International Journal of Future Generation Communication and Networking
Vol. 13, No. 2s, (2020), pp. 1005–1011

Design and Developement of Lightweight Magnetic Climbing Robot for Vessel Inspection

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Abstract

Currently, the inspection of sea-going vessels is performed manually. Ship surveyors do a visual inspection; in some cases they also use cameras and non-destructive testing methods. Prior to a ship surveying process a lot of scaffolding has to be provided in order to make every spot accessible for the surveyor. In this work a robotic system is presented, which is able to access many areas of a cargo hold of a ship and perform visual inspection without any scaffolding. The paper also describes how the position of the acquired data is estimated with an optical 3D tracking unit and how critical points on the hull can be marked via a remote controlled marker device. Furthermore first results of onboard tests with the system are provided.

Keywords: *sea-going vessels, robotic system,3D tracking unit, remote controlled, etc.*

I. INTRODUCTION

Marine vessels are subject to numerous and regular inspections and maintenance measures. Ship surveyors inspect the vessels on a regular basis. In most of cases, the surveyor performs only a visual inspection. In order to reach each spot on the ship, scaffolding has to be erected in the cargo holds. Typical heights of cargo holds are 15-20 m. Fig.1 shows two parts of a cargo hold of a bulk carrier with different wall structures. The installation of the scaffolding usually takes several days, before the surveyor can start the inspection process. Every day the ship stays in the dock and out of service results in a significant loss of money for the ship owner, making this (currently necessary) preparation time is very expensive. The EU-funded R&D project MINOAS (Marine Inspection Robotic Assistant System) addresses this challenge in an attempt to develop concepts for the automation of the ship inspection process.

ISSN: 2233-7857 IJFGCN

Fig. 1: One of the four cargo holds of a 10,000 DWT bulk carrier.

The key idea of the project is to develop and test a fleet of semi-autonomous robots which can provide visual data as well as thickness measurement data to the surveyor without the need for setting up scaffolding prior to the inspection process. While the idea to employ robotic agents for the inspection of hazardous environments is not new, a fully autonomous inspection of a cargo ship still is a long-term goal. The idea of the project is not to develop an autonomous inspection but rather focus on robotic tools that can enhance and simplify the current inspection process. One of the fleet's robots is a lightweight magnetic crawler which is able to climb along the vertical walls of a vessel. The robot provides a live video stream as well as offline images of the ship for later inspection. Apart from the locomotion capability of the inspection system, it is mandatory for the inspection process that the data is localized, i.e. the position of images and video streams are known within the vessel. For this purpose a 3D tracking unit was developed which acquires the position of the magnetic crawler in real-time. This allows a meaningful comparison of inspection data over a vessel's lifetime, because the exact position of the data can be stored and therefore replicated. A 3D user interface provides the necessary information to the surveyor and allows access to all acquired data within a 3D view.

Problem Statement:

In the research of literature survey the normal robot wheel are not climb on vertical position MS sheet construction structure.We are designing the new concept of magnetic crawler using a various operation of cleaning and security purpose for ship vessel inspection.

II. Objectives

Design and developing the magnetic crawler using cleaning application.

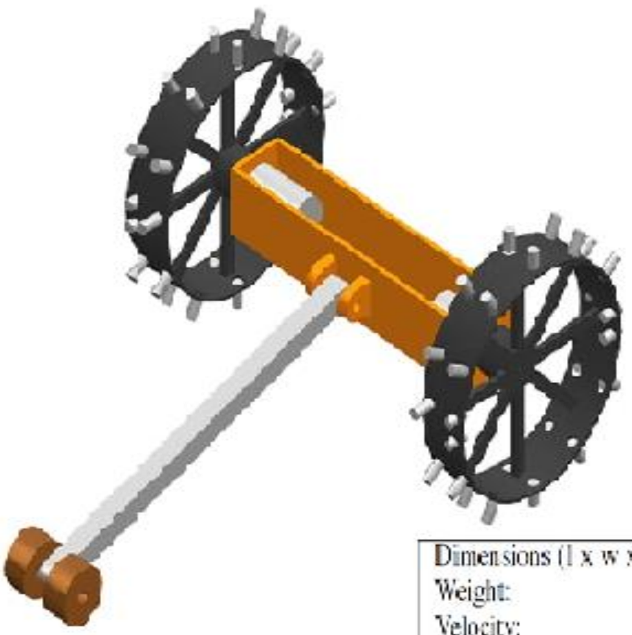
Design and developing the magnetic crawler using Security purpose application

Design and developing the magnetic crawler using Boiler cleaning application.

III. Methodology

1.	COLLECTION OF DATA
2.	CATIA MODEL
3.	PROTOTYPE OF PROJECT OR MODEL
4.	WORKING MODEL
5.	RESULTS
6.	CONCLUSION

IV. Design Of Magnetic Crawler



Dimensions (l x w x h) :	38 cm x 28 cm x 15 cm
Weight:	670 g
Velocity:	50 cm/sec on vertical ferrous surfaces
Actuation:	2 x 12 V DC gear motors
Battery:	11,1 V - 800 mAh - lithium polymer battery
Wheels:	2x50 neodymium magnets
Sensors:	Wireless video camera with internal light source
Control:	35 MHz remote control

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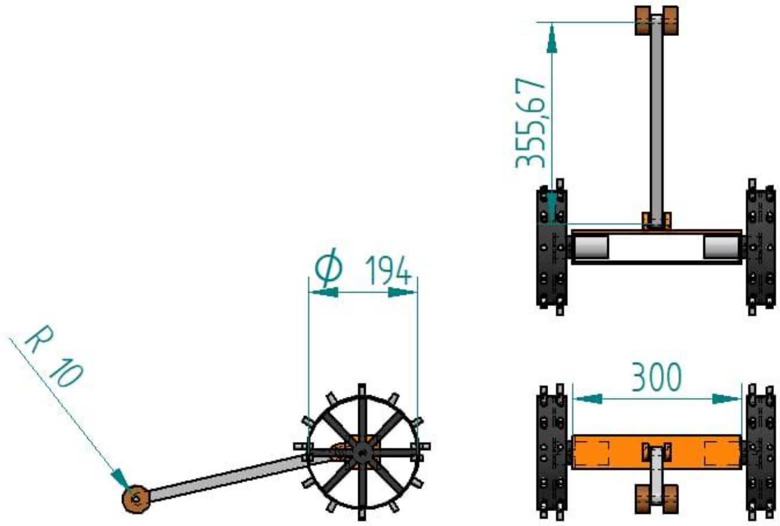

Fig. 2:Dimenssions of Magnetic Crawler

V. Experimental Working

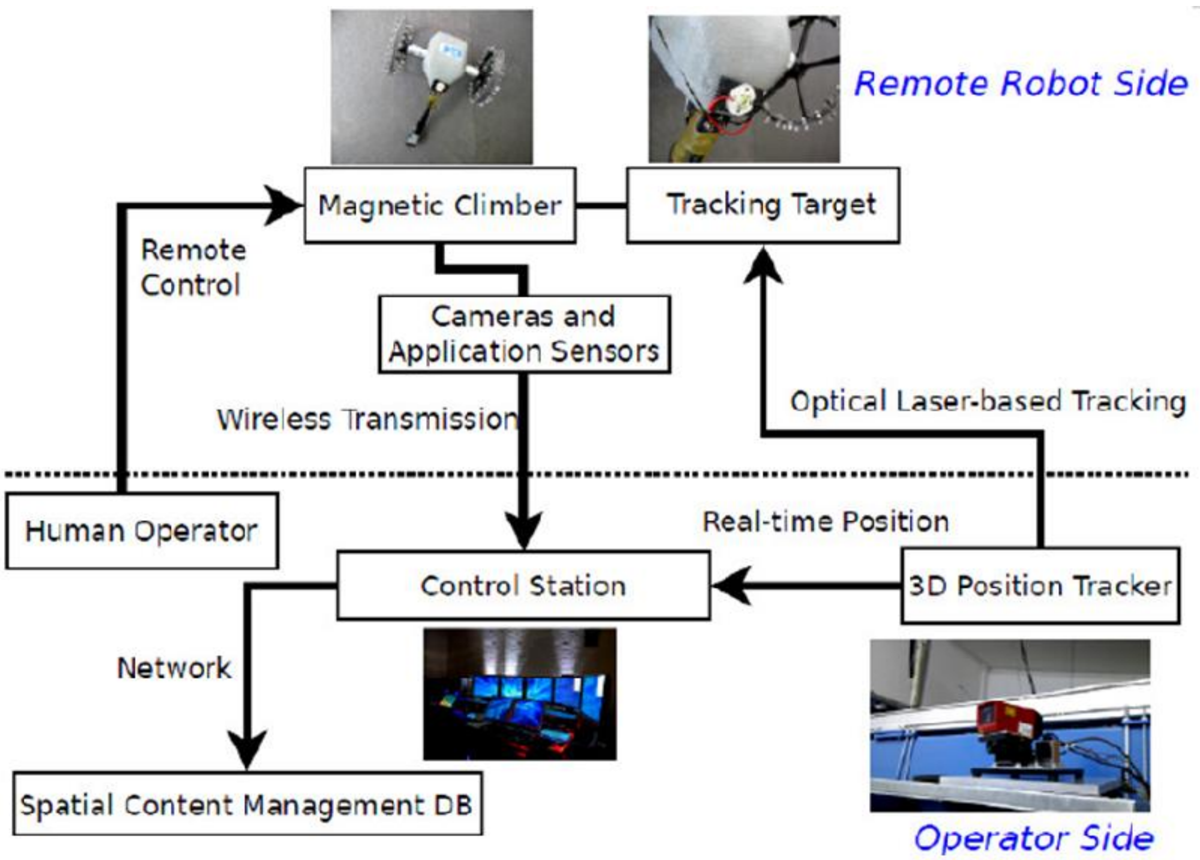

Fig. 3:3D Tracking Concept

In order to localize the crawler inside the vessel information from the two Dynamixel RX-28 servo motors, one Hokuyo laser scanner and one monocular Guppy F-036C camera are fused. The LED mounted on the crawler, is tracked by the monocular camera using Difference of Gaussian. The discrepancy between the current and desired position is mapped to servo motor commands to hold the crawler in focus. The 3D position is calculated based on distance measurements provided by the laser and current angles of the servo motors resulting in a 3-dimensional point which is sent to the user interface described. Using a laser range finder instead of a stereo camera rig for depth measurements saves computation time and is more accurate on larger distances. It is also more practical in our case, since vessels provide relatively homogeneous image content which is generally not beneficial for stereo vision *Barnard (1987*). The external position mapping depends on the position of the tracking unit. To generate replicable data over time the exact location of the tracking unit inside the vessel must be known.

The tracking system works together with the magnetic crawler as one inspection unit, Fig.3. The robot platform is operated via a remote control. The onboard video device transmits the data using a wireless 2.4 GHz connection. The position and the video data are stored together in a spatial content management system.

User Interface and 3D Representation:

For a user friendly inspection process, a graphical user interface (GUI) was added to the system where all data is easily accessible. Since positional information sent by the tracking unit and visual data sent by the camera are transmitted separately the user interface synchronizes all incoming data based on time stamps and constructs data items containing aligned positional and visual data. For an overview of the process, see Fig.4. ROS (Robot Operating System) is a communication middleware for robotic applications and takes care of the sensor data processing, *Quigley et al. (2009)*. In the left part of the interface, Fig.9, data items collected while the crawler moves along the wall are displayed in a list. In the right part, a 3D view of the vessel including a blob-like visualization of data items is given. It is possible to inspect data by selection either inside the list or directly inside the 3D environment, which in the latter case opens the corresponding item on the left. Data items are organized into “runs” whereby a run represents an entire acquisition process while the crawler moves along the wall. This assists inspection of vessels over their life time in making a comparison of data from different time periods possible. Since the availability and interchangeability of data is a common problem in the inspection of a vessel, *Bijwaard et al. (2009)*, standard XML-Files are used to save all information concerning one run. As the crawler provides offline visual data as well, an import for videos is available which

ISSN: 2233-7857 IJFGCN

automatically synchronizes the input video with the temporally closest item in the currently considered run. The timestamp of the video is extracted from its meta-data.

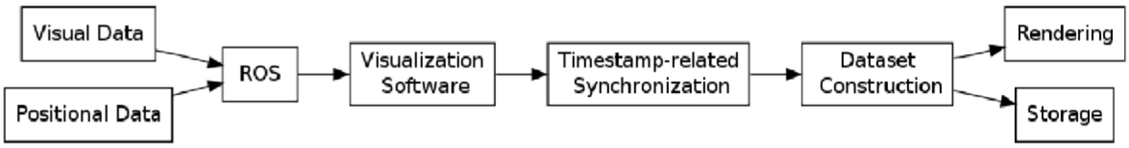

Fig. 4: Workflow of the Visualization

VI. Conclusion and Future Work

The new developments in the inspection system presented include an optimized mechanical design of both the crawler robot itself and the tracking unit. Furthermore the software to localize the data taken by the lightweight crawler and its graphical representation for the user is introduced. The presented marking unit can provide a way to label defects inside the hull for later inspection. The lab-trials and the real-world tests aboard the “Alaya” showed some issues that need to be corrected, before an application of this robotic system becomes a useful addition to conventional inspections. On the mechanical side the robot needs stronger magnets to provide a robust attachment to the steel walls in any orientation. Simply replacing the current magnets with stronger ones though, might lead to different issues that have to be considered, such as a decreasing motor speed due to higher loads or a possible failure of the current mounting system resulting in a loss of the magnets during the runs. To test possible outcomes the testing surface in the lab is to be adapted to resemble an actual ship wall more closely and allow for meaningful experiments without the need to board a ship. Stronger magnets may also help to transit from a horizontal to a vertical surface or between two vertical surfaces. Otherwise a new wheel design, e.g. *Tâche et al. (2009),* might help overcome these problems. To make a use of the marking unit in a real world environment, it needs to be equipped with a more suitable varnish for metallic surfaces. This varnish must not clog the outlet of the spray container and has to be suitable for multiple if not all surfaces in a ship. Another option for a marking system may be the use of a servo actuated marker pen. The transmission problems of the video images have to be prevented, as other repairs cannot be put to a hold during the inspections. Therefore a new video transmission was later integrated into the robot with a 5.8 GHz submission rate and 2.5 times stronger signal. The transmission remains to be tested onboard a ship but the noise ratio inside the lab decreased drastically with this setup. On the software side the tracking algorithms need to be optimized and sped up to enable the tracking unit to follow the robot robustly at all times. This could be achieved by using for instance a particle filter which estimates the motion before the motion is executed, *Fox et al. (1999*). The synchronization and matching of the sensor data with the localization data works well and reliably. Yet some problems remain: To actually use the data, an accurate computer model of the inspected ship is needed, which, oftentimes, is not available for the inspection process. Another robot of the MINOAS fleet might provide this model in later adaptations, namely the flying inspection unit, *Ortiz et al. (2011)*. Furthermore the tracking unit needs reproducible anchor points inside the ship. This might be put into practice by welding markers (i.e. screw nuts) to the anchor points or otherwise marking them inside the ship. Or it might be possible to map the anchor points virtually and retrieve them during the inspection process by measurements from certain landmarks in the hull. Nevertheless after the optimization of these factors the lightweight crawler can serve as a useful tool during the inspection of large cargo holds or even (with a watertight cover) for the outer hull. Before that can happen not only the technical problems need to be solved but also a wider acceptance of the reliability of such robotic tools for the commercial use has to be sought.

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ISSN: 2233-7857 IJFGCN