Journal of Naval Sciences and Engineering
2019, Vol. 15, No.2, pp.173-196
Naval Architecture and Marine Engineering/Gemi İnşaatı ve Gemi Makineleri Mühendisliği

RESEARCH ARTICLE

VIRTUAL REALITY APPLICATIONS ON SHIPS IN USE

Abdi KÜKNER[1]
Hasan Hüseyin AKKUŞ[2]

[1] *Istanbul Technical University, Faculty of Naval Architecture and Ocean Engineering, Istanbul, Turkey,*
kukner@itu.edu.tr; ORCID: 0000-0002-3746-4445

[2] *Istanbul Technical University, Faculty of Naval Architecture and Ocean Engineering, Istanbul, TurkeY,*
hasanakkus4040@gmail.com; ORCID: 0000-0001-6152-6928

Date of Receive: 19.07.2019 **Date of Acceptance: 05.11.2019**

ABSTRACT

Virtual Reality (VR) technology is one of the rapidly developing technologies. It's widespread usage varies from entertainment to education and engineering. While technological advancements in displays, graphic cards and processors let VR born, its underlying laws has not specified for every part of life. This paper examines applications of Virtual Reality on ships and other marine structures. Their implementation has been elucidated from two perspectives: hardware and software solutions, approximate cost analysis, mathematical equations for design, modeling, construction and inspection, as well as the co-operation and training of people as if they were on board. Two main articles are examined. It's found that some shipbuilders tried to develop their own software at first. But nowadays taking advantage of game engines is more preferred while the mathematical equations behind them are still reasonable.

Keywords: *Virtual Reality (VR), Ship, Naval Architecture.*

KULLANIMDAKİ GEMİLER ÜZERİNDE SANAL GERÇEKLİK UYGULAMALARI

ÖZ

Sanal Gerçeklik (VR) teknolojisi hızlı gelişen teknolojilerden biridir. Kullanımı, eğlenceden eğitim ve mühendisliğe kadar geniş bir çeşitlilik göstermektedir. Ekranlar, ekran kartları ve işlemcilerdeki teknolojik ilerlemeler VR'ın doğumuna izin vermiş, fakat hayatın her parçası için temel kuralları belirlenememiştir. Bu çalışma gemiler ve diğer deniz yapılarındaki Sanal Gerçeklik uygulamalarını incelemektedir. Geniş kapsamlı iki makale ele alınmak suretiyle uygulamaya geçirilişleri, farklı bakış açılarıyla ortaya çıkarılmıştır: donanım ve yazılım çözümleri, yaklaşık maliyet analizi, tasarım, modelleme, inşa ve teftiş etmek için gerekli olan matematiksel denklemler ve bunların yanında insanların sanki gemideymiş gibi birlikte çalışması ve eğitilmesi. İki ana makale incelenmiştir. Bazı gemi inşacılar başlangıçta kendi yazılımlarını geliştirmeye çalışmıştır. Ancak günümüzde arkalarında yatan matematiksel denklemler hala geçerli iken oyun makinelerinden faydalanmak daha çok tercih edilmektedir.

Anahtar Kelimeler: *Sanal Gerçeklik (VR), Gemi, Gemi İnşa.*

1. INTRODUCTION

In our global world technology is going on advancing each day. The countries and companies who started these advances are becoming leaders. These who can overtake the innovations can survive, while the others doomed to the failure. In last years, people wear some strange helmets and dive into an unreal world that is called Virtual Reality (VR). Instead of a small branch of computer engineering or entertainment, it's becoming part of our lives.

While virtual reality (VR) and Augmented Reality (AR) is widely used various areas of life to make simulations, shipbuilding industry must catch up with the latest technology. Some companies that are aware of the power of that technology have already begun to develop and use their own software. From the early design stages to the maintenance, ship companies benefit virtual reality. The ship builders, that can show the stages of construction to all the engineers at the same time, are reduce the errors and minimize the cost. Yacht sellers, who make feel the clients as inside of their new toy, are the leaders for now. The navies and shipping companies, that can train their crew in the virtual reality, eliminates the human errors.

Virtual and Augmented Reality are becoming the milestones of ship production and maintenance. This paper contains the most needed solutions of virtual reality to use on ships and other marine structures. While in 2012 Spain designed an aircraft carrier thanks to VR, in 2018 American Navy introduced its Virtual Reality simulation for aircraft carriers bridge [1-3].

2. LITERATURE SURVEY

Since virtual and augmented realities are new developments at naval architecture, only some interested people who keep up with the technology have some publishes. These publishes mostly written by the same people who are workers or owners of the companies that use VR and AR technologies currently. So impartiality of these publishes must be questioned.

Rodrigo Pérez Fernández and Verónica Alonso from marine sector of building company have some publishes about Virtual and Augmented Realities at international magazines [4]. Alexandros Ginnis develops virtual and mixed reality software for ships, besides being an Associate Professor at National Technical University of Athens [5]. Dennis Morais works in shipbuilding and writes on his blog [6]. These leaders have written articles and advanced their companies at the same time. Each group of writers focuses on different aspects of VR applications for ships.

"Virtual Reality in a shipbuilding environment" written by Rodrigo Pérez Fernández and Verónica Alonso in November 2014, tells settling Virtual Reality solutions for shipyards. Properties of virtual reality rooms and hardware are discussed in detail. On the other hand, case studies such as Implementation of a Virtual Design center for Spanish Navy's NAVANTIA warship could get articles of same team of writers. It's stated that besides numerous shipbuilding magazines over the last five years are full of articles about the application of Virtual Reality for 3D ship models, most of CAD suppliers are busy with developing the Virtual Reality concept for their software [4].

"VELOS - A VR Environment for Ship Applications: Current Status and Planned Extensions" written by A.I. Ginnis and others point out designing multi-user Virtual Environment simulations to improve the early steps of ship design. Writers claims that much effort has been devoted to the development of sophisticated models for performing advanced evacuation analysis of passenger ships which need to be advanced taking advantage of Virtual Reality. Virtual Environment for Life on Ships (VELOS) is a multiuser Virtual Reality (VR) system that supports designers to assess passenger and crew activities on a ship for both normal and hectic conditions of operations and to improve the ship design accordingly. It aims to use real human in escape scenarios in a system [5].

"VR in Shipbuilding" written by Denis Morais summarizes the current situation of VR technology in the big picture of 2017's November [7]. In his following annual reviews, he states that no satisfactory progress has done till 2019 [8-9] Writer has been internationally recognized for his published blogs, articles and papers and continues to provide insights on innovative solutions for the marine industries. He has worked hand in hand with industry partners all around the world to solve their most difficult business and technology challenges. This depth of understanding of both the current and future state of technology and the business of shipbuilding serve. It's stated that writer leads ship building industry towards the delivery of innovative products and services [6-7].

Each group of writers is the prime movers of the Virtual Reality on ships. This article examines the short history of this new technology and gathers the revolutionary rules and ideas relating to VR.

3. FUNDAMENTALS OF VR APPLICATIONS

Basically VR offers a panoramic view that person feel inside of the scene even though the scene is unreal. For 2019's technology, the main distinguishing element is display technique:

1. Virtual Reality room

2. Head mounted display (HMD)

Both systems are similar. Virtual Reality room is any room that is covered with screens which let collaborative working, it can be covered completely reminding a cube which is called Cave Automatic Virtual Environment (CAVE). Screen and the virtual environment is fixed, while the people inside move. Head mounted systems offer individual solution as the distance between screen and eye is expressed in millimeters. Person looks wherever he/she wants while the computer or cell phone computes the direction and view thanks to the sensors.

3.1 Visualization System

For the visualization, tree type of screen come forward: 3D projectors, 3D displays and helmets that are also called head mounted display (HMD). 3D displays are bright enough to be seen even in a luminous environment. It is also easy to set up almost everywhere. The biggest problem is size/price rate when it is compared to 3D projectors. For the big rooms, it costs too much expensive. For the lower cost projectors must be preferred. The costs of 3D displays is shown in Table 1, while costs of 3D projectors in 2011 is given in Table 2 and the costs of the whole solutions according to the screen type is listed in Table 3. Prices on the tables are belongs to 2015 year's Spain. In 2019, these prices are similar [4].

Helmets are the cheapest solution for VR applications. It provides a total immersion in all directions as a function of how the head is moved and it will see all the space around. Even though Fernández stated that that just one person can use the helmet at time, technology of 2018 permits users to interact these people, using VR helmets. Even though price of helmets in 2011 is shown at the Table 3 that is prepared by Fernández, Google cardboard, which costs less than 10 € must be in the options. Cardboard make people's mobile phones become a Virtual Reality display [4].

Dennis Morais claims that there are many clients that he has engaged with who have invested in the relatively inexpensive VR hardware such as the Oculus Rift and the HTC Vive. The cost of VR hardware continues to drop with Oculus Rift and Touch controllers [7].

Table 1. Cost prices for 3D displays, depending on the size and considering two different screen resolutions (from [4]).

Screen resolution	Maximum screen size	Cost
FULL HD	65"	5.000 €
4K	84"	15.000 €

Table 2. Cost prices for 3D projectors, depending on the size and considering the same range of products than before (from [4]).

Screen resolution	Maximum screen size	Cost
WXGA	2.5 m x 1.4 m	2.000 €
FULL HD	3 m x 1.68 m	5.000 €
FULL HD	4 m x 2.25 m	25.000 - 50.000 €
4K	6m x 3.17 m	< 120.000 €

Table 3. Prices of helmets and different manufacturers vary depending on the incorporating (from [4]).

Screen resolution	Cost
640 x 480	1.000€
800 x 600	5.000€
1280 x 1024	15.000€
FULL HD	30.000€

4. MODELING FOR VIRTUAL REALITY

The details of the display or processors are related to the hardware and develop over time. However, the essence of VR is the software used to model the real world and the accepted source.

Ship software companies produce their own software and use widely known hardware. Diversity of hardware makes users experiment more realistic, while software organizes all the correlation. Even though some other applications are available, this paper discourse mainly two softwares:

FViewerVR™ and VELOS. Differences of two systems are summarized on Table 4.

Table 4. Comparison of FViewer™ and VELOS.

	FVieverVR™	**VELOS**
Main purpose	Visual design review for shipyard	Experimental review for escaping simulations
Stages that are used	Design and Building Stages	Design and Early Design Stages
Costumer target	Shipyards, Design Offices	Designers
Number of users at the same time	1-10 (in room)	Numerous (Avatars can be used)
Aplication in real life	Navantia Naval Ship	Ro-Ro / Ro-Pax ship

FViewerVR™ is designed as a Virtual Reality kit of a CAD software. So its applications are limited with some basic commands such as clip plane to view a certain part of ship, shown on Figure 1. It uses dummies that are shown in Figure 2, to check ergonomic design. Any number of dummies can be added with different statures, postures and orientations. Software automatically detects and warns the user about clashes between the dummy and the model objects. 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. Also Review comments are attached to the model as annotations while objects with attached information may be highlighted to easily identify them in the model [4].

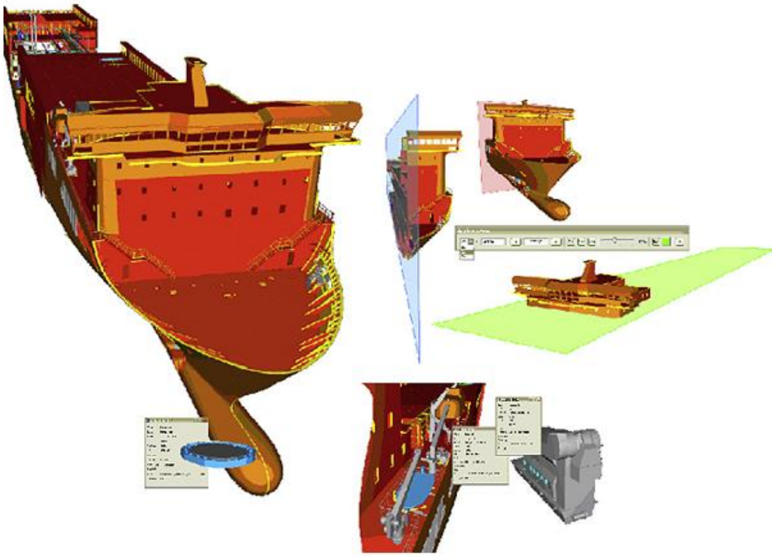

Figure 1. The interior view of a ship with clip plane (Source: [4]).

Figure 2. Ergonomic check of the design using dummies (Source: [1]).

Most of these properties of FViewerVR™ are similar to the CAD software and it may induce the opinion of being a primitive software. But it is needed to understand that such modules render image and computes lights, colors, textures etc. besides shapes.

Virtual Reality requires too much GPU power. So, FViewerVR™ uses OpenGL™, like VELOS, which is the most widely adopted graphics standard for high performance applications. Some different techniques are used to make rendering of big scenes faster which makes it possible to visualize an entire ship using the adequate hardware. The geometry is organized in KD-trees which partition data structures in geometry. KD-trees make fast occlusion culling possible, in other words, display is shown in higher quality and faster at the same time [4].

VELOS aims to calculate the needed time to evacuate the passengers and find the errors in the design, rather than being an ordinary CAD drawing or viewing software. So besides using VR headset, its obligatory to use a lot of parameters. The most crucial parameters are relevant to deciding velocity vectors of agents which is a part of motion behavior. Splitting motion behavior into three separate levels as; action selection, steering and locomotion will make understanding easier. In the action selection level, goals are set and plans are devised for the action materialization. The steering level determines the actual movement path, finally locomotion provides the articulation and animation details [5].

Steering is decided with vectors. After seeking, a target point is determined to move with the velocity that is computed as a weighting factor. The relation is shown [5]:

$$f = w\frac{q - p}{\|q - p\|} \tag{1}$$

where p is agent's position, q is the seek point and w is an appropriate weighting factor. In case of an obstacle, the velocity is dropped [5]:

$$v_{new} = c.\left(v_{prev} + f\right), \text{where } c = \min\left\{\frac{v_m}{\left\|v_{prev} + f\right\|}, 1\right\} \quad (2)$$

where v_m is the agent's maximum allowable velocity.

Last two equations are made to decide the movement vectors of the avatars controlled by the computer, but it is known that twenty steering behaviors such as Seek, Arrive, Wander, Separation, Cohere, Leader Follow, Obstacle Avoidance & Containment, Path-following, Pursuit, Flee, Evade are used at the design of VELOS. Ginnis have adopted these behaviors from the works of two scientists, C.W. Reynolds and R. Green [10-11]. Adding these steering behaviors make the simulation more realistic not only for VR, but also for the most simulations that works with moving people on board.

VELOS level up the simulation with modeling behaviors of a group of people, which called crowd modeling. Even though IMO circulars have some recommendations for modeling of people's movement, writers claim that VELOS's method is more realistic than the simplified approaches proposed in IMO circulars [12]. These circulars have some restrictive assumptions and omissions as ship motions, fire or smoke, crew assistance and passenger grouping effects, while VELOS's enhanced crowd modeling corrects these calculation mistakes that IMO ignores.

VELOS divides enhanced crowd modeling as:
1. Modeling Ship Motions and Accelerations
2. Passenger Grouping
3. Crew Assistance
4. Influence of Fire

4.1 Modeling Ship Motions and Accelerations

VELOS have some different methods to reckon motions of ship. It is possible to acquire data from precomputed ship motions. Accelerations during time can be either estimated via numerical differentiation of ship motions or imported from the experimental measurements. If location history by time of a given P point on board is known, we can calculate rotational motions (pitch, roll and yaw), linear velocity (v_p) and acceleration ($\dot{v}_p$), angular velocity (ω_B) and acceleration ($\dot{\omega}_B$) on the Q point of the ship. VELOS uses following well-known relations from rigid-body kinematics at every Q point on ship [5]:

$$Q = P + \omega_B \times r_{pq}, \;\; \dot{v}_q = \dot{v}_p + \omega_B \times \left(\omega_B \times r_{pq}\right) + \dot{\omega}_B \times r_{pq} \qquad (3)$$

where, r_{pq} is the vector formed by P and Q.

On the other hand, inclination on ship will hinder agent motion accordingly. VELOS appoints upper and lower thresholds; lower one discards plane motions with negligible effect on agent's motion, while the upper one cause movement inability, as the limit of agent's balancing capabilities. While the formula, that is underpinned by experimental data relating to threshold angles and the weight function is given below [5, 13-15].

$$f_i = \lambda(\varphi)\; g_p / \|g_p\| \qquad (4)$$

where g_p is the projection of g value, $\lambda(\varphi)$ is a suitable weight function that is decided by the angle φ formed between gravitational acceleration and the normal to the deck plane.

Rough weather conditions lead loss of balance on sailors because of sliding and tipping. VELOS suggest 3 adjustments depend on T_{LATp} and T_{LONa}. First relation is set for the consideration of tips to port, and second relation to aft [16-18]:

$$\mathrm{T}_{LAT_p} = \frac{1}{\mathrm{g}}\left(\frac{1}{3}\mathrm{h}\ddot{\eta}_4 - \ddot{\mathrm{D}}_2 - \mathrm{g}\eta_4 - \frac{1}{\mathrm{h}}\ddot{\mathrm{D}}_3\right) > \frac{1}{\mathrm{h}} \tag{5}$$

$$\mathrm{T}_{LON_a} = \frac{1}{\mathrm{g}}\left(\ddot{\mathrm{D}}_1 + \frac{1}{3}\mathrm{h}\ddot{\eta}_5 - \frac{\mathrm{d}}{\mathrm{h}}\ddot{\mathrm{D}}_3\right) > \frac{\mathrm{d}}{\mathrm{h}} \tag{6}$$

Variables of these formulas are the basic personal parameters determining balance of people on board. d, h and l stands for half-shoe width, the distance to person's center of gravity in vertical axis and half-stance length respectively, shown in Figure 4. Usually values of l/h lie in the interval (0.20, 0.25) while for d/h lie in (0.15,0.17). In the equations, η_1 (surge), η_2 (sway), and η_3 (heave) represent the translational movement, while η_4 (roll), η_5 (pitch) and η_6 (yaw) represent the rotational components of ship motion along the x−, y− and z− axis of the ship coordinate system respectively, as they are seen in the Figure 3. These components are also used to find the displacement of P(x,y,z) point according to the equation of $D=(D_1,D_2,D_3)=(\eta_1,\eta_2,\eta_3)+(\eta_4,\eta_5,\eta_6)\times(x, y, z)$.

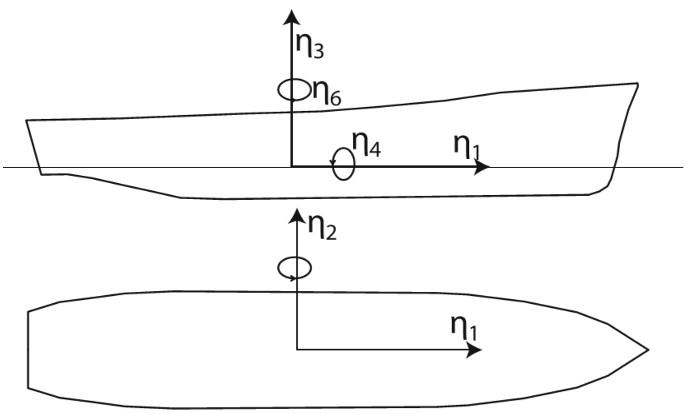

Figure 3. Ship coordinate system (Source: [5]).

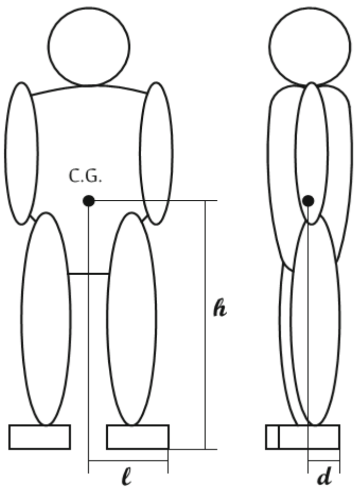

Figure 4. Person's center of gravity, half-stance and half-shoe width (Source: [5]).

Three implementation of the Equation 5 and 6 in the simulation are listed below:

1. Using new function of k values between 0 and 1, $\tilde{v}_m$ values that represent the maximum allowable velocity dropped according to the following rule [5]:

$$\tilde{v}_m = k \, . \, v_m \tag{7}$$

where: $0.20 < T_{LAT} < 0.25 \wedge 0.15 < T_{LON}$

$$k \begin{cases} = 1, & if \; T_{LAT} < 0.20 \wedge T_{LON} < 0.15 \\ = (-20T_{LAT} + 5), & if \; 0.20 < T_{LAT} < 0.25 \wedge T_{LON} < 0.15 \\ = (-20T_{LAT} + 5)(-50T_{LON} + 8.5), & if \; 0.20 < T_{LAT} < 0.25 \wedge 0.15 < T_{LON} < 0.17 \\ = (-50T_{LON} + 8.5), & if \; T_{LAT} < 0.20 \wedge 0.15 < T_{LON} < 0.17 \\ = 0, & if \; T_{LAT} < 0.25 \wedge T_{LON} > 0.17 \end{cases}$$

The values of k are made visible with a color pot shown in the Figure 5.

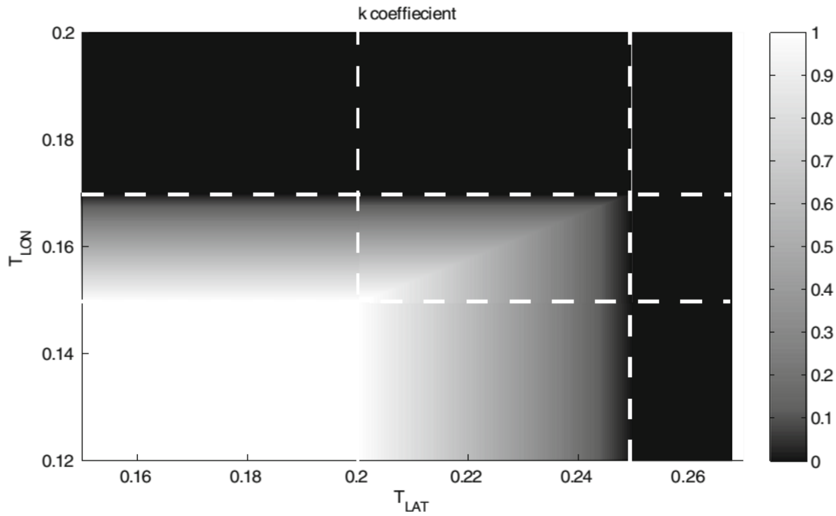

Figure 5. Color plot of k-coefficient values (Source: [5]).

2. Some steering behaviors are changed. It is claimed that such scenario would increase the wander behavior %10 and decrease the obstacle avoidance and separation contribution that determine both speed and direction of walking people in the simulation.

3. Parameters of each individual steering behavior are adjusted.

4.2 Passenger Grouping

Modeling ship motions and reactions of humans are not enough for a realistic human flow. People in hurry may wait or go back for someone instead of escape from the shortest path. Considering social reactions of people, VELOS uses Enhanced-Cohere behavior which clusters agents that are not only geometrically close to each other, but also belong to the same group, like families, co-operating crew and crew guided groups. For that purpose, people are endowed with ID to appoint different v_m values [24].

VELOS implement 3 different subgroups to make grouping more realistic. Calculating the locations of all the members of the group, standard cohere behavior, draws s-p steering vector [5]:

$$s = \frac{1}{\sum_i w_i} \sum_i (w_i \, p_i) \tag{8}$$

where $w_i = \frac{1}{\|p - p_i\|}$

In this equation position of the person symbolized as p, and the rest of group members as p_i, to calculate the s-p direction for each of 3 levels of subgroups below:

Grouping Level 0:

This level targets group members or leaders for the short-term using the last equation for the standard cohere behavior.

Grouping Level 1:

This level aims to create cohesion in the group, sharing a common ID. In case a member left the group, the others are not affected.

Grouping Level 2:

This level has the same properties with Level 1. In addition, group leaders are responsible for the one who leave the group. The leader or leaders are needed to take some corrective action, such as waiting or looking for the missing member.

4.3 Crew Assistance

In a real evacuation scenario crew knows escape routes better than the passengers. So if someway stuck, they can lead people alternative routes. VELOS effect passengers' behaviors according to crew members using triggers. Benefits of crew assistance have been shown by test cases.

4.4 Influence of Fire

In case of a fire, crew and passengers encounter some frustrating feelings which make incapable of running. Smoke, made by fire, obscures seeing while heat and toxic products on the air make people sick and unconscious. The program decides the influence of fire products on the behaviors of agents using Health Reduction Rate function [5]:

$$HRR(t) = F\big(\alpha T(t) + bC_{CO}(t)\big), \left[\frac{Health_{units}}{second}\right] \tag{9}$$

where F describes the used functional model, T is the temperature (°C) and C_{CO} the carbon monoxide concentration (ppm) of the space [5].

In addition, mortality and ability of walking is decided by the Health Index function [5]:

$$HI(t) = 1 - \int_0^t F(\alpha T(t) + bC_{CO}(t))dt \tag{10}$$

All of these relationships determine the basic parameters that the user feels during an escape scenario. Since these are for the movement of people in extreme situation, these results are reasonable for most of similar ship simulations [4].

Because calculating fire spreading is already a hard occupation, VELOS prefers to import pre-computed time-series of fire spread. In this way, setting the time when fire puts on or explosion happens is enough to attain the needed parameters for using Health Reduction Rate and Health Index functions as well as visual and auditory properties of ship.

5. VIRTUAL REALITY SOFTWARE

Apart from some CAD/CAM suppliers, developed their own software, some people can use game engines which are cheaper, such as Unity and Unreal. But even these game engines request a certain amount of money when they are used for commercial issues. According to Fernandéz, most of the software require a product license for projection channel ranging between 10,000 € and 300.000 € [4].

Morais claims that some shipbuilding companies have succeeded in creating VR solutions after spending years and a lot of money on software development. However now most companies are using some general gaming engine such as Unity or Unreal. These game engines require money, but it's more cost-effective for the purpose of getting more innovation from software vendors that are focused on VR [7].

6. TESTS OF VIRTUAL REALITY SYSTEMS

FViewerVR™ application is known to be used by the Spanish Navy in the construction process at the NAVANTIA ship's Virtual Design Center. Four different construction sites were coordinated in the VR room at Cartagena shipyard. It is stated that this application helps to provide the following advantages [1]:

Cost reduction: The experienced staff of the Spanish Navy recognized the problems with the location of the equipment on the ship. They could propose construction drawings for changes and new drawings in the 3D model, rather than large and high-priced changes in the production stage.

Space understanding: Putting dummies in realistic positions helps people understand the real distances within the ship's compartments.

Commercial activities: The whole ship has been introduced to new customers before it was built. Customers realized the complexity and appreciated the details of the model. The walkthrough navigation has informed new customers in-depth understanding of the ship's structure, such as decks, bulkheads, ladders. [1]

VELOS software was tested in a Ro-Pax ship evacuation scenario. Every variation of scenario are simulated 3000 times each, to find the weakness of ship [5].

Crew assistance: Ginnis says 3 variation of tests are done to measure the effect of crew assistance. In the first variation, passengers follow the designated escape route without crew assistance, while they take crew assistance at second and third variations. Average travel time for variations 1, 2 and 3 are equal to 147 s, 112 s and 113 s, respectively. Importance of crew assistance to evacuate passengers is proven by VELOS.

Fire event: Simulation is run 360 times to compare evacuation with and without fire. It is shown that in case of fire %30 of the passengers could not reach the muster station because of fire obscuring and toxic gases resulting fatalities.

Ship Motions' Effect: Considering ship motions 3 variation of tests have done with VELOS. First variation for without motion modeling, second variation for kinematic modeling of motion effects through inclination behavior, and the third one for dynamic modeling using tipping coefficients implementation.

Travel times resulted for both inclination and tipping coefficient modeling are approximately 70 seconds and considerably higher than the still water case which is around 50 seconds.

7. FUTURE WORKS

Computer Aided Modeling solutions have every time an impact on people, showing illustrations in different colors. People who have no knowledge about industry, can watch some views, and comment. Advertising to the customers who have never worked in ship building is much easier with VR technology. In a very close future, the companies that do not use VR and AR in their advertisements, cannot sell their products to the wealthy and illiterate customer in shipbuilding. Training procedure costs time, money and labor. Universities and companies which do not use VR and AR might share the same fate: failure.

Currently there are some ship building companies which have already built their own software [7]. However, ship builders began to paying some money to the game engines for more realistic effects. Next years' shipping industry can only cope with the adaptation to VR instead of creating an innovation. As a conclusion, some shipyards might need to employ some game developers to use these game engines efficiently.

Now VR technology only lets people move their heads offering a panoramic 3D view. AR technology adds some new characteristics with body movements. Because this technology is still developing, some features relating to ship building and marine life to be determined. These features can be listed as:

1) Swinging platform which imitates the behaviors of a ship between waves

2) Walking band which for the movement of feet

3) Moving walls and handrails for the sense of touching or bumping to a wall

4) Real objects or doors which people enter through

5) Some additional senses such as heat in case of fire, spraying water in case of rough seas, wind, odor etc.

Creating a detailed AR room is not cheap but a need. Most companies cannot attempt such a risky and expensive investment. So most probably AR technology in shipbuilding will initiate for some military trainings.

Mixed reality which offers unreal holograms in real life might be a cheaper solution for some trainings. This kind of solution can be used for fire simulations in the real environment of ship. Training crew wears glasses which is capable of adding flares at certain parts of ship. So crew members can cooperate to stop that fire in their own ship instead of using a special room for VR or AR. Studies are carried by Alexandros GINNIS and he founded his own company ShipReality Inc™ [19]. It seems not only VR and AR, but also MR will meet the requirements of ships in the future

8. CONCLUSION

Variables for Virtual Reality software and hardware solutions, used for ships are shown. Regarding the software, the use of advanced CAD applications ensures an accurate ship 3D model that can be used in Virtual Reality navigations with the aid of specific tools with the necessary capabilities for the visualization and navigation. From the hardware side, some advantages have been introduced that we can see in the market, both from the simplest and portable to the most sophisticated and complex ones.

It's seen that, in 2011, VR was used mainly for review of ships using CAD applications. Then it became an unreal ship environment for some real and unreal people to escape. Both VELOS and FViewer™ operated successfully. FViewer's™ success was proven at the building process of Navantia warship, while VELOS was proven in a Ro-Pax ship. It is possible to use some of the same data that is given on this report, relating to software and hardware solutions in the next VR solutions.

REFERENCES

[1] Alonso V, Perez R, Reidar T, y Sanchez L. (2012). Advantages of using a Virtual Realitytool in shipbuilding. ***COMPIT 2012***, ISBN 978-3-89220-660-6.

[2] Scott M. (2018). "Using virtual reality to train for one of the Navy's most dangerous jobs", Retrieved from https://federalnewsnetwork.com/navy-2018/2018/12/using-virtual-reality-to-train-for-one-of-the-navys-most-dangerous-jobs/ (Access Date:15.01.2019)

[3] Sener Press Releases (2012). "SENER Awarded Contract for the New Navantia´s VR room", Retrieved from https://www.naval-technology.com/contractors/warship/sener/pressreleases/presssener-contract-navantia-vr-room/(Access Date:15.01.2019)

[4] Pérez Fernández, R., & Alonso, V. (2011). Virtual Reality in a shipbuilding environment. ***Advances in Engineering Software***, *81*, 30–40. https://doi.org/10.1016/j.advengsoft.2014.11.001

[5] Ginnis, A. I., Kostas, K. V., Politis, C. G., & Kaklis, P. D. (2015). VELOS - A VR Environment for Ship Applications: Current Status and Planned Extensions. ***Virtual Realities International Dagstuhl Seminar, Dagstuhl Castle, Germany, June 9-14, (2013), Revised Selected Papers***, 33.

[6] Waveform, (2019). "About Denis Morais", Retrieved from https://blogs.ssi-corporate.com/waveform/author/denis/(Access Date:15.01.2019).

[7] Morais, D. (2017). "VR in Shipbuilding", Retrieved from http://blogs.ssi-corporate.com/waveform/2017/technology/vr-in-shipbuilding/#disqus_thread (Access Date:15.01.2019)

[8] Morais, D. (2019). "Shipbuilding 2018 In Review", Retrieved from https://blogs.ssi-corporate.com/waveform/2019/general/shipbuilding-2018-in-review/ (Access Date:15.01.2018)

[9] Morais, D. (2019). "Were my 2018 Shipbuilding Predictions Correct?", Retrieved from https://blogs.ssi-corporate.com/waveform/2019/technology/were-my-2018-shipbuilding-predictions-correct/ (Access Date:15.01.2019).

[10] Reynolds, C.W. (1999). Steering behaviors for autonomus characters, ***In: GDC 1999 (Game Developers Conference)***.

[11] Green, R. (2000). Steering behaviors. ***In: SIGGRAPH 2000 Conference Proceedings.***

[12] Kostas, K., Ginnis, A.I., Politis, C., Kaklis, P. (2011). Use of VELOS platform for modelling and accessing crew assistance and passenger grouping in ship-evacuation analysis. ***In: Sustainable Maritime Transportation and Exploitation of Sea Resources.*** Eds E. Rizzuto, C. Guedes Soares. Volume 2. pp. 729–736.

[13] Bles, W., Nooy, S., Boer, L. (2001). Influence of ship listing and ship motion on walking speed. In: Proceedings of the Conference on Pedestrian and Evacuation Dynamics.

[14] Crossland, P. (2003). The influence of ship motion induced lateral acceleration on walking speed. ***In: Proceedings of the 2nd International Conference on Pedestrian and Evacuation Dynamics, Greenwich.***

[15] Crossland, P., Evans, M.J., Grist, D., Lowten, M., Jones, H., Bridger, R.S. (2007). ***Motion induced interruptions aboard ship: model development and application to ship design.*** Occup. Ergon.7(3), pp. 183–199.

[16] Baitis, A.E., Holcombe, F.D., Conwell, S.L., Crossland, P., Colwell, J., Pattison, J.H. (1995). Motion Induced Interruptions (MII) and Motion Induced Fatigue (MIF) experiments at the Naval Biodynamics Laboratory. Techical report CRDKNSWC-HD-1423-01, Bethesda, MD: Naval Surface Warfare Center, Carderock Division.

[17] Graham, R. (1990). Motion-induced interruptions as ship operability criteria. J. Naval Eng.

[18] Graham, R., Baitis, A.E., Meyers, W. (1992). On the development of seakeeping criteria. J. Naval Eng.

[19] ShipReality Official Website, Retrieved from http://www.shipreality.com/ (Access Date:15.01.2019)