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Virtual Learning and Training Environment for Maritime Education

UCSC

SRI LANKA NAVY

University of Colombo School of Computing
Department of Electrical & Electronics, Sri Lanka Navy

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Virtual Learning and Training Environment for Maritime Education

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ABSTRACT

This paper presents the development of a virtual learning and training environment for maritime education (Vidu Sayura) which allows simulating ship models under complicated environmental conditions. This system simulates six degrees of freedom ship motions (pitch, heave, roll, surge, sway, and yaw) with respect to rudder, throttle and environmental conditions.

A major component of the conventional maritime education is done in real sea environment with real ships. There for the total cost of training is extremely high. However by using this proposed virtual environment, various phenomena of a ship can be explained easily and it can be used as a teaching aid to demonstrate ships maneuvering under different environmental conditions and threat scenarios in training sessions. Trainees can use this virtual environment and define various environmental conditions and threat scenarios in order to study ship maneuvering at their own pace.

1.0 INTRODUCTION

Ship simulations are important for naval training institutes because it can be used for learning and training purposes. Experience gained through this kind of virtual environment enables students to understand ship motions and the dynamic mechanism behind the ship maneuvering.

Simulation of ocean surface vehicles under various conditions has been used in ship simulators for naval training, ship hull designing, simulating military science and entertainment activities such as computer games. The motion of a floating rigid body in an ocean surface can be specified by Newton's laws, fluid dynamics and other basic physics, but it is extremely complicated and difficult [9]. All six possible degrees of freedom (6DOF) motions of a ship are illustrated in Figure 1. Surge, heave, and sway are translational motions. Roll, yaw, and pitch are rotational motions [1, 2].

Ship maneuvering characteristics consist of variety of phenomena occurring simultaneously in short time duration, including drift, turning, speed reduction, displacement of pivoting point, drift angle, heading, etc. However lectures in a conventional classroom can only explain these individual phenomena, one by one and it is not easy to correctly understand that phenomena. When we consider the training in real sea with real ships the operating cost is externally high.

However this virtual learning and training environment is capable of processing a variety of dynamic data and predict ship's motions into a visually understandable format.

A virtual ship simulation system is based on mathematical ship model. Currently there are many ship simulation systems with three degrees of freedom and four degrees of freedom [3], but it is difficult to find six degrees of freedom ship simulation systems focused on environmental disturbances such as sea waves, wind and sea currents [4,5]. There are many commercial ship simulation systems with six degrees of freedom such as *Transas*[6] *and Oceaniccorp* [7]**.** These commercial ship Simulators provide versatile and realistic ship simulation for maritime teaching, learning, assessment and research however these systems are extremely expensive, too complicated and proprietary.

2.0 RELATED WORK

Gatis Barauskis et al. [3] proposed a ship motion prediction system with three degrees of freedom (surge, sway and yaw motions) based on the *Nomoto* steering equation. *Ueng et al.* [5] proposed a ship motion prediction system and they predicted surge, sway, yaw heave, pitch and roll motions based on Newton's laws, fluid dynamics and other basic physics. However, less attention had been given to added mass/excess drag force due to combined yaw and sway motion and ship's orientation in XY- plane with respect to the ocean wave. *Sandaruwan et al.* [4] proposed a ship model based on *Nomoto* steering equation, Newton's laws, fluid dynamics and other basic physics in order to perform more productive and efficient ship motion predictions.

However above mention systems are free and open source but there is no significant product for Learning and Training purpose.

3.0 STRUCTURE OF THE "VIDU SAYURA"

3.1 Overview

We implemented the virtual learning and training environment (Vidu Saura) with Matlab Simulink [8] and C++. It consists of a trainer station, a trainee station, a navigational information display, a computational ship model and a Database as illustrated in figure 2. The trainer can define vessel's physical and mechanical properties, environmental conditions and threat scenarios. Navigational aids and other necessary indicators are generated and projected on to a multiple computer screens from which trainee will have the ability to maneuver the ship as shown in figure 3. While the trainee is maneuvering the ship trainer can change levels of difficulty by adjusting parameters such as environmental conditions and threat scenarios.

3.2 Database

In this virtual environment we use our own computational ship model so that we can incorporate ship data and environmental data which satisfy our algorithms and constrains.

The database consists of two major components ship data and environment data. Environmental data can be classified as wind data, ocean wave data and geographical data. Ship data can be classified as ship's physical and mechanical data.

3.3 Computational Ship Model

We use the mathematical ship model proposed by *Sandaruwan et al.* [4]. It is a six degrees of freedom ship motion prediction system and works at a fraction of the real-time under certin assumptions and limitations.

This computational ship model consists of two major stages. First stage is to compute ship's position and orientation in XY plane by using ship's physical data, mechanical data, user defined dynamic properties (Rudder, Engine RPM) and environmental disturbances (wind and sea current). The second stage is to compute heave, pitch and roll motions by using the out-puts of the first stage (ship's position and orientation in XY) and additionally consider the ocean wave model as illustrated in figure 2.

3.4 Trainee station

A trainee can use the perception enhanced (270^0 field of view) navigational display and maneuver the ship by varying rudder and throttle values as shown in figure 3. Trainee's navigational display

consists of Radar, Sonar, 2D map to show the location, Engine RPM indicator and Rudder angle indicator.

3.5 Trainer station

Trainer can select ship from the database within the program or he can define the following ships characteristics:

- Length between Perpendiculars
- Beam
- Draft
- Nominal Mass
- Rudder Area
- Propeller Diameter
- Maximum Engine RPM
- Static and Dynamic force coefficients

as Shown in figure 5.

Reasonable geographic database exists and trainer can customize it according to training requirement. Wind and wave database consists of various wind and wave conditions based on *Beaufort* wind scale [9] but depending on the requirements trainer can define the following characteristics.

- Wave amplitude
- Wave number
- Wave length
- Wave Frequency
- Direction of the wave.
- Initial phase
- Wind Speed
- Wind Direction .

4.0 SOME EXPERIMENTAL RESULTS

We used multipurpose ship data published by the Danish naval material command and the Danish maritime Institute [10]. Ship's length, beam, draft, mass and maximum effective thrust are respectively 48 m, 8.6 m, 2.2 m, 35.6×10^4 Kg and 15.0×10^4 N. This ship data is fairly identical to the *Jayasagara* Class offshore patrol vessel which has been locally built by the Colombo Dockyard [11]. We define reasonable environment conditions as follows:

- Wave Amplitude: 2m
- Wave length: 6m
- Wave Frequency: 0.4Hz
- Wave's Initial phase: 0^0
- Angle between X axis & direction of the wave: 30^0.

Several turning tests [9] were carried out with naval experts to experiment our virtual learning and training environment as shown in figure 5. Some navigational display results are shown in figures 6, 7, 8, 9, 10, & 11.

5.0 FUTURE WORK

All experiments were conducted based on our mathematical ship model with further enhancements. In the proposed system, we use constraints, coefficients and parameters so that we have to evaluate them or figure out reasonable values for them. In order to further validate the mathematical model, experiments have to be performed in various conditions with respect to real world scenario.

The whole system will be developed using C++ and Matlab with 3D visualization system based on distributed architecture to enhance the trainee's perception. Entire visualization system is based on OGRE 3D[12]. It is one of the leading free and open-source graphics rendering engine. Visualization system that can support multiple-display projectors instead of multiple-computer monitors greatly enhanced user perception as show in the Figure:12. At this point image stitching and blending algorithms [13][14] have to be used to get the desired output which is going to be projected on a semi cylindrical projection screen so the user can feel the actual maritime experience.

In order to use this virtual environment in a wide range of teaching and learning scenarios we have to incorporate commonly used naval vessels, geographical environments, and various environmental conditions to the existing database.

We currently are conducting experiments with naval experts to further identify the trainee's and trainer's requirements. Various training scenarios

will be designed in order to develop a more productive and efficient virtual learning and training environment. Development of a learning Management System that could monitor trainee, trainer and training activities is essential.

6.0 CONCLUSION

Experimental results show that the proposed framework is very effective for a virtual learnining and training environment. It can form real-time six degrees of freedom ship motions under various conditions. It is scalable and comparable to configurable to industry standard simulators.

In this VLTEME, we used our own model and algorithms and constrain in order to customize each and every building block to meet our requirement. This also has the ability to create tactical scenarios and teach a trainee how to react against each and every scenario. Moreover, through the virtual learning and training environment, students can create different scenarios (within different levels of difficulty) so that they can learn at their own pace. This VLTME is available under an open source licensee so that anyone can customize or further develop it according to their requirement.

References

1) Thor I Fossen- Guidance and Control of Ocean Vehicles ISBN 0 471 94113 1, Jhone Wiley & Sons, Chichester-New York-Brisbane-oronto-singapore, (1994)
2) Nomenclature for Treating the Motion of a Submerged Body Through a Fluid Technical and Research Bulletin No 1-5 ,The Society of Naval Architects and Marine Engineers, New York, (1950)
3) Gatis Barauskis and Peter Friis-Hansen Coastal (2007) - Fast Time Ship Simulator Safety at Sea conference – (2007)
4) Sandaruwan *et al* -Real-time Ship Motion Prediction System, Computer Games Multimedia and Allied Technology 09(CGAT 09) Singapore, (2009)
5) Shyh-Kuang Ueng, David Lin and Chieh-Hong Liu - A ship motion imulation system Virtual Reality- Volume 12, Issue 1, pringer-Verlag London, UK(2008)
6) http://www.transas.com - accessed on 2009/01/22
7) http://www.oceaniccorp.com - accessed on 2009/01/22
8) http://www.mathworks.com accessed on 2009.03.12
9) J.M.J Journee and Jakob Pinkster (2002) - Introduction in Ship Hydromechanics Delft University of Technology, Netherlands
10) Tristan Perezt and Mogens Blanket- Mathematical Modeling for Control Applications, Technical Report, University of Newcastle, Australia / Technical University of Denmark
11) http://en.wikipedia.org/wiki/Jayasagara_class_patrol_craft - accessed on 2009/02/22
12) Gregory Junker-Pro Ogre 3D Programming- ISBN-13-978-1-59059-710-1, Springer-Verlag (2006)
13) Vlandan Rankov, Rosalind J. Locke, Richard J. Edens, Paul R. Barber and Borivoj Vojnovic, ‘An algorithm for image stitching and blending’, SPIE vol. 5701
14) Petr Somo and Michal Haindl, ‘Novel path search algorithm for image stitching and advance texture tiling’, WSCG January 31-February 04, 2005, Plzen Czech Republic.

Annexure 01

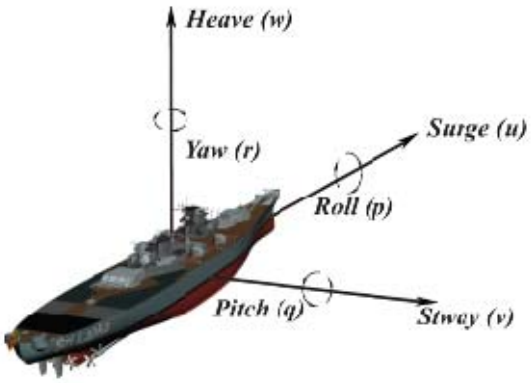


Figure 1: Six degrees of freedom ship motions

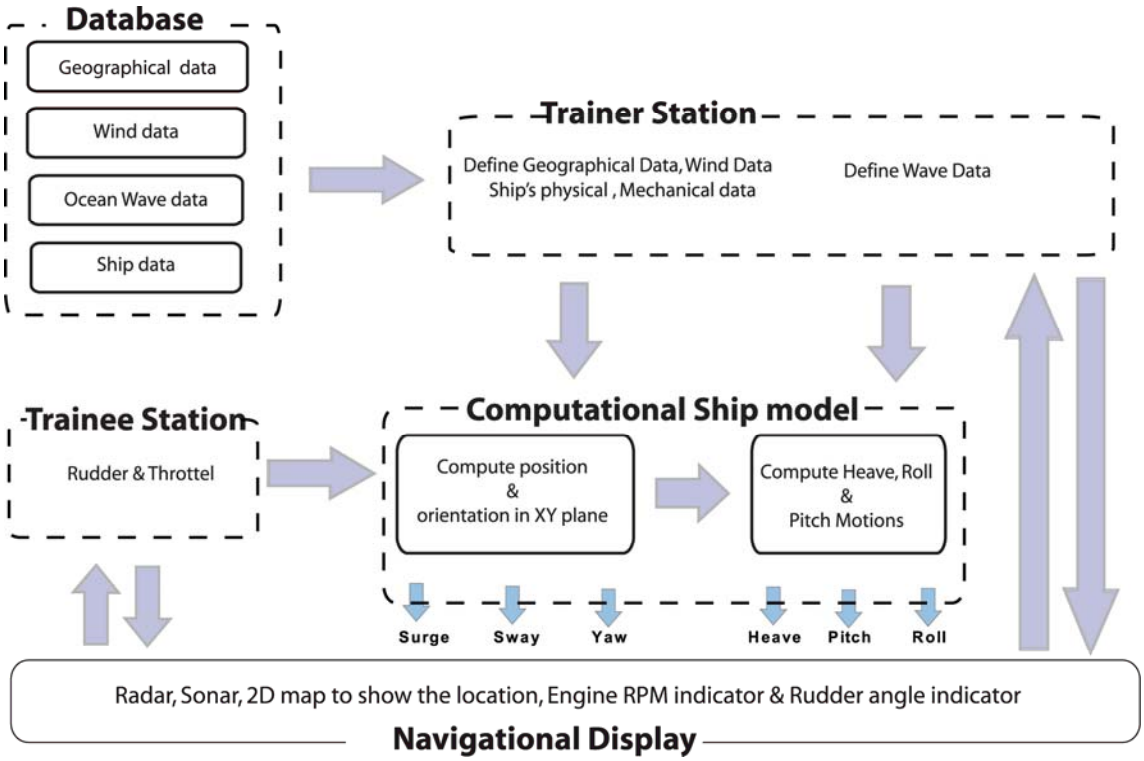


Figure 2: **Structure of the VLTEME**

Annexure 01

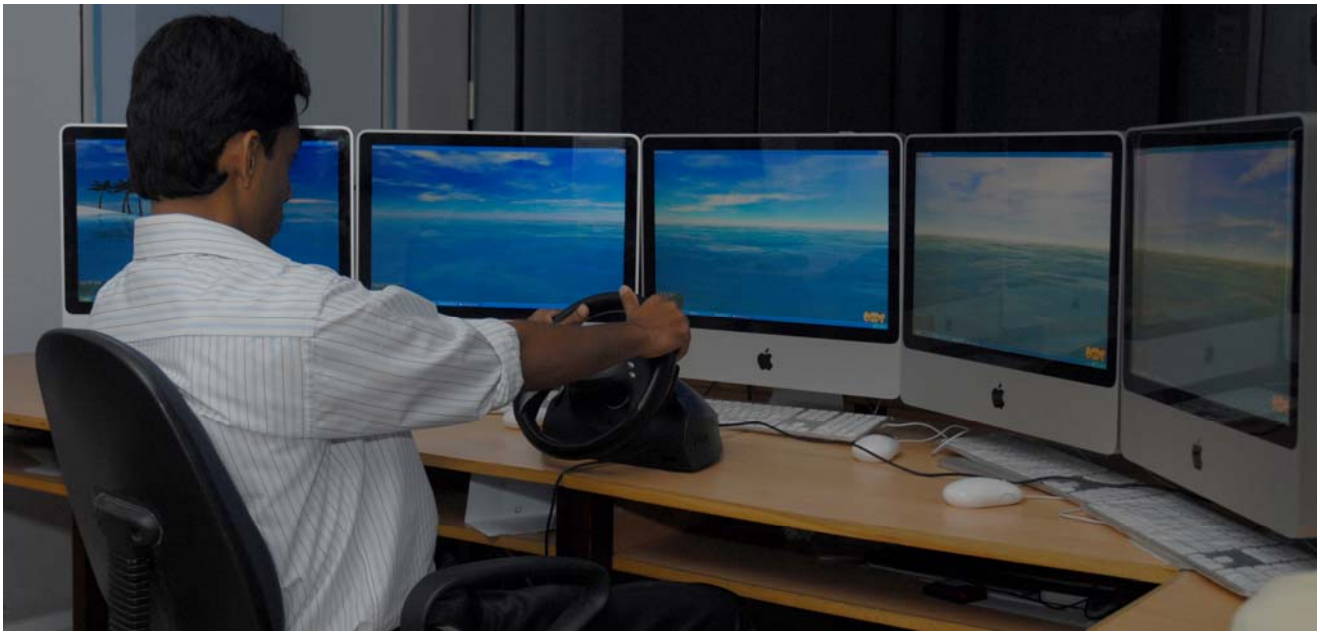


Figure 3: Trainee station -Maneuvering the virtual ship

Figure 4: Trainer station

Annexure 01

Figure 5: Naval expert experiment the virtual environment

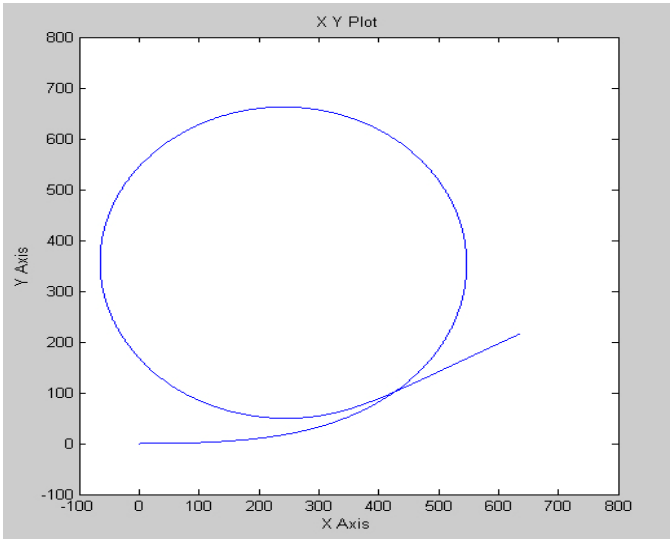


Figure 6: Ship's position in earth-fixed XY Plane

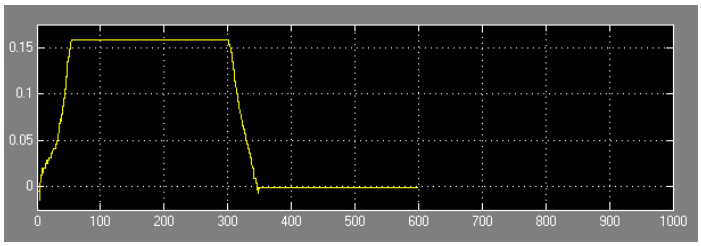


Figure 7 : Rudder angle (Max value $9^0 \approx 0.16$ rad)

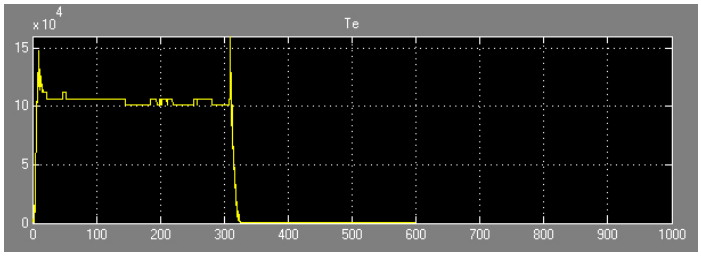


Figure 8: Effective Propeller Thrust (10^4 N)

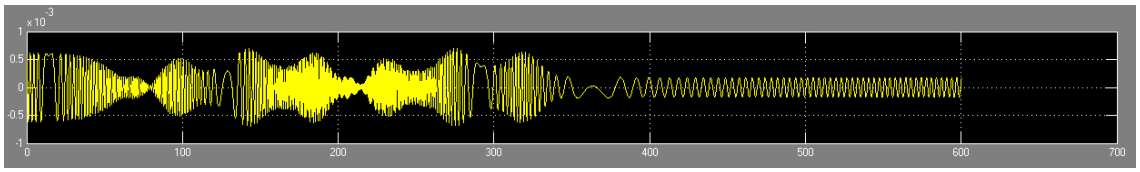


Figure 9: Pitch motion

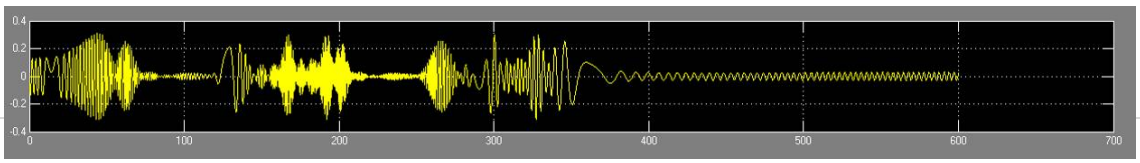


Figure 10: Heave motion

Annexure 01

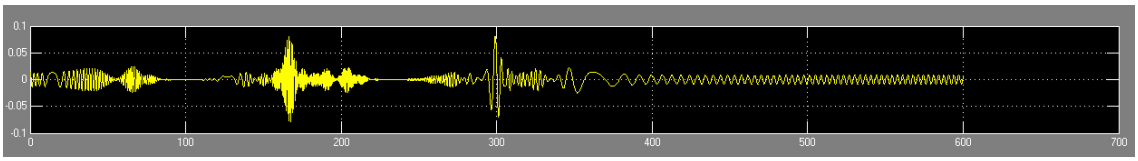


Figure 11: Roll motion

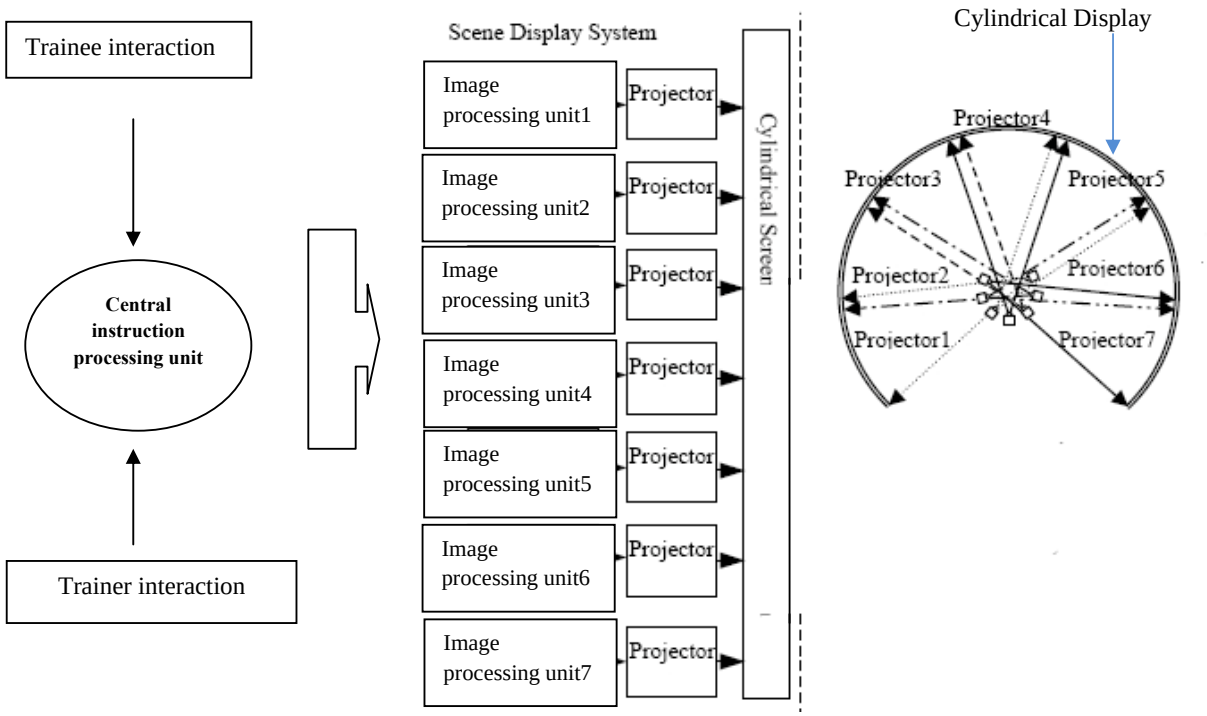


Figure 12: Multiple display panels for user perception enhancement (270^0 Field of view)

Annexure 02

Short Description for designing this project

Ships are extremely expensive platforms and need through training prior one actually handle them in order to avoid damage to men & assets. Real training is very costly due to high running cost of ships.

Aligned with the UN convention on the Law of the Sea, which was ratified by Sri Lanka in July 1994, Sri Lanka enjoys a total extent of approximately 489 000 km2 of maritime waters as shown below[1].

Now Sri Lanka in need of more well trained marine offices to access the above vast resource base. If Sri Lankan government goes to train naval officers by using real ships then the total cost will be extremely high. So development of a Virtual learning and training environment for marine trainers and trainees is extremely important for a developing island like Sri Lanka which has a land-to ocean area ratio of 1 to 7.5.

There are many commercial ship simulation systems such as *Transas*[2] *and Oceaniccorp* [3] and shipsimpro [4]**.** These commercial ship Simulators provide versatile and realistic ship simulation for maritime teaching, learning, assessment and research

However these systems are extremely expensive, too complicated, proprietary and do not meet all of our requirements. Naval maneuvers are unique and tactics need to be changed frequently. So operators should be trained for modern tactics by dry practices prior to the real operations.

This kind of simulation system can simulate various ships so the trainees can be trained for various ships within a short period. Different harbors restricted channels and risky situations can be simulated where real world training is not possible.

1. Proceedings of the Institution of Civil Engineers Maritime Engineering 158 *March 2005 Issue MA1, Pages 25–32*
2. http://www.transas.com - accessed on 2009/08/22
3. http://www.oceaniccorp.com - accessed on 2009/08/22
4. http://www.shipsimpro.com- accessed on 2009/08/22

Annexure 03

"Vidu sayura" is a National project with unique features

There are many commercial ship simulation systems with six degrees of freedom such as *Transas*[1] and *Oceaniccorp* [2] and shipsimpro [3]**.** These commercial ship Simulators provide versatile and realistic ship simulation for maritime teaching, learning, assessment and research however these systems are extremely expensive, too complicated and proprietary.

In Sri Lankan context there is only one ship handling simulator which is operating under privet sector Organization CINEC Maritime Campus and it has cost multimillion Euros.

There is no "virtual learning and training environment for marine education" available under an open source license. There are ship motion prediction systems under open source but no significant product for Learning and Training purpose [4] [5]**.**

We have decided to fill this gap by developing a virtual learning and training environment for marine education (Vidu Sayura). The innovativeness of this project can proven by the recognition of "Vidu Sayura" obtained from the National and International Research community.

Our own ship motion prediction algorithms and constrains were published:

> Real-time Ship Motion Prediction System (2009)
> **Computer Games, Multimedia and Allied Technology 09** conference in Singapore
> ISBN: 978-981-08-3165-3

Our virtual learning and training environment for marine education (Vidu Sayura) concept is published:

> Virtual learning and training environment for marine education (2009)
> **27th National Information Technology Conference** in Sri Lanka
> ISBN: 978-955-9155-17-1

Other Publications

> *A Ship Simulation System for Maritime Education* - **e-Asia 2009 Sri Lanka** ISBN: 978-955-9021-90-2
>
> *Modeling and Simulation of Environmental Disturbances for Real-time Six Degrees of freedom Ocean Surface Vehicle*- Sri **Lankan Journal of Physics** (Accepted)
>
> *Perception Enhanced Virtual Environment for Maritime Applications* - **Computer Games, Multimedia and Allied Technology 10** conference in Singapore (Accepted)

Annexure 03

Recognition and appreciation

"Vidu Sayura" Won National Best e-Content Award "e-Swabhimani 2009" .This is is a Local initiative for selecting and giving national level recognition to a best e-content and applications developed in Sri Lanka.

"Vidu Sayura" research was highly appreciated by His Excellency the Sri Lankan President and also drew tremendous public response at the recent e-Asia 2009 exhibition.

Virtual learning and training environment for marine education (Vidu Sayura) won the ***Best Poster Presentation award*** at 27th National Information Technology Conference in Sri Lanka 2009.

1. http://www.transas.com - accessed on 2009/01/22
2. http://www.oceaniccorp.com - accessed on 2009/01/22
3. http://www.shipsimpro.com- accessed on 2009/01/22

4. Gatis Barauskis and Peter Friis-Hansen Coastal (2007) - Fast Time Ship Simulator *Safety at Sea conference –(2007)*

5. Shyh-Kuang Ueng, David Lin and Chieh-Hong Liu (2008) - A ship motion simulation system *Virtual Reality- Volume 12, Issue 1, pringer-Verlag London, UK*

Annexure 04

There is a serious gap between content/services and the citizens at large. "Vidu sayura" can solve the problem of digital gap and content gap.

Sri Lanka Navy (SLN) has a varies needs in ship handling skills for navigation to blue water fighting to wolf peak attack by terrorist even using suicide craft. This demands high skills and experience in ships and craft maneuvering. However in real world the ships are very high value and their running cost also too high due to fuel consumption and man power the training on real domain prove to be expensive.

The Navy being a fighting citizen in the sea. But it is not possible to create real scenarios of fighting for their training purposes. However by using this proposed virtual environment, various threat scenarios can be simulated easily and it can be used as a teaching aid to demonstrate ships maneuvering under different conditions in training sessions. Trainees can use this virtual environment and define various threat scenarios and environment conditions in order to study at their own pace.

SLN Currently spent a lot of money to train naval personnel by using real ships. A ship handling simulator can drastically reduce this cost and improve the quality of training

Annexure 05

“Vidu Sayura” is sustainable and scalable.

As mention in the Annexure 01, section 5.0 (Future Work) Vidu Sayura is scalable and comparable to industry standard ship simulation systems.

“Vidu Sayura” is based on free & open source rendering engine Ogre3D, C++, Microsoft Windows operating system but is extendable to free and open source operating system. We plan to make “Vidu Sayura” available under an open source licensee so that anyone can customized or further develop it according to their requirement.

In the implementation stage we have to spent money for hardware but it is a onetime cost and running cost is extremely low. So in the long run this virtual learning and training environment for marine education (“Vidu Sayura”) is extremely favorable With respect to conventional maritime training done in real sea environment with real ships.

Contents of the Attached DVD

- Selected Pictures of the “Vidu Sayura”
- 3Min Video clip of the “Vidu Sayura”
- Pictures of the “Vidu Sayura” *Poster Presentation & demostration* at 27th National Information Technology Conference in Sri Lanka 2009
- Nationally and Internationally published Research articles

Annexure 06

"Vudu Sayura" won the ***Best Poster Presentation award*** at 27th National Information Technology Conference in Sri Lanka 2009

Computer Society of Sri Lanka (CSSL)

CSSL

Best Poster (Joint)

Award

Presented to

Damitha Sandaruwan, Nihal Kodikara, Chamath Keppitiyagama, Rexy Rosa Kapila Dias, Prabath Samarasinghe, Uditha M. de Soysa and Chandana Perera

for

"Virtual Learning and Training Environment for Maritime Education (VLTEME)"

at the

27th National Information Technology Conference held on the 9th and 10th September 2009 in Colombo Sri Lanka

Mr Chrisantha Silva
President CSSL

Dr Prasad Wimalaratne
Chairman,
Procedings Committee

Certificate No: NITC2009/001

Annexure 06

Vidu Sayura" Won National Best e-Content Award "e-Swabhimani 2009" .This is is a Local initiative for selecting and giving national level recognition to a best e-content and applications developed in Sri Lanka.

WINNER

Vidusayura

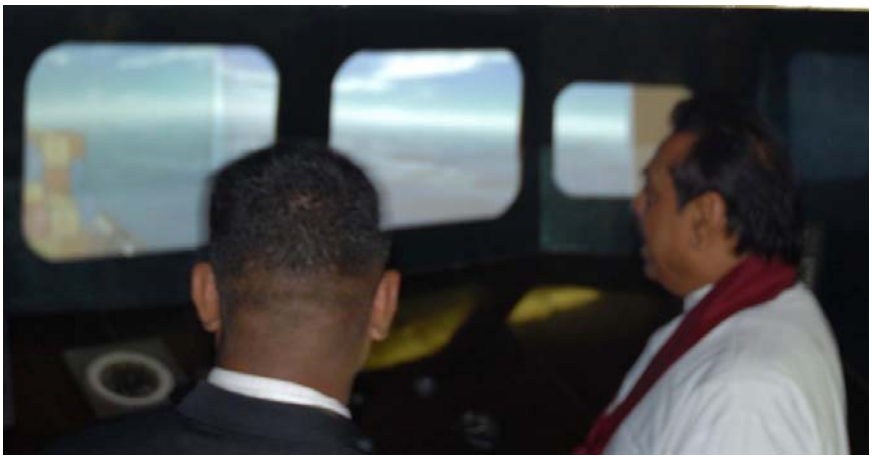
The e-Swabhimani Grand Jury hereby declares and certifies that Vidusayura produced by University of Colombo School of Computing together with Department of Electrical & Electronics, Sri Lanka Navy has been selected, as one of the Country's Best e-Content Applications in the category e-Science and Technology.

Prof. Vijaya Kumar, Chairman, e-Swabhimani Grand Jury
Prof. P.W. Epasinghe, Chairman, ICT Agency of Sri Lanka
Osama Manzar, Director, World Summit Award

Colombo – November 6 , 2009

Annexure 06

“Vidu Sayura” research was highly appreciated by His Excellency the Sri Lankan President and also drew tremendous public response at the recent e-Asia 2009 exhibition.



Annexure 06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Annexure 06

Visited Trincolmale Naval Academy for requirement gathering and present current simulation system.

Annexure 06

Collaborative work experience with SL Navy