Infrastructure for 3D Model Reconstruction of Marine Structures

Hanna Kurniawati¹, James C. Schulmeister², Tirthankar Bandyopadhyay¹, Georgios Papadopoulos², Franz S. Hover², Nicholas M. Patrikalakis¹,²

¹ Singapore–MIT Alliance for Research and Technology
Singapore

² Department of Mechanical Engineering, Massachusetts Institute of Technology
Cambridge, MA, USA

ABSTRACT

3D model reconstruction of marine structures, such as dams, oil-rigs, and sea caves, is both important and challenging. An important application includes structural inspection. Manual inspection of marine structures is tedious and even a small oversight can have severe consequences for the structure and the people around it. A robotic system that can construct 3D models of marine structures would hopefully reduce the chances of oversight, and hence improve the safety of marine environment. Due to the water currents and wakes, developing a robotic system to construct 3D models of marine structures is a challenge, as it is difficult for a robot to reach the desired scan configurations and take a scan of the environment while remaining stationary. This paper presents our preliminary work in developing a robotic and software system for construction of 3D models of marine structures. We have successfully tested our system in a sea water environment in the Singapore Straits.

KEY WORDS: Marine robotics, Inspection of marine structures, 3D mapping.

INTRODUCTION

We are interested in 3D model reconstruction of marine structures, i.e., structures where some part is submerged under water, such as dams, oil-rigs, ships, and sea caves. Model reconstruction of marine structures is both important and challenging. An important application includes structural inspection. For safety reasons, man-made structures need to be inspected regularly for cracks and other deformations. For repair purposes, technicians need to inspect ship-hulls to ensure no damage is left unattended. Manual inspection is tedious and even a small oversight can have severe consequences for the structure and the people inside or around it. This process is vulnerable to mistakes because inspectors must work in uncomfortable positions aboard boats or with SCUBA (Self-Contained Underwater Breathing Apparatus). A robotic system that can construct 3D models of marine structures would enable inspectors to inspect the structures from a more comfortable position in their offices, and hopefully reduce the chances of oversight, which would then improve the safety of marine environment.

Developing a robotic system to construct 3D models of marine structures is challenging due to the nature of water environment. Water currents and wakes make it difficult for a robot to reach the desired scan configurations and take a scan of the environment while remaining stationary (Fig 1 illustrates this difficulty). This difficulty is worsened by the lack of commercial positioning sensors that are accurate enough for the purpose of model reconstruction. For example, a commonly used commercial GPS today would have a standard error of around 5m. This is insufficient for model reconstruction considering the size of the structures we want to inspect, e.g., the diameters of the pillars of a pier, may be around 1m. Although DGPS can have less than one meter accuracy, this high level of accuracy can be achieved only when the DGPS is near to the ground base station, which is not always feasible when the robot operates in the sea environment. As a result, due to the robot’s motion uncertainty and lack of accurate commercial positioning sensor, the scanned data may have been taken from a position far from the intended scanning position and even significantly far from the position logged by the positioning sensor. This position uncertainty causes difficulties in merging the scanned data into a single 3D model.

This paper presents our preliminary work in developing a robotic and