Human-Computer Interface for Doğuş Unmanned Sea Vehicle

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Abstract. Unmanned vehicle systems are becoming increasingly prevalent on the land, in the sea, and in the air. Human-Computer interface design for these systems has a very important role in mission planning. The objective of this work is to design a unmanned sea vehicle and necessary software that can perform off-line path planning, vision management, communication, sensor control, and data management and monitoring of the unmanned sea vehicles.

1 Introduction

Sea power is a very important factor in military, commercial and transportation applications. There is a great interest in unmanned vehicles in the maritime domain from military and research institutes. The history of unmanned vehicles has its roots as far back as 425 BC [11]. The first self-flying robot bird is propelled by compressed air. Modern concepts were begun to be developed during the First and Second World Wars. The first navy USVs were radio-controlled drone boats which was used for collecting radioactive water samples (1946) and performing mine clearance operations (1960s). In 1985, the first modern USV "The Owl" was designed around the base of a jet-ski by International Robotic Systems Inc. In 1995, Navtec Inc was established and developed a fully autonomous navigation system using global positioning system and compasses along with a radar-based obstacle avoidance system. The MK II [5] was the first USV to be deployed for a

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real world mission in 1995 in the Middle East. There are also many academic research projects involved in the development of USVs. Several Catamaran type USVs have been developed such as SESAMO, an Italian catamaran USV [11]. In 2004, the Marine and Industrial Dynamic Analysis (MIDAS) Research Group at Plymouth University designed a twin-hull catamaran USV named Springer [7]. Springer research programme aimed to design and build a new advanced intelligent integrated navigation and autopilot (IINA) system.

Energy efficiency and use of renewable energy are very important for long missions. Wave powered USV "Wave Glider" has this ability and it crossed the Pacific Ocean, the longest distance ever attempted by a USV in 2012 [11].

The Dogus Unmanned Sea Vehicle (Dogus-USV) project is funded by Dogus University with the goal of reconnaissance and surveillance of the Turkish coasts. Being unmanned makes it possible for the vehicle to stay in the open sea for a long time without returning to base. It uses solar energy and maneuvers into different positions and paths using onboard cameras and global positioning system (GPS). As shown in Fig. 1, it is equipped with solar panels and batteries. The specifications of the vehicle are given in table 1.

Fig. 1 Doğuş-USV trials on Aydos lake, 05, July, 2012

Table 1 The Specifications of Dogus-USV

Weight	256 kg
Length/Width/Height	330/151/110 (cm)
Power	5 HP
Speed	16 knot
Motor	Parsun F5ERL
Motor Cooling	Water
Batteries	Gel
Battery Capacity	100 Ah per battery
Number of Batteries	4
Solar Panels	Lorentz LA-Series
Solar Panel efficiency	For 10 year 90%, for 20 year 80%
Rudder Control	DC motor
Controller	U1 Ultra PC-Intel Atom Z520 single core, 1.33 GHz
Communication	WiFi, GPS, RF, 3G
Vehicle Controller	Arduino Mega 2560

2 System Components

The Dogus-USV was constructed as a sea vehicle that could be either remotely controlled or autonomous. The team designed and built the boat starting with the body of a inflatable boat and modified it to fit an electric motor, propellers, U1 computer, microcontroller, sensors, cameras, batteries, and solar panels. The components are selected and constructed to perform long missions in harsh environments without stopping or recharging. Dogus-USV is designed to be able to operate in harsh sea conditions; it is equipped with sensors that can instantly report errors to the control center. The movement of the rudder is achieved via mechanical steering with a geared motor and a powered chain.

2.1 Motor Specifications

The vehicle is powered by a high efficiency brushless motor. Max power is 4.8 KW (over 6hp) but this motor is rated at 5 hp continuous. It has a high current protection system [2]. The water-cooled version is preferred since the boat is designed to work over long ranges. It needs 100 amps of continuous current and a 10 second "power boost" of 140 amps for full speed. It needs a 48 V DC battery system. The inverter box is also water cooled. For the forward and reverse modes, relay based on-off control is applied. A servo motor is used for changing speed.

There is also another relay that cuts the power using a different channel in case of an emergency. Standard props are used. We have installed and tested our system in a lake with great results.

2.2 Solar Panels

The boat can supply its own energy and completely refill its empty batteries in 7 hours from its solar panels (Fig. 1). The power supply consists of two solar panels of 130 W, four marine gel batteries of 100 Ah for 12 V each. The panels are highly efficient and durable against sea water. The panel surface is coated with a hydrophobic layer. The dimensions of each solar panel is 669x1556x37mm and its weight is 16 kg [8]. Fig. 2 shows the electrical performance of solar panels.

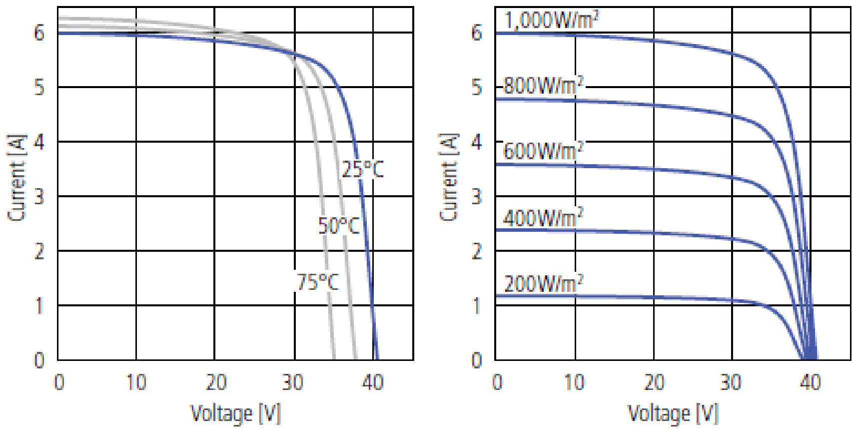

Fig. 2 Solar Panel Electrical Performance[5]

2.3 Batteries

The marine gel type batteries selected can power the electric motor for up to 6 hours at top speed. Lead acid gel batteries are common choice for sea vehicles to prevent foaming. Four accumulators have been placed in Dogus-USV with care being taken to ensure they balance correctly. The characteristics of the batteries are shown in Fig. 3.

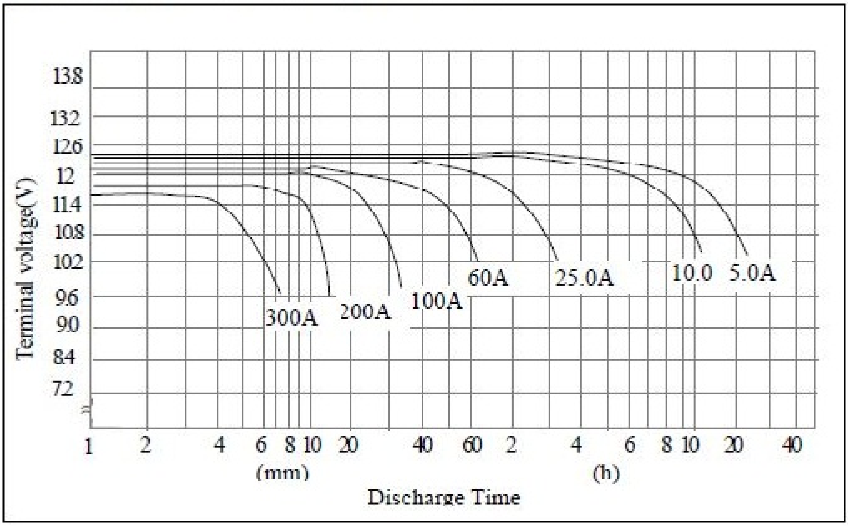

Fig. 3 Discharge curve of marine type gel batteries [1]

2.4 Rudder

The rudder is driven using a 214:1 gear head motor[4]. An external encoder[3] shown in Fig. 4 is mounted to measure the position of the rudder

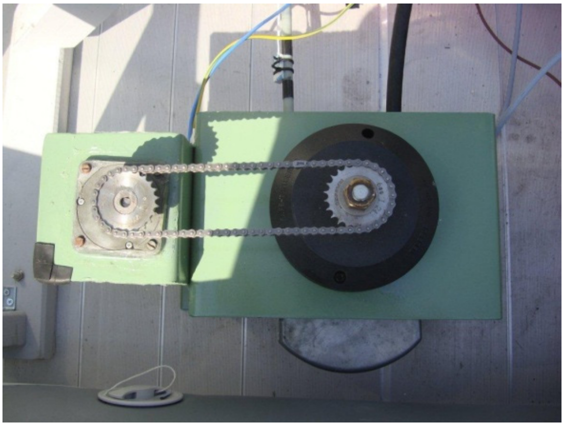

Fig. 4 Rudder mechanism an external encoder- ϕ 50mm-500 pulses/turn[3].

2.5 Inverter

An inverter is a critical component, performing voltage and DC/AC conversion to recharge the batteries which it can do in under 5 hours.

2.6 Solar Panel Charge Controller Circuit

This is a waterproof circuit controlling the current flowing from the solar panels to the batteries.

3 Controller Hardware

A general system overview of unmanned surface vehicles is shown in Fig. 5. Three different controllers have been used in our system: a master computer, an onboard computer and a microprocessor based controller. The master computer in the base station runs the Windows 7 operating system; the onboard computer is a U1 computer with the Debian 6.0 Xfce Linux with kernel 2.6.38 operating system which communicates with the microcontroller and master computer. The microcontroller board gathers sensors information and sending it to the onboard computer and receives commands back via a 9600 bps software serial port. The master computer displays and monitors the current status of the vehicle. The connections between the computers are controlled by a trigger system which checks for discontinuities in the links.

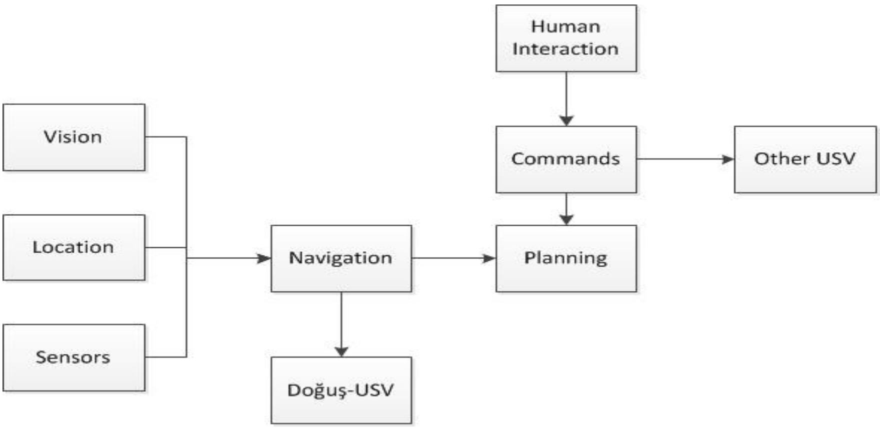

Fig. 5 General System Overview

The connection between master and onboard computers was implemented by sending and receiving commands over TCP/IP and UDP sockets. UDP packet contains GPS location and status information. The TCP socket can issue speed and direction commands.

4 Human-Computer Interface

The Human-Computer interface (HCI) design for Doğuş-USV (Fig. 6) aims to provide a user friendly environment for mission planning and monitoring. The developed software tools should have the capability to provide operators of a multi-vehicle, common control station with decision support for real-time re-tasking and re-planning of multiple assets and the ability to visualize data and information. The interface software for this system is implemented in the C# programming language, with communications developed in Java. It includes four main sections:

- Vision management
- Off-line planning and localization
- Vehicle control
- Monitoring and data acquisition

Fig. 6 Computer-Human interface main screen

HCI provides the communication and visualization mechanism between the operator and the navigation system on board. The operator uses this interface to receive video streams, as well as other data acquired onboard, and to define the route, given as a set of locations which can be located with a geographical information system using a simple point-and-click interface. As part of the HCI, littoral maps of the Fenerbahçe and Marmara Sea were used in conjunction with an onboard global positioning system (GPS). A human operator can monitor the coordinates as longitude and latitude which aids the determination of a point for manual usage. The USV is commanded using a joystick. Some other tasks, such as motor on/off, are assigned to additional joystick buttons. For turning while maneuvering forward with a constant speed, the joystick's slider property was used while the speed was fixed. The polling sets only one direction, backward or forward. The monitoring module was developed using DevExpress; adding a set of gauges and different kinds of indicators to the user interface. The speed, position and battery status of USV and motor temperature can be monitored. The design is flexible and it is very easy to add new properties. In addition to DevExpress gauge controls, progress bars are also used to monitor joystick polling. The interface provides video streams to the operator for monitoring the vehicle path. Following the route on a map makes it easier to visualize spatial coordinates.

4.1 Vision Management

Two different Internet Protocol Cameras (IP Cam) are installed in the USV. Each camera is built upon a 640 x 480 pixels resolution image sensor [2] with digital output. The camera (Fig. 7) allows about 330 degrees of horizontal pan and about 70 degrees of tilt and has night vision capability supported by ten infrared illuminators built in. To stream these images, the video sub-library of AForge.NET[9] was used. AForge.NET is an open source C# framework designed for developers and researchers in the fields of Computer Vision and Artificial Intelligence, image processing, neural networks, genetic algorithms, fuzzy logic, machine learning and robotics .

Fig. 7 Night vision Ip Camera

4.2 Offline Planning and Localization

A map was used to see the real time position of Doğuş-USV by obtaining the coordinates from an onboard GPS. While moving the mouse, the user can see the longitude and latitude coordinates on the map, which helps with him for manual task planning mode. In addition to these properties the user can plan a path , drawing it in a similar manner to a painting program, sending the coordinates to the on-board computer. Drawing a path using a mouse clicks is easy and user friendly. The designed route can be simulated as shown in Fig. 8. In the figure, the small dots represent the user entry points. When the operator presses the "simulate button", the simulation starts and the D shaped circles appear which represent the USV positions.

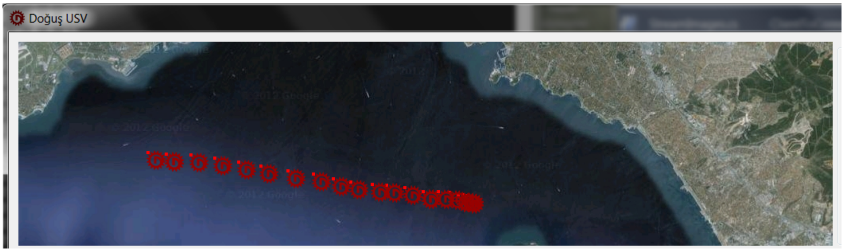

Fig. 8 Doğuş-USV Path Simulation

Navigation without obstacle avoidance, however, provides only limited capabilities in a real-world mission[7]. In order to reduce the reliance on operator oversight, we will add an obstacle avoidance capability to our system in the next step of our project.

4.3 Vehicle Control

A low level layer was run on the Arduino microcontroller and interfaced to the motors, sensors and GPS. It received commands via a serial port from the onboard computer which was running a Linux based operating system. Through this interface the onboard computer could send target positions and receive data from the sensors and status information.

4.3.1 Connection through Master Computer to Arduino

The main mission of the onboard computer is managing the connection between the master computer and an Arduino microprocessor shown in Fig. 9 as a link bridge to receive and transmit for both sides. The application receives control data from the joystick via the master computer and sends it to the Arduino, and receives data from the Arduino including GPS information, temperature and speed. This data is then sent to the master computer which than displays the status of Doğuş-USV to the user.

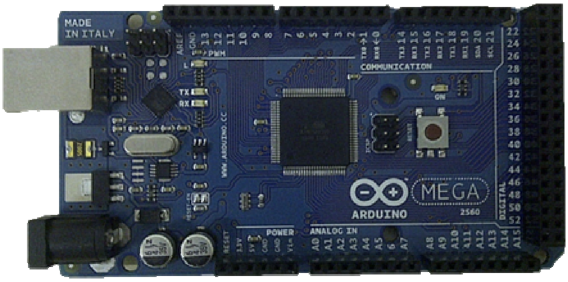

Fig. 9 Arduino Microcontroller Board

The master computer application was written in C#, the onboard computer application was written in Java, and the Arduino code was in a form of C++. This caused problems with cohesion. The data flow itself was designed as a byte stream The solution was efficient, however transmission of the datasuffered from noise problems. We tried to solve the problems using by removing the noise and retransmitting the data.

An Arduino Mega was used to control motors and gather sensor and GPS data. It sent the sensor data to the onboard computer, and it received the control data from the onboard computer. The Mega's 54 digital I/O pins are enough to receive sensor data and transmit the control data.

4.4 Monitoring and Data Acquisition

The onboard control and navigation subsystems are responsible for sensor data acquisition and actuator control based on tasks uploaded to it from the base station. The communications were implemented using Wi-Fi links which transmit data, commands and video stream between the Doğuş-USV and the base station. A single 1024 byte UDP or 1024 byte TCP packet was sent at a rate of 5 Hz.

The compression method of the images captured by cameras mounted on the USV is M-JPEG [2]. Motion JPEG (M-JPEG) is a video codec where each video frame is separately compressed into a JPEG image. At low bandwidth availability, priority is given to image resolution. The available camera can capture and compress, 15 images (640 x 480 pixels resolution) per second, and then make them available as a continuous flow of images over the network to the base station.

5 Conclusions

We have shown our approach to building an unmanned sea vehicle with the goal of reconnaissance and surveillance. In July 2012, we tested our hardware and basic software components. In the next stage, we will improve the path-planning and sensor integration parts of our project.

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