**Research Question: What is the best way to accurately determine the draft measurement of a ship**

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|  | **Source/Evidence/Data #1** |
| **Citation** | Y. Ikemoto, K. Hoshino, M. Makino, R. Fukasawa, H. Goto and T. Hamada, 'Development and evaluation of a new measurement system for ship hull-side wave profiles using electro-conductive paint', *Oceans, 2012 - Yeosu*, pp. 1-6, 2013. |
| **Purpose** | The purpose of this paper is to describe the usefulness of a new method of measuring the draft of a ship as well as the overall wave profiles interacting with the hull of the ship by using a previously established method of measuring electrical resistance along a set of wires or sensors. This new method replaces the currently used electrodes with a form of electrically conductive paint to decrease interference from the waves.  |
| **Why is the study necessary?** | This study was necessary to determine if this electrically conductive paint is a viable method to accurately model the wave data that can be processed by other methods with the added goal of reducing the disturbance of the wave field interacting with the hull.  |
| **Methods** | The performance of this conductive paint as an electrode was tested on both a flat plate and along several locations of the hull of a model ship both a static condition as well as at three different towing speeds. The wave conditions of these tests were recorded by cameras with a clear view of the side of the ship. These images were then used to compare the values recorded by the electrodes to the true conditions of the waves interacting with the ship.  |
| **Results** | The results of the testing were displayed graphically to display the readings gathered from each of the different sensors in each of the wave conditions with almost identical graphical data. The results of the electrodes were also plotted against the data recorded by the imaging system to display the accuracy of the testing.  |
| **Discussion/Conclusion** | The data collected shows that the method proposed in this article is a viable method for measuring wave profiles without added interference from protruding sensors. This method was also proven to be accurate in measuring wave profiles of waves coming from the side of the ship which models the effects of rough seas.  |
| **How can this help my senior project?** | The methods and systems that were outlined in this article may help my senior project by providing a baseline for determining the draft of a ship in varying wave conditions. An accurate method like this may be useful but may not leave room for much improvement from a mechanical standpoint and may be more invasive than is allowable for the outline of this project.  |

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|  | **Source/Evidence/Data #2** |
| **Citation** | Wuhan Jingeishan Mechanical & Electrical Manufacturing Co., Ltd., 'Intelligent Draft Gauge for Ships', 13/899,558, 2013. |
| **Purpose** | The purpose of this patent application is to document the development of a new form of draft gauge to be used on ships. This method of measuring the draft of a ship presents a more mechanical adaptation to solving the problem at hand with the use of several float tanks combined with a scanner on either side of the ship’s hull. This patent application details the mechanics behind this system.  |
| **Why is the study necessary?** | The study conducted behind this application was necessary to prove the effectiveness and accuracy of the system that had been designed. Conducting a study of this system also allowed for the analysis of its performance to outline both its strengths and weaknesses.  |
| **Methods** | The methods used in this measuring technique are thoroughly detailed in this patent application and in summary consist of connecting two float tanks on either side of the ship’s hull equipped with a scanning device to a lateral beam by means of several brackets to allow a degree of movement. This combination of scanners along the lateral and hull side allow for the draft of the ship to be calculated by combining the scanned data and the value of the swing arms which are attached to the floats.  |
| **Results** | The results of this testing claimed that the system is fully functional and would accurately display the draft of the ship within 2mm as compared to more traditional methods which are accurate to a degree of 5mm. This invention allows the draft of a ship to be measured accurately from the safety of the control room and can also be used to determine the load on the ship.  |
| **Discussion/Conclusion** | This invention greatly simplifies the task of measuring the ships draft and eliminates the need for personnel to make measurements by eye, thus shortening the process, improving the accuracy, and making the overall process safer for the operators.  |
| **How can this help my senior project?** | This device provides a more mechanical solution to the task of measuring the draft of a ship. However, the use of physical measuring devices in combination with digital ones rather than strictly digital devices that can be mounted more seamlessly to the hull of the ship. This detailed description of this measuring device will be of use if the requirements of our project lean more towards a stand-alone device that can be used in a docking station, rather than an integrated one what will be mounted to the surface of the ship.  |

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|  | **Source/Evidence/Data #3** |
| **Citation** | [3]'Standard Practice for Depth Measurement of Surface Water', *ASTM International*, no. 5073-02, 2013. |
| **Purpose** | The purpose of the paper is to outline the standard practices that are used to measure the depth of water through various methods in various conditions.  |
| **Why is the study necessary?** | This study was necessary to provide a concise guide of the most common practical ways to measure the depth of water through various methods. This guide provides detailed information on manual methods, electronic measurement through sounding devices, and electronic measurement through non-sounding devices.  |
| **Methods** | The methods of each technique vary with the device being used, in a brief summary the following are outlined in the standard: Manual procedures* Sounding rod uses a long hollow tube with a large flat plate to physically measure the depth of the water.
* Sounding line/reel uses a long rope with given markings and an anchoring weight which will act as a tape measure provided a low fluid velocity and a non-stretching rope.

Sounding devices * Sonic-echo sounders use a sound emitting transducer that sends a sound wave to the bottom of the waterway and measures the time it takes to return. From this, the depth can be calculated.
* Several methods are used to create and measure this reflective noise from an array of transducers outstretched from the sides of the boat, to towing a device behind the vessel with separate sounder and recorder.

Non-sounding devices* Ground penetrating radar uses electromagnetic pulses sent out around an antenna. When these pulses hit the surface of an object some of the pulse bounces back to the antenna and is measured for its intensity. The intensities of the scan can then be plotted to display an accurate depiction of the bottoms surface.
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| **Results** | The result of each of the methods listed above varies with the devices. The manual devices do provide a satisfactory level of accuracy, but are limited to shallow depths in optimal conditions as to not move the vessel during the measuring procedure. The sounding devices are very accurate when properly calibrated to the current water conditions, but require a range of compensation for varying water conditions as well as conditions of the surface from which the sound is reflected. The sounding devices also require adjustments for the velocity of the vessel which can skew the results sizably. The Ground Penetrating radar, when properly calibrated, can produce a graph of not only the bottom surface but can also show intermediate surfaces like ice thickness covering the body of water being measured. There are no necessary adjustments needed for this device listed in the standards.  |
| **Discussion/Conclusion** | The different methods of measuring depth outlined in this paper show a variety of solutions for multiple conditions. Ranging from manual techniques that are best used in small crafts, to precise sonar/radar techniques that can be attached or towed behind a vessel of any suitable size. The ranging accuracy for this multitude of devices allows for a wide variety of choices based on level of precision required, conditions of its use, and budget allotments.  |
| **How can this help my senior project?** | These methods demonstrate a key factor that is required by this senior project; measuring the depth of water. In this paper all of the methods are focused on reaching from the bottom of the vessel, or a similarly known location, to the bottom of the body of water through which it is traveling. However, I believe that these methods could easily be adapted to measure from a known location above the surface of the water to a point on the bottom of the ship thus providing its draft measurement. The most promising of these options would be the sounding and non-sounding options because they provide an accurate digital measurement, however in some situations a simple manual method is often the quickest and most cost effective solution.  |

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|  | **Source/Evidence/Data #4** |
| **Citation** | G. Giorgi, T. Gourlay, P. Teunissen, L. Huisman and K. Klaka, 'Carrier Phase Ambiguity Resolution for Ship Attitude Determination and Dynamic Draught', *Positioning Techniques for Hydrography*, vol. 31, 2010.. |
| **Purpose** | The purpose of this article is to describe the new method of measuring ship location and various attributes through means of communication between several antennas on the ship and a shore based station.  |
| **Why is the study necessary?** | This study was needed to demonstrate the functionality and reliability of this new system. This report also gives technical details as to how the system functions and what obstacles must be overcome for its usefulness. A major portion of this report is focused on what calculation methods can be used most effectively to properly identify the attributes of the ship the system is measuring.  |
| **Methods** | The main testing of this research was conducted to determine the accuracy of two separate models of Ambiguity Resolution, namely the LAMBDA method and the C-LAMBDA method. These methods were tested on 5 cargo ships that were equipped with the antenna equipment necessary for communication with the corresponding location antenna on-shore, conducted either as the ships entered or exited a port. The data collected from the on shore station was then compared to similar data gathered from more traditional methods, as well as being processed with each of the two ambiguity resolution methods listed earlier.  |
| **Results** |  Both of the ambiguity resolution methods provided accurate adjustments that allowed the measurements taken from the antenna systems to be properly calculated and used to determine several characteristics of the ships movement including its direction, pitch, roll, draft, and height from the bottom of the waterway. However, the information gathered from the C-LAMBDA method was able to match the data obtained from the traditional method, but at a reduction in cost.  |
| **Discussion/Conclusion** | The main focus of this paper was the ambiguity resolution methods that were compared during the testing conducted, however, this article also gave valuable information about the background of the system from which the data was originally recorded for analysis. This system that uses a combination of antenna onboard the ship as well as a reference antenna on a on shore location allows for improved accuracy due to the elimination of error that are found in systems that rely solely on on-board measuring devices.  |
| **How can this help my senior project?** | The testing equipment that is described in this article gives a new perspective on measuring the attributes of a ship. Most methods that are traditionally used in determining the draft of a ship rely on measuring equipment mounted to the ship’s hull, which due to the rough conditions it is subjected to, can often be inaccurate. This report may provide groundwork to create a system for this senior project that does not rely only on ship mounted measuring equipment.  |

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|  | **Source/Evidence/Data #5** |
| **Citation** | Determining Weight of Cargo Onboard ship by Means of Optical Fibre Technology Draft Reading', *Promet - Traffic&Transportation*, vol. 23, no. 6, pp. 421-429, 2011. |
| **Purpose** | The purpose of this paper is to describe the methodology and accuracy of using a form of fiber optic measuring device to estimate the cargo load of a ship by determining the draft.  |
| **Why is the study necessary?** | This study was needed to determine if the new form of optical measuring was feasible and accurate as compared to other methods currently being employed. The study also focused on establishing the increased reliability, safety, and versatility of the equipment being tested.  |
| **Methods** | The method behind this form of measuring equipment is a combination of simple elements, a light emission source, the fiber optic cable which is run along the desired area, and a detector which reports back to the processing station. This paper focused on using this method in combination with sounding pipes which would be mounted at several locations across the ship and fill with water to the corresponding level of the draft of the ship. The fiber optic sensing equipment mounted within these pipes would then be able to accurately measure the water level within these pipes and translate that data into an average draft of the ship.  |
| **Results** | The results of this testing showed that the system was in fact a feasible means of measuring the depth of the water contained in the sounding pipes. When properly calibrated for the current water conditions the relationship between water height and signal intensity could be graphed in a linear fashion, indicating an accurate relationship. |
| **Discussion/Conclusion** | This method for determining the draft of a ship shows great promise in both its accuracy and its simplicity. The equipment described in this testing is characterized by its reliability in use, safety, and reduction in complexity by eliminating the need for electromagnetic measuring devices. This experimentation also shows a great reduction in error, which is largely seen in manual measurements made by eye, which allows for more accurate calculation of draft and in turn the weight of cargo onboard the ship.  |
| **How can this help my senior project?** | The equipment that is used in this testing is a simple but accurate way to determine the draft of a ship. This form of measurement could easily be adapted to fit the needs of this senior project.  |

Bibliography

[1] Y. Ikemoto, K. Hoshino, M. Makino, R. Fukasawa, H. Goto and T. Hamada, 'Development and evaluation of a new measurement system for ship hull-side wave profiles using electro-conductive paint', *Oceans, 2012 - Yeosu*, pp. 1-6, 2013.

[2] Wuhan Jingeishan Mechanical & Electrical Manufacturing Co., Ltd., 'Intelligent Draft Gauge for Ships', 13/899,558, 2013.

[3] 'Standard Practice for Depth Measurement of Surface Water', *ASTM International*, no. 5073-02, 2013.

[4] G. Giorgi, T. Gourlay, P. Teunissen, L. Huisman and K. Klaka, 'Carrier Phase Ambiguity Resolution for Ship Attitude Determination and Dynamic Draught', *Positioning Techniques for Hydrography*, vol. 31, 2010..

[5] Determining Weight of Cargo Onboard ship by Means of Optical Fibre Technology Draft Reading', *Promet - Traffic&Transportation*, vol. 23, no. 6, pp. 421-429, 2011.