processes to be automatically adjusted based on information gathered from outside sources, for example artificial intelligence combined with android mobile SCADA could be used for production management automating even more the activity in the factories.

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Vehicule submersibile de tip SCADA

Rezumat: Multe dintre misiunile submersibilelor necesita specialisti de inalta pregatirre si mplica punerea in pericol a vietii celor implicati. Aceasta este una dintre principalele motive pentru a inlatura operatorul unul din mediile periculoase si de a implica roboti special cotruiti petru aceste misiuni. Acesti roboti pot fi echipati pentru a cartografia 3D bazinele de acumulare, preluare de imagini videa, evaluarea parametrilor fizico-chimici, etc. Deasemenea un important rol il joaca si desigul fiabil capabil de a fi dezvoltat ulterior.

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