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STUDY OF POSSIBILITIES OF USING A STEAM PLANT TYPE "REHEAT" AND MIXED BOILERS OF COAL AND FUEL-OIL FOR THE PROPULSION OF BULKCARRIERS

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Abstract

This study aims to analyze the possibilities of using a steam turbine plant for propulsion of vessels for transporting coal; and they use the coal carried by themselves as fuel to propulsion system. The study analyze the operating cost of this system using as reference the crude oil prize because tha t is an international economic reference and the most merchant ships use heavy fuel oil as fuel for their propulsion.

Key words: Coal, steam turbine, reheated cycle, regeneration stages.

INTRODUCTION

One of the parameters that affect a greater or lesser extent, to determine the viability of propulsion plant are fixed operating costs, with fuel costs being one of the most important. So great may be its importance, depending on the type of vessel concerned, that a price increase might conflict with the possibility of operating in a competitive way (Economía y globalización, 2009). It is therefore essential to investigate how to reduce these costs when defining a project.

The marine fuel price is directly and proportionally linked to the crude oil price. Until 1973, the fuel cost was minimal and therefore the vessels did not have big ener-

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gy-saving provisions. It was to achieve the engine power and operation simplicity and easy and cheap maintenance, rather than thermal and economic efficiency. Steam turbines were used in few stages, boilers without economizers, diesel engines burning marine diesel oil, designed with short strokes, simple turbochargers, and even non-supercharged engines, deck machinery working with steam, turbogenerators (Gourgoulis, 2010) also and a wide range of low energy efficiency equipment. Rising crude oil prices of the seventies led to the rapid abandonment of these systems onboard ships (see fig. 1).

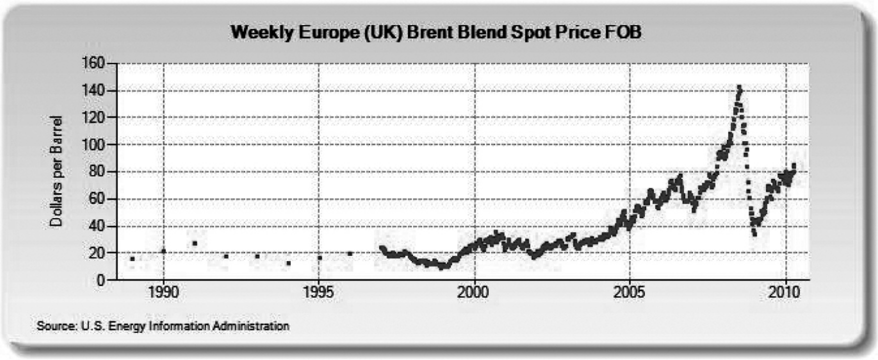

Fig. 1. The evolution of crude oil prices.

At the end of the seventies there was a fever of fuel saving in the main shipping companies in the world. With huge investments, the propulsion turbines were changed and replaced by diesel engines in many large container ships, some tankers, as well as some landmarks cruise ships such as the *Queen Elizabeth 2*. Many vessels powered by steam turbine were scrapped in advance and thereafter the tanker powered by diesel engines devoted in front of the steam engine.

In Spain, at the beginning of the eighties, an interesting experiment was made; two *Suezmax* tankers were cut and two *Capesize* bulk carriers too by the stern zone, then joining the stern of the steam-tankers in the bow of bulk carrier converted into bulk carriers to carry coal, with boilers that burst coal, coal carried by the ship. While the bulk carriers with diesel engine sterns were adequate to meet the maritime rules and regulations at that time and also pump chamber were renovated a segregated ballast tanks were installed (see fig. 2).

Currently, the thermal efficiency of a diesel engine is much greater than that obtained with a steam turbine cycle (Turbine cycle information, 2009). However, the engines are not able to consume solid fuels such as coal, which is cheaper than crude oil products and it has a more stable price (also the estimated reserves of both fuels are very different with a view to long-term future (Fossil fuel information, 2009)). That is why a ship using coal as fuel could be profitable today, and with opportunities to

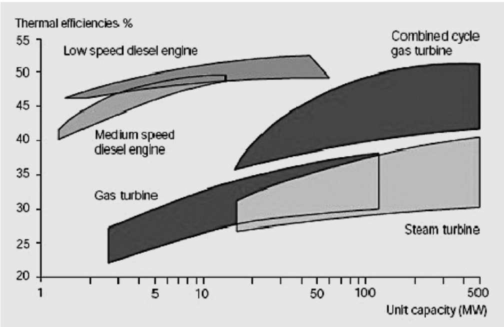

Fig. 2. Different vessels powered system with its efficiencies (MAN Diesel & Turbo).

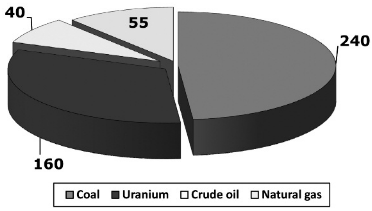

Fig. 3. Estimated years of each fossil fuel reserves.

improve their profitability in the future if crude oil prices continue to rise.

A suitable vessel for installing the propulsion steam turbines using coal as fuel would be a bulk carrier type Capesize for transporting coal, which would use part of the cargo as fuel (see fig. 3).

CURRENT STATUS

With regard to merchant vessels with engines of power ratings above 15,000 kW, the two-stroke diesel engine is used almost always and no other alternatives being considered.

Although the steam turbine is very reliable and requires almost no maintenance, it depends on boilers which need regular maintenance; usually double boilers are installed to improve reliability.

However, the thermal efficiency of this type of system is about 30%. In contrast, other alternatives such as internal combustion engines have efficiencies of 45% to 50%, which make them, therefore, in a huge opportunity to save fuel by changing the propulsion system. Despite this difference, the system of steam turbine propulsion remained the preferred solution for its reliability, and L.N.G. vessels are among the larger ones that still employ this form of propulsion.

The type of propulsion plant also influences, as gas turbines and steam are generally used to operate at near maximum power, while diesel engines should not be used to operate at over 90% of rated power. For this reason, the maximum continuous power installed on a ship with diesel powered exceeds that of other similar vessels but with steam turbine powered. The engine operating area often coincides with the lowest specific fuel consumption. In addition, the projection for the service life of components, recommendations for surveys and maintenance and service intervals are usually based on operation area.

The largest engine rooms are the slow diesel engine, but its large space makes up that they be directly coupled to the propeller without reduction gears. The engine room with steam turbines are also very voluminous, especially if it is compared the diesel engines and steam turbines engines room to small propulsion power. For this reason they are especially interesting for high power, over the range of diesel power.

The steam plant can improve its efficiency through the cycle with reheat and regeneration. The steam turbine plants are generally optimized for a given power and as a result, its power ranges are usually close to their design capabilities (in practice there is no limitation to the maximum power of steam turbines, as it happens with diesel engines). The steam is generally obtained through boilers with burners, which can consume the worst quality fuel oil (natural gas can also be used). With the low fuel prices and lower consumption of lubricating oil, for a time it was possible to compensate its worst specific consumption compared to other types of propulsion plants.

Slow diesel engines have the highest thermal efficiencies, but it seems they are reaching the limits of evolution and improvements are not expected. Slow diesel engines are specifically designed for vessel propulsion and are more tolerant of low quality of heavy fuel oil than the medium speed engines (normally 4 strokes). Their qualities of economy are quite competitive and their simplicity facilitates automation. The maintenance costs are lower than in medium-speed diesel engines. The specific fuel consumption is also better in the slow diesel engines and residual heat is more readily usable.

PLANT COST

Bear in mind that when making the selection of the propulsion machinery, three types of costs should be evaluated: initial costs (price of the plant, installation costs, etc.), variable costs (fuel, maintenance, crew...) potential costs (derived from the reliability and availability expected).

In general, in a merchant ship the operating costs (fuel costs, crew and maintenance required) are the primary consideration when evaluating the candidates to select the propulsion plant, while the initial costs have a relative importance.

Under this, the most common types of plants used in the propulsion of merchant ships are:

- Slow diesel engines, are those with the highest price.
- Steam plants have a high cost for low powers, but they are more profitable when the power is higher

STEAM POWER PLANTS IN VESSELS

The steam turbine plant still has advantages in certain areas such as marine propulsion system, but its main weakness is that its overall efficiency is relatively low.

Mitsubishi Heavy industries ltd “MHI”has proposed a reheat turbine plant, “UST plant” (Ultra steam turbine information, 2009), in that the global efficiency is improved over 15% compared to conventional steam turbine plant, “CST plant,” and can rival with diesel propulsion systems “DFE / DRL” in the total plant cost, including in this cost the sum of the initial costs, operating costs and maintenance costs.

The main points of difference between the plants “UST” and “CST” are:

- Implementation of reheating of the steam.
- The application of higher pressure and higher temperature of steam.
- The introduction of the latest technologies to improve the internal efficiency of the turbines.

The success of the plant depends mainly on the group UST turbine propulsion with reheated steam (UST turbine). The group is composed of a high pressure turbine, intermediate pressure turbine and low pressure turbine with an astern turbine incorporated in the casing of the low pressure turbine. The group will be arranged to drive the propeller through a gearbox and tail shaft line.

KEY FEATURES OF UST TURBINES

The most significant feature of the UST turbine is the remarkable improvement of efficiency that can be achieved with adequate security in all the modes of operation considered. The high reliability, easy maintenance, and operation are kept the same as in conventional CST plant.

The main features including those listed above are:

- **Security**. Superior creep resistance, no leaks of steam in the flanges and joints.
- **Quality of life**. Low vibration noise.
- **Maintenance**. No consumable parts, extremely low maintenance costs, easy refurbishment.
- **Lifetime**. Robust design with large safety margins, with a long life expectancy.
- **Turbine Performance**. About 25% improvement of steam consumption compared to CST.
- **Reliability**. Proven design based on reheat turbine used in ground facilities.

The turbine performance improvement expected, as mentioned above, it is more than 12% in specific fuel consumption (SFC). That performance change is due to changes in steam plant conditions from CST to UST; the application of reheating cycle and increasing the turbine internal efficiency.

The turbine internal efficiency increasing is based on the latest technology manufacturing, that which has already been tested by MHI with reheat turbines on shore and the expected results were found by them. The UST turbine is set and optimized for marine use and the performance and efficiency proposed have been validated empirically and methodically.

THE NEWEST TECHNOLOGIES USED TO IMPROVE THE INTERNAL EFFICIENCY OF THE UST TURBINE

As mentioned above, more than 12% improvement in fuel consumption (FOC) can be achieved through the implementation of the UST turbine, its associated boiler and steam plant.

- **Improved condition of steam to UST turbine**. Approximately 2% improvement in specific fuel consumption (FOC).
- **Implementation of reheat cycle**. Approximately 8% improvement in specific fuel consumption (FOC).
- **Improved internal efficiency of the turbine**. About 2% improvement in specific fuel consumption (FOC).

To achieve the greatest improvement in specific fuel consumption (FOC) is absolutely necessary to improve internal efficiency in the UST turbine. The following points are used to optimize performance of UST turbine.

a) Optimization based on the diameter of the turbine rotor (HR / T).
b) Optimizing the number of turbine stages and the steam pressure of each extraction.
c) **Implementation of ISB with Multi-seal blade.**
d) Optimization of the angle of the nozzle at high pressure stages (HP).
e) Development of the last stages Curtis (Control) with a much higher efficiency for UST steam conditions.
f) Implementation of 3-D Rateau nozzles.
g) Implementation of 3-D stationary blades in LR reaction stages.
h) Implementation of blades with small non stationary-losses.
1) Optimization of a guide for exhaust flow (LR / T).

PROPULSION PLANT WITH DIESEL ENGINE OF 200,000 DWT BULK-CARRIER

The propulsion is through a fixed-pitch propeller (and thus an axes line), driven by a two-strokes diesel engine of high performance.

The main engine is MAN engine, model 7S80ME-C7. It is a slow diesel engine, two-stroke, which has a crosshead and incorporates modern electronic control system, which also has advantages for fuel consumption.

ALTERNATIVE PROPULSION PLANT WITH REHEATED STEAM

In this study we will build on the use of a UST steam plant, with reheated steam at high pressure, commercialized by Mitsubishi Heavy Industries ltd.

The models of UST steam plant marketed currently by Mitsubishi Heavy Industries Ltd, and are the most suitable for use in the propulsion of 200,000 dwt bulk carrier, would be the MR36-II model, that with 26 MW would remain a little below the specified power, and the following model MR40-II with 30 MW would remain a little above the required power (see fig. 4).

Although the specified power for the bulk carrier does not exactly match the power rating given by these models, the important thing is that the power is within the range

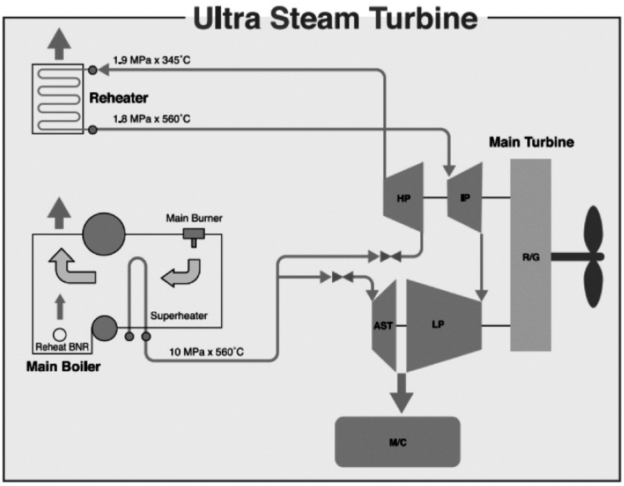

Fig. 4. Scheme of Mitsubishi UST plant (Mitsubishi Heavy Industries ltd).

of powers available. and the possibility of a specific adaptation for each application would be feasible and of this way to optimize fuel consumption for each vessel.

For the practical implementation of this project, the issue referring to steam turbines would have no difficulty, because the steam turbines issue could be solved by contacting of steam plant manufacturers and acquiring the most appropriate model for each vessel. However, the steam generators (Gourgoulis, 2010) using coal as fuel would represent the biggest challenges of this project so as to carry out their practical realization.

Currently, the use of steam generators that have coal as an energy source only has practical application in power stations on shore. Wherefore suitable steam generators should be developed for marine applications, as well as transportation, feeding and preparation coal facilities to the boilers, which must be designed for the use onboard of this kind of vessels. The use of steam generators from shore facilities would be a good starting point for developing marine boilers suitable for this application.

The steam generators installed in the ship should be at least two units (two large units and a smaller third assistant would be an optimal solution), and would be needed to take the possibility of burning coal and H.F.O. at the same time. The dual boilers would be needed to support and to compensate irregularities and distortions in the supply of coal, to make faster the manoeuvring of load change and both start and stop processes.

The determination of the steam generator system more suitable to install in the vessel exceeds the scope of this study, even though it is also a technology that should be developed specifically for this type of vessel that is currently absent.

On the other hand, although we are aware of the technologies used on shore facilities, it must be taken into account that to adapt these for use at naval facilities may not be feasible, practical or economically viable.

The types of boilers used on shore facilities and likely to be used on ships could be:

- Boilers with pulverized coal furnace.
- Boilers with cyclone furnace.
- Boilers with fluidized bed combustion.

The boilers should have an advanced regulation and control system, so that the variation of the spraying of H.F.O. could normalize and stabilize the pressure and mass flow rate in the boiler if the coal supplies were altered. A pilot burner of H.F.O. should always be in place to adequately control the boiler.

The treatment system of coal, its transportation from the vessel`s holds to the engine room and the feeding in the boiler should be fully automated and designed according to specific operating conditions of vessels, such as movements in the sea, maximum heeling and redundancy. Pre-treatment of coal depends on the type of boiler used.

Another possibility to simplify the installation on the vessel would be buying coal ready for burning or installing on shore facilities near the cargo terminal where the treatment of coal is carried out to be used as fuel during the voyage. It would be necessary to do economic studies to select the best option. If a particular fleet of coal-powered vessel was available; the pre-treatment facility option on shore might take on greater importance.

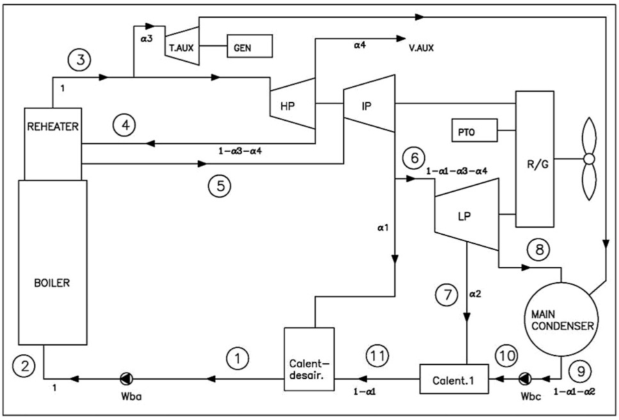

Fig. 5. Scheme of Rankine cycle with reheat and two bleedings.

The scheme of the steam plant made in this study is based on information from Mitsubishi UST installation

Electrical power can be generated in three ways, 1º by tail generator coupling in a PTO (power take off), 2º through the Turbine Auxiliary (AUX T.) 3º or through diesel generators. The cheapest way is producing electricity with the tail generator. In case that the tail alternator was connected, the specific fuel consumption of the installation is less than if it uses the auxiliary turbine, as the main turbine efficiency is higher.

The auxiliary steam extraction (V. AUX) is used to supply the ship's services using steam for its operation. Keep in mind that most steam consumers are pre treatment heavy fuel oil equipment and at this facility it consumes mostly coal, so we have less mass of fuel-oil to heat, which could have reduced the amount of auxiliary steam, of this way the installation efficiency would improve.

In the diagram below we can see the Rankine cycle with reheat and two extractions of the facility that we have set (see fig. 5-7).

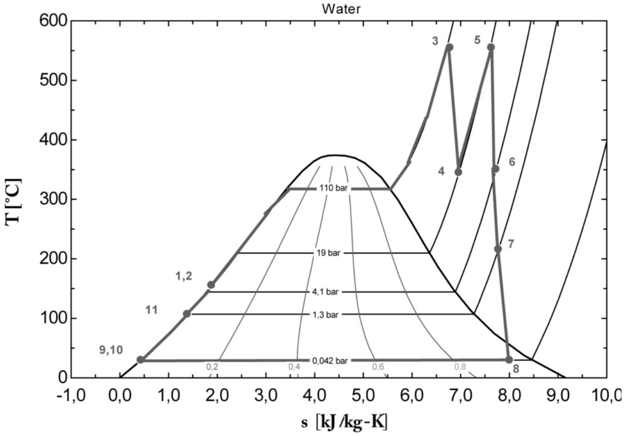

Fig. 6. Rankine Diagram with reheat in UST steam plant.

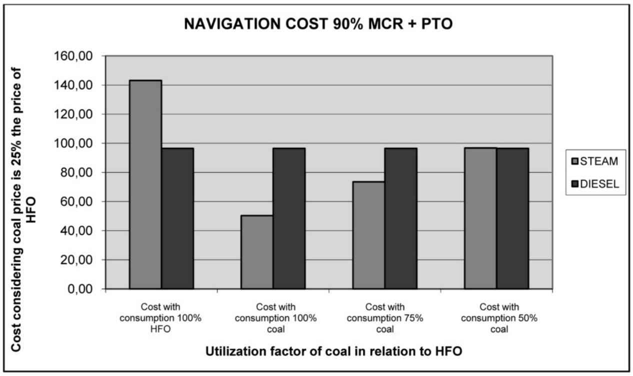

Fig. 7. Costs sailing at 100% of MCR+PTO, considering coal price 25% of crude oil price.

CONCLUSIONS

- It is expected that crude oil and natural gas prices experience a strong upward trend with respect to current prices.
- The use of steam cycle using coal as fuel based its reason for being in the huge price difference between coal and crude oil, which is expected, tends to increase in the future.
- It is a good solution to diversify the fuel sources to maritime sector, one almost exclusively dependent on crude oil for its operation.
- Small quantities of coal used can lead to big savings of money, due to the huge price difference between the two fuels.

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ECOMARS: SPEECH DATABASE FOR EXTERNAL COMMUNICATIONS IN MARITIME SETTINGS

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Abstract

Results obtained from different international research projects clearly show the feasibility of implementing simultaneous automatic translation systems to key areas when there is limited content. One of these controlled areas, in regards to vocabulary and syntactic structure, is that of routine oral conversations that take place in maritime settings between ships or between ships and shore services through the use of Standard Marine Communication Phrases.

Hence, the University of A Coruña has conducted a study titled "Language industries applied to oral communications in maritime settings" which had as its main goal to study the legal and technical possibilities and the commercial suitability of the development of an automatic language translator for oral communications in that area.

Among the many activities to be developed in this project, is the compilation of actual oral samples of such communications; samples that have given rise to the emergence of the speech database ECOMARS.

ECOMARS is the first and unique spontaneous speech database for external communications in maritime settings in Spanish and English that has been compiled and dealt with in accordance with the needs stated in the aforementioned project. The specifications corresponding to its design, realization and treatment will be broadly discussed in this article.

Key words: speech database, maritime communications, controlled languages, speech translation.

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INRODUCTION

As it is widely known, the main goal of speaking automatic translation is to allow conversations among and between diverse peoples who only speak their mother tongue. Automatic translations thus position the speaking technologies as mediators between two people, exceeding the traditional role of interface between users and machinery (Mariño, 2002).

In general, we can talk about two approaches for the realization of automatic speech translation: the classical approach and the statistical approach. (Casacuberta, 2001, Casacuberta and Vidal, 2006; Llisterri, 2004).The latter, which is newer and nowadays more often used, is also known as an integrated and consistent approach in the simultaneous realization of voice recognition and automatic translation. Regarding this approach, Casacubierta and Vidal (2006) state, "the acoustic models of words that are part of a speaking recognition system are integrated in the translation model." From a statistical point of view, the goal of the translation system is to generate the most probable replies to a given phrase. The most significant advantages of this approach are the capacity of recognition and the simultaneous and homogeneous translation, and the possibility to automatically generate and – based on examples – sources of acoustic, lexical and translation knowledge (Casacubierta, 2001; Casacubierta and Vidal, 2006.).

The main problems associated with this system are:

- They can only be used in specific and restricted areas.
- Vocabulary must be restricted to a range of 5000 to 10000 words.
- Great volumes of learning data or training corpus are needed and its compilation is very expensive.
- The size of the models obtained also constitutes a problem, which, once more, make it necessary to restrict the application environment.
- Even the systems and approaches that are working most efficiently have had extremely high error rates.
- That they are based on language pairs, that is, different translators must be compiled for each language pair. This implies the extra difficulty of composing an aligned training corpus for both languages (Mariño, 2002.).

On the other hand it seems logical to assume that systems of voice recognition will deteriorate under severe environment conditions, such as noise, the use of variable channels such as telephones and radiotelephones, and the usual vocal problems in human speakers such as hoarseness or impaired pronunciation due to a cold.

In this sense, and in order to improve the stability and accuracy in voice recognition systems, several techniques are being researched for the purpose of reducing disturbing effects due to noise. Villarubia (2004) indicates that the techniques currently being employed in this area are the spectral subtraction of noise, the standardization of durations, and the extraction of robust features of AURORA.

For his part, Mariño (2002) proposes the training of Markov's hidden models based on a database that includes the highest number of possible situations where the recognizing party will be able to find an actual application as a way of resolving the problem of attaining robustness in the system. This implies the availability of a large database, which includes speaking samples from different interlocutors and communication channels.

AUTOMATIC TRANSLATION APPLIED TO MARITIME SETTINGS

Results obtained from different projects such as Verbmovil, EuTrans or ALIADO clearly show the feasibility in the implementation of simultaneous automatic translation systems for specific tasks whose discourse commands are limited. One of these controlled areas, specifically with regards to vocabulary and syntactic structure, is that of routine oral conversations that take place in maritime settings between ships or between ships and shore services through the use of Standard Marine Communication Phrases.

Therefore all these processes, previously studied, may be applied, to a certain extent, to maritime communications in order to reduce the problems arising from the multiple languages spoken in the environment, by and large in regards to those communications that are made through radio devices, where the introduction of an automatic translator would permit, for example, that two people of different nationalities may communicate with each other using their mother tongue. This system could be very useful when the messages emitted are standardized, thus, assuring a quality translation and a perfect understanding.

On the other hand and given the increasing prevalence of automated systems on board ships, such equipment could help to reduce bridge officers' workload (Hanz-Pazara et al 2008; Meck, Strohschneider and Brüggermann, 2009).

In order to perform this task, three types of corpus – that would generate the respective models – would be necessary:

- An acoustic corpus that could be obtained by the recording of actual conversations on board ships.
- A grammatical corpus or set of grammatical rules that allows the recognition of the source phrases and the construction of phrases translated into the target language. These grammatical rules could be extracted from the same structure used by the Standard Marine Communication Phrases.
- And thirdly, vocabulary, whose base would be the contents of these standardized phrases.

For this reason, the University of A Coruña is conducting a study called "Language industries applied to oral communications in maritime settings" whose main goal is to study the legal and technical possibilities and the commercial suitability of the development of an automatic translator for oral communications in that area and, as the case may be, to set the basis for its development and further study the implications that such a device would have in maritime safety.

Among the activities to be developed in this project is the compilation of actual oral samples of such communications, samples that has given rise to the construction of the speech data base ECOMARS that will be described below.

ECOMARS: DATABASE PROJECT FOR EXTERNAL COMMUNICATIONS IN MARITIME SETTINGS

ECOMARS is the first and unique oral database of spontaneous speaking correspondence for external communications in maritime settings in Spanish and English that has been compiled and dealt with in accordance with the needs stated in the aforementioned project. The specifications corresponding to its design, realization and treatment are detailed below.

Basic design specifications

Taking into account that one of the goals of this project "Language industries applied to oral communications in maritime settings", which also serves as a support for the realization of other goals that are no less significant, is the obtaining and analysis of actual oral samples in communications ship to ship and ship to shore, the need for the design and creation of the database or oral corpus arose and its main uses would be the following:

- Study the actual use of standardized vocabularies in maritime communications.
- Coordination of the recognition of and association between standardized phrases and those that are not standardized.
- The possibility of non-standardized phrase conversion into standardized phrases.
- Identification of noise present in maritime communications made through the VHF in order to set an adequate filtering method.

Aside from the objectives of the project, and that the database was designed at the onset to comply with these goals, it shall be possible to use this corpus – with the proper treatment of its data – in other applications corresponding to the automatic speech translation, and the training and test of systems of speech recognition designed for its use in these settings.

Therefore, and always with the objective of serving the abovementioned goals, the database to be designed should comply with the following specifications:

- It must be an oral database, that is to say, it should contain sound, so transcription is not necessary at first. Currently, the database contains a total of 120 acoustic records of which only 20% have been transcribed in a basic way in order to comply with the other previously stated goals of the project.

- It should be a specialized corpus due to the fact that the recordings should be performed on external communications made through VHF between ships and between ships and shore services. The database, then, contains examples of unilateral and bilateral communications performed in maritime settings. Among the former, we find conversations between the vessel and harbour services; reports to traffic separation schemes and communications between ships, while the latter case basically consist of bulletins with weather forecasts and notice to mariners.
- It should be a spontaneous speech corpus. Compiled conversations had to be, and they have actually been, compiled in the natural settings where they take place and at the time and way in which they were performed. Communications were recorded in the working environment, including those that are usually read, such as meteorological bulletins, but they were not specially performed for their recording even when they were recorded at the time of being retransmitted.
- It should be a multilingual corpus as the goal of the project is the study of the Spanish and the English languages. It could be said that we are dealing with a comparable corpus, as it is compiled in different languages that share similar origin, thematic and extension. In this regard, the number of texts in Spanish is 18, there are 83 texts in English, and 19 texts are expressed in both languages.
- Finally, the channel to be used should be radiotelephony, as it is through this means that most of the oral communications between ships and between ships and shore services are performed.

Selection of speakers' features

In a database as specific as that proposed here, the selection of speakers' characteristics is almost mandatory. In the first place and in regards to the number of speakers, we would want it to be as high as possible, as the greater the number of speakers, the more variety of communication, that is, due to the fact that communications in these settings are quite limited in regards to topic and that the way they are performed should be standardized, the highest number of speakers performing the same type of communication will give a more accurate idea of the deviation experienced by actual communications in comparison with the standard way in which they should be performed. This database has around 231 speakers, out of which, 190 are men and only 41 are women. This recent data is particularly significant, as we must take into account that the proportion of men and women who work in maritime settings is far from 50/50 and thus it is reflected in the communications recorded in the corpus. It is also important to remark that the same nature of maritime trade and the special characteristics of the communications performed in these settings makes it difficult for us to know the identity of the speakers, their nationality or mother tongue.

Another important aspect about the data of the speakers has to do with their age. Because the recorded conversations have been performed through the VHF between ships or between ships and shore services, it is logical to assume that duty officers and captains of ships, or duly qualified and professional inshore personnel perform communications. It is for the this reason that we estimate that the minimum age of the speakers should not be less than 20 years old in any cases, nor, except for occasional cases, over 60 years. This would be a perfectly appropriate age range in order to avoid voice degradation.

Also related to these speakers' characteristics, we found little social diversity, as we should assume that speakers are all people who have attained at least a medium or higher academic education and who are working in a common environment, therefore their social status should be similar.

Finally, in regards to the diversity of dialects, we will distinguish among the recordings performed: those that are in Spanish and those that are in English. In relation to the recordings taken in Spanish, we can guarantee that there are only 40 speakers and that the conversations held – all of which are related to the settings in question – do not leave much room for differences in dialects.

On the other side, and in relation to the conversations held in English, we can state that, taking into account the statistics, which show that the number of non-native English speakers in maritime settings is near to 60%, we can assure that most of our speakers in ships (71 over 118) are non-native English speakers and that the entire sample of land speakers (113) are also non-native English speakers due to the fact that they belong to services located in Spain and Italy.

Data compilation

As this is a corpus of spontaneous speech of the communications between ships and between ships and shore services, the conversations should be recorded from either vessels or from shore services, that is, maritime traffic control schemes and other currently used ship-shore communication devices.

In order to take the samples from the vessels, the presence of several members of the research team on board was necessary. These team members would take the samples and make the initial database. To achieve it, three members of the team have been recording communication exchanges that would take place during navigation duties and prepare, while on board, a first database related to the conditions under which each of the conversations was held. 95 recordings have been compiled and this constitutes 78.5% of the corpus.

In order to acquire samples of shore devices, a formal request was made for collaboration with the institutions of maritime rescue (SASEMAR) in this project through the contribution of recordings conducted from the maritime traffic control schemes and Spanish rescue coordination centres; a request that was favourably received and which provided us with 26 recordings, constituting 21.5% of the total database.

Recording

In the database, the time and date of each of the recordings from ships are registered while there is no data for those given by the shore services. The method of data collection was through a digital recorder for conversations held in ships and in the case of recordings performed on land, direct connection to a CPU. For this reason, the quality of the former is lower than that of the latter, while the level of noise is – in general – higher in the first case. Also, in the case of conversations taken from the ship, these were later transferred to a CPU in order to be coded and treated. The samples acquired constitute a total of 3 hours 50 minutes and 49 seconds of acoustic material in total.

Treatment

As was mentioned previously the treatment to be performed on the acoustic data depends upon the use we want to give to the corpus. Out of the four processes that have been studied: transcription, notes, labels and alignment, we have only applied two of them to our corpus: a partial transcription and labelling.

Transcription was made because it is the study of standardized phrases in actual conversations, one of the main goals for the compilation of this corpus. This transcription has been made partially and orthographically.

The justification for a partial transcription is mostly due to lack of human and technological resources that are needed to perform this task completely. At the same time, the phonetic and acoustic transcription needs many hours of work on the part of specialized research personnel, and neither of them is attainable within the parameters of the current project, for which, nonetheless, this specific type of transcription was unnecessary. In sum, a total of 24 conversations were transcribed, constituting approximately 20% of the available material. We must remark that those transcriptions were not made on conversations randomly chosen but that they were selected from among those with the best acoustic features.

With regard to labelling, a series of data detailed below were registered in each conversation. Some of these data, such as date, time or ship's status were registered *in situ* at the same time that the conversations were recorded. Other information, such as the type of communication, number of speakers or number of *turns*, was obtained later during the first treatment of data. The labelling/coding exercise explained below was further conducted on the entries in the database.

Organization

All the compiled acoustic data in addition to those features added during the labelling stage, have been organized in an easy to use Microsoft Access database. Data corresponding to labelling features are the following: record ID, date, time, duration, type of communication, communication conditions, ships' conditions, status between ships, reason for communication, environmental features, distance, location, quality, number of speakers, gender of speakers, language, recording place, speaking features, recording method, number of *turns*, transcription, number of words. Of all these characteristics, the following can be remarked upon:

- Type of communication: refers to whether the communication was bilateral, ship to ship or ship to land services, or unilateral, that is, made from the ship or from land. In our corpus, 78.3% of the communications are bilateral, while 21.7% are unilateral.
- Communication conditions: in this case we explain whether the bilateral communication was ship to ship or ship to shore and if the unilateral communication was from the ship or from shore. In this case 3.2% of the bilateral communications were ship to ship and 96.8% were ship to shore, while in the case of unilateral communications, 84.6% were made from shore and only 15.4% were made from ships, as it is shown in Figure 1.
- Ship/s Status: in the case that one ship took part of the conversation, data should be compiled in relation to its navigation circumstances such as transit, anchorage, arriving port, leaving port, or any others. Figure 2 shows the distribution of results where most conversations were observed taking place by ships in transit 50%, arriving port 34%, leaving port 10% and other circumstances 6%. Figure 3 shows the number of ships participating, 78.58%, in contrast to the number of recordings in shore stations, 21.5% .
- Reason for communication: this sections gives us an idea of the type of message transmitted through communication, that is, it indicates the reason why the communication was made, such as calls to pilot stations 28.4%; call to port control stations 10.8%; report to maritime traffic control schemes 25.8%; weather forecasts 11.7%; and others (EVAMED, SECURITÉ, collision report, request for anchor permission, report to navy ship, notices to mariners, etc.), 23.3%. This information is represented in Figure 4.

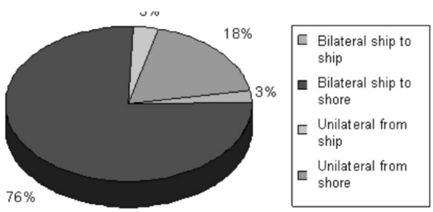

Figure 1: Communication conditions.

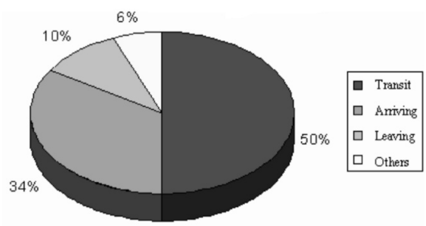

Figure 2: Condition of ships.

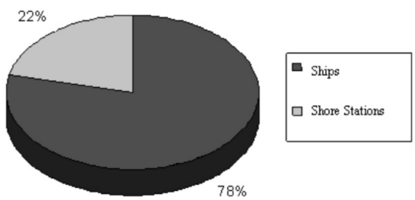

Figure 3: Number of recordings from ships and from land services.

- Environmental features: refers to the current meteorological conditions at the time of recording. The percentages corresponding to these conditions were the following: clear 70%; cloudy 15.5%; precipitation 3.3%; and others 11.2%.
- Recording quality: refers to the final acoustic quality of the recording obtained under the criteria of noise presence in the sample. The range of quality is indicated as good when maximum noise level is up to 700 Hz, fair when maximum noise level in the sample is between 700 and 1000 Hz , and bad when noise peak levels are over 1000 Hz. As Figure 5 reveals, the average quality of recordings have been deemed of good (58.3%) quality while only 10% are considered to be bad quality.
- Number of speakers: we refer to the number of speakers in each conversation which will vary between 1, as in unilateral communications and up to 4 registered speakers in a particular bilateral conversation. The total number of participating speakers is 231.
- Gender of speakers: we have already remarked that maritime settings constitute a professional environment mainly composed of men, circumstance that is reflected in the data obtained for this corpus where the proportion of male speakers is much higher than that of women. In concrete, 34% women have participated in the conversations.
- Language: languages compiled in this corpus are Spanish and English. In Figure 6 we can compare the number of recordings made in Spanish, 15% with those made in English, 69.2%. Furthermore, we have added a section called “mixed” which comprise conversations made in both languages with a total of 15.8%.
- Location and recording method: the location of recording could be a ship, 78.5% of the conversations, or the Rescue Coordination Centre of Finisterre, with 21.5%. The recording location also conditions the recording method, as conversations recorded on the ship could only be performed with a portable digital recorder, and the recordings corresponding to the Rescue Coordination Centre of Finisterre were directly made with a PC.

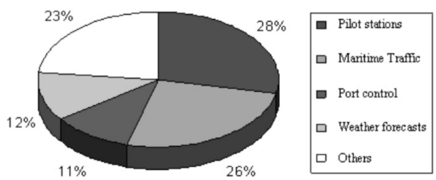

Figure 4. Reason for communication.

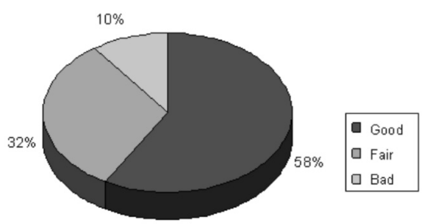

Figure 5. Recording quality.

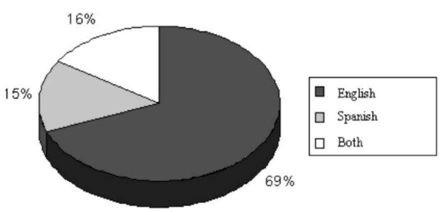

Figure 6. Languages.

- Speaking features: as we have remarked upon earlier, is basically a corpus of spontaneous speech and 82.5% of communications of this type are to be found. However, there is a small percentage of communications made on the basis of a written script (17.5%), corresponding to weather forecasts and notice to mariners, which, although they not intended to be recorded, were conducted nonetheless at the time the information was transmitted to the rest of the stations.
- Number of *turns*: at this point, the number of turns in each conversation is compiled so that we can obtain the number of interventions per recording and furthermore, the total number of interventions.
- Transcription and number of words: the orthographical transcription of the conversation is attached, if necessary. Furthermore, for those transcribed conversations, we know the number of words for each record as well as the total number of words and the number of distinct words contained in the database.

Table 1. shows some of the general data finally obtained in this corpus.

Table 1: General data of ECOMARS

Duration	3h 50m 49s
Number of speakers	231
Total number of turns	985
Number of transcribed words	2648
Number of diferent transcribed words	562

FUTURE PERSPECTIVES

The ECOMARS database was created in order to comply with the goals of the project "Language industries applied to oral communications in maritime settings". However, for the purpose of its design it was decided to register the most likely variety of data about recorded conversations in order to obtain a usable database for the future compiling and treatment of useful data for the training and test of voice recognition systems specially designed to the improvement of oral external communications in maritime settings.

Therefore, in spite of the fact that the amount of compiled data is little more than symbolic, being far from the registered quantities from other national and international projects, the variety of information on this data is valid and its format allows, furthermore, the realization of a later and much broader treatment.

At the same time, there is enormous potential to use this corpus as a database for the compiling and treatment of conversations of this type on the basis of more specific future projects, with human and economic resources to that effect, where the cooperation of official institutions, such as those in charge of maritime traffic control in separation schemes, port control and pilotage services along national and international lines, would be the most interesting due to the amount of data that these institutions obtain and manage on a daily basis.

Finally, we would like to add that a database with these features could be useful in and for the creation of didactic materials, applicable to the teaching of the English language in maritime settings, as these samples reflect the actual "language in use" in communications made in these particular settings.

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ECOMARS: BASE DE DATOS ORAL PARA LAS COMUNICACIONES EXTERNAS EN EL ÁMBITO MARÍTIMO

Resumen

Los resultados obtenidos en diversos proyectos internacionales muestran claramente la viabilidad de implementar sistemas automáticos de traducción simultánea en tareas concretas, cuyo dominio del discurso es limitado. Una de estas áreas restringidas, tanto en lo que a vocabulario se refiere como a estructura sintáctica, son las conversaciones orales rutinarias realizadas en el ámbito marítimo entre buques o entre buques y dispositivos de tierra mediante el uso de las Frases Normalizadas para las Comunicaciones Marítimas.

Así pues, desde la Universidad de A Coruña se ha afrontado un estudio denominado "Industrias de la lengua aplicadas a las comunicaciones orales en el ámbito marítimo" cuyo objetivo es estudiar las posibilidades legales y técnicas, así como la conveniencia comercial del desarrollo de un traductor automático para las comunicaciones orales en este.

Entre las acciones a desarrollar en este proyecto se encuentra la recopilación de muestras orales reales de tales comunicaciones, muestras que han dado lugar a la base de datos acústicos ECOMARS.

ECOMARS es una la primera y única base de datos oral del habla espontánea correspondiente a las comunicaciones externas marítimas en lenguas española e inglesa, que se ha recogido y tratado conforme las necesidades establecidas en el mencionado proyecto. Las especificaciones correspondientes a su diseño, realización y tratamiento serán ampliamente comentadas a en el presente artículo.

Palabras clave: Base de datos orales, comunicaciones marítimas, lenguajes controlados, traducción automática del habla.

ECOMARS: PROYECTO DE BASE DE DATOS PARA LAS COMUNICACIONES EXTERNAS MARÍTIMAS (External communications in maritime settings)

ECOMARS es la primera y única base de datos oral del habla espontánea correspondiente a las comunicaciones externas marítimas en lenguas española e inglesa, que se ha recogido y tratado conforme las necesidades establecidas en el anteriormente mencionado proyecto: "Industrias de la lengua aplicadas al ámbito marítimo". Las especificaciones correspondientes a su diseño, realización y tratamiento serán ampliamente comentadas a continuación.

Especificaciones básicas de diseño

Teniendo en cuenta que uno de los objetivos de trabajo del proyecto "Industrias de la lengua aplicada a las comunicaciones orales en el ámbito marítimo", que sirve además de apoyo para la realización de otros objetivos no menos importantes, es la obtención y análisis de muestras orales reales sobre las comunicaciones marítimas buque-buque y buque – tierra, se nos planteó la necesidad del diseño y creación de una base de datos o corpus oral, cuyas principales utilidades serían:

- Estudio sobre el uso real de vocabularios normalizados en las comunicaciones marítimas.
- Ayuda al reconocimiento y asociación entre frases normalizadas y no normalizadas.
- Posibilidad de conversión de frases no normalizadas en frases normalizadas, y
- Caracterización del ruido presente en las comunicaciones marítimas realizadas a través del VHF, con el fin de establecer un método de filtrado adecuado.

Si bien los puntos marcados son objeto del mencionado proyecto, y la base de datos se diseñó en principio para cumplir estos objetivos, será posible utilizar este corpus, con el debido tratamiento previo de los datos, en otras aplicaciones propias de la traducción automática del habla, como el entrenamiento y prueba de sistemas de reconocimiento del habla diseñados para su uso en este ámbito.

Así pues, y siempre con objeto de servir a los fines anteriormente marcados, la base de datos a diseñar debería cumplir las siguientes especificaciones:

- Ser una base de datos oral, es decir, debería contener sonidos, no siendo necesaria, a priori la transliteración. De hecho la base de datos contiene un total de 120 registros acústicos, de los cuales sólo un 20 % han sido transliterados de forma básica con el fin de cumplir otros objetivos del anteriormente mencionado proyecto.
- Ser un corpus especializado, ya que los registros se realizarían sobre las comunicaciones externas realizadas a través del VHF entre buques y entre éstos y los servicios de tierra. Así pues, la base de datos contiene comunicaciones bilaterales y unilaterales realizadas en el ámbito marítimo. Entre las primeras encontramos, entre otras, conversaciones entre el buque y los servicios de practicaje, notificaciones al paso por dispositivos de separación de tráfico, y comunicaciones entre buque, mientras que las segundas consisten básicamente en boletines con información meteorológica y avisos a los navegantes.
- Ser un corpus del habla espontánea. Las conversaciones recogidas debían, y de hecho así ha sido, recogerse en el ambiente natural en que éstas se producían, en el momento y de la forma que se realizaban. Las comunicaciones fueron registradas en el ambiente de trabajo, incluso aquellas que son leídas de forma habitual, como los boletines meteorológicos, no fueron realizadas de especialmente para su registro, si que se grabaron en el momento en que eran retransmitidas.

- Ser un corpus multilingüe, ya que el objetivo del proyecto es el estudio de las lenguas española e inglesa. Podría decirse que se trata éste de un corpus comparable, ya que recoge textos en distintas lenguas que comparten similar origen, temática y extensión. Por otro lado, el número de textos en español es de 18, 83 se hayan únicamente en lengua inglesa, y 19 textos están expresados en ambas lenguas.
- Finalmente el canal utilizado debía ser la radiotelefonía, ya que es a través de este medio como se realizan la mayoría de las comunicaciones orales entre buques y entre éstos y los servicios de tierra.

Organización

Tanto los datos acústicos recogidos como todas aquellas características otorgadas a los mismos durante el etiquetado se han organizado en una base de datos de Access fácilmente consultable. Los datos de características correspondientes al etiquetado son los siguientes: número de registro, fecha, hora, duración, tipo de comunicación, condición de comunicación, condición de los buques, situación entre los buques, motivo de la comunicación, características ambientales, distancia, situación, calidad, número de locutores, sexo de los locutores, lengua, lugar de grabación, características del habla, método de grabación, número de turnos, trascripción, número de palabras. De éstas, las siguientes características merecen una mención especial:

- Tipo de comunicación: se refiere este dato a si la comunicación era bilateral, bien buque-buque o buque- tierra, o unilateral, realizadas desde el buque o desde tierra. En nuestro corpus un 78.3% de las comunicaciones son bilaterales, mientras que el 21.7% son unilaterales.
- Condición de comunicación: en este caso se explicita si la comunicación bilateral era buque –buque o buque– tierra, y si la comunicación unilateral era desde un buque o desde tierra. En este caso el 3.2% de las comunicaciones bilaterales eran buque –buque y el 96.8% buque– tierra, mientras que para las unilaterales el 84.6% fueron realizadas desde tierra y sólo el 15.4% se realizaron desde un buque. El Gráfico 1 muestra los datos de estas dos características.
- Condición del buque o buques: en caso de que uno o más buques participasen en la conversación, debían recogerse datos sobre su situación de navegación: tránsito, fondeo, entrada, salida u otros. El Gráfico 2 muestra la distribución de resultados, donde puede apreciarse que la mayoría de las conversaciones fueron realizadas por buques en tránsito, 50%, Entrada, 34%, salida 10 %, y otras circunstancias 6%. Por otro lado el Gráfico 3 muestra el número de buques participantes, 78.5%, frente al número de grabaciones de estaciones de tierra , 21.5%.
- Motivo de la comunicación: este apartado nos da idea del tipo de mensaje transmitido en la comunicación, es decir, nos indica le motivo que originó la

comunicación: llamada a prácticos . 28.4%, llamada a control de tráfico portuario, 10.8%, notificación a control de tráfico marítimo, 25.8%, boletines meteorológicos, 11.7%, y otros (EVAMED, SECURITÉ, notificación de colisión, permiso para fondear, notificación a buque militar, avisos a los navegantes, etc.), 23.3%. Estos datos se muestran en el Gráfico 4.

- Características ambientales: este punto hace referencia a las condiciones meteorológicas reinantes en el momento de la grabación. Estas condiciones podían ser: despejado, 70%, nublado , 15.5%, lluvia, 3.3%, y otros, 11.2%.
- Calidad de la grabación: hace referencia este dato a la calidad acústica de la grabación final obtenida, según el nivel de ruido encontrado en la misma. El rango de calidades debería encontrarse entre bueno, con un nivel de ruido inferior a 700Hz, regular, con un nivel de ruido entre 700 Hz y 100 Hz, y mala con picos máximos de ruido superiores a 1000 Hz. Como se muestra en el Gráfico 5, la calidad media de las grabaciones ha sido considerada como buena, 58.3 %, mientras que sólo el 10% de las grabaciones poseían mala calidad.
- Número de locutores: se hace mención aquí al número de locutores de cada conversación, que variará entre 1, para las comunicaciones unilaterales, y hasta 4 locutores registrados en alguna conversación bilateral puntual. El número total de locutores participantes es de 231. Aproximadamente el 80% de estas voces aparecen únicamente en un texto.
- Sexo de los locutores: ya hemos señalado con anterioridad que el ámbito marítimo es un ámbito profesional preferentemente masculino, circunstancia que se refleja en los datos obtenidos para este corpus, donde el número de locutores masculino es mucho mayor que el número de locutores femenino. Concretamente, han participado mujeres en 34% de las conversaciones.
- Lengua: Las lenguas recogidas en este corpus son española e inglesa. En el Gráfico 6 podemos comparar la cantidad de grabaciones realizadas en español, 15%, con las realizadas en inglés, 69.2%. Además hemos añadido un apartado al que hemos dado en llamar mixto, y que recoge conversaciones realizadas en ambas lenguas con un total del 15.8%.
- Lugar y método de grabación: el lugar de grabación sólo podía ser, o bien un buque , 78.5% de las conversaciones, o bien desde el Centro de Coordinación de Salvamento de Finisterre, 21.5 %. El lugar de grabación condiciona, así mismo, el método de grabación, ya que las conversaciones grabadas desde el buque sólo podían hacerse con una grabadora digital portátil, y las grabaciones desde el Centro de Coordinación de Salvamento de Finisterre se realizaron directamente a un PC.
- Características del habla: como hemos comentado con anterioridad, este es un corpus básicamente del habla espontánea, y el 82.5% de las comunicaciones de este tipo así lo corroboran. Sin embargo existe un pequeño porcentaje de

comunicaciones realizadas desde la base de un guión escrito, 17.5%, correspondientes a los boletines meteorológicos y avisos a los navegantes, cuya realización, por otra parte, no fue ex profeso para su grabación, sino que ésta se realizó en el momento en que la información era transmitida al resto de las estaciones.

- Número de turnos: se recogen en este punto el número de turnos de cada conversación, de forma que podamos obtener el número de intervenciones por grabación, el número total de intervenciones.
- Trascripción y número de palabras. Se acompaña aquí la trascripción ortográfica de la conversación, si procede. Además para aquellas conversaciones transcritas podemos conocer el número de palabras, así como el número total de palabras y número de palabras diferentes contenidas en la base.

PERSPECTIVAS PARA EL FUTURO

La base de datos ECOMARS fue creada para cumplir los objetivos del proyecto "Estudio sobre la aplicación de las industrias de la lengua a las comunicaciones orales marítimas". Sin embargo para su diseño se pensó en registrar la mayor variedad posible de datos sobre las conversaciones grabadas, con el fin e obtener una base utilizable, en un futuro, para la recolección y tratamiento de datos útiles para el entrenamiento y prueba de sistemas de reconocimiento de voz especialmente diseñados para su uso en la mejora de las comunicaciones orales externas en el ámbito marítimo.

Así pues, a pesar de que la cantidad de datos recogida es poco más que simbólica, distando mucho de las cantidades registradas en otros proyectos nacionales e internacionales, la variedad de informaciones sobre dichos datos no es despreciable, y su formato permite, además, la realización de un tratamiento posterior más amplio.

Así mismo, sería posible utilizar este corpus como base para la recogida y tratamiento de conversaciones de este tipo en el seno de un posible proyecto futuro más específico, dotado económica y humanamente para tal fin, donde la colaboración de las instituciones oficiales, tales como las encargadas del control de tráfico marítimo en dispositivos de separación e tráfico, tráfico portuario y corporaciones de prácticos, tanto a nivel nacional como internacional, sería de lo más interesante, debido a al cantidad de datos que estas instituciones obtienen y manejan diariamente.

Finalmente señalar que una base de datos de estas características podría ser utilizada para la creación de materiales didácticos aplicables a la enseñanza de la lengua inglesa en el ámbito marítimo, ya que estas muestras reflejan el uso real de la lengua en las comunicaciones orales realizadas en dicho ámbito.

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AUTONOMOUS SHIP MODEL TO PERFORM MANOEUVRING TESTS

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Abstract

The paper describes the development of one guidance, control and navigation platform for autonomous surface vehicles, as well as a specific application of using it in a vehicle for performing a set of manoeuvring tests autonomously. In order to be possible to guide the model from land and in a back-up manual mode or to transmit a mission profile for operation in automatic mode a bidirectional communication is established via radio. A set of experiments have been conducted in a lake and the first set of results is presented here. The experiments were performed successfully and have shown the validity of the whole system.

Key words: Autonomous surface vehicle; Manoeuvring tests; Ship control; Navigation systems.

INTRODUCTION

While the knowledge of the manoeuvring capabilities of vessels have always been required in the ship design process, presently there are even stricter requirements that have been imposed by IMO (2002, 1994, 1993), which require all ships to have results of their manoeuvring tests on board. This implies that the need to perform manoeuvring tests will increase in the future.

The knowledge of the manoeuvring characteristics of a ship allows time simulations of its path as a function of its control settings (Sutulo *et al.*, 2002). Presently the

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assessment of the coefficients of the manoeuvring equations is mostly done experimentally. Captive-model tests, in which at least three components (surge and sway forces and yaw moment) must be measured, are the most popular and currently the most adequate mean for creating ship mathematical models.

Circulating tanks with a rotating-arm facility were the first to appear to perform these tests. However to avoid having one specific tank just for this type of tests, the Planar Motion Mechanisms (PMM) allows carrying out captive-model tests in traditional towing tanks and this made it very popular. This mechanism imposes an oscillating motion to the model while it is towed along the tank (Brix, 1993).

To determine the manoeuvring coefficients from these tests a large number of them need to be carried out, even if experimental design techniques are used to reduce the number of tests and to extract the maximum information from them (Sutulo and Guedes Soares, 2004, 2006).

The experimental studies of ship manoeuvring can be performed with full scale ships. Some tests of this type have been performed by the authors (Guedes Soares *et al.*, 1999, 2004), but this method only serves to confirm the qualities of an existing ship, while at design stage tests must be made with models, so as to improve their performance if necessary.

An alternative to the use of models in captive tests in laboratories is to test remote controlled scaled models equipped with appropriate rudders and propulsion plants (Shin *et al.*, 2002, Luo and Zhang, 2007, Philips *et al.*, 2009).

Free-running model tests are often preferred Moreover, often these experiments are preferred as they confirm manoeuvring properties of a ship configuration in the most direct and convincing way. Furthermore, this approach does not require the large investments in laboratory infrastructures. The obvious conclusion is that development of an experimental setup dedicated to scaled manoeuvring experiments with self-running models even nowadays is a wise way to develop experimental studies in the field of ship manoeuvring.

This is the option that has motivated the application described in this paper which intends to substitute the remote control of such models by a system that allows performing all those tests in an autonomous way.

This paper presents the results of the development of a system that is envisioned for Autonomous Surface Vehicles (ASVs) to perform automatically a set of manoeuvring tests, which would otherwise be possible only with radio controlled models. For this task, the design and implementation of an accurate and reliable navigation, guidance and control system is fundamental.

The development of the ASV included control designs, guidance algorithm development, navigation system implementation in the ship model and respective validation through experimental results, making possible the identification of the new hydrodynamic coefficients for the autonomous model. The main idea focused on this research was to develop a control system to turn the ship model operation into an autonomous one and at the same time to become possible to determine its manoeuvring characteristics.

The developed guidance, control and navigation platform can also be applied in vehicles aiming at other kind of missions such ports surveillance, hydrographical activities, bathymetry survey, among others.

The system presented here would represent a simulator that can be applied to any pre-fabricated model of a surface ship (Moreira, 2008). One of the new developments implemented in this system is the vessel manoeuvring guidance design based on a waypoint guidance algorithm by Light of Sight (LOS) (Moreira *et al.*, 2007), which is used to compute the desired heading angle. A new approach concerning the calculation of a dynamic LOS vector norm was implemented in order to improve the convergence of the LOS algorithm.

The developed system was implemented in a model of the "Esso Osaka" ship (see Figure 1) to demonstrate the execution of manoeuvring tests in a controlled and autonomous way, which means that the model must perform predefined manoeuvres in a sequential and operator independent way, acquiring simultaneously the records of the data obtained through the onboard sensors. In addition to this, the system allows the remote control of the manoeuvres and respective parameters from a fixed position onshore (Moreira *et al.*, 2008, 2007).

Figure 1: The "Esso Osaka" ship model.

The missions could be predefined based on waypoints, with the guidance developed through a LOS algorithm or, alternatively, through commands of advance speed and rudder angle. The missions will be controlled and monitored by the user through a server computer located onshore. If necessary the user can abort the mission at any time. The data obtained by the sensors which are relevant to the user actions will be transmitted via radio by the on board computer (client) to the server. The connection between computers and radios uses TCP/IP communication, making it possible to use standard Ethernet connection for long distance operation, and all data will be stored in the on board computer for posterior analysis. The tests could be performed in lakes, with proper depth and within an area that allows the execution of trajectories without danger of collision.

The sensors used for data acquisition during the first set of tests presented here were an inertial sensor – Crossbow's NAV420 combined GPS Navigation and GPS_Aided AHRS (Attitude and Heading Reference System), and an anemometer. The sensor data was collected in real time by a computer running a MatLab/Simulink Real-Time application developed for this purpose.

DESCRIPTION OF THE EQUIPMENT

The construction of the model hull was made by using balsa wood coated with a 3 mm thick layer of polyester resin. Inside the model, polyester resin was applied and strengthened with fibre glass.

During each manoeuvre the model's heading and advance speed is controlled through the rudder position and propeller rotations, respectively. The propeller shaft is driven by a brushed DC motor mounted on the stern compartment and is excited by a Pulse Width Modulated (PWM) signal. This motor is connected to a transmission gear and the motion is imposed on the propeller shaft through a universal joint. The whole propulsion system consists of the motor, a cardan joint, two shaft adaptors, a shaft, a propeller and specific hardware for its control. Regarding the vehicle's manoeuvring system, this is constituted by a rudder, a shaft, an electric stepper motor and hardware for its control. Figure 2 illustrates the model's manoeuvring actuator system.

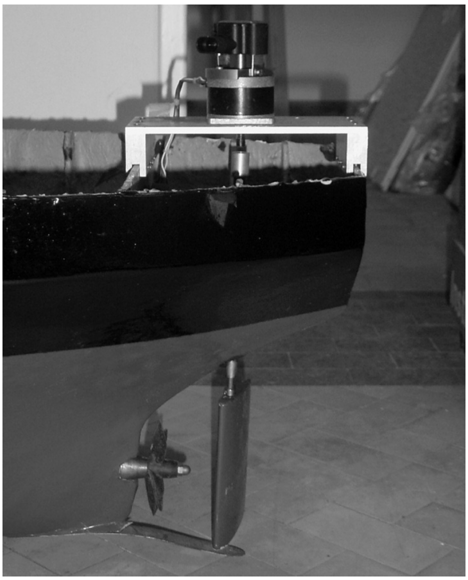

Figure 2: Manoeuvring actuator system of the "Esso Osaka" model.

The system allows the control of the ship model through the components and the respective information flow is represented in Figure 3. The control system architecture and hardware configuration can be seen in this illustration.

To better understand the whole system, each element will be explained separately but always keeping in focus the interactions between each other, namely:

Computer (on shore)

More relevant when the system is used in manual (or remote) mode, that is, the mode in which the command orders are given by the user, making it possible to guide the model through

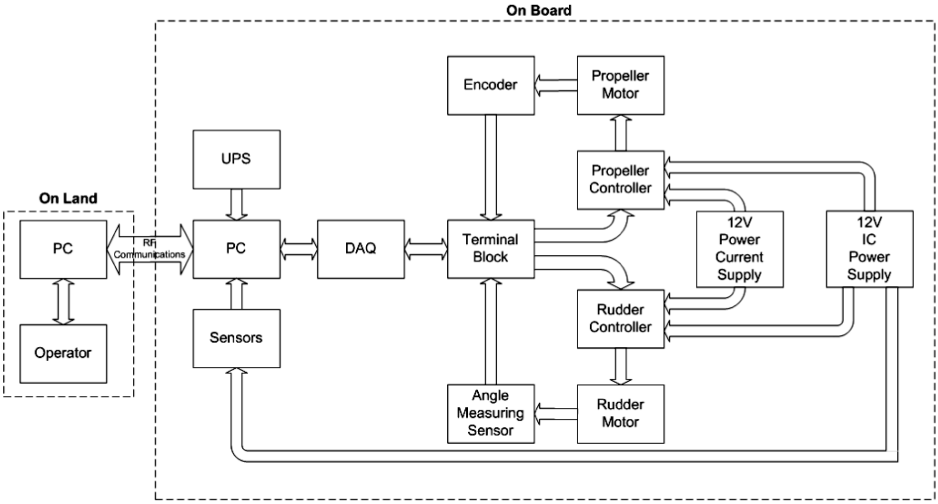

Figure 3: Control system of the "Esso Osaka" tanker model

advance speed and rudder angle orders, according to the intended objectives and paying attention to the sensor information provided on the monitor.

In the automatic guidance mode, the control is performed based on predefined parameters and by two distinct options: either by insertion of the waypoints to follow in a table or, optionally, files with pre-programmed missions (manoeuvres) can be made and uploaded later. In the same way, the files can contain either the waypoints of the trajectory to follow or, alternatively, the rudder and speed command to execute during the manoeuvre. In order to guide the model from land and in any of the working modes a bidirectional communication is established via radio, between the server computer (on shore) and the client (on board).

Computer (on board)

This behaves as a bridge for the computer on shore and supervisor to the low level controllers on board the model. It receives the orders from the computer on shore, processes them, and through the Data Acquisition card (DAQ) and the rest of the hardware, controls the model, also sending, to the computer on shore, relevant information collected by the onboard sensors. It is convenient to notice that this information is recorded on the hard disk of the on board computer.

DAQ

The DAQ card (National Instruments DAQCARD 6024E) is connected to the on board computer and to a terminal block, it performs the A/D and D/A conversion. The desired values (in voltage) for the rudder angle and for the propeller rotations are given through this card. The DAQ has, as input, the signal from the sensors. Its internal clock is used to calculate the propeller rotation speed. This signal comes directly from the encoder optical sensor.

NI Terminal Block

The DAQ card is connected to the microcontrollers responsible for the control of the rudder and propulsion motors through a 68-pin National Instruments digital and trigger I/O terminal block. This accessory allows an easy connection of field I/O signals to the counter/timer devices.

Rudder motor controller

The command signal for the rudder angle, provided by the computer, and the signal of the angle measuring sensor (potentiometer) are compared by the computer on board software in order to control the rudder positioning through the PIC16F877 microcontroller which receives the command order. From this comparison results an error. When either this error is null or it lies within a certain tolerance interval (one step) the rudder motor has reached the desired position. The above mentioned potentiometer is solidary with the rudder stepper motor shaft. Amongst several components, the rudder controller printed circuit board (PCB) has the microcontroller and a stepper driver placed in it.

Propulsion motor controller

The main objective of the PIC18F4620-I/P microcontroller is to control the rotational speed of the propulsion motor by using a PWM signal. This kind of signal and control has the advantage of generating a higher momentum than other solutions. Until the error from the software comparison between the computer command signal for the propeller speed and the encoder signal is null the microcontroller manages to control the propulsion motor in order to achieve the desired rotational speed. Through the terminal block-DAQ the commuter will receive an encoder input signal. This way the DAQ is able to count the impulses by unit time for rps calculation purposes. Amongst several components, the propeller controller PCB has the microcontroller and a MOSFET (Metal Oxide Semiconductor Field Effect Transistor) H-bridge placed on it, allowing two rotational directions.

These boards fully developed for the control system, have other main features, as follows:

- Automatic and manual switching control mode (one pushbutton) and two pushbuttons for manual control;
- Power switch button;
- By default, and as a safety measure, the motors are left in manual control mode;
- Basic hardware debugging possibility (LCD display interface) by the user;
- Motor and IC power LEDs.

Encoder

The encoder coupled to the propulsion motor shaft is constituted by an aluminium disk with 120 teeth and an opto switch (with infrared wavelength). The disk rotation provides a square wave as output of the optical sensor, allowing the counting of the pulses by the DAQ hardware and the rps calculation.

UPS

The Uninterruptible Power Supply (UPS) supplies the on board computer by converting 24V DC into a 220/230V AC modified sine wave.

12 V power supplies

There are two 12V power supplies, one for the motors power supply and the other for the two control boards.

Sensors

The following digital sensors will be used on board the model:

- Crossbow's NAV420 combined GPS Navigation and GPS_Aided AHRS (Attitude and Heading Reference System), which allows one to obtain:

— the vehicle's position coordinates (latitude, longitude, altitude);
— the heading, roll and pitch angles;
— the surge and sway velocities;
— the yaw rate;
— the surge and sway accelerations;

- Anemometer – velocity and direction of the wind.

The sensors listed above are the ones that comprise the navigation system which allows the model of the "Esso Osaka" tanker ship to perform trajectories in an autonomous way. Several successful tests to the equipment were performed on land before going to execute the initial set of experiments in the lake.

SOFTWARE

The existing software, developed both in LabView and MatLab, allows sending the control signals to the microcontrollers, through the NI-DAQ card, needed to control the motion of the rudder and propulsion motors. The architecture is designed to operate using a computer on shore (server) and another on board (client), connected to each other through a wireless network interface. An Extended Kalman Filter (EKF) and a Second Order Filter (SOF) are incorporated in the navigation process which will provide filtered estimates of positions, heading, sway and yaw velocities and advance speed of the vehicle through the data obtained by the sensors. The information acquired and computed on the onboard computer will be transmitted to the server computer on shore through radio modems with Ethernet interface.

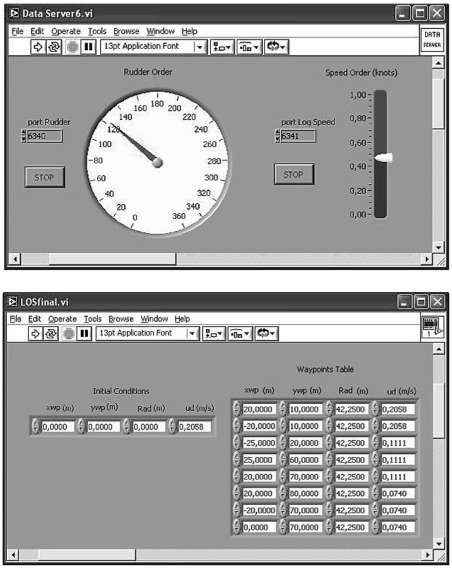

Figure 4: User interface screens for manual command and definition of the trajectory waypoints to be travelled.

As previously mentioned, the behaviour of the vehicle can be determined by the user either through an interface for manual command or through the insertion of the waypoints to be travelled. Optionally, files with preprogrammed missions (manoeuvres) can be uploaded. These files can equally contain either the waypoints of the trajectory to be travelled or, alternatively the rudder and speed commands to be executed during the manoeuvre. Figure 4 illustrates an interface screen of the manual command and a screen with waypoints pre-definition in LabView.

Summarizing, in LabView, the modules with the description of the developed Virtual Instrument files (VIs) which are implemented in the system are the following:

Communications and Manual Command Module

Its function comprises the verification, synchronization and management of the communications between the server computer (on shore) and the client (on board). It is responsible for the transmission of the command orders and monitoring of the outputs acquired by the sensors. The correct establishment of the remote communications is performed through the TCP/IP protocol.

This module contains the software that allows the direct command of the model through the rudder and vehicle's speed orders provided, by the user, through an interface specifically designed for that purpose. The orders given through this model have priority relatively to the ones of the automatic command module. It is also in this model that the VIs allowing acquisition of NMEA codes from the sensors were developed.

Estimation Parameters Module

This module allows the estimation of the values of the parameters either in case of failure in the acquisition of the information provided by the sensors or failure of the sensors themselves.

For this, a VI with an EKF and a SOF was developed in order to estimate positions values (x and y), advance speed (U), sway velocity (v) and yaw rate (r) and heading angle (Ψ) of the model based on the records of these parameters.

Guidance and Manoeuvring Module

This module is responsible by the automatic guidance of the vehicle, either by passing through predefined waypoints or through the execution of manoeuvres following certain pre-programmed rudder and speed orders. The automatic guidance mode comprises two distinct algorithms: a LOS algorithm for the definition of the pre-established trajectory by waypoints, to be followed by the model, and an algorithm of the quadrant correction where the heading angle lies, which is directly related to the previous algorithm.

Control Module

This module contains the code whose function is the direct control of the propeller and rudder, accordingly with the commands received from the server, from the guidance algorithm or from the pre-defined manoeuvres. This module runs on the client computer, on board the model. On it are included the VIs which are responsible by the speed control, heading control, as well as the respective reference models. This module also has a VI that uses the data acquisition (DAQ) card clock to count the number impulses from the encoder, in order to compute the rps of the propulsion motor, and the VI that performs the respective control of the rps.

Recording and Monitoring Module

This module is responsible for the recording of the parameters of interest in text-files and for their monitoring on the server computer screen. It allows the selection of the sampling time in each test. Figure 5 illustrates a scheme of the architecture and system information flow.

Due to the fact that the developed LabView code is interpreted and provided very slow communication timing rates, which were not realistic for the system, and it was not possible to compile that code it was decided to change to a MatLab platform. The LabView code is still valuable when TCP/IP communication is not used as it is the case, for instance, when the tests with the model are performed with one person on board.

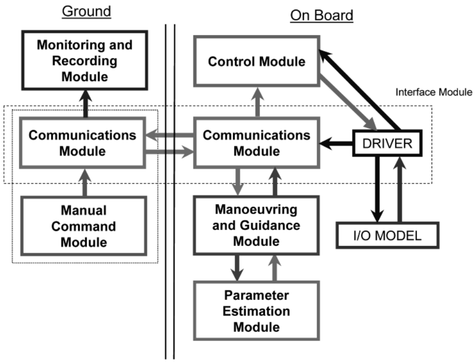

Figure 5: Schematic representation of the architecture and system information flow.

Within MatLab, the Real-Time Windows Target is used, which enables Simulink models to run in real time on desktop or laptop computers for rapid prototyping or hardware-in-the-loop simulation of control system and signal processing algorithms. In this way, a real-time executable with the whole system entirely through Simulink was created and controlled. With the Real-Time Workshop, C code is generated and compiled, and then the real-time execution is started on the Windows-based computer, while interfacing with real hardware using computer I/O boards.

The Real-Time Workshop provides code to implement bidirectional communication based on TCP/IP. Figure 6 shows the structure of the TCP/IP-based implementation. In external mode, Real-Time Workshop establishes a communication link between the model running in Simulink and the code executing on a target system.

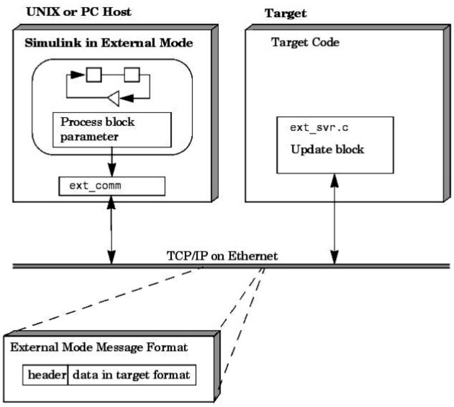

Figure 6: TCP/IP-Based Client/Server implementation for external mode.

The external mode allows the two separate systems – the host and the target – to communicate. The host is the computer where MATLAB and Simulink are executing. The target is the computer where the executable created by Real-Time Workshop runs. The host (Simulink) transmits messages requesting the target to accept parameter changes or to upload signal data. The target responds by executing the request. External mode communication is based on a client/server architecture, in which Simulink is the client and the target is the server. External mode allows modifying, or tuning, the block parameters in real time. In external mode, whenever the parameters are changed in the block diagram, Simulink automatically downloads them to the executing target program. This allows tuning of the parameters of the program without recompiling. In external mode, the Simulink model becomes a graphical front end to the target program.

It is possible to view and log block outputs in many types of blocks and subsystems. Signal data from the executing target program can be monitored and/or stored, without writing special interface code. Also, the conditions under which data is uploaded from target to host can be defined. For example, data uploading could be triggered by a selected signal zero upcrossing. Alternatively, data uploading can be triggered manually. External mode works by establishing a communication channel between Simulink and the code generated by Real-Time Workshop. This channel is implemented by a low-level transport layer that handles physical transmission of messages. Both Simulink and the generated model code are independent of this layer. The transport layer and the code directly interfacing with the transport layer are isolated in separate modules that format, transmit, receive messages and data packages. The Real-Time Windows Target implements external mode communication via shared memory.

DESCRIPTION OF THE MANOEUVRING TESTS

A photo of the model used in the experiments is shown in Figure 7. The main particulars of the tanker model "Esso Osaka" are presented in Table 1. The propulsion system of the real tanker consists of a single shaft arrangement with fix pitch propeller, driven through a reduction gear, by a diesel engine. In the model the diesel engine is substituted by an electric motor. The rudder of the model was built based on a NACA 0015 airfoil.

Figure 7: Photo of "Esso Osaka" model during the manoeuvring tests.

"Esso Osaka" Model	
Length overall	3.430 m
Length between perpendiculars	3.250 m
Breadth	0.530 m
Depth	0.283 m
Draft (estimated at trials)	0.063 m
Block coefficient	0.831
Number of rudders	1
Displacement (estimated at trials)	90.18 kg
Rudder Area	0.0120 m^2
Propeller Area	0.0065 m^2
Longitudinal CG (fw of midship)	0.103 m

Table 1: Esso Osaka model particulars.

The first set of manoeuvring tests with the "Esso Osaka" model was carried out during one day on the "Estufa Fria" lake, in the centre of Lisbon. The weather conditions were good. The absolute wind speed was varying between 0 and 4 knots (wind force between 0 and 2 in the Beaufort scale).

The manoeuvres performed in manual mode were the turning circles and several trajectories were performed in automatic mode.

Altogether 9 test runs were executed with "Esso Osaka" model. As a result, 3 turning circles (1 was aborted), and 5 automatic trajectories were considered suitable data for analysis.

#	Parameter	Unit	Measuring tool	Range	Estimated uncertainty
1	Geographical Coordinates	m	Inertial Sensor	—	± 3
2	Surge and sway velocities	m/s	Inertial Sensor	—	< 0.4
3	Roll and pitch angles	degs	Inertial Sensor	± 180, ± 90	< 0.75
4	Heading angle	deg	Inertial Sensor	± 180	< 3
5	Yaw rate	deg/s	Inertial Sensor	± 200	< ± 0.1
6	Rel. Wind speed	knots	Anemometer	0 –60	± 2
7	Rel. Wind Direction	deg	Anemometer	± 180	± 5

Table 2: Measured parameters.

Measurement and registration of the kinematical parameters listed in Table 2 were envisaged and all parameters indicated in the table were measured during the tests. The uncertainty estimates are approximate and were obtained from the instruments documentation.

The inertial sensor unit generated instantaneous ship coordinates, latitude φ and longitude λ. These were transformed to the standard Cartesian Earth coordinates of the ship's origin, x_{eC} and y_{eC} (Figure 8), coinciding with the location of the sensor antenna, placed in the ship centre plane, near the midship plane by:

$$\begin{aligned} x_{eC} &= x_{eC0} + \kappa(\varphi - \varphi_0), \\ y_{eC} &= y_{eC0} + \kappa(\lambda - \lambda_0)\cos\varphi_0, \end{aligned} \tag{1}$$

where the subscript '0' denotes the initial values of the corresponding variables and κ is the conversion coefficient equal to 1852m/arc.min. After this initial transformation the coordinate x_e is supposed to be measured along the true meridian while y_e is along the parallel. However, when analyzing the trajectories the coordinates were transformed further so that the origin of the Earth axes matches the ship's position at the start of a manoeuvre and the X_e-axis is directed along the approach path.

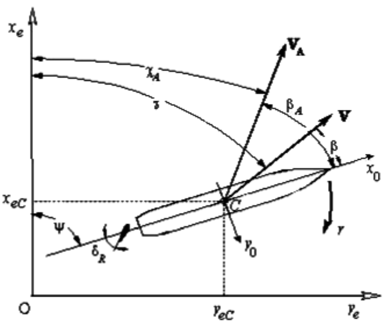

Figure 8: Definition of kinematical parameters (all shown quantities are positive)

The recording and simulation sampling time was equal to 0.1 second for all the instruments that comprise the system.

The relative wind speed V_A=$|\mathbf{V_A}|$ and the wind drift angle β_A (relative wind speed) were measured directly with an anemometer.

The MatLab/Simulink software stores the collected data in the ".mat" format (in workspace) and it is transformed to in ".txt" format (text) with the post processing software.

ANALYSIS OF TESTS RESULTS

In this section the results of the are presented. In manual mode three time histories of turning circles are presented. In automatic mode the plots of time histories of the five trajectories performed are shown.

Manual Mode

Figure 9 presents the time histories for a turning manoeuvre of the model with an average speed of 0.7 knots and rudder angle of 30 degrees. Also presented is the speed estimated time history computed using the EKF.

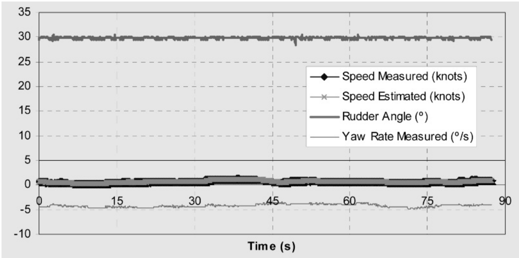

Figure 9: Turning 30º (≈ 85% Full), average speed 0.7 kn.

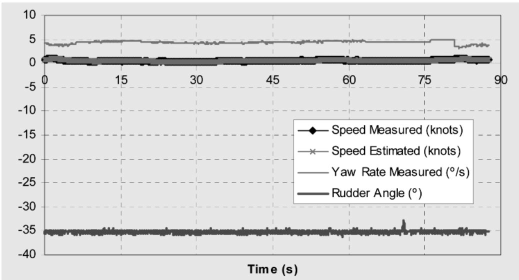

Figure 10: Turning 35º (Full), average speed 0.54 kn.

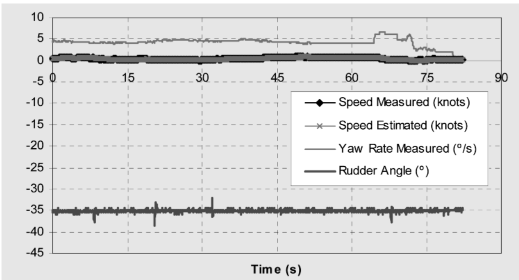

Figure 11: Turning 35º (Full), average speed 0.42 kn.

Figure 10 presents the time histories for other turning manoeuvre of the model with an average speed of 0.54 knots and rudder angle of -35 degrees.

Figure 11 presents the time histories for the last turning manoeuvre of the model with an average speed of 0.42 knots and rudder angle of -35 degrees.

Notice that in Figures 9-11 the speed measured (dark) and speed estimated (light) are approximately superimposed. From these figures the good performance of the heading and speed controllers can be verified. The results confirmed the system performance characteristics previously acquired from simulations.

Automatic Mode

The first, second, third, fourth and fifth desired paths will consist of a total of 7, 7, 5, 8 and 7 way-points, respectively, as given in Table 3:

1st and 2nd trajectories:	3rd trajectory:	4th trajectory:	5th trajectory:
$Wpt_1 = (0, 0)$ m	$Wpt_1 = (0, 0)$ m	$Wpt_1 = (0, 0)$ m	$Wpt_1 = (0, 0)$ m
$Wpt_2 = (0, 5)$ m	$Wpt_2 = (5, 0)$ m	$Wpt_2 = (-1.5, 1.5)$ m	$Wpt_2 = (-1.5, 0)$ m
$Wpt_3 = (-2.5, 12.5)$ m	$Wpt_3 = (6, 2.5)$ m	$Wpt_3 = (-3, 3)$ m	$Wpt_3 = (-3, 0)$ m
$Wpt_4 = (-5, 17.5)$ m	$Wpt_4 = (7.5, 5)$ m	$Wpt_4 = (-4, 4)$ m	$Wpt_4 = (-4, 0)$ m
$Wpt_5 = (-10, 20)$ m	$Wpt_5 = (12.5, 10)$ m	$Wpt_5 = (-5, 5)$ m	$Wpt_5 = (-5, 0)$ m
$Wpt_6 = (-20, 17.5)$ m		$Wpt_6 = (-6, 6)$ m	$Wpt_6 = (-6, 0)$ m
$Wpt_7 = (-20, 5)$ m		$Wpt_7 = (-8, 8)$ m	$Wpt_7 = (-8, 0)$ m
		$Wpt_8 = (-10, 10)$ m	

Table 3: Way-points of the desired paths.

The ship's initial states for the trajectories are:

$(x_0, y_0, \Psi_0) = (0\text{ m}, 0\text{ m}, 0\text{ rad})$ for the 1st, 2nd and 4th trajectories;
$(x_0, y_0, \Psi_0) = (0\text{ m}, 0\text{ m}, 2\text{ rad})$ for the 3rd trajectory;
$(x_0, y_0, \Psi_0) = (0\text{ m}, 0\text{ m}, -3\text{ rad})$ for the 5th trajectory;
$(u_0, v_0, r_0) = (0.23\text{ m/s}, 0\text{ m/s}, 0\text{ rad/s})$ for all the trajectories.

The desired speed is kept constant along the fifth trajectory with a value of 0.21 m/s, that corresponds to a Froude number F_n equal to 0.0372. From the first up to the fourth paths the desired speed will be considered as follows:

$$r^b = \begin{cases} 0.05\,\text{m/s} \;\; (F_n = 0.0089) & if \quad t_1 < t < t_3 \\ 0.38\,\text{m/s} \;\; (F_n = 0.0673) & if \quad t_3 \le t < t_5 \\ 0.12\,\text{m/s} \;\; (F_n = 0.0213) & if \quad t_5 \le t < t_6 \\ 0.23\,\text{m/s} \;\; (F_n = 0.0407) & if \quad t_6 \le t \le t_7 \end{cases} \quad \text{for the 1}^{\text{st}} \text{ trajectory ;}$$

$$r^b = \begin{cases} 0.13\,\text{m/s} \;\; (F_n = 0.0230) & if \quad t_1 < t \le t_4 \\ 0.46\,\text{m/s} \;\; (F_n = 0.0815) & if \quad t_4 < t \le t_6 \\ 0.16\,\text{m/s} \;\; (F_n = 0.0283) & if \quad t_6 < t \le t_7 \end{cases} \quad \text{for the 2}^{\text{nd}} \text{ trajectory ;}$$

$$r^b = \begin{cases} 0.53\,\text{m/s} \;\; (F_n = 0.0939) & if \quad t_1 < t \le t_2 \\ 0.15\,\text{m/s} \;\; (F_n = 0.0266) & if \quad t_2 < t \le t_4 \\ 0.01\,\text{m/s} \;\; (F_n = 0.0018) & if \quad t_4 < t \le t_5 \end{cases} \quad \text{for the 3}^{\text{rd}} \text{ trajectory ;}$$

and

$$r^b = \begin{cases} 0.13\,\text{m/s} \;\; (F_n = 0.0230) & if \quad t_1 < t \le t_2 \\ 0.16\,\text{m/s} \;\; (F_n = 0.0283) & if \quad t_2 < t \le t_5 \\ 0.18\,\text{m/s} \;\; (F_n = 0.0319) & if \quad t_5 < t \le t_8 \end{cases} \quad \text{for the 4}^{\text{th}} \text{ trajectory .}$$

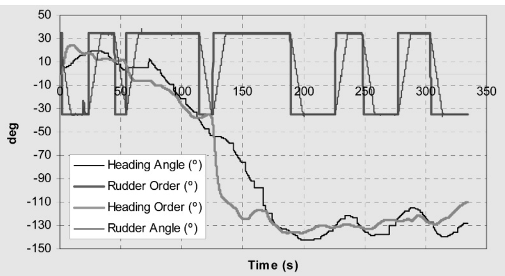

Figure 12: Time histories trajectory 1.

For all trajectories the radius of acceptance for all way-points was set to two ship lengths ($R_0 = 2L_{pp}$).

Figures 12 up to 16 show the time histories of heading and rudder angles and respective command orders.

Figures 12-16 show the good performance of the LOS algorithm

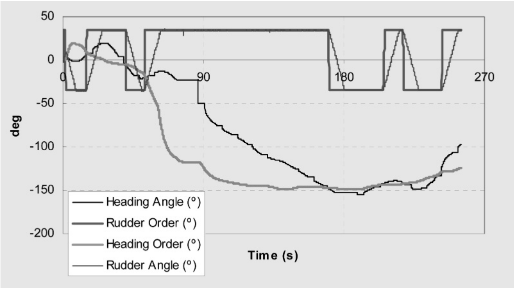

Figure 13: Time histories trajectory 2

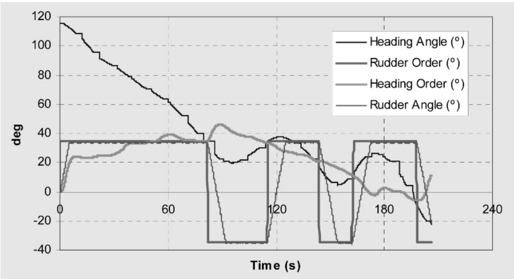

Figure 14: Time histories trajectory 3.

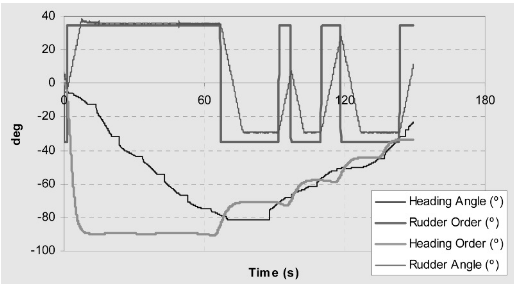

Figure 15: Time histories trajectory 4.

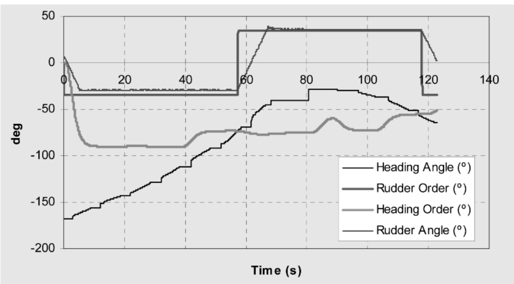

Figure 16: Time histories trajectory 5.

and the heading and speed controllers. With the results of these experiments in automatic mode in addition to the ones performed in manual mode one can say that the first set of the "Esso Osaka" tanker model manoeuvring tests were performed successfully and have shown the validity of the control, guidance and navigation systems.

FINAL REMARKS AND CONCLUSIONS

The control, navigation and guidance system of the "Esso Osaka" tanker model was described which allows it to perform trajectories in an autonomous way. An architecture was described that allows the vehicle to receive commands from a computer on shore to the one on board, using TCP/IP network communication. The vehicle is able to control its heading and advance speed, both through manual commands or through pre-programmed missions.

After the manoeuvring tests performed in calm waters, some conclusions may be drawn:

The results confirmed the system performance characteristics previously acquired from simulations. The guidance, control and observer systems have shown to work satisfactorily except the loss of accuracy in the measurements at low speeds and the presence of environmental disturbances.The first set of the "manoeuvring tests were performed successfully and have shown the validity of the control, guidance and navigation. In future tests the data obtained can safely be used for the identification, simulation and validation of the model manoeuvring mathematical model.

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The experiments with the "Esso Osaka" model were not possible without the collaboration of Mrs. Alexandra Canha, from the Lisbon City Council, who allowed the realization of the manoeuvring tests in the "Estufa Fria" lake. We are especially grateful to her and the rest of the staff for all the support and availability given to our team in the preparation and execution of the tests. Also, thanks to Ricardo Pascoal, Fernando Santos, António Paço, João Pessoa and Filipe Pedroso for the help given during the experiments. The first author has been financed by the Portuguese Foundation for Science and Technology (Fundação para a Ciência e Tecnologia) under contract number SFRH/BPD/48088/2008.

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USER INTERFACE ORIENTED TO THE SPECIFICATION OF UNDERWATER ROBOTIC INTERVENTIONS

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ABSTRACT

This paper presents our recent work in a graphical user interface (GUI) oriented to specify a robot intervention mission in underwater environments. The complete mission is divided in two phases: the survey and the intervention. The GUI helps the user to set the survey area and identify the target by using images compiled by the I-AUV (Autonomous Underwater Vehicle for Intervention) in the survey phase. Some GUI implementation details and their facilities, which assist assisting the user in the required specification of underwater intervention missions will be addressed. Finally a short description of the simulator, currently under development, will be described. Furthermore, preliminary simulation results will be shown, demonstrating the viability of the survey mission specified by the user through an available I-AUV.

Key Words: Graphical User Interface, Autonomous Underwater Vehicle for Intervention (I-AUV), underwater task specification, user assistance, object recovery.

INTRODUCTION

Nowadays a relevant number of field operations with unmanned underwater vehicles (UUVs) in applications such as marine rescue, marine science and the offshore industries, to mention some but a few, need intervention capabilities in order to undertake the desired task. In the offshore industry, UUVs have to dock to an under-

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water panel to manipulate valves with their robotic arms. It is of interest, for marine scientists, to further develop the capability of accurate deploy and recover specialized instrumentation. In the context of the permanent observatories currently under design and development, the intervention capability for maintenance operations will be of vital importance. Interventions in marine rescue, are needed for instance to tighter ropes to wrecks for towing or recovery.

Currently, most of the intervention operations are being undertaken by manned submersibles endowed with robotic arms or by Remotely Operated Vehicles (ROVs). Manned submersibles have the advantage of placing the operator in the field of operation with direct view to the object being manipulated. Their drawbacks are the reduced time for operation (e.g. a few hours), the human presence in a dangerous and hostile environment, and a very high cost associated with the need of an expensive oceanographic vessel to be operated. Work class ROVs, are probably the more standard technology for deep intervention. They can be remotely operated for days without problems. Nevertheless, they still need an expensive oceanographic vessel with a heavy crane and automatic Tether Management System (TMS) and a Dynamic Position system (DP). It is also worth mentioning the cognitive fatigue of the operator who has to take care of the umbilical and the ROV while cooperating with the operator of the robotic arms. For all these reasons, very recently some researchers have started to think about the natural evolution of the intervention ROV, the Intervention Autonomous Underwater Vehicle (I-AUV). Without the need for the TMS and the DP, light I-AUVs could theoretically be operated from cheap vessels of opportunity reducing considerably the cost. With the fast development of batteries technology, and the operator being removed from the control loop, we can even think about intervention operations lasting for several days, where the ship is only needed the first and the last day for launching and recovering operations (Trident, 2010) But this fascinating scenario, where I-AUVs are launched to do the work autonomously before recovery, comes at the cost of endowing the robot with the intelligence needed to keep the operator out of the control loop. Although standard AUVs are also operated without human intervention, they are constrained to survey operations, commonly flying at a safe altitude with respect to the ocean bottom while logging data. I- AUVs must be operated in the close proximity of the seabed or artificial structures. Therefore, they have to be able to identify the objects of interest (i.e. for manipulation purpose) and the intervention tasks to be undertaken, while safely moving within a cluttered area of work.

Aim of the project

This work is part of two coordinated projects, RAUVI (Spanish national project) and TRIDENT (European Commission FP7). The main goal of these projects is to develop and improve the necessary technologies that will allow an I-AUV to autonomously perform an intervention mission in underwater environments.

In the RAUVI/ TRIDENT projects an intervention mission is divided in two phases: the survey and the intervention (see Figure 1). The GUI presented in this paper plays a significant role in these two steps. It is in charge of assisting the user in all the tasks related with the specification of the mission. The main advantages of the GUI are its friendly use and the low requirements of user expertise.

Figure 1: The different phases of the RAUVI/ TRIDENT projects and the role of the GUI.

In the first phase, the user specifies the survey area. The robot deploys (1), performs the survey task (2) and finally, the robot surfaces (3). In the second phase, after acquiring the images taken on the survey, the user can identify the Target of Interest (ToI) and select what kind of intervention should be performed. The robot deploys again (4), searches the ToI (5), performs the intervention (6) and docks again into the vessel platform (7).

State-of-the-Art

The I-AUV concept appears as the evolution of the AUV and the need to perform some kind of task along the mission. Most of the pioneering works relied on numerical simulations of the coupled dynamics of both systems, the coordinated control of the vehicle and the manipulator system. Some of these first robots were the ODIN AUV at University of Hawaii (Choi et al., 1993), the OTTER AUV (MBARI) (Wang et al., 1996) and the VORTEX/PA10 robot within the UNION European project (Rigaud et al., 1998).

During the mid 90s, AMADEUS EU project (Bono et al., 1998) represented a step forward in the field of dexterous underwater manipulation. It included within its objectives the realization of a set-up composed of two 7-DOF ANSALDO manipulators to be used in cooperative mode. After this period, researchers proposed new concepts to avoid the complexity of the coupled motion of the vehicle-manipulator system in order to achieve true field operations in open sea conditions. In 2001, Cybernetix tested its hybrid AUV/ROV prototype with the SWIMMER project (Evans et al., 2001a). In this case, an autonomous shuttle (an AUV) carrying a ROV, is launched from a support vessel to autonomously navigate and dock into an underwater docking station in an offshore infrastructure. The docking station provides a connection to the AUV and from it to the ROV, without the need of a heavy umbilical. The ALIVE (EU) (Evans et al., 2001b) project is a 4 DOF I- AUV with a 7 DOF manipulator which has shown its capability of autonomous navigation towards a position nearby an underwater intervention panel, detection of the panel using an imaging sonar and finally, approach and docking to the panel with the help of a vision system and two hydraulic grabs. Once the AUV is grabbed to the panel, and assuming the panel is known, the manipulation is a simple task. ALIVE's project was complemented with the European Research and Training (RTN) network FREESUB devoted to the fundamental research on areas like the Navigation, Guidance, Control, Tele-Manipulation and Docking needed to further develop the I-AUVs.

Probably the most advanced I-AUV is the one developed on the SAUVIM project (USA) (Yuh et al., 1998)(Marani, 2009), which is an AUV with a 7 DOF electrically driven arm (ANSALDO), the same used in the AMADEUS EU project, which is intended to recover objects from the seafloor using dexterous manipulation. One of the most noticeable aspects is the increasing amount of information exchanged between the system and the human supervisor. The user makes use of the Sauvim Programming Language (SPL) for writing in a console high-level information (e.g. "unplug the connector") for a particular mission.

Structure of the paper

This paper is structured as follows: Section 2 presents the graphical user interface, and describes in detail the facilities included in order to specify an underwater intervention mission. Section 3 briefly describes the integration of the GUI with the rest of the software architecture. Section 4 shows the use of the GUI with a simulated survey and intervention task. Finally, Section 5 concludes the paper.

THE GRAPHICAL USER INTERFACE

Usually, Remotely Operated Vehicles (ROVs) are controlled within master/slave architectures by pilots, who have to be experts in the particular task and the specific robot (see Figure 2 for an example). The main drawback in this kind of systems, apart from the necessary degree of expertise among the pilots, concerns the cognitive fatigue inherent to master/slave control architectures (Sheridan, 1992).

In order to improve this situation, our main goal is to develop a new GUI that does not require expert users with a high level of technical knowledge for its use. A description of the proposed GUI is given in the following.

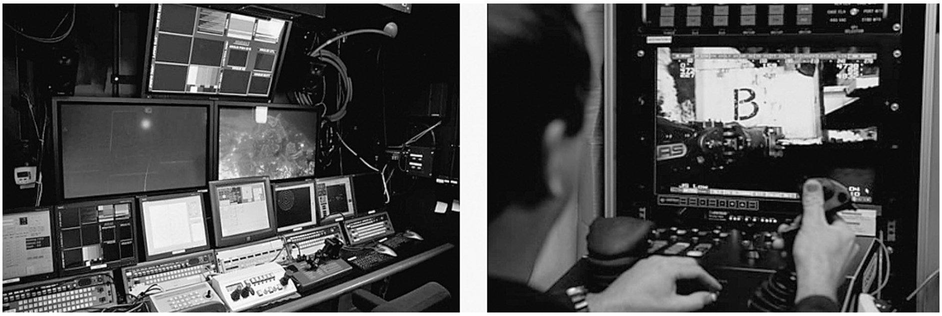

Figure 2: usual ROV resources and ROV pilot GUI.

Input characterization

The initial input compiled in the survey mission will always be different to the final conditions arising during the intervention mission, due to the fact that the underwater scenario provides a hostile and very changing environment. In this way, an intuitive GUI is very important to help the user specify the survey and the final intervention missions. Some of the images used along the GUI development can be observed in Figure 3.

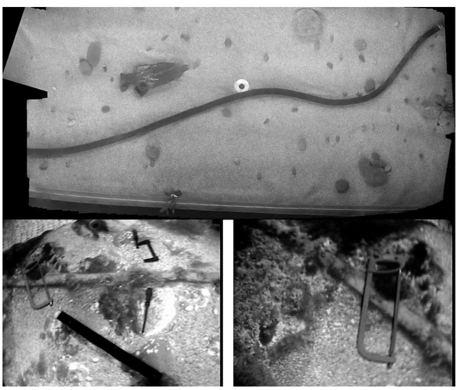

Figure 3: real mosaics, which have been taken by different AUVs.

The University of Girona AUV obtained the Figure 3-above in a real scenario, while the University of the Balearic Islands AUV obtained the Figure 3-below using real tools on a photo-mosaic. As we can observe, the quality of the images varies significantly, depending on the scenario and the robot used. So, the GUI should have different tools that allow the user to perform the mission successfully.

GUI features

When the user runs the GUI, it gets a clear interface where there are only few buttons enabled. These buttons are the "Predefined Intervention Task", "Open an image" or "Connect to the simulator".

Although Figure 4 shows different types of interventions, currently only the "Survey" and the "Object Recovery" task are available. We expect to implement the rest of the tasks in the future.

Depending on the user selection, a panel with task options is enabled. In this panel, the user can find different parameters that allow modification of the default behaviour. This panel can be observed in Figure 5.

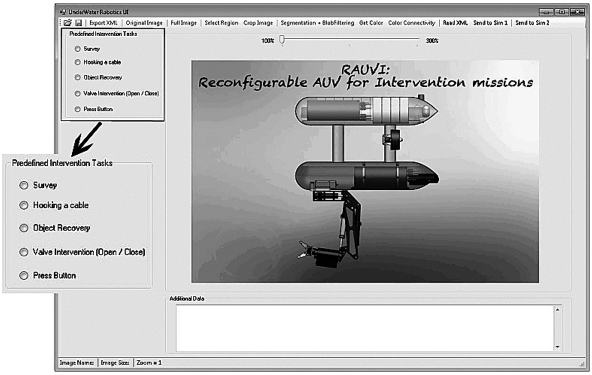

Figure 4: initial GUI appearance.

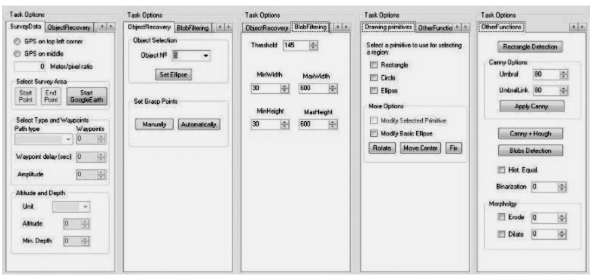

Figure 5: "Task O ptions" panels, more options for the user.

The GUI output is a XML file that contains the relevant information for performing the mission. The beginning of the file is the same for all the interventions, containing information related to the photo used and the type of intervention. The rest of the file depends on the type of intervention. In a Survey intervention, this section contains a list of waypoints and other relevant data, but in an Object Recovery intervention, this section contains information about the target: size, orientation, position and grasp points (fig. 6).

Defining a "Survey" task

For the first phase of the mission (the survey) the GUI offers the user two possibilities: use GoogleEarth or load a map. The use of GoogleEarth provides the user with some advantages: the maps are always up-to-date by Google, so there is no work for the user; it is a free service; the user can customize the selected view with more detailed data or add images into the map; the user can store information and maps for using it in offline mode. On the other hand, there are few drawbacks: an Internet connection is needed and it does not work properly if the area of interest is too small. We are still trying to get all the benefits of this feature, which is under development (fig. 7).

If the user has a custom map, it can also be opened into the GUI. For specifying the survey area, the user selects the initial and final point of the survey. Then, in the Task Options panel, the user selects what type of path the robot has to follow: either a one-way trip, return trip or sinusoidal trip. Depending on this selection, the user indicates some specific parameters such as the amplitude of the sinusoidal path, the altitude and depth, and so on. Forthcoming developments, a more realistic path planner will be included (Garau et al., 2009).

In order to finish the mission specification, the user can export all the data to a XML file or simulate the mission in our simulator, which will be detailed in Section 4.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<Root>
  <Image>
    <ImagePath>E:\Maps\map1.png</ImagePath>
    <ImageWidth>791</ImageWidth>
    <ImageHeight>445</ImageHeight>
  </Image>
  <Intervention>
    <Type>Survey</Type>
  </Intervention>
  <StartPoint>
    <xPoint>324</xPoint>
    <yPoint>126</yPoint>
  </StartPoint>
  <WaypointsList>
    <Waypoint1>
      <xPoint>376</xPoint>
      <yPoint>188,4</yPoint>
    </Waypoint1>
    …
<UserOptions>
    <GpsOnTop>GpsOnTop</GpsOnTop>
    <PixelRatio>0,91</PixelRatio>
    <WaypointDelay>60</WaypointDelay>
    <Unit>Meter</Unit>
    …
```

Figure 6: XML file example.

Defining an "Object Recovery" task

We assume that once the robot has finished the first phase (the survey), the robot has got a mosaic of the seabed. The user can load this mosaic into the GUI and navigate through it until finding the Target of Interest (ToI) (fig. 8).

The mosaics can vary a lot depending on multiple parameters. Algorithms that work well with one mosaic, may fail when applied to other mosaics due to different visibility conditions, different backgrounds, etc. For this reason, the GUI offers the user three different types of use, where the system autonomy increases as the user responsibility decreases. Further information can be found in (Garcia et al., 2010a).

Mode 1: when the user clicks on the ToI, the GUI gets the greyscale colour of that point and uses this value as starting threshold value to segment the scene. Then, the algorithm processes the image identifying all the blobs detected and the GUI shows the blobs that fit within a size range set by the user. If the ToI is smaller than the size threshold, it is not shown. In this case the user can modify the blob filtering parameters until the ToI is found. This is the lowest-level interaction mode for the user.

Mode 2: the user selects one point of the ToI and the GUI applies a colour connectivity algorithm to get all the colour pixels with a similar RGB colour value. Then, the GUI will show a blob containing that area.

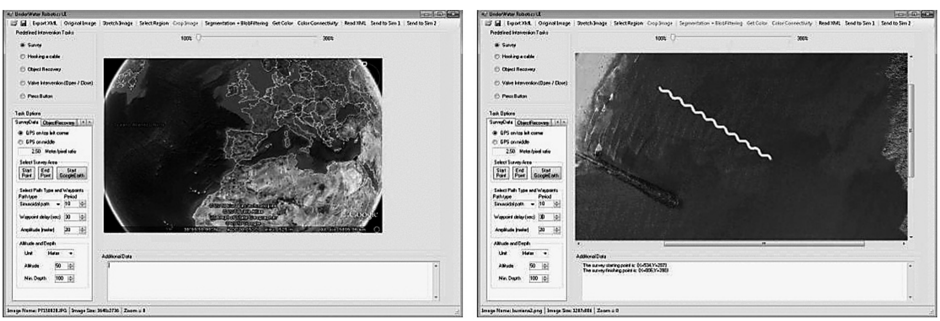

Figure 7: different ways to specify a "Survey" mission: using GoogleEarth or using a map.

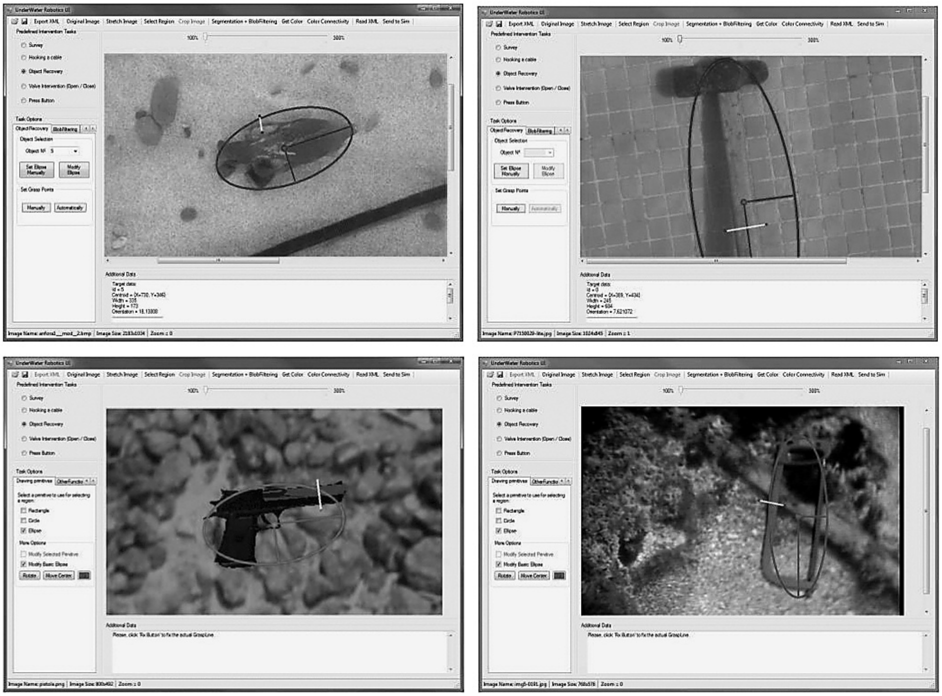

Figure 8: Target of Interest identified, selected and grasping points defined manually.

Once the user has identified the target, the user selects its identifier number in the Task Options panel. Then, automatically, the GUI prints an ellipse over the ToI. This ellipse follows the *best fitting ellipse principle*, which gets the object length and width, as well as object centroid and orientation.

Finally, the last user interaction mode:

Mode 3: the user draws the ellipse directly on the ToI. This is the lowest system autonomy mode, so the user has all the responsibility.

Regardless of the mode, the user always gets an ellipse on the ToI. This moment is called "Target Selection". If the ellipse does not correctly match with the object centroid and orientation, the user can manually adjust them using specific methods.

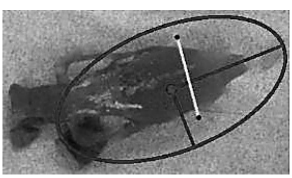

Figure 9: grasping points defined manually by the user.

We are currently focusing our research on an "Object Recovery" intervention mission. In order to select the grasping points, the user has two possibilities:

— Drawing a line, where the extreme points represent the grasping points (Figure 9).

—Running a function. This function searches the first point placed out of the blob, starting on the centroid and following the ellipse minor axis in both direc-

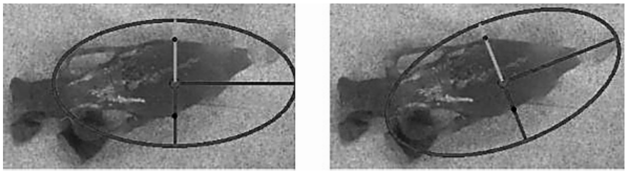

Figure 10: grasping points defined automatically.

tions. When the function detects this point, it stops and marks the point as grasping point (see Figure 10).

After marking the grasping points, the user can export the intervention mission in a XML file and the specification process finishes.

ARCHITECTUR E INTEGRATION

The project architecture is distributed and has four main nodes: the GUI, the Mission Control System (MCS), the Architecture Abstraction Layer (AAL) and the real robot and simulator architectures. The MCS is the central node: it transforms the GUI XML file into the Mission Control Language, creates a Petri net for the mission, and uses the AAL for sending actions and events to the architectures. At the lowest level, the control signals can be sent to either the real robot or a simulated one. This allows using the same GUI and control algorithms independently of the low-level layer. Further information about this can be found in (Palomeras et al., 2010).

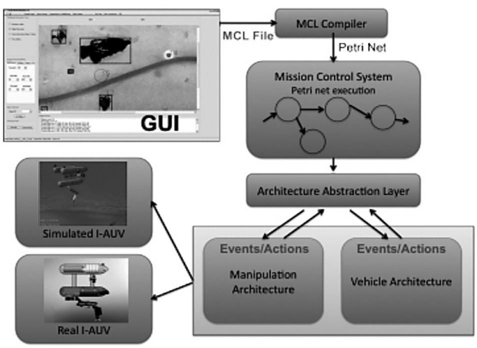

Figure 11: general diagram of the software architecture.

A MISSION SIMULATION

In order to validate the GUI and the control algorithms, a simulated underwater environment has been developed. It has been implemented in C++ on top of the OpenSceneGraph libraries (OpenSceneGraph, 2010) and osgOcean nodekit for OpenSceneGraph (osgOcean, 2010). This allows visualizing underwater effects like silt, light attenuation, water distortion, etc. More specifically, the simulation environment includes:

— The I-AUV 3D model, including both the vehicle and the arm. Arm kinematics have also been implemented, thus allowing the movement of the arm joints.

— A virtual camera attached to the bottom of the vehicle and looking downwards. Another virtual camera has been attached to the wrist of the arm. These cameras capture images of the seabed in real-time.

— A lamp, placed on the bottom part of the vehicle and pointing towards the floor.
— A seabed model including a texture.
—Different object models that can be placed on the seabed.

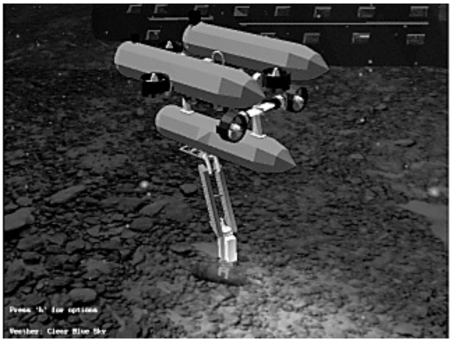

Figure 12: a screenshot of our developed underwater simulator, where an I-AUV grasps an amphora according to the user specification on the GUI.

The simulator has been implemented as a network server, where other software modules can be connected in order to update the pose of the vehicle-arm, or to receive input from sensors like joint odometry or images from the virtual cameras. This allows using it as a mere visualizer, where the actual control algorithms are not part of the simulator, but external to it, and can be interfaced to the real robot without modification. This leads to more realistic simulations. In fact, the simulator is external to the control architecture and interfaced to it in the same way the real robot is interfaced (see Figure 11). This enables the user to switch easily between the real robot and the simulated one without modifying the rest of modules.

Control algorithms in the software architecture take as input the XML file generated by the GUI, and provide control signals to the vehicle and arm (either real or simulated) in order to perform survey and intervention.

In the particular case of survey simulation, the vehicle path, specified in pixel units in the GUI, must be transformed into 3D coordinates given with respect to the origin frame of the simulated environment. Given an image waypoint in pixel units:

$$p_i = (p_x, p_y) \tag{1}$$

its 3D homoge neous coordinates with respect to frame I (see Figure 13), are given by:

$$^{I}P_i = \left(\frac{Z \cdot p_x}{f_x}, \frac{Z \cdot p_y}{f_y}, 0, 1 \right) \tag{2}$$

where Z/f_x and Z/f_y are the meter/pixel ratio of the image on the horizontal and vertical directions. Having the frame I expressed with respect to a global positioning reference system, G, by the homogeneous transformation matrix $^{G}M_{I}$, and a local reference system M used for the survey (in simulation M corresponds to the origin of the simulated world), also given with respect to G by ${}^{G}M_{M}$, the point p_i can be transformed to the local reference frame as:

$$ {}^{M}P_i = \left({}^{G}M_M\right)^{(-1)} \cdot {}^{G}M_I \cdot {}^{I}P_i \tag{3} $$

In the particular case of the sinusoidal path used in the GUI for survey specification, the curve is sampled at regular intervals and each image waypoint is transformed into the 3D frame where the vehicle is localized (M) as mentioned above. These 3D points are sent to the vehicle navigation module that performs the vehicle control. After doing the survey, the ToI is detected and a grasp is specified using the GUI. Figure 12 shows a grasp performed on the simulated environment, taking as input the user specification on the GUI.

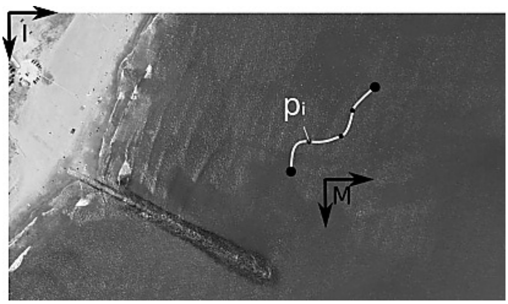

Figure 13: all the different reference systems in a "Survey" mission.

CONCLUSION

We have developed a user-friendly GUI for autonomous underwater intervention missions specification. The GUI is used for indicating a survey area, identifying the target object and specifying a suitable intervention task, in the context of the Spanish and European research projects RAUVI and TRIDENT.

We have focused our GUI on the user requirements. Our approach differs from other solutions in the little need of user experience. In fact, the user does not need to learn a specific language to manage the GUI and does not require a long previous experience in the field.

Future work

Future work will be mainly focused on enhancing the human-robot interaction, using different types of Virtual and Augmented Reality devices and techniques. Currently, our work is focused on nVidia 3D, which allows the user to have a 3D experience with low hardware requirements and costs.

Furthermore, there is still more work to do related with GUI features, such as adding more functions to the GoogleEarth integration or adding new types of intervention (i.e. hooking a cable, pressing a button…).

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INTERFAZ GRÁFICA DE USUARIO ORIENTADA A LA ESPECIFICACIÓN DE UNA MISIÓN DE INTERVENCIÓN PARA UN ROBOT EN ENTORNOS SUBMARINOS

RESUMEN

El presente artículo muestra nuestro reciente trabajo de una interfaz gráfica de usuario orientada a la especificación de una misión de intervención para un robot en entornos submarinos. La misión se divide en dos fases: el reconocimiento y la intervención. La interfaz asiste al usuario estableciendo el área de reconocimiento e identificando el objetivo, usando las imágenes compiladas por el I-AUV (Vehículo Autónomo Submarino para Intervención) en la fase de reconocimiento. A continuación, se detallarán algunos detalles de implementación de la interfaz, así como sus facilidades para la asistencia al usuario en la especificación de las tareas de misiones de intervención submarinas. Finalmente, se describirá brevemente el simulador bajo desarrollo.

METODOLOGÍA

Actualmente, los sistemas de intervención submarina más comunes son los sistemas Vehículo Operado Remotamente (ROV), que mediante una arquitectura maestro/esclavo se operan por un piloto de ROV altamente cualificado. Estos sistemas requieren de una gran cantidad de recursos, desde grandes buques oceanográficos, cables umbilicales, grandes salas para el control de los mismos, etc. Además, toda la responsabilidad de la intervención recae sobre el usuario, que debe ser un experto tanto en el robot como en el tipo de intervención a realizar. Desde los proyectos de investigación español y europeo RAUVI y TRIDENT, se pretende desarrollar y mejorar las tecnologías necesarias que haciendo uso de un Vehículo Autónomo Submarino para Intervención (I-AUV) se consigan realizar satisfactoriamente tareas de intervención.

Uno de los nodos dentro de la arquitectura de ambos proyectos es la interfaz gráfica de usuario (GUI), mediante la cual, se podrán establecer cada una de las dos fases en las que consta una intervención: la fase de reconocimiento y la fase de intervención. Para la fase de reconocimiento, el usuario tiene a su disposición dos métodos distintos, que son el uso de GoogleEarth, que aún está en fase de desarrollo, o bien cargar un mapa. Una vez se ha cargado el mapa dentro de la aplicación, el usuario tan solo tiene que especificar los puntos iniciales y finales del área a reconocer, así como ciertos parámetros necesarios (tipo de recorrido, profundidad, altitud). Para la fase de intervención, y tras cargar el mosaico de fotos realizado por el robot en la anterior fase, el usuario podrá buscar, identificar y seleccionar su objeto de interés. Dado que se prevén diversos tipos de intervención, en la actualidad nos hemos centrado en el tipo *recuperación de un objeto*. Para poder identificar el objeto de interés, el usuario dispone de 3 modos de interacción distintos, dependiendo de la complejidad de las imágenes. Así pues, a parte especificar el objeto de interés, el usuario deberá especificar los puntos de agarre de dicho objeto, para lo cual, dispone de dos funciones: especificarlos manualmente o usar una función que calcula una aproximación a los puntos de agarre óptimos.

Finalmente, se ha integrado la interfaz en la arquitectura del proyecto mediante el uso de un archivo XML donde se guardan los datos más importantes de cada fase de la intervención. Además, existe la posibilidad de simular la fase de reconocimiento en el simulador que estamos desarrollando, usando una conexión vía sockets.

CONCLUSIONES

Se ha desarrollado una interfaz de usuario de fácil uso para la especificación de misiones de intervención submarinas autónomas. La interfaz se usa para establecer el área de reconocimiento, identificación del objeto de interés y la especificación de la tarea final de intervención, en el contexto de los proyectos de investigación español y europeo RAUVI y TRIDENT.

Durante el desarrollo, nos hemos centrado en los requisitos del usuario. Nuestro enfoque difiere de otras soluciones, en la poca necesidad de experiencia por parte del usuario. De hecho, el usuario no necesita aprender un lenguaje específico para usar la interfaz y no requiere una experiencia previa en dicho campo.

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PROGRESS ON SECURITY OF SEAFARERS IN THE MLC MARITIME LABOUR CONVENTION

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ABSTRACT

In the year 2010 which marks the year of seafarers, Spain has ratified the Maritime Labour Convention, 2006 of the International Labour Organization. Becoming the first EU member to ratify. This important Maritime Labour Convention, also called "super convention", was adopted by the 94th (Maritime) Session of the International Labour Conference held in Geneva in February 2006. To ratify the MLC, 2006, Spain implemented a decision of the Council of the European Union 2007, which allows member countries to ratify in the interests of the European Community and invites them to do so before December 31, 2010.

The objectives of this article are to introduce and analyze the contents of the Convention in relation to safety and prevention of occupational accidents in the maritime environment.

To do this will be discussed in the text of the agreement in relation to Rule 4.3-Health and safety protection and accident prevention which is designed to ensure that the working environment of seafarers on board ships promotes safety and health at work.

From this analysis conclusions that will ratify the importance of this agreement to ensure decent working conditions for seafarers.

Key words: occupational accidents, occupational safety, accident prevention, seafarers, international convention.

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INTRODUCTION

The Maritime Labour Convention (2006) is an important new international labour Convention that was adopted by the International Labour Conference of the International Labour Organization (ILO), under article 19 of its Constitution at a maritime session in February 2006 in Geneva, Switzerland. It sets out seafarers' rights to decent conditions of work and helps to create conditions of fair competition for shipowners. It is intended to be globally applicable, easily understandable, readily updatable and uniformly enforced. The Maritime Labour Convention, 2006 has been designed to become a global legal instrument that, once it enters into force, will be the the "fourth pillar" of the international regulatory regime for quality shipping, complementing the key Conventions of the International Maritime Organization (IMO) such as the International Convention for the Safety of Life at Sea, 1974, as amended (SOLAS), the International Convention on Standards of Training, Certification and Watchkeeping, 1978, as amended (STCW) and the International Convention for the Prevention of Pollution from Ships, 73/78 (MARPOL).

METHODOLOGY

The material used is the text of the agreement MLC, 2006, Title 4: Health protection, medical care, welfare and social protection. Within this title is in Regulation 4.3 – Health and safety protection and accident prevention. Purpose: To ensure that seafarers' work environment on board ships promotes occupational safety and health.

There are several novel features as far as the ILO is concerned. The whole structure of the new Convention differs from that of traditional ILO Conventions. It consists of the basic provisions, i.e. the Articles and Regulations, followed by a two-part Code and divided into five Titles, one of which is devoted to compliance and enforcement. The Regulations and the Code, which contains Standards and Guidelines, are organized under the five Titles.

- Title 1: Minimum requirements for seafarers to work on a ship.
- Title 2: Conditions of employment.
- Title 3: Accommodation, recreational facilities, food and catering.
- Title 4: Health protection, medical care, welfare and social security protection.
- Title 5: Compliance and enforcement.

There is also an Explanatory note to further assist Members implementing the Convention. The Convention also uses a new "vertically integrated" format with a numbering system that links the Regulations, Standards and Guidelines. Each Regulation also has a "plain language" purpose clause.

The status of Part B of the Code is based on the idea of firmness on principle and rights combined with flexibility in implementation. Without this innovation the new Convention could never aspire to wide-scale ratification: many of the provisions of existing maritime labour Conventions, which relate to the method of implementing basic seafarers' rights (rather than to the content of those rights), have been transferred to the non-mandatory Part B Guidelines of the Code. Their placement in the mandatory Regulations and Part A (Standards) could have resulted in clear obstacles to ratification.

Each Member shall ensure that seafarers on ships that fly its flag are provided with occupational health protection and live, work and train on board ship in a safe and hygienic environment. Each Member shall develop and promulgate national guidelines for the management of occupational safety and health on board ships that fly its flag, after consultation with representative shipowners' and seafarers' organizations and taking into account applicable codes, guidelines and standards recommended by international organizations, national administrations and maritime industry organizations. Each Member shall adopt laws and regulations and other measures addressing the matters specified in the Code, taking into account relevant international instruments, and set standards for occupational safety and health protection and accident prevention on ships that fly its flag.

THE 4.3 STANDARD SAYS

Standard A4.3 – Health and safety protection and accident prevention

1. The laws and regulations and other measures to be adopted in accordance with Regulation 4.3, paragraph 3, shall include the following subjects:

(a) the adoption and effective implementation and promotion of occupational safetyand health policies and programmes on ships that fly the Member's flag, including risk evaluation as well as training and instruction of seafarers;

(b) reasonable precautions to prevent occupational accidents, injuries and diseases on board ship, including measures to reduce and prevent the risk of exposure to harmful levels of ambient factors and chemicals as well as the risk of injury or disease that may arise from the use of equipment and machinery on board ships;

(c) on-board programmes for the prevention of occupational accidents, injuries and diseases and for continuous improvement in occupational safety and health protection, involving seafarers' representatives and all other persons concerned in their implementation, taking account of preventive measures, including engineering and design control, substitution of processes and procedures for collective and individual tasks, and the use of personal protective equipment; and

(d) requirements for inspecting, reporting and correcting unsafe conditions and for investigating and reporting on-board occupational accidents.

2. The provisions referred to in paragraph 1 of this Standard shall:

(a) take account of relevant international instruments dealing with occupational safety and health protection in general and with specific risks, and address all matters relevant to the prevention of occupational accidents, injuries and diseases that may be applicable to the work of seafarers and particularly those which are specific to maritime employment;

(b) clearly specify the obligation of shipowners, seafarers and others concerned to comply with the applicable standards and with the ship's occupational safety and health policy and programme with special attention being paid to the safety and health of seafarers under the age of 18;

(c) specify the duties of the master or a person designated by the master, or both, to take specific responsibility for the implementation of and compliance with the ship's occupational safety and health policy and programme; and

(d) specify the authority of the ship's seafarers appointed or elected as safety representatives to participate in meetings of the ship's safety committee. Such a committee shall be established on board a ship on which there are five or more seafarers.

3. The laws and regulations and other measures referred to in Regulation 4.3, paragraph 3, shall be regularly reviewed in consultation with the representatives of the shipowners' and seafarers' organizations and, if necessary, revised to take account of changes in technology and research in order to facilitate continuous improvement in occupational safety and health policies and programmes and to provide a safe occupational environment for seafarers on ships that fly the Member's flag.

4. Compliance with the requirements of applicable international instruments on the acceptable levels of exposure to workplace hazards on board ships and on the development and implementation of ships' occupational safety and health policies and programmes shall be considered as meeting the requirements of this Convention.

5. The competent authority shall ensure that:

(a) occupational accidents, injuries and diseases are adequately reported, taking into account the guidance provided by the International Labour Organization with respect to the reporting and recording of occupational accidents and diseases;

(b) comprehensive statistics of such accidents and diseases are kept, analysed and published and, where appropriate, followed up by research into general trends and into the hazards identified; and

(c) occupational accidents are investigated.

6. Reporting and investigation of occupational safety and health matters shall be designed to ensure the protection of seafarers' personal data, and shall take account of the guidance provided by the International Labour Organization on this matter.

7. The competent authority shall cooperate with shipowners' and seafarers' organizations to take measures to bring to the attention of all seafarers information concerning particular hazards on board ships, for instance, by posting official notices containing relevant instructions.

8. The competent authority shall require that shipowners conducting risk evaluation in relation to management of occupational safety and health refer to appropriate statistical information from their ships and from general statistics provided by the competent authority.

GUIDELINE B4.3
HEALTH AND SAFETY PROTECTION AND ACCIDENT PREVENTION

Guideline B4.3.1 – Provisions on occupational accidents, injuries and diseases

1. The provisions required under Standard A4.3 should take into account the ILO code of practice entitled Accident prevention on board ship at sea and in port, 1996, and subsequent versions and other related ILO and other international standards and guidelines and codes of practice regarding occupational safety and health protection, including any exposure levels that they may identify.

2. The competent authority should ensure that the national guidelines for the management of occupational safety and health address the following matters, in particular:

(a) general and basic provisions;
(b) structural features of the ship, including means of access and asbestos-related risks;
(c) machinery;
(d) the effects of the extremely low or high temperature of any surfaces with which seafarers may be in contact;
(e) the effects of noise in the workplace and in shipboard accommodation;
(f) the effects of vibration in the workplace and in shipboard accommodation;
(g) the effects of ambient factors, other than those referred to in subparagraphs (e) and (f), in the workplace and in shipboard accommodation, including tobacco smoke;
(h) special safety measures on and below deck;
(i) loading and unloading equipment;
(j) fire prevention and fire-fighting;
(k) anchors, chains and lines;
(l) dangerous cargo and ballast;
(m) personal protective equipment for seafarers;
(n) work in enclosed spaces;
(o) physical and mental effects of fatigue;
(p) the effects of drug and alcohol dependency;

(q) HIV/AIDS protection and prevention; and
(r) emergency and accident response.

3. The assessment of risks and reduction of exposure on the matters referred to in paragraph 2 of this Guideline should take account of the physical occupational health effects, including manual handling of loads, noise and vibration, the chemical and biological occupational health effects, the mental occupational health effects, the physical and mental health effects of fatigue, and occupational accidents. The necessary measures should take due account of the preventive principle according to which, among other things, combating risk at the source, adapting work to the individual, especially as regards the design of workplaces, and replacing the dangerous by the nondangerous or the less dangerous, have precedence over personal protective equipmentfor seafarers.

4. In addition, the competent authority should ensure that the implications for health and safety are taken into account, particularly in the following areas:
(a) emergency and accident response;
(b) the effects of drug and alcohol dependency; and
(c) HIV/AIDS protection and prevention.

DISCUSSION

The MLC Maritime Labour Convention, 2006 sets out seafarers' rights to decent conditions of work and helps to create conditions of fair competition for shipowners. It is intended to be globally applicable, easily understandable, readily updatable and uniformly enforced.

The Convention will enter into force 12 months after the date on which there have been registered ratifications by at least 30 Members with a total share in the world gross tonnage of ships of 33 per cent. This is a much higher than the usual ratification level (for ILO Conventions) and it uses a new formula that is intended to assure greater actual impact of the Convention. It reflects the fact that the enforcement and compliance system established under the Convention needs widespread international cooperation in order to be effective. Since many of the obligations under the Convention are directed to shipowners and flag States it is important that ILO Members with a strong maritme interest and a high level of tonnage operating under their legal jurisdiction ratify the Convention.

The existing ILO maritime labour Conventions will be gradually phased out as ILO Member States that have ratified those Conventions ratify the new Convention, but there will be a transitional period when some parallel Conventions will be in force. Countries that ratify the Maritime Labour Convention, 2006 will no longer be bound by the existing Conventions when the new Convention comes into force for them. Countries that do not ratify the new Convention will remain bound by the existing Conventions they have ratified, but those Conventions will be closed to further ratification.

In ships flying the flags of countries that do not exercise effective jurisdiction and control over them, as required by international law, seafarers often have to work under unacceptable conditions, to the detriment of their well-being, health and safety and the safety of the ships on which they work. Since seafarers' working lives are spent outside the home country and their employers are also often not based in their country, effective international standards are necessary for this sector. Of course these standards must also be implemented at a national level, particularly by governments that have a ship registry and authorize ships to fly their countries' flags. This is already well recognized in connection with ensuring the safety and security of ships and protecting the marine environment. It is also important to understand that there are many flag States and shipowners that take pride in providing the seafarers on their ships with decent conditions of work. These countries and shipowners face unfair competition in that they pay the price of being undercut by shipowners which operate substandard ships.

The Convention aims to achieve worldwide protection for all seafarers. It seeks to meet this goal in a number of ways. It is estimated that there are over 1.2 million people working at sea in the world. Until now it had not been clear that all of these people, particularly for example, those that work on board ships but are not directly involved in navigating or operating the ship, such as many personnel that work on passenger ships, would be considered seafarers. The new Convention clearly defines a seafarer as any person who is employed or engaged or works in any capacity on board a ship that is covered by the Convention. Except for a few specific exclusions and areas where flexibility is provided for national authorities to exempt smaller ships (200 gross tonnage and below) that do not go on international voyages from some aspects of the Convention, the Convention applies to all ships (and to the seafarers on those ships) whether publicly or privately owned that are ordinarily engaged in commercial activities.

Both the Constitution of the ILO and many ILO instruments seek to take account of national circumstances and provide for some flexibility in application of Conventions, with a view to gradually improving protection of workers, by taking into account the specific situation in some sectors and the diversity of national circumstances. Flexibility is usually based on principles of tripartism, transparency and accountability. When flexibility with respect to a Convention is exercised by a government it usually involves consultation with the workers' and employers' organizations concerned, with any determinations that are made reported to the ILO by the government concerned. This is seen as a necessary and important approach to ensuring that all countries, irrespective of national circumstances, can engage with the international legal system and those international obligations are respected and implemented, to the extent possible, while also making efforts to improve conditions. This is particularly important for an international industry such as shipping.

The Maritime Labour Convention, 2006 generally follows this approach as well as also providing for additional flexibility, relevant to the sector, at a national level. The Convention seeks to be "firm on rights and flexible on implementation". A major obstacle to the ratification of existing maritime labour Conventions is the excessive detail in many of them. The new Convention sets out the basic rights of seafarers to decent work in firm statements, but leaves a large measure of flexibility to ratifying countries as to how they will implement these standards for decent work in their national laws.

The Maritime Labour Convention, 2006, aims to establish a continuous "compliance awareness" at every stage, from the national systems of protection up to the international system. This starts with the individual seafarers, who – under the Convention – have to be properly informed of their rights and of the remedies available in case of alleged non-compliance with the requirements of the Convention and whose right to make complaints, both on board ship and ashore, is recognized in the Convention. It continues with the shipowners. Those that own or operate ships of 500 gross tonnage and above, engaged in international voyages or voyages between foreign ports, are required to develop and carry out plans for ensuring that the applicable national laws, regulations or other measures to implement the Convention are actually being complied with. The masters of these ships are then responsible for carrying out the shipowners' stated plans, and for keeping proper records to evidence implementation of the requirements of the Convention. As part of its updated responsibilities for the labour inspections for ships above 500 gross tonnage that are engaged in international voyages or voyages between foreign ports, the flag State (or recognized organization on its behalf) will review the shipowners' plans and verify and certify that they are actually in place and being implemented. Ships will then be required to carry a maritime labour certificate and a declaration of maritime labour compliance on board. Flag States will also be expected to ensure that national laws and regulations implementing the Convention's standards are respected on smaller ships that are not covered by the certification system. Flag States will carry out periodic quality assessments of the effectiveness of their national systems of compliance, and their reports to the ILO under article 22 of the Constitution will need to provide information on their inspection and certification systems, including on their methods of quality assessment. This general inspection system in the flag State (which is founded on ILO Convention No. 178) is complemented by procedures to be followed in countries that are also or even primarily the source of the world's supply of seafarers, which will similarly be reporting under article 22 of the ILO Constitution. The system is further reinforced by voluntary measures for inspections in foreign ports (port State control).

CONCLUSIONS

The MLC, 2006 is globally applicable, easily understandable, readily updatable and uniformly enforced.

The Convention achieves to worldwide protection for all seafarers. It seeks to meet this goal in a number of ways. It is estimated that there are over 1.2 million people working at sea in the world. Until now it had not been clear that all of these people, particularly for example, those that work on board ships but are not directly involved in navigating or operating the ship, such as many personnel that work on passenger ships, would be considered seafarers.

The Maritime Labour Convention, 2006, establishes a continuous "compliance awareness" at every stage, from the national systems of protection up to the international system.

All this makes the MLC, 2006, to be effective to ensure that the working environment of seafarers on board ships promotes safety and health at work.

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AVANCES DE SEGURIDAD PARA LA GENTE DE MAR EN EL CONVENIO MLC

Resumen

La necesidad de la creación de este convenio surge de una resolución conjunta adoptada en 2001 por las organizaciones internacionales de armadores y de gente de mar, y que más tarde fue apoyada por los gobiernos. Se pidió a la OIT la elaboración de un instrumento que unificara, de ser factible en un texto refundido, la mayor parte posible del cuerpo de instrumentos existentes de la OIT, con el fin de mejorar la pertinencia de estas normas para las necesidades de todas las partes interesadas en la industria marítima. El gran número de convenios marítimos vigentes dificultaba a los gobiernos tanto la ratificación como el control de la aplicación de todas las normas. Además, era necesario elaborar un sistema más eficaz de cumplimiento y control de la aplicación que facilitara la eliminación de los buques que no se ajustaran a las normas.

METODOLOGÍA

El método utilizado ha sido el análisis del convenio MLC, 2006. El convenio MLC, 2006, establece los derechos de la gente de mar a disfrutar de unas condiciones de trabajo decentes y ayuda a crear condiciones de competencia justa para los armadores. Además ha nacido con la pretensión de ser un instrumento aplicable en todo el mundo, fácil de entender, fácil de actualizar y aplicado de manera uniforme. Este Convenio, tiene el objetivo de convertirse en un instrumento jurídico de alcance mundial. Tras su entrada en vigor, será el «cuarto pilar» del régimen normativo internacional garante de un transporte marítimo de calidad, que complemente los convenios fundamentales de la Organización Marítima Internacional (OMI), como el Convenio Internacional para la Seguridad de la Vida Humana en el Mar, 1974, enmendado (Convenio SOLAS), el Convenio internacional sobre normas de formación, titulación y guardia para la gente de mar (Convenio de Formación), 1978, enmendado, y el Convenio internacional para prevenir la contaminación por los buques (MARPOL 73/78).

El nuevo Convenio reúne casi todos los instrumentos sobre el trabajo marítimo vigentes (68 instrumentos sobre el trabajo marítimo) en un solo convenio en él que se han introducido algunas actualizaciones necesarias.

El Convenio consta de tres partes principales: los artículos, en primer lugar, que establecen los principios y obligaciones generales; van seguidos de las disposiciones más detalladas del Reglamento y el Código (partes A y B).

El Reglamento y las normas (parte A) y pautas (parte B) del Código están integrados y organizados en temas de interés general desglosados en cinco Títulos:

Título 1: Requisitos mínimos para trabajar a bordo de buques
Título 2: Condiciones de empleo
Título 3: Alojamiento, instalaciones de esparcimiento, alimentación y servicio de fonda
Título 4: Protección de la salud, atención médica, bienestar y protección social
Título 5: Cumplimiento y control de la aplicación.

Es el Título 4 él que se ocupa de la Protección de la seguridad y la salud y prevención de accidentes.

En este punto, es importante señalar que este Convenio está compuesto por normas (A) y pautas (B). Las partes A y B del Código están relacionadas entre sí. Las disposiciones de la parte B, no son obligatorias, aunque sí que son útiles, y en algunos casos fundamentales, para entender correctamente el Reglamento y las normas obligatorias de la parte A. En algunos casos, las normas obligatorias de la parte A están formuladas de una manera tan general que puede resultar difícil aplicarlas sin consultar las orientaciones de las disposiciones correspondientes de la parte B. Sin esta formulación el Convenio nunca hubiera podido aspirar a ser ratificado ampliamente.

Una novedad importante de este convenio es la definición de «gente de mar» o «marino» que se hace en el artículo II del Convenio:

f) los términos gente de mar o marino designan a toda persona que esté empleada o contratada o que trabaje en cualquier puesto a bordo de un buque al que se aplique el presente Convenio.

Otra novedad será que se exigirá que los buques lleven a bordo un certificado de trabajo marítimo y una declaración de conformidad laboral marítima. También se prevé que los Estados del pabellón velen por que la legislación nacional por la que se aplican las normas del Convenio se respete en los buques más pequeños que no están cubiertos por el sistema de certificación. Los Estados del pabellón tendrán que llevar a cabo evaluaciones periódicas de la calidad y la eficacia de sus sistemas nacionales de cumplimiento, y las memorias que presenten en virtud del artículo 22 de la Constitución de la OIT deberán proporcionar información sobre sus sistemas de inspección y certificación, incluidos sus métodos de evaluación de la calidad. La expedición del certificado corresponde al Estado del pabellón para los buques que enarbolen su pabellón, una vez que el Estado (o una organización reconocida que haya sido autorizada a llevar a cabo las inspecciones) haya verificado que las condiciones de trabajo en el buque están de conformidad con la legislación nacional por la que se aplica el Convenio. El certificado tendría una validez de cinco años, a reserva de las inspecciones periódicas que realice el Estado del pabellón.

También este Convenio vela para que los buques se encuentren en una situación de desventaja por el hecho de que su país haya ratificado el nuevo Convenio. Tal y como se recoge en las disposiciones del Título 5 del Convenio sobre el control por el Estado rector del puerto, en virtud de las cuales los buques de todos los países (con independencia de que hayan ratificado o no el Convenio) serán objeto de inspección en cualquier país que haya ratificado el Convenio, y podrán ser inmovilizados si no cumplen las normas mínimas del nuevo Convenio.

Este convenio entrará en vigor en el 2011.

CONCLUSIONES

1. El convenio MLC, 2006, es un instrumento aplicable en todo el mundo, fácil de entender, fácil de actualizar, reuniendo casi todos los instrumentos sobre el trabajo marítimo vigentes. Esto hace que sea una herramienta muy efectiva para incrementar la seguridad abordo.
2. El Convenio alcanza a la protección para todos los marinos en todo el mundo. Se busca cumplir con este objetivo de múltiples maneras. Se estima que hay más de 1,2 millones de personas trabajan en el mar en el mundo. Hasta ahora no había quedado claro que todas estas personas, que realizaban trabajos a bordo de buques que no están directamente involucrados en la navegación y el manejo del buque, como muchos miembros del personal que trabajan en buques de pasaje, se fueran gente de mar. En este convenio sí que se consideran gente de mar.
3. El Convenio de Trabajo Marítimo, 2006, establece una continua «cultura del cumplimiento» en cada etapa, desde los sistemas nacionales de protección hasta el sistema internacional.
4. Todo esto hace que el MLC, 2006, sea una herramienta eficaz para asegurar que el entorno de trabajo de la gente de mar a bordo de buques promueva la seguridad y salud en el trabajo.

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FINANCING AND DEVELOPMENT OF INNOVATION IN COMMERCIAL SEA PORTS

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ABSTRACT

Innovation is fast becoming a major driving force in the improvement of social welfare, a crucial factor in the long-term growth and survival of companies and a key element in achieving the sustainable development of economies. In the port sector, the big changes caused by the globalization process are leading commercial sea ports to design strategies in the field of innovation allowing them to take on present and future challenges in a sector where deregulation and competition are increasingly present.

In this context, the present paper analyses innovation in the commercial sea ports. The specific objective is to determine who develops and finances innovation in the commercial sea ports. The methodology of analysis applied is the Rasch technique. Categorical variables have been used in the surveys carried out on the Port Authorities of the Spanish port system. The results obtained on innovation in Spanish ports provide answers to questions such as: Who finances the innovation? Who develops it internally or purchases it? Who acts individually? Who resorts to cooperation and which partners are chosen for the joint development of innovations?

Key words: Innovation, Ports, Rasch, Cooperation for R&D

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INTRODUCTION

In the business world in general, innovation acts not only as an engine of progress but also as a source of differentiation, a means to achieve a competitive edge that distinguishes one company from the rest. In fact, faced with the increasing international competition, innovation has become a central axis of the long-term design strategy of companies (Veugelers & Cassiman, 1999).

This importance of innovation is also reflected in the increase in expenditure on the investment which, to a greater or lesser extent, both companies and countries and international organizations dedicate to R&D+i (Research and Development and innovation).

Innovation can be defined as "the introduction of a new product, a new method of production, new markets, the discovery of new supplies of raw materials for manufactured products and even the appearance of a new sector or the redirection of a previously existing one " (Schumpeter in Solé Parellada, 2008 p.14). It is also one of the key driving forces in the improvement of social welfare and a crucial factor in the long-term growth and survival of businesses (Baumol, 2002; Schumpeter, 1939). It is also considered a key element in achieving the sustainable development of economies (OECD).

Traditionally, the literature has identified two main forms of development of innovations: "internal" and "external" (Cassiman, 2004; Cassiman & Veugelers, 2006; Veugelers & Cassiman, 1999) or, in the words of the literature, the decision to "make or buy" (the "make or buy" decision) (Cassiman & Veugelers, 2006; Chang, 2003; Perrons & Platts). More recently, a new form has been identified, that of cooperation with other agents for the development of innovations (Chen & Yuan, 2007; Hull, 2003; Navarro Arancegui, 2002), which may be considered a hybrid between the internal and external developments of innovations (Pisano, 1990). Generally, companies do not rely exclusively on one of the three alternatives proposed but rather combine internal innovation with external innovation and cooperation in order to obtain all of the capacities required to profit fully from their innovations (Hartung & MacPherson, 2000; Rigby & Zook, 2002; Teece, 1986).

The internal development of innovations has advantages such as the exclusive knowledge of all of the advances generated or the technological independence with respect to suppliers and competitors. However, it also has serious drawbacks such as a higher risk, both in economic and technological terms, or a greater need for resources to finance the development to be made. Meanwhile, in the case of external development, the situation is just the opposite.

It could be said, then, that cooperation is a hybrid solution combining the advantages of both and eliminating some of the drawbacks. Thus, the joint development of new knowledge allows riskier, more expensive and complex projects to be taken on

(Chang, 2003) and new skills to be developed through the complementarities and synergies between agents (Arora & Gambardella, 1994).

It might be asked, then, who are the agents with whom cooperation agreements can be established. According to a study by COTEC, five types or sub-systems of agents can be identified: firms, governments as providers of resources and legislation on innovation, the public R & D system, innovation support organizations (e.g. technology centers) and the environment (economic system, legal system, public and private markets, infrastructures, etc.) (Cotec, 2007 in Sacristán García, 2008).

In particular, the port sector also needs to develop innovations that enable it to adapt to the new world situation that it faces, characterised mainly by a high level of competitiveness (Escorsa Castells, 2008). Most international trade in goods is transported by sea, especially in transoceanic traffic, but there has also been a consolidation and development of short sea shipping, at least in Europe (Marco Polo Project).

Numerous studies reveal current problems as the low traffic or insufficient activity; or otherwise, congested marine terminals (as an example, see Kiani, M. 2010); the need for networking efficient logistics, creation of new elements in these networks, as has been the development of hub ports (see for example, Onyemechi, C. 2010); the issue of security to control traffic drugs, illegal immigration, terrorism, etc.; or pressure from environmental groups who claim improvements in environmental management, especially in port-city.

Therefore ports, if they are to be competitive, must be able to handle (process / load / unload / transfer) large quantities of merchandise quickly, to incorporate new activities and logistic services that add value and to adopt the new requirements. To do this, they will have to adapt and make investments such as building new infrastructures, acquiring new equipment, creating telematics platforms, developing ICT, improving management systems, etc. Similarly, countries must encourage and promote this type of innovative actions since, if they are to be competitive, they will need a port system that allows them to form part of the international logistics chains.

However, the innovations to be made may be substantial and may involve the investment of large amounts of resources (financial, human, time), which might mean that it is highly complex or even impossible for them to be developed by a single agent, all of which justifies resorting to cooperation.

In addition to the international competition, the ports also compete nationally, especially with the closest ports geographically. Therefore, differentiation is a key factor in ensuring survival and success, and innovation constitutes a possible means to achieve this.

The Spanish port system is not immune to the situation outlined above. It consists of 44 general purpose ports, managed by 28 Port Authorities, dependent in turn on the public entity, The State Port Authority of the Ministry of Development. In a previous era of centralised decision-making, the State Ports Authority established the tariffs, funded the infrastructures and covered the deficits of the ports. After the change of model, when the ports were handed managerial and financial autonomy, in competition (hard and unequal) with the other ports of the Spanish system, the need arose to differentiate themselves in order to achieve long-term survival.

Moreover, given the great number of resources required and the scarcity of resources available in the ports, a number of ways to address the situation and cover the needs were implemented: private business was allowed in, mainly through government concessions; Autonomous Communities became involved, with more and more competences and freedom of management as well as increasing budget provisions, to avoid having to assume the political cost of losing their port infrastructures; partners were sought to join logistics chains, etc. In short, a great number of agents, private and public, became involved, directly or indirectly, in support of port activity. They can, therefore, be considered as potential partners when it comes to financing, developing and implementing the required innovations.

The aim of the present study is to determine who finances the innovation in the Spanish port sector and how it is developed, by applying the Rasch methodology.

METHODS

The methodology of analysis used is the Rasch technique. This tool makes it possible to use categorical variables and to order the factors or items to be analysed according to the importance assigned to these by the subjects surveyed. The software used was Winsteps (Linacre, 2010).

To obtain information on innovation in the Spanish port sector, a survey was sent by post and / or e-mail to the 28 Port Authorities in Spain (see Table 1).

Table 1. Specifications of Survey.

Universe	Spanish port authorities
Geographical scope	Ports of General interest in Spain
Sample size	28 Port Authorities (100% of the population)
Field work	July - August 2009

The questionnaire was developed in two phases. The first phase was comprised of the performance of a national and international literature review of material related to our subject, meetings between members of the research team and representatives of the State Ports and the Port Authority of Santander, and the drafting of the first version of the questionnaire. In the second phase, the content of this first version was shown to industry representatives in order to gain their opinions and suggestions for adapting the questionnaire to the specific reality of the port environment. With the incorporation of these suggestions, the final questionnaire was produced.

The distribution of the questionnaire was centralised through the Port Authority, who took responsibility for the subsequent monitoring of the respondents in order to ensure an adequate response rate. The number of valid responses received eventually rose to 25, representing 89.28 percent of the population under study.

The original questionnaire consists of 15 questions. However, the present work focuses on the analysis of questions 4, 8 and 9 of the questionnaire, which are gathered in Appendix 1. Question 4 asks who is funding innovation, Question 8 who develops it and Question 9 asks who are on the preferred partners to cooperate with.

RESULT

This section presents the results regarding the reliability and validity of the data and the measurements taken, as well as the ranking of the agents for each of the questions analysed. The "Items" refer to each of the sections of the questions (see Appendix 1) and "individuals" are the Port Authorities surveyed.

Analysis of reliability and validity of the measurements

The validity, reliability and correlation are summarised in Tables 2 and 3, associated with individuals and items, respectively. These have been compiled from information from the Winsteps results tables denominated "Summary Statistics".

Table 2. Reliability and validity of Individuals,

	INFIT[a]		OUTFIT[b]		RELIABILITY	CORRELATION
	MNSQ[c]	ZSTD[d]	MNSQ[c]	ZSTD[d]		
Question 4	1	-0,1	0,97	-0,1	0,47	0,97
Question 8	0,85	0	0,93	-0,1	0,12	0,98
Question 9	0,98	-0,1	0,99	-0,1	0,6	0,79

Table 3. Reliability and validity of "Items".

	INFIT[a]		OUTFIT[b]		RELIABILITY	CORRELATION
	MNSQ[c]	ZSTD[d]	MNSQ[c]	ZSTD[d]		
Question 4	0,99	0	0,97	0	0,46	0,05
Question 8	0,98	0,1	0,93	0,1	0,89	-1
Question 9	0,98	-0,1	1,01	0	0,34	-0,68

a INFIT is an information-weighted fit statistic, which is more sensitive to unexpected behavior affecting responses to items near the person's measure level. **b** OUTFIT is an outlier-sensitive fit statistic more sensitive to unexpected behavior by persons on items far from the person's measure level. **c** MNSQ is the mean-square infit/outfit statistic. **d** ZSTD is the infit/outfit mean-square fit statistic t standardized to approximate a theoretical mean 0 and variance 1 distribution.

The overall validity of the measures can be evaluated from the INFIT and OUTFIT indices. As noted, the values obtained are consistent with those required (Linacre, 2010; Febles Acosta, 2008; Oreja, 2005), both for the case of the measures (MNSQ valid in the range (0.5 to 1.5)) as the standard of variances (ZSTD close to 0) and for all questions asked, both to individuals and items.

On analysing the reliability however, it can be observed that all the values are low (the appropriate reliability value is close to 1), especially in the case of the individuals for Question 8, which, curiously, shows the best reliability of all the study for the case of the items.

The low reliability of the individuals may be due, among other things, to the size of the sample (Linacre, 2010). While it is true that the percentage of responses obtained is almost 90% of the population (Port Authorities), these values would seem to point to the need for the survey to be extended to other members who also participate in the daily operations of the port, such as companies, terminals, shippers, freight forwarders, agencies of the port community, etc. The question arises as to whether the results for Question 9, to mention one specific case, might not vary if it were not just the Port Authority who was asked who their most valuable partners are, but also other members of the port community, as there is a possibility that cooperation agreements might be made in which the Port Authority does not participate.

Also, the low reliability of the items may indicate that the number of items included in the question is scarce (Linacre, 2010). It would be interesting to include the private agents covered in question 4 in both Questions 8 and 9, and vice versa, to include the organisations indicated in Questions 8 and 9 in Question 4. In addition, in this last question it would be advisable to incorporate more private agents (especially firms), institutions and organisms of the region. This is likely to improve the reliability of the survey and to provide a more thorough and clearer picture of who is responsible for the innovation and the cooperation between them.

Finally, the correlation should be 1 for individuals and –1 for items when the information or data is complete (Linacre, 2010). In our application, the correlation is acceptable for all questions in the case of the individuals, but it is only acceptable for the items in question 9, not being acceptable for the items in Question 4.

The results obtained in the reliability analysis mean that the interpretation and conclusions presented below cannot be asserted categorically. It would be appropriate to extend the population in a future survey to other agents apart from the Port Authorities, especially to the private businesses that operate in the ports.

Innovation in the ports sector

In this section we discuss, for each of the questions selected for the survey, the results from the Winsteps tables, "Variable maps" and "Item: Measure".

The results presented establish: who funds innovation in the port area; whether they develop it internally or buy it; who the agents responsible for the development are; if they do it individually or rely on cooperation; and who the partners chosen for the joint development of innovations are.

This section presents the global analysis of the results grouped around 3 main ideas: financing, development and cooperation. All the concepts relate to perceptions from the field of the Port Authorities.

Table 4 in Appendix 2 gathers "variables maps" for the three questions analyzed. In general there are some missing gaps in the discrimination of the behavior, which leads us to conclude that not all the items are identified and, therefore, that there are more agents that have not been identified or discretised sufficiently.

Moreover, in all cases there is an overlapping of two items. An overlap occurs when there are 2 or more items at the same height on the right of the map, as for example, items 4 and 5 for all the questions. This may be because both have the same significance (they are on the same level) or because the respondent does not differentiate one from another, they are unclear (they refer to the same thing).

In our case, we believe that the respondent does not clearly differentiate the concepts. In Question 4 the overlap occurs in two intermediaries. In Questions 8 and 9, the respondents do not differentiate between public and private research institutions.

Question 4 analyses who are the agents that make the greatest innovative effort in the port itself, according to the perception of the Port Authorities.

Innovation is a phenomenon which is highly valued by all concerned in the Spanish port system (Blanco, Pérez-Labajos, Sánchez, & Serrano, 2010), but the effort made by the various agents involved in the normal running of the ports is not the same. The results obtained, ordering the agents from highest to lowest effort, are (see Table 5 in Appendix 2):

1. P4-3 Shipping agents
2. P4-6 Other Administrations (Inspection Services, Harbour Master, etc.)
3. P4-2 Terminals (general y specialised)
4. P4-4 Customs Agents
5. P4-5 Forwarding Agents
6. P4-1 The Port Authorities

The least participative have been the Port Authorities and the most, private businesses, the shipping agents (who are the representatives of the shipowners in port), those who operate the terminals (often through administrative concessions) and the intermediaries (customs agents and freight forwarders). Also of importance has been the role of other Public Administrations, mainly through the incorporation of the new technologies into their systems (inspection, detection, electronic processing, etc.).

It can be seen, then, that the financing of innovation takes place mainly through private initiative, from all involved in the area of influence of the port and that the port authorities are involved to a lesser extent.

The idea expressed in the above paragraph is coherent if we consider that one of the barriers to innovation identified by the Port Authorities, though not the most important one, was the shortage of their own financial resources (Blanco et al., 2010). It is logical to expect then, that faced with the lack of financial resources available to the Port Authorities, it will be the private companies operating in the port who carry out the investment.

Question 8 focuses on which organisms have been responsible for the development of the latest innovations (listed in Question 7 of the questionnaire). In addition, this question makes it possible to establish what percentage of these innovations have been developed in a coordinated manner, that is, if the Port Authority has selected in its answer more than one agent, the corresponding innovations are assumed to have been developed through cooperation agreements.

The results show that those responsible for developing innovations have been, from most to least (see Table 6 in Appendix 2):

1. P8-1 Port Authority
2. P8-3 State Ports and/or other Port Authorities
3. P8-5 Private research entities (consulting companies, private research centres)
4. P8-4 Public research entities (universities, public research centres)
5. P8-2 Entities of the Port Community itself

As can be seen, the "entities of the same port community", which encompasses among others private participation, are those that make the greatest effort, but those who develop innovations the least. This apparent contradiction has a clear interpretation: they finance the innovation but do not develop it. The innovations are bought, but not developed internally.

The role of the Port Authorities and State Ports is a very active one in the development of innovations, but not in their funding.

In addition, 45.5% of the innovations carried out were made jointly between several agents, so that it can be stated that the Port Authorities often resort to the strategy of cooperation in developing innovative activities.

In a previous study (Blanco et al., 2010), it was shown that the third obstacle to innovation faced by the Port Authority was "Difficulty in finding partners for cooperation in innovation". Despite this, almost half of the innovations in recent years have been implemented through cooperative agreements. Thus, one asks the question who are these partners who, together with the Port Authority, have made the innovations.

Question 9 asks which entities, of those enumerated in the previous question, are most valuable when it comes to finding a partner for cooperation in innovation. The results obtained for the ranking of agents, establishing who is or are considered as potential partners for future developments are as follows, from highest to lowest preference (see Table 7 in Appendix 2):

1. P9-1 Entities of the Port Community itself
2. P9-5 Private research entities (consulting companies, private research centres)
3. P9-4 Public research entities (universities, public research centres)
4. P9-3 Other port Authorities
5. P9-2 State Ports

As can be appreciated from the above classification, the preference is to cooperate with those who are within the area of influence of the port, rather than with other Port Authorities, who are normally seen as competitors, and also rather than the State Ports, which is the umbrella-group for all, but not a dynamic agent of differentiation, at least in theory.

The need for differentiation in order to survive leads us to prefer potential partners who may have common interests and do not represent competition.

From the classification outlined in the previous paragraphs, it can be deduced that the preference is for partners with similar characteristics, those whose scope and influence largely coincides with that of the Port Authority itself. Thus, first are the entities of the port community itself. Second are the research entities whose scope may be broader, covering several provinces, communities or even the whole country. Then come the other Port Authorities, who, obviously, are located in another geographical area but can share common interests in some cases and be rivals in others. And finally are the State Ports who, since this is an organism on which all of the Port Authorities depend, is not the first candidate to act as a partner for one main reason: the search for differentiation on the part of the Port Authorities.

DISCUSSION

Ports have to be competitive in order to be integrated, as links, in the international supply chains. In addition they also have to face internal competition in the country where they are located. To improve efficiency, innovation is needed, considered as a source of competitive advantage and differentiation.

The investments required share some characteristics:

a. They are usually quite substantial, making it difficult for them to be financed exclusively by the Port Authority.
b They are usually highly specific investments that do not always have alternati ve uses. Although they may have a degree of flexibility, they are not easily adaptable. This point means that agreements must be reached with the users (clients become logistical partners).
c. The problem of scale. The investments cannot normally be dimensioned (increased or decreased) gradually as the activity varies. Thus, problems of underuse or saturation may arise. In general, the facilities are over-dimensioned in anticipation of a growth in the activity.

However, since the resources of the ports to be assigned to innovation are scarce and since these are not conceived as independent entities, but rather as members or as a part of the logistics chain, it might be considered that the innovation strategy will affect the whole chain and thus that the development and financing will be shared among all those who form part of the port community.

CONCLUSIONS

1. The Rasch method is a suitable tool for undertaking studies on port innovation with categorical variables. We consider that, in comparison with other techniques, it provides a greater wealth of information. It enables more detailed analyses that allow us to find explanations, especially in rare cases. Its findings may guide decision-making by those responsible for port policy and, by establishing areas for improvement, guide future research.
2. Private enterprise in the port community assumes most of the financing of innovation, along with other authorities (Inspection Services, Harbour Master, etc.). However, they do not develop it. Most innovation is developed externally (it is bought).
3. The Port Authorities, given their limited resources, participate little in financing. However, together with the State Ports, they are the main driving force behind the development of innovations.
4. Cooperation is often recurred to for the joint development of innovations. This strategic approach is often aimed at entities of the port community itself. The preferred potential partners are those that enable us to achieve a greater differentiation and do not represent competition.

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APPENDIX 1: Questions and associated items

Question 4

In your view, assess the level of innovative effort made within the operation of the port by:

P4-1 The Port Authorities
P4-2 Terminals (general y specialised)
P4-3 Shipping agents
P4-4 Customs Agents
P4-5 Forwarding Agents
P4-6 Other Administrations (Inspection Services, Harbour Master, etc.)

Question 8

Indicate the main entity responsible for undertaking the main innovations carried out during the period 2004-2008 (you can mark several options, if the innovation has been developed in cooperation with other entities):

P8-1 Port Authority
P8-2 Entities of the Port Community itself
P8-3 State Ports and/or other Port Authorities
P8-4 Public research entities (universities, public research centres)
P8-5 Private research entities (consulting companies, prívate research centres)

Question 9

In your view, evaluate from 1 (not at all) to 5 (a lot) what type of partner you consider of most value for the innovation activities of your organisation:

P9-1 Entities of the Port Community itself
P9-2 State Ports
P9-3 Other port Authorities
P9-4 Public research entities (universities, public research centres)
P9-5 Private research entities (consulting companies, prívate research centres)

APPENDIX 2: Tables of Results

Table 4. Variable Maps.

<table>
<tr><th>Question 4</th><th>Question 8</th><th>Question 9</th></tr>
<tr>
<td><pre>
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</table>

Table 5. Question 4. Item statistics: Measure order.

ENTRY NUMBER[a]	TOTAL SCORE[b]	COUNT[c]	MEASURE[d]	MODEL S.E.[e]	INFIT[f]		OUTFIT[g]		PT-MEASURE		EXACT MATCH		ITEM[n]
					MNSQ[h]	ZSTD[i]	MNSQ[h]	ZSTD[i]	CORR.[j]	EXP.[k]	OBS%[l]	EXP%[m]	
1	76	25	0,74	0,36	1,33	1,3	1,34	1,3	0,49	0,64	52,2	60,1	P4-1
5	64	25	0,5	0,47	0,92	-0,4	0,83	-0,6	0,55	0,5	65,2	68,7	P4-5
4	54	25	0,44	0,43	0,81	-0,5	0,81	-0,5	0,68	0,56	69,6	71,3	P4-4
2	85	25	-0,4	0,39	0,88	-0,4	0,89	-0,3	0,6	0,54	60,9	63,7	P4-2
6	60	25	-0,59	0,45	1,19	0,7	1,17	0,6	0,32	0,47	60,9	71	P4-6
3	59	25	-0,69	0,43	0,83	-0,6	0,81	-0,6	0,66	0,56	78,3	69,5	P4-3
MEAN	66,3	25	0	0,42	0,99	0	0,97	0			64,5	67,4	
S.D.	10,7	0	0,58	0,04	0,2	0,7	0,21	0,7			8,1	4,1	

Table 6. Question 8. Item statistics: Measure order.

ENTRY NUMBER[a]	TOTAL SCORE[b]	COUNT[c]	MEASURE[d]	MODEL S.E.[e]	INFIT[f]		OUTFIT[g]		PT-MEASURE		EXACT MATCH		ITEM[n]
					MNSQ[h]	ZSTD[i]	MNSQ[h]	ZSTD[i]	CORR.[j]	EXP.[k]	OBS%[l]	EXP%[m]	
3	3	23	2,17	0,74	0,89	-0,2	0,36	-0,1	0,52	0,5	85,7	87,8	P8-2
5	4	23	1,66	0,69	0,79	-0,6	0,4	-0,1	0,61	0,6	90,5	85,2	P8-4
6	4	23	1,66	0,69	1,05	0,3	0,53	0,1	0,55	0,6	81	85,2	P8-5
4	8	23	-0,07	0,66	1,45	1,2	1,55	0,9	0,63	0,7	81	85	P8-3
1	10	25	-0,95	0,67	0,17	-2,6	0,15	-2,1	0,92	0,8	100	87,6	P8-0
2	19	23	-4,46	0,77	1,17	0,5	6,5	2,3	0,37	0,5	90,5	90,1	P8-1
MEAN	8	23,3	0	0,7	0,92	-0,2	1,58	0,2			88,1	86,8	
S.D.	5,5	0,7	2,27	0,04	0,39	1,2	2,24	1,3			6,6	1,9	

Table 7. Question 9. Item statistics: Measure order.

ENTRY NUMBER[a]	TOTAL SCORE[b]	COUNT[c]	MEASURE[d]	MODEL S.E.[e]	INFIT[f]		OUTFIT[g]		PT-MEASURE		EXACT MATCH		ITEM[n]
					MNSQ[h]	ZSTD[i]	MNSQ[h]	ZSTD[i]	CORR.[j]	EXP.[k]	OBS%[l]	EXP%[m]	
2	80	22	0,46	0,3	0,84	-0,5	0,85	-0,4	0,67	0,62	47,6	49,9	P9-2
3	70	21	0,24	0,3	0,92	-0,2	0,93	-0,1	0,66	0,65	40	49,5	P9-3
5	77	22	0,01	0,31	0,81	-0,5	0,84	-0,4	0,69	0,65	42,9	52	P9-5
4	79	22	-0,05	0,31	0,5	-1,6	0,55	-1,5	0,79	0,64	61,9	53,6	P9-4
1	87	21	-0,66	0,31	1,83	2,4	1,87	2,3	0,27	0,54	45	48,1	P9-1
MEAN	78,6	21,6	0	0,3	0,98	-0,1	1,01	0			47,5	50,6	
S.D.	5,5	0,5	0,37	0,01	0,45	1,3	0,45	1,2			7,6	1,9	

a ENTRY NUMBER is the sequence number of the person, or item, in your data, and is the reference number used for deletion or anchoring.

b TOTAL SCORE is the raw score corresponding to the parameter, i.e., the raw score by a person on the test, or the sum of the scored responses to an item by the persons.

c COUNT is the number of data points used to construct measures

d MEASURE is the estimate (or calibration) for the parameter, i.e., person ability or the item difficulty. Values are reported in logits with two decimal places.

e MODEL S.E. is the standard error of the estimate.

f INFIT is a t standardized information-weighted mean square statistic, which is more sensitive to unexpected behavior affecting responses to items near the person's measure level.

g OUTFIT is a t standardized outlier-sensitive mean square statistic, which is more sensitive to unexpected behavior by persons on items far from the person's measure level.

h MNSQ is the mean-square infit or outfit statistic with expectation 1.

i ZSTD is the infit or outfit mean-square fit statistic t standardized to approximate a theoretical "unit normal", mean 0 and variance 1, distribution.

j PT-MEASURE CORR is the point measure correlation between the observations on an item and the corresponding person measures, or vice-versa. The point-measure correlation has a range of -1 to +1.

k PT-MEASURE EXP is the expected value of the correlation when the data fit the Rasch model with the estimated measures.

l EXACT MATCH OBS%: observed % is the percent of data points which are within 0,5 score points of their expected values.

m EXACT MATCH EXP%: Expected % is the percent of data points that are predicted to be within 0,5 points of their expected values.

n ITEM is the name of the list of persons (data rows) or items (data columns) reported her.

FINANCIACIÓN Y DESARROLLO DE LA INNOVACIÓN EN PUERTOS MARÍTIMOS COMERCIALES

ESUMEN

La innovación se está convirtiendo en un motor fundamental en la mejora del bienestar social, un factor crucial para el crecimiento y la supervivencia de las empresas a largo plazo y un elemento clave para conseguir un desarrollo sostenible de las economías.

En el sector portuario, las profundas transformaciones originadas por el proceso de globalización, están llevando a los puertos marítimos comerciales a diseñar estrategias en el ámbito de la innovación, que permitan asumir retos presentes y futuros, en un sector en el que la desregulación y la competencia son elementos de presencia creciente.

En dicho contexto, en el presente trabajo se analiza la innovación en los puertos marítimos comerciales. El objetivo específico es determinar quién desarrolla y financia la innovación en los puertos marítimos comerciales. La metodología de análisis aplicada es la técnica de Rasch. Se han utilizado variables categóricas en las encuestas pasadas a las Autoridades Portuarias del sistema portuario Español. Los resultados obtenidos en torno a la innovación en el ámbito portuario español, permiten responder a cuestiones tales como: ¿quiénes la financian? ¿quiénes la desarrollan internamente o la compran? ¿quiénes actúan individualmente? ¿quiénes recurren a la cooperación y qué socios eligen para el desarrollo conjunto de las innovaciones?

METODOLOGÍA

Para obtener información sobre la innovación en el ámbito del sector portuario español se realizó una encuesta por correo postal y/o electrónico a las 28 Autoridades Portuarias existentes en España. El número de contestaciones válidas ascendió a 25.

El cuestionario original consta de 15 preguntas. El presente trabajo se centra en el análisis de las preguntas 4, 8 y 9 del citado cuestionario que se recogen en el anexo 1. La 4 sobre quién financia la innovación, la 8 sobre quién la desarrolla y la 9 sobre los socios preferidos para cooperar.

La metodología de análisis utilizada es la técnica de Rasch, y el software empleado ha sido el Winsteps (Linacre, 2010).

CONCLUSIONES

1. El método Rasch es una herramienta adecuada para realizar estudios sobre innovación portuaria con variables categóricas. En comparación con otras técni-

cas, creemos que aporta una mayor riqueza informativa. Permite análisis más detallados que nos ayudan a encontrar explicaciones, especialmente en los casos raros. Sus resultados pueden orientar la toma de decisiones de los responsables de la política portuaria y, al establecer aspectos a mejorar, orientan la investigación futura.

2. La iniciativa privada de la comunidad portuaria es la que asume la mayor parte de la financiación de la innovación, junto con otras Administraciones (Servicios de Inspección, Capitanía, etc.). Sin embargo, no la desarrollan. La mayoría de la innovación es desarrollada externamente (se compra).
3. Las Autoridades Portuarias, dada su escasez de recursos, participan poco en la financiación pero, junto con Puertos del Estado, son los principales agentes dinamizadores del desarrollo de las innovaciones.
4. Frecuentemente se recurre a la cooperación para el desarrollo conjunto de innovaciones. La apuesta estratégica se dirige a entidades de la propia comunidad portuaria. Como socios potenciales se prefiere a los que nos permitan alcanzar una mayor diferenciación y que no representen competencia.

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- ☐ E-mail of the author to whom correspondence should be addressed.
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- ☐ Font: Times New Roman, normal style, 12-point type.
- ☐ Double spacing should be used for all the paper except for the references which are to be single-spaced.
- ☐ Notes, when necessary, are to be placed at the end of the paper and numbered in their order of appearance in the text. Mathematical derivations should not be included in these endnotes.

The abstract is to be presented on one page and should include the following information:

- ☐ Title and subtitle of the paper
- ☐ Field and sub-field of the work presented.
- ☐ Abstract, which is to be no longer than 200 words, and should have no spaces between paragraphs.

- Key words (between 3 and 5) which will be used for computerised indexing of the work, in both Spanish and English.
- The complete work should be no longer than 23 pages (about 7000 words) and should be structured as is shown below.

The first page will contain the same information as the summary:

- Title of the paper, as specific and brief as possible, and subtitle if desired.
- Field and sub-field of the work presented.
- Abstract of 200 words.
- Key words.

The rest of the article:

- Introduction or Problem
- Methods
- Development (application and results)
- Conclusions
- Endnotes
- References. Only those included in the article in alphabetical order.
- Appendix containing a condensed version of the article in Spanish. This is to be 3 or at most 4 pages in length (approximately 1000-1200 words) with the following sections: abstract, methods and conclusions.

The body of the article is to be divided into sections (bold, upper-case), subsections (bold, italics) and optionally into sub-subsections (italics), none of which are to be numbered. Insert line spaces before and after the title of each section, subsection and sub-subsection. Symbols, units and other nomenclature should be in accordance with international standards.

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The Harvard System is to be used, following the guidelines indicated below.

The way in which *bibliographic citations* are included in the text will depend on the context and the composition of the paragraph and will have one of the following forms:

- One author: Farthing (1987); (Farthing, 1987); (Farthing, 1987 pp. 182-5)
- Several authors: Goodwin and Kemp (1979); Ihere, Gorton y Sandevar (1984); Ihere et al.(1984); (Ihere et al., 1984)

The *bibliographic references* are to be arranged in alphabetical order (and chronologically in the case of several works by the same author), as is indicated in the following examples:

Books

Farthing, B. (1987) *International Shipping.* London: Lloyd´s of London Press Ltd.

Chapters of books

Bantz, C.R. (1995): Social dimensions of software development. In: Anderson, J.A. ed. *Annual review of software management and development*. Newbury Park, CA: Sage, 502-510.

Journal articles

Srivastava, S. K. and Ganapathy, C. (1997) Experimental investigations on loop-manoeuvre of underwater towed cable-array system. *Ocean Engineering* 25 (1), 85-102.

Conference papers and communications

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Technical Reports

American Trucking Association (2000) *Motor Carrier Annual Report*. Alexandria, VA.

Doctoral theses

Aguter, A. (1995) *The linguistic significance of current British slang*. Thesis (PhD).Edinburgh University.

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Illustrations are to be inserted in the appropriate point in the text using Microsoft Word. All illustrations (graphs, diagrams, sketches, photographs, etc.) will be denominated generically Figures and are to be numbered consecutively using Arabic numerals with the title centred at the top. The source is to be indicated at the bottom on the left. Photographs must be in black and white with a quality of at least 300 ppp.