Advantages of using a virtual reality tool in shipbuilding

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Abstract

In a world where virtual reality is widely used for all kinds of simulations, shipbuilding industry could not stay behind. Vessels are expensive and complex platforms integrating multiple systems and equipments. In a very competitive environment with no room for error, both the design and production phases must be monitored and reviewed to avoid unnecessary costs. The availability of an advanced tool for the virtual navigation through the ship model, from the early design stages, facilitates the project control and the decision making quickly and efficiently.

The key factor is the creation of a ship 3D model developed with a 3D CAD tool, integrating all design disciplines in a single environment. As a natural consequence, the development of a solution allowing the 3D navigation and even the interacting with the model in an immersive experience, open a huge range of possibilities that benefit all stakeholders.

This paper describes the benefits of using a virtual reality environment in the shipbuilding industry, taking into consideration all the agents involved in the design, production and life-cycle of ships. Some of these advantages are the quick evaluation of modifications and design changes, the production checking and approval, simulation of maintenance, disassembly and operation tasks, training of crews and for commercial and marketing purposes.

The solution presented, based on FORAN System, shows the virtual navigation tool developed by SENER. It is described the architecture of the solution, all its functionality, benefits and how it could be applied in different environments.

Abbreviations

CAD	Computer Aided Design
CAM	Computer manufacturing Design
GPU	Graphics Processing Unit
GSSL	OpenGL Shading Language a high-level shading language for programming of the GPU
KD-Tree	A space-partitioning data structure for organizing geometry in space
OpenGL	The most widely adopted graphics standard for high performance applications
HMD	Head Mounted Display
VDC	Virtual Design Center
VR	Virtual Reality

1. Introduction

A natural consequence of the extended use of CAD systems for the design and production of any kind of vessel is its use in VR environments, mainly because now it has become an accessible technology. VR is extended in every industry, in every sector, at any level. Important improvements both in software and hardware have had an important impact in its use in the shipbuilding industry, where it is necessary to handle complex ship 3D models with huge amount of data.

So, efficiency is the base condition in the VR navigation around a vessel. To enhance it, there are

three important factors that play a fundamental role. The first one is having an appropriate CAD system with all the information of the ship in a single data base. The second important issue is to have a viewer, which is a tool that allows the management of the 3D model to be used in VR environments. No need to say that a good integration between the viewer and the CAD system will be translated into more functionality and better performance. Finally, the third important player is hardware, which makes possibility the VR navigation in many different environments.

This paper describes first of all different efficient uses of VR in the shipbuilding industry, taking in consideration all the agents involved and describing in particular the advantages for any of them. Regarding the software requirements, it will be described in particular the new FVIEWER, developed by SENER for the VR navigation & Design review and based on the FORAN System. From the hardware side, it will be described some of the most relevant and feasible applications of the VR, taking in consideration potential uses and accessible technology in the market. The future of the VR in shipbuilding will be explained after that.

To conclude, a relevant case study of the efficient use of VR in shipbuilding will be described, the new VDC in the Spanish NAVANTIA, to be used in their current development of the series of submarines S-80 for the Spanish Navy.

2. Applications and advantages of VR in shipbuilding

Shipbuilding industry is affected by a global and extremely competitive environment. All processes and systems have to be adapted to this challenging scenario, making special efforts in innovation and applying the most advanced technology available in the market. The VR application to shipbuilding is not new, but it is more extended now thanks to the important improvements in software and hardware. From a user point of view, it is possible now to find a wide range of solutions to meet the most demanding requirements, to achieve measurable results, in terms of efficiency and costs.

The ship 3D model is the core to all tasks related to ship design and manufacturing.
It is the starting point of a series of thousands of tasks that are absolutely based on the coherence of the model. As an added value, CAD suppliers develop smart tools to use this model in realistic navigations in VR environments with multiple purposes. Some of the most important uses of VR in shipbuilding are described in the following paragraphs.

2.1. Design, engineering and production

Maybe the engineering department of a shipyard is where is more extended the use of this kind of solutions. And production department is maybe where it should be extended because is where there are the most costly errors. They are not usually working with a VR solution but now it is starting to be clear that it is very useful to check the model, to avoid errors and inconsistencies but also to improve the tasks of production.

So, the first and most important use of VR is for avoiding errors. The possibility of viewing the ship 3D model as much realistic as possible is really effective to find out errors, in all stages of the design. From early design stages, to manufacturing and production phases, it is possible to use it to check all the elements, to see inconsistencies, to prevent interferences and collisions, to query about properties and attributes and to study different design alternatives and changes dynamically. In addition, the user and model interaction has become much more realistic with the implementation of tracking devices which give the sense of being inside the model, walking and moving on it, touching it.

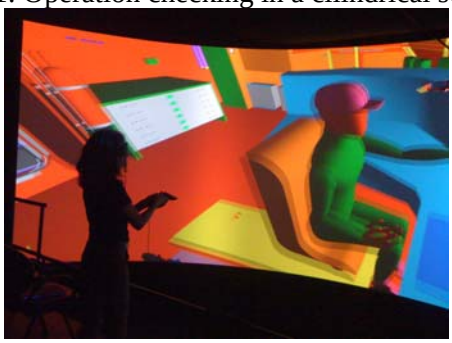
Viewers allow an easy navigation and a fast-movement. Different modes of visualization, search and query options, inclusion of annotations and measurement of distances are important and useful capabilities. Ergonomic aspects in the design can be studied and checked better having a VR solution, with the possibility to include dummies. It is possible also the collision detection, to check interferences and the insertion of annotations.

Simulation is another important area of application of VR in ship design, engineering and production. It is being applied in the study of many tasks with different purposes, from the study of escape routes to the simulation of dismantling for maintenance of equipments. The help in the study of critical assembly tasks and how the surrounding elements are affected is relevant too.

No need to say that the use of VR for the control of the design is very useful, just to see the progress of the project. And more, once it is being built, the comparison between the model and the real ship is necessary and VR can help to find out errors that need to be solved as soon as possible eliminating further unnecessary costs.

On the other hand, it is very common that the ship design and engineering and also the manufacturing is divided in different blocks that are subcontracted to different design offices, subcontractors and shipyards. The shipyard receives all the information of the ship and needs to supervise that everything is correct. Having a VR tool that allows the integration of all the information in a simple way makes possible to have a single model, which is much more effective than having many different models.

Fig. 1: Operation checking in a cilindrical screen



2.2. Marketing and commercial uses

Benefits of using VR for marketing and commercial purposes are evident. That is why VR tools are having a great reception in sales and marketing activities. Thanks to the wide range of possibilities available in the market, from small and portable solutions to big and on-demand solutions, the present and future applications of VR is higher than we can imagine.

From the marketing point of view, the possibility to present a ship 3D model with the higher level of detail in an immersive VR experience adds incalculable value to the sales activity. Many shipyards are already taking advantage of this technology, not only in their facilities but also in fairs and exhibitions thanks to the portable solutions that will be described later.

2.3. Management

Shipyard management play the role of ensuring that the commitments made to the clients are fulfilled. The project needs to be accurate, with the highest quality level and in accordance with estimations to ensure customer satisfaction. To achieve it, it is very important to have a clear idea about the progress of the project and also about changes that can affect further requirements, schedules and costs. Having the opportunity to check the VR model from early design stages is a great advantage and allows a friendly checking, quick evaluation of alternatives and fast decision-making. At the end, the great impact in cost reduction is possible thanks to the early error detection, being much more expensive the modifications in manufacturing and production stages.

2.4. Ship-owners

The presentation of the progress of the ship project to ship-owners is another important use of VR,

adding the value of being very easy to conceive the project in a very realistic and intuitive way. This has become a great advantage in comparison with conventional presentations. In fact VR can substitute the old scale ship models that are expensive and with short level of detail. The capabilities to present the information available in the VR solutions are as big as the user´s ability, because now it is possible to provide realistic finishes and all the level of detail required. Ship-owners can also check and monitor the progress of the model and also to promote design alternatives less cost-effective than in further stages.

2.5. Naval shipbuilding

Military shipbuilding industry is affected by the most demanding requirements both in the design and production stages. It is true that this kind of naval projects, both in submarines and in surface ships, are lengthy and complex although they have more human resources. But, at the end, the project needs to comply with the strictest rules and also with the budgets imposed by the ministries. This is not an easy task, and that is why all the help in the control and supervision of the process is really welcome. Is in this area of shipbuilding where VR solutions have been well received time ago. The application of the most advanced technologies usually starts in ambitious programmes with major innovations and budgets. That is the case of application of VR in shipbuilding, because we can not forget that having an appropriate VR solution is costly, and that long-term military projects are those that a priori have a larger budget to afford them.

Other important use around the naval shipbuilding is in the side of the Army. The use of VR is an advantage for the crew training. In submarines this can be particularly interesting for the lack of space. Simulation is the other important activity, since there is really difficult to enhance some kind of operations inside a submarine but also in a surface ship. The help of VR to simulate operations and dismantling and maintenance tasks is unquestionable. Here there is a great area of improvement.

2.6. Drawbacks and areas of improvement

From another point of view, there are still some drawbacks to mention around the use of this kind of technology in shipbuilding. The most important one is the price, because although there are cheaper devices available in the market, the true is that the hardware is expensive, and it is necessary to add the costs of the software, the implementation, the conditioning of the room, the training, etc.

Another important drawback is that there is necessary to have a good ship 3D model of the ships. Sometimes this is not possible, because there are multiple CAD systems applied in the same project, with the difficult of having just one model of the ship with all the information. To avoid this situation it is much better to develop the whole project in the same CAD, or at least to have the necessary tools to integrate the information in a viewer compatible to all of them, which sometimes it is a very difficult task.

Finally, the ergonomic aspect of the solution is important too. The use of 3D glasses for a long time is annoying for the eyes, and the standing position looking to a screen without any light could be unpleasant if used too often.

3. FVIEWER, a VR tool in FORAN

As it has been mentioned before, the software is one of the key factors to consider in the efficient use of a VR solution. SENER has developed a state-of-the-art solution for the VR navigation and design review, called FVIEWER, the second generation application that improves and replaced the VISUAL 3D application in FORAN. The new application offers real-time walkthrough for ship model review and it can be used both on a normal workstation and with high-end hardware specially made for immersive virtual reality environments.

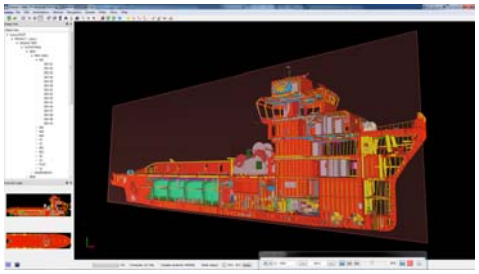
The important advantages of using FVIEWER as a VR solution are based on both its technology and

functionality, as it is described in detail below.

3.1. General functionality

FVIEWER implements the graphic using OpenGL which is the most widely adopted graphics standard for high performance applications. Several additional techniques are employed to speed up the rendering of big scenes which makes it possible to visualize an entire ship using the adequate hardware. The geometry is organized in KD-trees (space-partitioning data structures for organizing the geometry in the space) which make fast occlusion culling possible. The occlusion culling consists of filtering out the objects that are entirely hidden behind other opaque objects from the graphic pipeline significantly reducing the number of polygons processed by the GPU. OpenGL shaders (GSSL) are employed to pass part of the graphic rendering calculations directly to the GPU. These techniques together with the use of native 64 bits application architecture makes it possible to handle a great quantity of geometry real-time, in fact on a normal workstation it may even be possible to visualize an entire ship.

Fig.2: The interior if the ship is made visible by use of a clip plane in FORAN FVIEWER



3.2. Review facilities

FVIEWER facilitates the navigation in the model by offering several manners to move around. For beginners the navigation is made easy by limiting the movement to a plane while more advanced users may take advantage of navigation functions like moving using inertial speed, inspection mode, orbiting camera around a defined centre and others.

The overview maps show small images of the model in two different projections with a symbol which indicates the camera position and orientation. The use of the maps simplifies to see where the camera is located in the scene and to move to a determined location by selecting a new position in the maps. Camera bookmarks may be used to store named camera position for rapid positioning.

Items obstructing the review may be easily moved by dragging them to new temporary positions or by making them invisible or transparent. Clip planes are available for quick occlusion of parts of the model by clipping out portions.

All the objects in the scene are available for selection and interrogation to obtain model information. A tree structure view displays the design structure and the build strategy defined in the product model, and may be used for object selection, interrogation and moving the camera to an object or an interim product. Distance and angle measuring is easily available by selecting geometrical points or exact reference points defined in the product model. The ship frame may be displayed to act as a quick visual reference for the location.

A query by example search tool makes it easy to look up items in a big model by specifying the object identification or by attributes.

The appearance of the model may be enhanced by changing the object color, texture and transparency. Light sources can be applied and modified to give a more realistic presentation of the model. The lights are specified by color, attenuation and the position which may be a fixed point or attached to the

camera.

Review comments are attached to the model as annotations while objects with attached information may be highlighted to easily identify them in the model. An annotation manager makes all the attached information accessible together with the product model identification for the objects. The annotation information can be exported for processing in other applications.

3.3. Dummies

Dummies may be used to carry out an ergonomic check of the design. Any number of dummies can be added with different statures, postures and orientations. When placing them in the model the system automatically detects and warns the user about interferences between the dummy and the model objects. Clashes are indicated both audible and visually by marking the interferences with a different colour.

Fig.3: Ergonomic check of the design using dummies. Interferences are marked in red

3.4. Object and camera paths

The definition of paths can be used for both camera and objects. The camera path is a feature which offers recording of the navigation (camera movement) in the model. The recorded paths can be reproduced and modified in the path editor which makes it a valuable tool for presentations and design reviews.

Object path is the tool for simulation of the mounting and dismounting of equipment in the ship. The path specifies the object movement and orientation. The reproduction of the object paths is used for visual verification and includes notification of clashes between the object moved and the rest of the model.

3.5. Immersive visualization

FORAN VR & Design review solution offers support for stereoscopic 3D displays which enhances the illusion of depth in the image. This feature is available on any workstation with a graphic card supporting OpenGL 3D and with a 3D ready monitor.

To give the user a sensation of being inside the model a powerwall is an attractive solution. The wall projects the image in 3D on a big screen and a head tracking device registers the movement of the user. The users head position and orientation is used to calculate the camera which gives the user a sensation of moving around inside the model. A wand device is used to replace the keyboard and mouse and handles functions as navigation, object interrogation, measuring, moving object and clip planes.

A 3D Head Mounted Display together with tracking is another solution which gives the user an even more realistic sensation of moving inside the model. The head-mounted displays are used with tracking sensors that allow changes of angle and orientation to be recorded. The tracking data is used to generate the appropriate projection for the angle-of-look at the particular time. This allows the user

to "look around" in a virtual reality environment simply by moving the head without the need for a separate controller to change the angle of the imagery. When a HMD is used the screen cursor is replaced by a virtual hand controlled by the wand, the hand is used to handle the user interaction.

4. Virtual Reality tools: Hardware and applications

As it was mentioned before, shipbuilding industry is taking advantage of the benefits of using VR. There are in the market many applications where it is possible to navigate through the 3D model of the ship in a VR experience. Depending on the different working environments and the specific shipbuilding VR applications, different hardware solutions are available in the market. Some of the most relevant will be described below.

Fig. 4: Schedule of a VR solution

4.1. VR rooms

The most common use within the applications of VR is a room with a screen where multiple viewers with their glasses can review the 3D model. These rooms are equipped with a large high-resolution display wall (Powerwall) used for projecting large computer generated 3D images. Powerwall is a 3D immersive display that is used to present and interact with a wide variety of media and content. The main advantage of these flat screen visualization walls is the amplitude of the field of vision, providing an excellent sense of immersion as the 3D objects are displayed close to life size.

Most part of the applications of the VR to shipbuilding can be carried out in a common VR room. The engineering design review, navigation through the 3D model, analysis and inspections, etc can done by a group of people working in the same environment. Another important application is focused towards supporting business development, where this installation can be used in marketing and commercial presentations to potential customers, ship-owners or management teams, where live navigations around the ship 3D model, videos or even shipyard facilities may be displayed.

These rooms have to be dimensioned according to certain parameters: the maximum required capacity of people that will participate in a working session; the desired size of the screen; and the consideration of the use of rear projection. These are all factors that will dictate the size requirements of such candidate rooms.

The screen size and aspect ratio are important factors to consider for the selection of a projector or projectors, being the technical specifications required in order to display the 3D images at highest quality. In case of using a rear projection, an extra space is required at the back of the screen. The length of this space is relative to the size of screen and the lens fitted to the projector. This length can be reduced by using a solution with a mirror. The main advantages of rear projection are the clearing of space in front of the screen to allow users a more freedom to move, and also to avoid the possibility of shadows being cast by the users onto the images they are viewing.

The most common components required in a VR room are described below.

There are two different modes of 3D viewer technology called active and passive. Active viewers have displays in the glasses which interact with the images. An alternative to active glasses is the passive approach or ZScreen, which is a special kind of liquid crystal polarization modulator and requires the installation of a silver screen. The ZScreen is placed in front of the projector lens like a sheet-polarizing filter. The device changes the characteristic of polarized light and switches between left and right handed polarized light at the set field rate.
This will be described later in the projector and glasses description.

4.1.1. Filmscreens

In most cases this is a flexible rear projection surface that can be available in either fixed frame or retractable models. There are different standard sizes and used to be tailored to specific room requirements. They are made of a special fabric that is designed to optimize stereoscopic view. The fabric employs special metallic elements, formulated to preserve light polarization. The high gain and high contrast of the fabric compensate the lost of quality in case of using polarization filters.

Fig. 5: VR room

4.1.2. Projector

There are a wide range of advanced 3D visualization projectors available offering different illumination platforms, such as LED or Xenon. The main features of them are maximum image quality, best resolution, solid reliability, excellent brightness capability, color and brightness uniformity and multi-channel capability. Due to the high resolution used, the projected 3D images maintain fidelity even at very close viewing distances. The decision on projection method, active or passive, will dictate the type of projector and the glasses that will be required.

Some projectors use DLP technology with the following advantages: highest definition and wide resolution, filter free design, lamp free design, quality colors, low cost maintenance and highest readability. The use of multiple projectors for a single display wall creates large, bright, detailed and truly eye-catching images. However, where the projected images overlap, there is often a visible band across the display. The appearance of banding effect can be eliminated using blending software or hardware devices.

Fig. 6: Example of a 3D projector

4.1.3. 3D glasses

Depending on having active or passive technologies, different glasses are needed. Active eyewear devices are wireless battery-powered glasses with liquid crystal shutters that are run in synchrony with the video field rate. Synchronization information is communicated to the glasses by means of an infrared (IR) emitter. Passive glasses are cheaper and simple.

4.1.4. Tracking system

The possibility to add a motion tracking system is the most effective way to improve interaction with the information in case of working with complex 3D objects or data sets in an immersive environment. Motion tracking is achieved via special devices that can track a users head movements. They consist of a head tracker that attaches to the stereo glasses and a tracked wand that incorporates buttons and a joystick for interaction with the content. These devices are available in wired and wireless versions with a convenient rechargeable docking station.

Head tracking allows the user's perspective viewpoint to be communicated to the application software, which gives the ability to walk in and around simulated objects for a very convincing and viewer-oriented experience. Tracking systems may use different technologies: mechanical, optical, magnetic, acoustic or inertial.

4.1.5. Head Mounted Displays

Head/helmet mounted displays are used to insert the user into a virtual environment in a realistic 360 degree immersive experience.

4.1.6. Workstation: server

In order to manage the vast quantity of information such as large 3D ship models, a computer with the optimum specification is required. In these immersive solutions, workstations are used tailored to get the most out of the processor, memory, graphics, operating system and software technology. In order to process tasks faster, quad or six-core processors are normally used.

The most important component in this kind of computer is the graphic card. Professional GPUs are the professional graphics solution of choice for the majority of Virtual 3D applications. High level GPUs can process more than one billion triangles per second – completely outperforming all real-world professional 3D solutions.

4.1.7. Sound system

Many corporate videos have music and audio and therefore the installation of a digital audio system is required. VR rooms can be equipped with high fidelity speaker systems.

4.1.8 Room conditioning

The final requirement it the preparation of the visualization room itself. The floor should be covered using a grey or black carpet so as to avoid reflected light interfering with the projected display. The walls and ceiling should be painted in matt black so as to reduce the ambient light and allow the participants to focus on the screen clearly. Sound insulation should be considered also.

4.2. Meeting rooms

All companies have rooms that are available to conduct meetings. These spaces are also used in the presentations of projects, shipyard facilities or for technical sessions. They are often equipped with media displays such as conventional projectors and LED or plasma monitors.

Meeting rooms can be upgraded to professional high grade 3D projectors or to the latest large format 3D monitors. 3D monitors give viewers a real experience that can't be achieved through standard definition or simple high-definition monitor sets. 3D Monitors and 3D projectors allow viewers to observe corporate videos and CAD presentations in 3D simply by wearing a special pair of compatible 3D glasses. Tracking solutions for portable systems also exist and their components can be quickly mounted around a display frame for quick and easy use.

4.3. Workstations

Designers use workstations that have advanced CAD software applications. These computers are fitted with high performance processors and graphic cards and normally TFT monitors in the size range of about 22". This is the common screen size for designers in shipbuilding. With the use of software applications where stereoscopic viewing can be activated, the standard monitor could be replaced by a 3D monitor and 3D glasses.

4.4. Portable solutions

There are compact VR technology devices, apart from 3D monitors, TVs and projectors, available in today's markets that are very useful for application at exhibitions and events. Some of these devices are:

4.4.1. 3D Laptops

A wide range of new laptops are equipped with specialized screens and software that add a third dimension to corporate videos and stereoscopic software. *nVidia's 3D Vision*, is the technology solution employed in many of these laptops. They can provide an immersive 3D experience, and indicate the exciting potential of these future virtual products and applications taking advantage of the small size and weight of this solution.

4.4.2. 3D Pico projectors

There are ultra portable and compact projectors that can be used anytime, anywhere. These are easily connected to video-out ports of countless devices. The main features of these projectors are the long lasting solid state LED illumination, amazing picture quality and DLP Pico chipset technology.

5. VR future application in shipbuilding industry

VR technology is going to be evolved for the purpose of providing virtual experience to users. Not only do they reproduce a real-world experience in a virtual space, VR systems could also provide, in future, virtual experiences that are impossible to reproduce in real life. In some cases, experiences in virtual spaces appear to work even better than in real-world situations in terms of safety and cost.
The future applications of VR to shipbuilding and the technology progression will be analysed in the following paragraphs.

5.1. New ways of dealing with ship design

The VR is a tool to evaluate, analyze, simulate and visualize the design/model in advance on a secure and interdisciplinary basis to take necessary decisions. This solution could be improved to be used for more purposes: for reviewing projects, examining and demonstrating content, searching for ground-breaking solutions, etc. All depicted in a one-one scale model, which will be a tremendous aid for engineering work. Through this system, the 3D environment could be watched by users in full-size, giving them an accurate idea of the model dimensions, the real feelings it will produce or the ergonomics of a system.

Shipbuilding industry is known to be one of the most labour-intensive industries and requires skilled workers. Hundreds of people in a shipyard work together with different specialties including welding, painting, heating, piping, and so on. While most of the jobs in the shipbuilding industry involve hard and difficult work, there some tasks that create a continuous demand on human resources since many workers resign due to the poor working environment, for example, workers are exposed to noxious gasses and heat produced in paint and welding processes. In these tasks, the VR could help simulating the virtual environment in as real a manner as possible, providing additional information for training, such as virtual motion guides could improve the proposed training system. With such features, it would be much easier for trainees to correct their faults and practice in a more standardized way.

5.1.1. Design, manufacturing and production phases

The use of modern digital design and evaluation tools is indispensable to take safe predictions about the future characteristics of a ship. The evaluation about how certain engineering and design changes impact the overall ship can be done with the help of modern simulation and visualization technologies, much easier and faster than before. For this reason one of the main task in the future, for the shipbuilding software developers is to improve the VR tools.

There are important challenges in the ship design and production around the VR application. This is especially true when dealing with heterogeneous data structures (multiple, discrete authoring systems). Also the high collaboration and discussion efforts in the construction and detail design stage (especially for distributed, collaborative projects) and the high degree of interaction between supplier and customer during the development and production phase (triggered by the time and cost pressures in the design and production and the often very complex systems and equipment) are another important issues to be considered.

Painting and welding jobs in the shipbuilding industry require a continuous supplement of human resources since many workers leave due to the poor working environment. While painting and welding are known to be difficult jobs, they are also ones of the most important processes in ship construction. Not only affecting the construction schedule, these processes are also directly related to the quality of the ship under construction. So it is particularly important to train workers so that they can paint evenly on large surfaces with a uniform thickness and they can weld properly too.

The VR greatly simplifies the planning and re-planning process, making it easy to create a good production plan and keep it current. This simulation model of the shipyard production process captures both the essential physical shipbuilding activities and the essential management decision-making activities that support the physical production processes.

The VR could identify the overall shipyard facility and manpower resources and the construction tasks required to build a ship. The VR will interact to calculate the specific allocation of resources over time necessary to produce the ship. The VR will provide both schedule and resource use. The VR can also help to quantify the cost and schedule impact of delay and disruption as well as assist in identifying the most effective management actions to overcome such problems.

Nowadays simulators only can handle simple object movements. In the future it will be possible to do complex consecutive movements with, for example, equipments, topological movements, dismounting elements, advance information displayed and connexion to PLM.

5.1.2. Ships in operation

A VR navigation tool could involves superimposing a 3D virtual model on a user’s real-time, natural perception of reality. The VR concept is designed to enrich perception of the real world by adding virtual elements that are not normally perceptible. The VR system would moreover, improve management of bridge crew stress in conditions of reduced visibility, fog, poor visibility, darkness,

etc

Training, as it is mentioned before, is one of the representative application fields of VR technology where users can have virtual experience in a training task and working environment. Widely used in the medical and military fields, VR-based training systems are also useful in industrial fields, such as the aerospace industry, since they show superiority over real training environments in terms of accessibility, safety, and cost.

5.3. The current and future software research

A quick examination of shipbuilding magazines over the last five years will reveal that there has been much talk about the application of 3D models and applications of VR. This all presupposes the existence of a digital prototype, in other words, a digital or virtual mock-up of a ship. The concept behind using digital prototypes is to do as much work, analysis, and communication as possible within a 3D digital environment, rather than in the physical world. This involves using computer simulations more than physical models and viewing videos and fly-through, rather than interpreting paper drawings. The concept of digital prototyping goes beyond simply creating product designs in 3D. Having digital prototypes on a screen of the engineers in their office is one thing but getting the 3D model down onto the shop floor, extends the concept even further. This goes beyond than simply having production workers viewing the design. It involves production department utilizing the CAD model on a day to day basis.

5.3.1. VR in CAD

Most of CAD suppliers are developing the VR concept in order to achieve future success. For example, some of them are promoting the use of the shop floor 3D concept as a logical extension of its digital prototyping tools used in their programs. There are still limitations on the number of parts that the software can handle. Only limited strides have been taken in the direction of shop floor 3D at even the most progressive shipbuilding companies.

Another way where the CAD companies want to improve the VR tools is using tablets. Showing complete build sequences, via 3D animations in tablets, would dramatically aid in communication compared to simply viewing static models. The use of tablets would also allow mobile shipyard workers to bring the digital prototyping experience with them, further enhancing productivity. It is true that due to the size and complexity of 3D CAD models used in shipbuilding, there are current limitations imposed by the software and hardware that affect the viability of this approach.

5.3.2. VR in PLM

PLM tools are used for configuration management of the digital mock-up. The VR applied to PLM will bring together the product, tooling and production line around a single database. The totality of processes and data necessary for the different functions will be included. As well as integrating the different skill areas, this VR applied to PLM could be used to apply the design-to-build concept and enable complete product lifecycle management. Industrialization process must be optimized. The VR applied to PLM could also be used to simulate production processes and maintenance operations. Finally, VR applied to PLM will achieve ever greater degrees of optimization: automatically produce instructions and documentation and follow project progress, reviewing the mock-up in VR.

5.4. Advanced technology applications

Progression is running very fast in hardware VR applications. One the most representative applications in this field are the immersive displays. There are two main types of immersive displays widely used in VR systems for providing high-level spatial presence: Cave display and HMD. Cave displays utilize a number of large projection screens forming a cubical room to cover the whole view of the user. On the other hand, an HMD is worn by the user, and the display screen is attached to the

user's head, following the user's view. By tracking the user's head motion, an omni-directional view of a virtual scene can be provided to the user by updating the virtual scene image according to the user's view direction.

5.4.1. Immersive Cave

The future is a six-walled Cave (Cave Automatic Virtual Environment) equipped with six projectors, designed for a complete immersion of the user in the simulation. The viewer is surrounded by six walls (front, left, right and back side, floor and ceiling) so that they can experience a true feeling of realism and of touching objects which seem to be next to the viewer in the middle of the room. The immersive cave is the main challenge, in this moment, of VR installation. This system is very difficult to get right, because the images must be razor-sharp and adjust perfectly to the different walls, to the mirrors hanging in the middle and the position of the projectors.

5.4.2. Connexion with Haptic Technology Devices

Developers are constantly seeking new ways to increase the realism of the experience of VR. A way to do this is by allowing users to use their sense of touch through a peripheral device such as a control, to move. This technology allows users to use their sense of touch is called haptic technology. The haptic technology is the study of how to couple the human sense of touch with a computer-generated world. There are two types of haptic feedback: kinesthetic force feedback and tactile feedback. In VR the haptic feedback usually is originated in the control of the actions. All haptic devices are derived from a convergence of mechanical and electrical engineering and software.

5.4.3. Collaborative work environment remote between VR caves and multiuser interface

One of the advantages of doing 3D visualization of a ship in an immersive environment is the ability to have geographically distributed participants sharing space with each other and the objects under discussion. This allows the different participants to point at specific objects in the scene or set the parameters of the simulation to specific values to clarify the information. It gives the users a common context for their discussions, especially in international collaborations.

When there are collaborators (very common in this days), and they are distributed in different workstations, inclusive around the world, VR becomes more challenging as this involves multiple networks, multiple time zones, and multiple cultures. Because of time zone issues it may be inconvenient to schedule meetings, so Multiuser Interface may be the most appropriate mode for transoceanic VR. Multiuser Interface will also have the advantage that geographically distributed teams could work on the same VR project.

6. Case of success: Implementation of a VDC in NAVANTIA

Navantia is an international reference in the design and construction of military vessels with high added-value, as well as in control and combat systems, repairs and conversions, diesel engines and naval and power generation equipment. Navantia´s production facilities are split into four geographical centres: Ferrol Estuary, Cartagena Wharf, the Bay of Cadiz and Madrid.

Navantia has recently installed a new VR room in Cartagena Shipyard, a turnkey project developed by SENER. It is being used for the visualization of the 3D model of the series of submarines S-80, that has been developed with FORAN in all disciplines. The solution allows the navigation 3D by Stereo Active technology contents that are generated in FORAN, with the FVIEWER module. The estimated number of people who will be viewing the 3D information is 25 to 30 people and the system is fixed.

The solution also has a tracking system wireless for use within the display module.

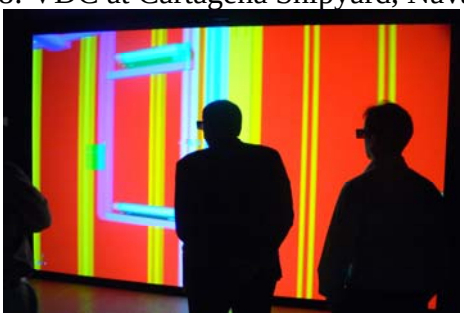
The use of the Virtual Design Center (VDC) in Navantia is being very productive so far. It could be highlighted the following aspects:

- Cost reduction. A number of design issues have arisen in the different meetings between the Navantia engineering department and the Spanish Navy. The trained people of the Spanish Navy are able to detect issues regarding the position of the equipments having in mind the operation of the vessel. These changes imply modifications to the 3D model and new releases of constructive drawings rather than major and expensive changes in the production stage. Many people in the production department are not trained to understand 3D models and they find much easier to visualize the vessel in the VDC due to the immersive sensation. During the sessions they are foreseeing later production issues in a very easy way.

- Space understanding. The possibility of placing dummies is very important in vessels with little room (especially submarines). Placing dummies in realistic positions grants a full understanding of the real space in the vessel compartments.

- Commercial activities. The whole vessel is being presented to new customers before it is built. They realize the complexity of it and appreciate the high level of details in the models (because the lack of room). Explanations of the functionality of the different systems are better understood if they are visualizing them at the same time. The walkthrough navigation is very realistic and makes the new customer to have a deep knowledge of the vessel structure (decks, bulkheads, ladders...).

Fig. 8: VDC at Cartagena Shipyard, Navantia



7. Conclusions

VR is being used from years in shipbuilding, especially in naval environments, but is now that it has become much more extended. The great advantage from the old VR is based in important improvements in hardware and software. Regarding the software, the intensive use of advanced CAD applications ensures an accurate ship 3D model that can be used in VR navigations with the aid of specific tools with the necessary capabilities for the visualization and navigation. This tools, the viewers, need to handle a huge amount of data, need to have advanced capabilities to ensure a friendly navigation to the user, and more, they need to give users important advantages such as the possibility to see in 3D (stereoscopic vision) and the interaction with the model (tracking). From the hardware side, important advantages have been introduced in the market, which now offers solutions for any kind of requirement, both from the most simple and portable to the most sophisticated and complex.

In this paper it has been described in detail the main application and uses of VR in shipbuilding, from different points of view. As an example of a modern VR viewer, FVIEWER has been described in detail. Regarding the hardware, it is true that technology is changing very fast and now there are available in the market many devices to achieve the on-demand solution that every company needs. From a single and portable solution, to a cave in 5 dimensions, a wide range of solutions have been described. In case of working with complex 3D objects or data sets in an immersive environment, the addition of motion tracking system is the most effective way to improve interaction with the information.

Finally, there are many areas of improvements for the future. Some of them seem to be unrealistic in the short term, but the reality often exceeds expectations in the field of technology. The future applications and technology have been explained too. The combination of better technology plus better software allows a great step forward in the use of VR in shipbuilding. Real and measurable benefits are obtained in the use of new technologies in many different areas involved in the ship design and production process.

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