

# TURNING CIRCLES OF AN AUTONOMOUS HIGH SPEED CRAFT MODEL

ELÍAS REVESTIDO

Dept. Electronics Technology and Systems Engineering and Automatics  
Univ. Cantabria.  
E.T.S. de Náutica - C/ Gamazo 1- 39004 Santander (Cantabria)  
SPAIN

FRANCISCO J. VELASCO

Dept. Electronics Technology and Systems Engineering and Automatics  
Univ. Cantabria.  
E.T.S. de Náutica - C/ Gamazo 1- 39004 Santander (Cantabria)  
SPAIN

TERESA M. RUEDA

Dept. Electronics Technology and Systems Engineering and Automatics  
Univ. Cantabria.  
E.T.S. de Náutica - C/ Gamazo 1- 39004 Santander (Cantabria)  
SPAIN

EMILIANO MOYANO

Dept. Applied Mathematics and Computing Sciences  
Univ. Cantabria.  
E.T.S. de Ingenieros Industriales y Telecomunicaciones - Avda. de los Castros,s/n  
-39005 Santander (Cantabria)  
SPAIN

ELOY LOPEZ

Dept. Sciences and Navigation Technics, Engines and Naval Architecture  
Univ. País Vasco (UPV/EHU).  
E.T.S. de Náutica y Máquinas Navales – C/ M<sup>a</sup> Diaz de Haro 68 – 48920 Portugalete (Vizcaya)  
SPAIN

LUIS ÁNGEL ESQUIBEL

Dept. Electronics Technology and Systems Engineering and Automatics.  
Univ. León  
E. de Ingenierías –Campus de Vegazana, s/n – 24071 León  
SPAIN

**Abstract:** - This paper describes the undertaking of several tests and manoeuvres, using a marine vehicle experimentation platform, to verify the stability and steerability of these vehicles with autonomous in-scale physical models. The model has an Industrial PC which communicates by means of a wireless network with the

laptop on land, which can be connected to another or other PCs through Internet using 3G UMTS technology. A software support has been implemented in the Industrial PC, which is capable of acquiring and storing data from all of the instruments from the test platform from a distance. It is possible from a distance, via the web and via DataSocket, to view data and modify the parameters of all of the instruments of the platform using the wireless network with WiFi technology and also internet network with 3G UMTS technology. A software support developed in LabVIEW is used for this. The software admits different protocols of communications with the platform and is suitable for carrying out the Guidance, Navigation and Control of the physical model. This software makes it possible to perform the sea trials most widely used to determine the main characteristics of the steering and manoeuvring of a sea vessel, such as: evolution curve, zig-zag manoeuvre, pull-out manoeuvre and spiral manoeuvre.

*Key Words:* - Sensorial integration, In-scale manoeuvring, DataSocket, web server, WiFi, wireless, environment, cooperation, marine vehicles.

## 1 Introduction

Within the framework of the project 'Automatisation of Marine Vehicles for Cooperative Actions' (Environment for Cooperation of Marine Vehicles) DPI2003-09745-C04-03, one of the main lines of research is the study of a ship's manoeuvres for actions in cooperation with other vehicles, such as aiding a damaged ship, tow manoeuvre and joint actions or sailing in close proximity. The aim of the project is to design controllers for the control of these manoeuvre [4] and for the monitoring of pre-planned trajectories. Experiments are also carried out in an uncontrolled medium, in the form of sea trials in the Bay of Santander, for the validation of the designs made, as a prior step to their actual implementation.



Fig. 1. High speed craft model

All of the elements that make up the system, which will be described in the following sections, are of an industrial type. The main reason for this choice is the robustness and reliability provided by these elements. With this test environment, the installations of a vessel are efficiently emulated. The tests with the autonomous in-scale physical model of the high-speed ship were carried out in the surroundings of the Bay of Santander.

The software application designed is capable of making all of the calculations required to plan the trajectories using the input data, which are: starting

point, final point, trajectory and time invested in finding this trajectory. With these calculations, the programme generates the references required to make the dynamic controls [9] of the physical model, using the control strategy considered most appropriate.

## 2 Elements that make up the Platform

A brief description will now be made of all of the components that form part of the remote experimentation environment for marine vehicles. This environment is divided into two parts: one includes the elements on board and the other the elements which are on land. The communication between the two parts is made through a wireless system with two points of access: one on land connected via a wireless system to a laptop and another, for the marine vehicle, connected to the Industrial PC through network cable. The laptop also has a 3G UMTS card, which allows another PC or PCs to connect through Internet to the laptop.

The elements on board are as follows: the propulsion and control elements, the control electronics, the receiver station, the instrumentation, the Industrial PC and one access point. The elements on land are: the portable PC with the possibility of connecting to another or other PCs through Internet, the access point and the transmitter station.

## 3 Development of software support

For the development of the software support, version 7.1 of LabVIEW [3] has been selected as

the graphic programming environment, as this is an industry Standard and because it enables the simple undertaking of graphic interfaces in real time..

In this software support, all of the manoeuvres are programmed so that they can be performed automatically. To do this, the Industrial PC is equipped with an application called SCADA\_Industrial.vi, which, apart from performing the manoeuvres, deals with the gathering and storage of the data from all of the instruments which make up the platform.

### 3.1 Software support communications system

The communication between the computer located on land and the one positioned on the sea vessel is made through a wireless network using WiFi (Wireless Fidelity) technology based on the standard 802.11g [1]. The laptop PC can in turn communicate with one or several PCs equipped with a 3G UMTS (3 generation Universal Mobile Telephone System) mobile telephone card with transmission speeds of 384 Kbps.

The laptop links with the industrial PC through the access points by means of omnidirectional antennas which allow a distance between access points of around 250 metres. The laptop PC also has a 3G PCMCIA card, which allows access to Internet. Once connected to Internet, it is possible to connect with any other PC or PCs connected to Internet. These PCs may be connected to Internet via an Ethernet cable or using a 3G PCMCIA card, as can be observed in figure 2.

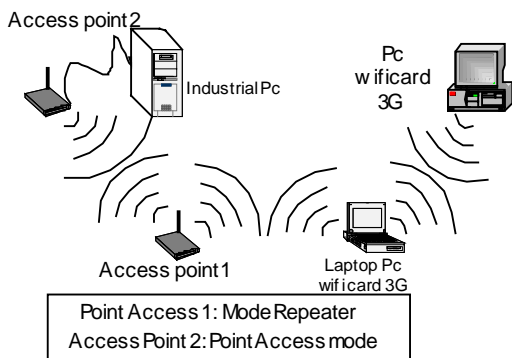


Fig. 2. Elements that make up the wireless network

The decision to use this wireless network configuration and not to select one single access point and a wireless network card, is based on grounds of improving security in the communication and extending the reach of the wireless signal.

### 3.2 Publication of Vis in DataSocket and Web Servers

In order to be able to access the SCADA type application being run on the Industrial PC via the wireless network and at the same time be able to access this application from another or other PCs through Internet, it was necessary to combine DataSocket technology [5][8] and the web publication of LabVIEW [6], in the software support, as can be seen in figure 3.

There are two graphic interfaces with the same appearance: one called SCADA\_Industrial.vi which is run on the Industrial PC and another called SCADA\_Laptop.vi which is run on the laptop.

These two applications interchange information bidirectionally through the LabVIEW DataSocket server in the laptop. Any control modified by the user in the remote application of the laptop will automatically be modified in the application of the Industrial PC. At the same time, the SCADA\_Laptop.vi application publishes its data on the web server which is also in the laptop. Thus, any other PC connected to Internet may have access to this application and take over the control at any moment. A PC, or more than one PC, can be connected through Internet, as can be observed in figure 3. It must be borne in mind, however, that only one of them can assume control of the application while the others can only visualise the data.

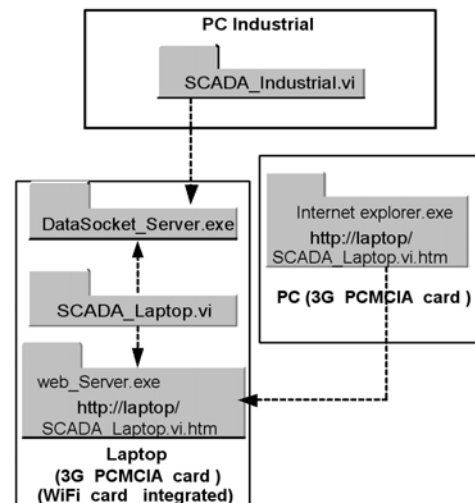


Fig. 3. Software System Applications

The implementation of the communications system described above might have been undertaken using only DataSocket technology. However, apart from the SCADA\_Industrial.vi for the Industrial PC and SCADA\_Laptop.vi for the laptop, it would have

been necessary to design one application for each computer connected to Internet that wanted to connect to the laptop. This is why web server technology is also being used since, in this way, any computer connected to Internet can access the laptop by keying in the corresponding address in a search engine, such as Internet Explorer, without the need to create a new application for each computer that wants to connect to the laptop. For all of these reasons, the most adequate solution is to combine DataSocket technology with the LabVIEW web server technology.

Once the above-mentioned applications are connected to the wireless network using DataSocket technology, the network can access from an external network, such as Internet, the SCADA\_Laptop.vi application via the web server. For this, it is necessary to key in the corresponding address in a search engine such as Internet Explorer. All of this is shown in figure 4.

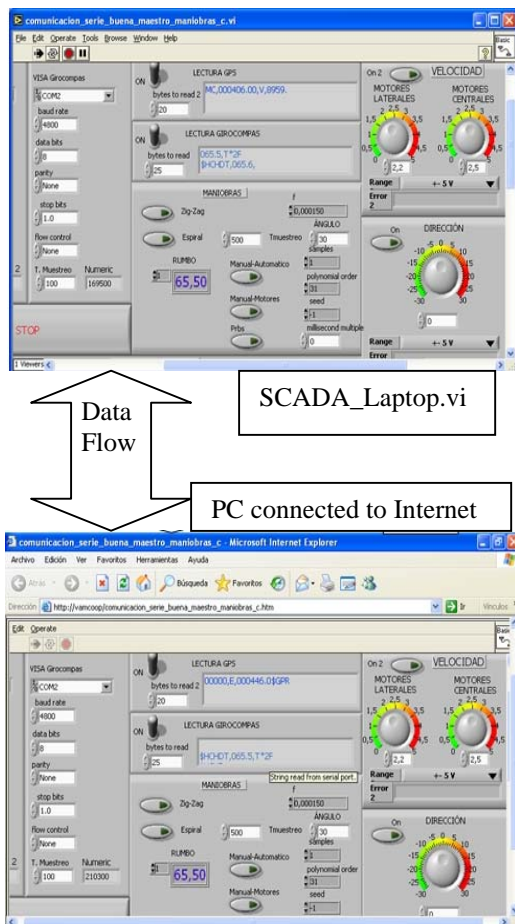


Fig. 4. Communication via web between the Industrial PC and the laptop

## 4 Sea trials with the Test Platforms

A ship must be capable of maintaining the projected path in the open sea, manoeuvring without danger in restricted ports and canals, and stopping within a reasonable distance, independently of the load and speed conditions and the external disturbances of current, tide and/or wind

Several tests are normally performed on a newly built ship, allowing the manoeuvring characteristics of the ship to be determined: evolution curve, zig-zag manoeuvre, “pull-out” manoeuvre and spiral manoeuvre [7]. These tests allow the characteristics of the dynamic behaviour of the ship to be measured, an indication of its stability in a straight-line trajectory to be obtained, the robustness and limitations of the control system to be assessed and the ship’s behaviour in emergency situations to be evaluated.

Moreover, the data obtained from the zig-zag and evolution curve tests allow the identification of a mathematical model of the ship which relates the rotation angle with the propulsion angle [2]. With this mathematical model, controllers can be designed for the control of the manoeuvres mentioned above and for the following of the planned trajectories, which can be validated on the test platform as a prior stage to the actual implementation.

### 4.1 Types of Sea Trial

To verify the manoeuvring characteristics of the ship, several sea trials can be performed which allow the ship’s dynamic behaviour characteristics to be measured and its robustness and the limitations of the steering control system to be assessed. The manoeuvre characteristics can be obtained systematically maintaining or changing a preestablished heading and ship’s speed

### 4.2 Development of sea trials with the platform

The various manoeuvres described above can be performed in the experimentation platform developed.

In order to perform the change of heading required in each of the manoeuvres, the rotation angle of the in-scale vessel model’s turbojets is modified. Next, the data from the various instruments of the platform such as the electronic gyrocompass and the GPS are gathered and stored.

It should be noted that for the turning circle, the platform allows maximum rotation angles of around 30° to port and to starboard.

The zig-zag manoeuvre is performed as follows: assuming that the physical model starts from an initial heading of 0°, the software support makes a change in the turbojet angle of 0° to 20°. Thus, until the platform exceeds 10° of heading, measured with the electronic gyrocompass, the platform does not surpass from 20° to -20° of angle of the turbojet. In the same way, until the platform exceeds -10° of heading, the platform does not change from -20° to 20° of angle of the turbojet. A minimum of five cycles are required to perform the full manoeuvre. The platform is prepared to modify the angle of comparison of the actual heading from 10° to 20° and the rotation angle of the turbojet from 20 to 10°, so that various combinations of the zig-zag manoeuvre can be performed.

In order to carry out the spiral manoeuvre trial in the remote laboratory, the marine vehicle must initially sail in a straight line. The rotation angle of the turbojets is then changed 25° to starboard and is kept thus until the system establishes itself. Then, the rotation angle is successively reduced by 5° each time until it reaches 25° to port. In the rotation angle range near 0°, the angle is decreased to values lower than 5° in order to obtain more accurate data.

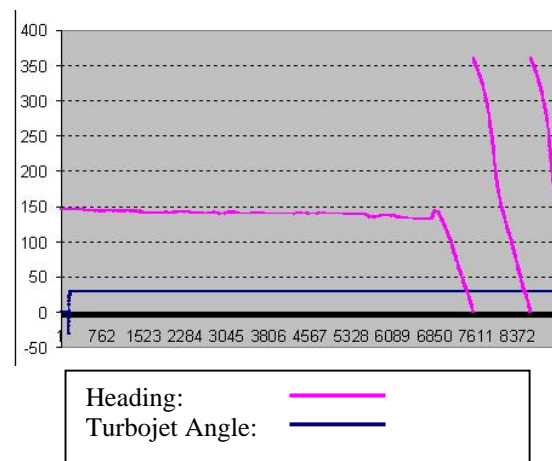
The remote laboratory is capable of capturing the data on the heading of the vessel using a gyrocompass, of making a numerical derivation and thus obtaining the change of heading speed. This allows the pull-out manoeuvre to be performed. If the marine vehicle is stable for the straight line navigation, the change of heading speed, when the angle is modified from 20° to 0°, should drop by the same value to starboard as to port. If not, the vessel is instable.

The results obtained in the remote experimentation platform for the in-scale vehicle allow the behaviour of the real size vessel to be predicted. There is a formulation which relates the geometry, cinematics and dynamics of the in-scale model with the real vessel, so that a good approximation of what the behaviour of the real vessel would be like can be achieved .

**4.3 Results of the Sea Trials with the Platform**

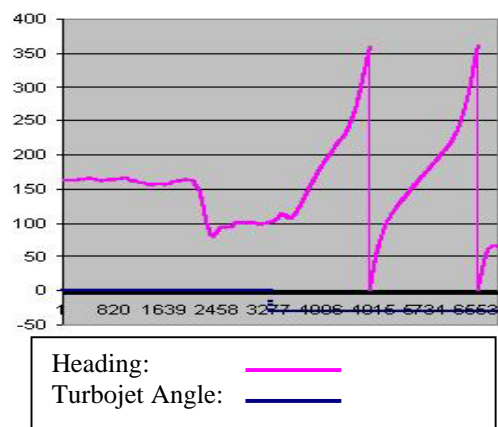
figure 5 shows the turnign circle towards starboard. In the abscissa axis, the number of samples captured with a sampling period of 100 miliseconds are represented. In the ordinates axis,

the data on the heading measured with the electronic gyrocompass are shown as well as the rotation angle of the turbojets. In the case of the evolution towards port, a turbojet angle of 30° has been set. This figure shows a first phase of approximation, typical of the manoeuvre, in which the heading of the physical model remains constant with a turbojet angle of 0°. Then, the turbojet angle is modified to 30°, which is when the physical model begins to rotate towards port, and this turbojet angle is maintained until the model passes 360° twice to perform the full manoeuvre.



**Fig. 5 Turnign circle towards port curve**

figure 6 shows the turning circle towards starboard curve, following the same philosophy as for the port manoeuvre. For this curve, a turbojet rotation of -30° has been set.



**Fig. 6. Turning circle towards starboard curve**

In the development of these trials, a constant position of 0° degrees has been set for the bow flaps and 7,5° for the stern T-foil. The meteorological conditions were the most suitable possible, with a calm sea and gentle winds.

## 5 Conclusions

A test platform for marine vehicles has been used to obtain the evolution curves of a physical model.

This platform is equipped with the actuators and instrumentation necessary for carrying out the data-gathering and control of the platform in such a way that an optimum following of the trajectories can be performed. A software system has been designed for this platform which is equipped with a wireless network for communicating the vehicle with the laptop on land and there is also the possibility of accessing this network through Internet. The application designed deals with the gathering of data and the control of the physical model.

The correct functioning of the installation in the manual/automatic/manual operating modes has been verified. The correct functioning of the electronic gyrocompass has also been checked, thus discarding any possibility of electromagnetic incompatibility and a suitable performance has been observed in the various sea trials.

It has been verified that the establishment of communications through the wireless network is correct. To do this, the communication between each PC and their access point are verified. Once these checks have been made, the data published on the web server of the Industrial PC can be accessed from the laptop without any problem. Communication between the 3G PCMCIA of the laptop and Internet is also verified as well as the correct communication between another or other PCs to Internet, whether it be using ethernet cable or other 3G PCMCIA cards. LabVIEW allows the connection to the web server of up to a maximum of five 5 PCs. The software support design is intended to make an efficient use of the CPU memory and resources.

This environment also includes stabilisation elements: a T-foil and the stern flaps which serve to stabilise the vertical movements of the physical model. Fins can be added with their corresponding servomotor without any great difficulty for the improvement of the sway movement of the physical model in the near future.

### Acknowledgement:

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