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DESIGN, CONTROL AND APPLICATIONS OF THE UNDERWATER ROBOT IS FAR

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Research Article

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Abstract:
The underwater robot Isfar, which falls within the mini ROV and AUV vehicle classifications, is designed and described in this study. Together with the classification of the Isfar into certain classes of underwater vehicles, the mechanical construction, control system architecture, and the most important applications of such a vehicle are discussed.
choices on their own. The definition of a new class of underwater vehicles, known as AUVs (Autonomous Underwater Vehicles), is the outcome of these recent advancements. AUVs are designed to gather information from the sensory system—like captured pictures and certain measurements—without the operator's assistance. In order to combine the tether less, autonomous operation of AUVs with the mane uverability and wide range of uses of mini ROVs, this study introduces the robot Isfar, which is a member of the mini ROV class and has the capacity to change into the AUV class. 'Isfar' means 'yellow' in Maltese.

1. Introduction

In 1889, the first UUV (Unmanned Underwater Vehicle), built by Serbian engineer and inventor Nikola Tesla, was shown at the annual Electrical Engineering Exhibition [10], [11]. The introduction of the CURV (Cable-controlled Underwater Research Vehicle) and TONGS (Television Observed Nautical Grappling System) in the late 1950s, however, marked the beginning of the fast development of such vehicles [12]. Such boats' primary objective was to operate at depths that were inaccessible to divers. Vehicles that could explore marine depths of several thousand meters were becoming more and more popular. In addition to exploring great depths, modern engineers also prioritize environmental surveillance and providing divers with safety while doing their jobs. The significance of small undersea units has increased. They are designed by scientists and engineers to be operated manually in littoral zones and shallow seas [9].

The ability to build more robotized vehicles was made possible by the commercialization of specialized, inexpensive, mechanical, and electrical components. Because of the application of intelligent sensory and control systems that can detect underwater objects, avoid obstacles, indicate collisions, or send information about the actual location and orientation of the vehicle, it is now possible to build miniROV (mini Remotely Operated Vehicle) vehicles that can either replace or help the diver in monitoring and searching missions. The software that is loaded on the teleoperator's console is used to manually control them. The teleoperator's primary concentration is on getting to the desired location and analyzing the photos that the onboard vision system transfers. Automation technological advancements allowed for the replacement of the operator with machine intelligence that might make

2. Overview of existing UUV solutions

These listed below are among the most sophisticated of the several UUV systems now in use. It is important to note that these classes differ not only in their control systems and sensory equipment but also in their mechanical designs. For example, ROV class vehicles have a "crate-style" design (see Fig. 1), while AUVs are streamlined and "torpedo-shaped," sporting wings but fewer motors (see Fig. 2). As a result, various classes have different levels of maneuverability.

2.1. ROV/ mini ROV class

Mineros of the SeaBotix LBV series are designed for rescue operations and to support divers while they are working. They all have a teleoperator console, a video camera, and four to six thrusters. Numerous alternatives are also available, such as extra illumination or a basic, detachable manipulator with swappable grabbers. vLBV950 has a maximum depth of 950 meters. These vehicles have a very low weight (18 kg for the vLBV950) due to the use of an external power source that is connected to the tele-operator console, which is situated on the surface [13].

Fig.1.SeaBotixLBV300miniROV.

For underwater examination of both inland and marine waterways, VideoRay offers a variety of miniROV types. Numerous external parts, including grabbers, cameras, imaging sonar, radiation detectors, and water quality measurement equipment, may be added to these vehicles.

2.2. AUVclass

In 1990, Kongsberg Maritime (Norway) collaborated with the Norwegian Defence Research Establishment to develop HUGIN, a heavy AUV [3]. The most sophisticated models include HUGIN 3000 (which can reach a maximum depth of 3000 meters), HUGIN 1000 (which is a smaller version of HUGIN 3000), and HUGIN 4500 (which can reach a depth of 4500 meters). HUGIN is made for a variety of uses, including mine seeking, oceanography, environmental monitoring, and undersea resource investigations [4].

A pioneer of an autonomous, small, inexpensive vehicle intended to gather environmental data to aid in the study of stability and change in marine ecosystems, the Remote Environmental Measuring Unit(s) (REM-US) was created in 1994 at the Woods Hole Oceanographic Institution [1]. It has temperature sensors, depth sensors, and an audio navigation system. During its development in 2000, RE-MUS acquired several additional features, such as a compass, gyroscopes, and Doppler Velocity Log (DVL) [2]. REMUS is being sold for commercial usage by the Hydroid corporation [16].

Fig.2.REMUSAUV.

The Australian Scientific and Research Organization created the vision-based AUV Starbug for seabed imaging. It is intended for Great Barrier Reef environmental monitoring. The visually guided navigation system, pressure sensor, magnetic compass, IMU, and GPS (used on the surface) are all features that Starbug has [5, 6]. Starbug and the vehicle Isfar, which is described in this article, are quite similar.

2.3. Underwatergliders

3. An AUV class vehicle with a particular drive is an underwater glider. Through the use of wings and buoyancy changes, gliders generate forward motion. To alter buoyancy, alter the vehicle's volume to generate a buoyancy force. While the forward buoyant force balances drag, wing lift balances the across-track buoyant force [6]. The Seaglider, which was constructed at the University of Washington, is the vehicle that best represents glider class. It has a fluorometer, temperature, conductivity, and dissolved oxygen sensor [8].

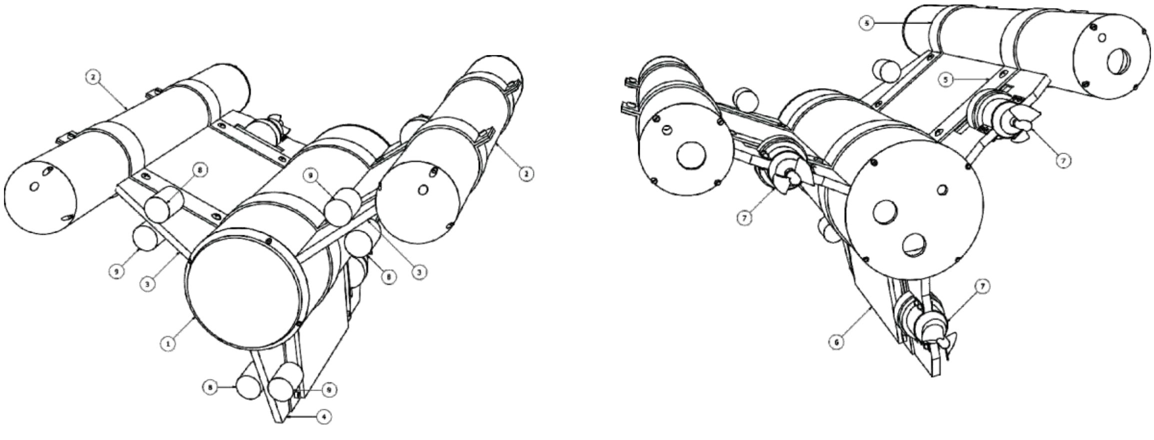
Fig.3.SeagliderAUV.Isfaroverview

Fig. 4. The general view of the Isfar (Lake Malta in the background).

Isfar is a prototype of a hybrid of the miniROV and AUVin a single car. The primary objective was to construct a compact, inexpensive vehicle that could be used as a universal platform for testing various sensors, actuators, and intelligent algorithms. In addition, it should be capable of using the teleoperator to conduct search and rescue operations in ROV mode. The following are the robot's attributes: • Operation area: inland waterways, both natural and man-made • attached to a teleoperator; • exterior dimensions (0.6 x 0.9 x 0.4) m; • weight (in air) 25 kg; • maximum depth of 15 m; • high bandwidth communication protocol, • Maximum speed: 0.36 m/s in reverse and 0.7 m/s in forward motion The ability to maneuver: 5 DOF, • On-board batteries that can provide power for up to three hours • a hybrid control system that may operate alone or in conjunction with the operator (using a dedicated console), • Sensory devices include an IMU (Inertial Measurement Unit), a depth sensor, and a vision system that can function in two modes—visible and near-infrared—under illumination.

Construction using mechanical means Three hulls make up Isfar. Hulls are fastened to the flat-beamed frame. Two fins fill the gap between the main hull and side hulls. The third fin, which is positioned underneath the main hull, serves as a typical boat keel (see Fig. 5). At the extremities of the fins are maneuvering motors that have propellers. Inside the side hulls are the buoyancy drive components. The power supply module, actuator drivers, sensors, and the primary control unit are all located in the main hull. The yellow polyethylene PE80 used to make hulls is very resilient to moisture and pressure. White polyethylene PE1000 is used to make the fins and plugs, which stop water from penetrating. The transparent porthole for camera, made from thick perspex, is mounted at the front of the main hull. The frame is made from inox steel. Additional ballasts, composed of rectan- gular plates made from stainless steel, are mounted on the keel.

a)



Aluminum capsules with tiny perspex plugs are used to make the lighting components. On the rear of the main hull are specialized, underwater connections. Small diameter hoses carry the cables that link the main hull to the floats, maneuvering drives, and lights. The choice of a three-hulled robot style allowed for precise planning of the number, positioning, kinds, and sizes of all internal components during the design phase since there was no way to alter the mechanics during testing.

4. Hybridcontrolsystem

The control system was created with three layers. Figure 6 shows the block diagram of the control system's design.

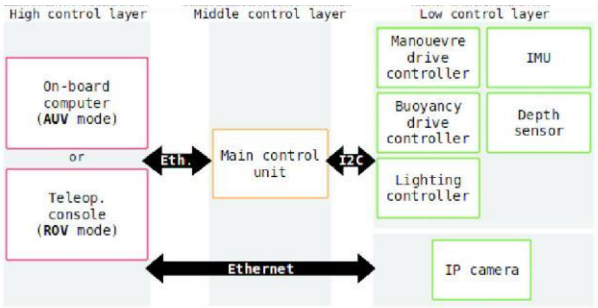


Fig.6.ThearchitectureofthecontrolsystemofIsfar.

The ability to run Isfar in two modes (ROV and AUV alternately) was made possible by the use of Ethernet as the primary communication line. High channel capacities (a series of high-resolution pictures relayed from the undersea at 30 frames per second) and a sizable tether length between the robot and teleoperator (in ROV mode) are made possible by the Ethernet specification. The on-board computer must receive the chosen AI algorithms in order for the robot to function in AUV mode.The human operator will only be a passive operator as a result of the missions that would be carried out in such mode. To transition between these modes, no hardware changes are required.

4.1. Lowcontrollayer

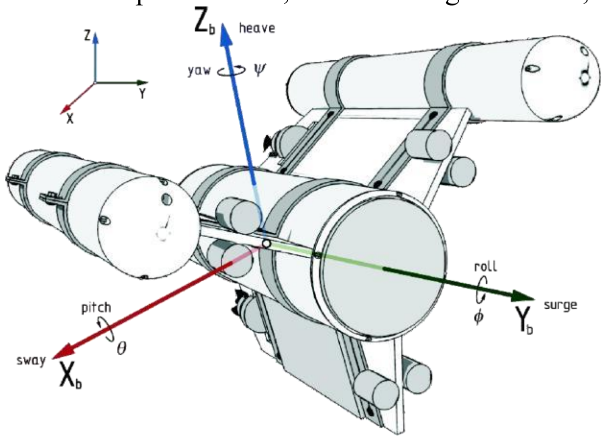
Actuators, their drivers, and sensory systems make up the low control layer.

Themanoeuvringdrive

Three DC motors with propellers were attached so that it could travel forward and backward. Since these motors, which are marketed as the maneuvering drive, are derived from Johnson L550 bilge pumps, the tight enclosure for the motors did not need to be designed. Because these motors are inexpensive and widely available, the authors chose to employ them.The maximum operating current for each motor is 3 A, and its output is 36 W. These motors have a maximum torque of 50 mNm apiece. The two-blade propellers had a diameter of 40 mm. When the propellers were tested using a dynamometer, the results showed that each one produced 6 N of push, which translated into an 18 N thrust for the robot.The drives were positioned in an equilateral triangle's vertices. Because of the placement of the motors and the maneuvering drive, Isfar can: • surge, or move ahead and backward; • alter orientation, or change heading angle and pitch angle, which is helpful while ferreting during the searching missions.H-bridges incorporated in the ST Micro-electronics VNH2SP30 chip and an Atmel AVR ATmega8L micro-controller were used in the design of the maneuvering drive's controllers. The VNH2SP30 circuit's features, particularly its low internal transistor resistance, make the drive energy-efficient. Two modes of operation are available to the driver: closed-loop with current feedback (the VN2HSP30 chip contains an integrated current sensor) or open-loop with pulse width modulation. The drive's studies demonstrated that current and motor thrust are exactly related.

Thebuoyancydrive

Four piston tanks, each holding 0.5 liters, make up the buoyancy drive. Transmission gears are



positioned outside the piston tanks, which house DC motors. The Archimedes principle states that the buoyancy force changes as the amount of water within the tank increases. Due to the unique configuration of the robot's piston tanks, the The ability to regulate the buoyant force allows the dri-ve • heaving, or movement along a vertical axis (emerging and submerging); • roll angle, or change in orientation.

All of the piston tanks have a range of around ±10 N. The robot emerged at a recorded speed of around 0.2 m/s. The location of the piston within each tank serves as the drivers' set point. Similar drivers, such as the ST Microelectronics VNH2SP30 maneuvering drive, are employed in the design of the controllers. The AVR ATmega8L microcontroller assumes the job of communication. Isfar is a nonholonomic robot because to all of the drives that were mounted on it.

Fig.7.Bodyframeaxesandorientationangles.

Thelighting

High power LEDs are the foundation of the illumination. Six power diodes make up the lighting, including three 3 W cold-white diodes and three 1 W diodes that produce 850 nm-long, near-infrared radiation. A collimator and a star-shaped radiator are attached on each LED. The diode-containing capsules were positioned symmetrically in front of the aforementioned fins (see Fig. 5), resembling maneuvering motors and forming the base of a triangle.An AVR ATmega8L microprocessor and MBI1801 High-Power LED drivers form the basis of the lighting driver. The current that MBI1801 controls determines how bright the LEDs are.

Theon-boardcamera

A vision system that sends the recorded picture sequence straight to the surface is the most important component of underwater inspection vehicles. Since the pictures are almost unreadable, a specialist vision system had to be created since Isfar was built for inland underwater inspection. The Intellinet 550291 network IP camera, which can capture pictures in low light, is installed at Isfar to address this issue. The camera is distinguished by its infrared-sensitive lenses, which expand the light carrier's spectrum into the near-infrared region (wavelength up to 850 nm). The camera is equipped with an embedded Linux operating system, communicates via Ethernet, and sends pictures via Motion-MPEG-4 or Motion-JPEG format.Through HTTP queries, the picture recording's parameters—such as brightness, contrast, saturation, etc.—are managed. In addition, the camera has a 1/3/" Sony CCD sensor, 720x576, 640x480, or 352x288 picture resolutions, and a 30 fps frame rate.

InertialMeasurement Unit

The specially designed Inertial Measurement Unit is mounted on board to perform the estimate of the vehicle's orientation. The IMU is made up of two 3-axis accelerometers and three digital gyroscopes that measure angular velocities along the body frame's axes. The gyroscopes are positioned along three orthogonal axes on the board in a certain arrangement. Redundant accelerometers that serve as inclinometers and show the board's orientation when it is perpendicular to the vector of gravity assist the operation of gyroscopes. This makes it feasible to reset the pitch and roll angles, which makes the angle detected with gyroscopes dubious (the error is cumulative) due to thermal noise. Accelerometers may also be used to warn of impacts with barriers. We utilized three Atmel ADIS16060 iMEMS gyroscopes. The gyros are distinguished by their 14-bit resolution, SPI output interface, and ±80 deg/sec range. The ADXL330 accelerometers offer analog outputs and operate within a ±3g range. An AT91SAM7S128 microcontroller with an ARM7 core serves as the primary component of this sensory subsystem. Reading the angular rates, converting them to floating point representation, integrating them (to compute the angles), and sending them to the middle control layer are its objectives.

Thedepthsensor

The in-dustrial pressure sensor WIKA A-10 is used to build the depth sensor since Pascal's law states that the pressure applied to a submerged body determines its depth. The sensor can operate at depths of up to 40 meters because of its analog output and range of pressure readings, which is around 5 ba. An ATMega8L microcontroller controls this component's operations.It is important to note that the low control layer is modular in design, meaning that every driver and sensor controller was installed on a different board. Only the damaged board has to be replaced in the event of failure. The C programming language is used to write the bottom control layer applications. This layer uses 32-bit ARM7 and 8-bit AVR MCUs. Both the middle and low control levels implemented the I2C bus fault detection technique.

4.2. Middlecontrollayer

The primary control unit is the sole device in the middle layer of the control system. Data synchronization and connection between the high and low control levels are the functions of that board. This layer also handles basic regulatory functions including heading control and buoyancy. The Ethernet controller and the ARM7 family microcontroller are the two integrated circuits that form the basis of the primary control unit.

Two levels of the ISO/OSI model—the Physical Layer (PHY module) and the Data Link Layer (MAC module)—are included in the Ethernet controller, Microchip ENC28J60. The manufacturer put in place practical methods for checksum computation, packet filtering, collision detection, and retransmission. Through the SPI interface, the controller and processor unit exchange information. The I2C bus makes the system that uses it ubiquitous and customizable and allows up to 127 slave devices to be connected simultaneously.The Ethernet protocol serves as the foundation for the basic message protocol that facilitates communication between the high and low control layers, enabling real-time Isfar control. IP is used at the OSI model's Network Layer, along with UDP, a Transport Layer protocol. Datagrams are sent in a stream, which is important to note. The middle control layer's software is written in the C programming language. Every protocol from OSI levels three and above was implemented independently of the microcontroller.

High control layer

The topology of the star network is adhered to by the high control layer. At this tier, two distinct device types are permitted: a supervisory computer with autonomous operation algorithms and the teleoperator's remote console. Although it is clear that these devices may operate simultaneously, only one of them functions as an active driver, with the others acting only as passive observers.

Theremoteconsole(ROVmode)

The teleoperator has access to a console that contains a joystick or gaming pad. A mobile PC running a graphical program that displays the current underwater picture is the primary component of the scam [13]. The graphical user interface (GUI) of the console program is based on the Heads-Up Display (HUD) used in contemporary military aircraft, which means that the pilot does not have to swivel his head to examine the flying data. The PyGame library and the Python programming language were used to create the application. The program works on several platforms; Linux and Windows were both used for testing.

Theon-boardcomputer(AUVmode)

In autonomous operation, the on-board computer may take the position of the remote console. At that point, the motion tether would not be necessary for the robot to function. This layer's decision-making algorithms would be knowledge-based and backed by the data now provided by sensory devices, particularly sonar and cameras.The process of creating algorithms for autonomous operation is now underway.

4.3. Powersupply

\Four Li-Poly batteries with a nominal voltage of 11.1 V and a capacitance of 5600 mAh each are included in the Isfar power module. The favorable capacitance to volume ratio of lithium-polymer accumulators justifies their selection effective. By using the PoE (Power over Ethernet) standard and an appropriate contactor, the robot may be turned on or reset simply by inserting the Ethernet RJ-45 connector into its socket.

5. Applications

Isfar's main function is to carry out search operations. As is well known, every operation calls for highly skilled and specialized divers to operate in hazardous and challenging environments. It makes sense to use a robot to take the diver's position.Without coming to the surface, Isfar may operate for a lot longer than the diver. The health of the diver is severely harmed by extended diving sessions.It is clear that robots are immune to diseases that divers may get as a consequence of their employment, such as illnesses brought on by environmental pollution in the water.Rescue operations cannot be separated from search and reconnaissance activities. Such vehicles may be of interest to specialized groups of researchers. Isfar may also be used for underwater plant or object inspection and characterization, such as monitoring submerged infrastructure like bridge pillars or boat pylons that need regular repair. Another function of Isfar is to map the lake or river bed. As a result, the robot might be used for environmental care, searching for and identifying the source of pollution, particularly with the use of NIR-recorded photos. Additionally, the robot could help with underwater archeological re-searches.

6. Summary

Isfar is an example of a vehicle that still has special operational capabilities, especially when considering the present stage of development of robots that assist people while working in hazardous and challenging areas. The first tests conducted on Poznan's Lake Malta validated the presumptive underwater operating characteristics. Isfar is now prepared to carry out operations in ROV mode, that is, with a teleoperator. The development of the robot's increased autonomy is now underway.The existing design leads to the following conclusions: • The DVL (Doppler Velocity Log), GPS transceivers, and digital compasses (based on magnetometers) should cooperate with the Inertial Measurement Units in cars like Isfar. The use of these components is undoubtedly worthwhile in order to enhance the robot's localization, orientation, and linear velocity measurements. Multi-beam sonar could also be used to enhance the sensory system, allowing for the scanning or mapping of the lake or river bed. Additionally, the output of visual and acoustic sensory systems could be combined to create a fusion of recorded images. Because of its openness and adaptability, the control system that was shown might be used with other robots that aren't always submerged.

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