A NOVEL DESIGN OF UNDERWATER VEHICLE-MANIPULATOR SYSTEM FOR CLEANING WATER POOL

by

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Abstract

A NOVEL DESIGN OF UNDERWATER VEHICLE-MANIPULATOR SYSTEM FOR CLEANING WATER POOL

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This paper presents an underwater robot specifically designed for cleaning water pool, the idea comes from the requirement of Macau Water Company. We have designed underwater robots to meet the needs of cleaning job. The cleaning job can be distinguished into two main parts: bottom cleaning and side-wall cleaning. Most of the pool cleaning robots available in the market is typically a mobile robot. It is easy to find that a mobile robot cannot cleanse up some areas inside the water pool, such as the corner areas and the surface above the water level. Hence an underwater vehicle-manipulator system *(UVMS)* developed can tackle the cleaning issue efficiently.

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LIST OF ABBREVIATIONS

AGV	Auto-Guided Vehicle
GPS	Global Positioning System
ROV	Remotely Operated Vehicle
UUV	Untethered Underwater Vehicle
AUV	Autonomous Underwater Vehicle
PCR	Pool Cleaning Robot
CCPP	Complete Coverage Path Planning
RB	Rigid Body
UVMS	Underwater Vehicle-Manipulator System
CFD	Computational Fluid Dynamics
D-H	Denavit-Hatrnberg
PSS	Parallel to the Long-Side
PLS	Parallel to the Short-Side
SF	Spiral Filling

PREFACE

This thesis has evolved for a Master degree research. The contribution of it is to develop a robotic system, so called underwater vehicle-manipulator system, for cleaning up a water pool. The intention was to design this kind of robot is that the trend of utilizing robot to the domestic and industrial services is growing in every district. An enormous humanistic power can be retrenched and even substituted by only a robot system. The purpose of this thesis is to be able to integrate a robot in the appropriate application. The content of the thesis covers a fair amount of mechanics, dynamics and kinematics, it also covers the path planning of the robot. And the designed is called Pool Cleaning Robot, PCR.

The thesis comprises eight chapters:

Chapter 1 provides a brief review of the historical development and a classification of the underwater robot. It covers introductory subjects that familiarize the reader with the necessary background information of cleaning robot and underwater robot.

Chapter 2 covers the mechanical design of the pool cleaning robot. The mobile robot and the manipulator will be introduced part by part. The mobile robot of the PCR consists of several main components, i.e. water pump, actuator, driving belt and cleaning brush. The manipulator of the PCR is a 6R manipulator with a cleaning plate as the end-effector.

Chapter 3 deals with the dynamics analysis of the PCR. All the underwater robotic system must consider the hydrodynamics effect that a normal robot will not face, such as the added mass and inertia, damping effect and buoyancy. The dynamics equation of the PCR is studied in matrix from. And for the manipulator, after considering the kinetic energy and potential energy, by applying the Lagrangian formulation, the dynamics equation is obtained.

Chapter 4 covers the complete coverage path planning (CCPP) of the PCR when it is operating the cleaning job. The most basic CCPPs are classified into three types. For the first type, the PCR is moving back and forth along to the longer side of the pool. The second type is similar to the first one but it is moving along to the shorter side of

the pool. The spiral movement in the pool is the third type. For cleaning the side walls of the pool, the PCR can basically use its manipulator only or use the cylindrical brushes by climbing to the side wall.

Chapter 5 addresses the workspace of the PCR. By obtaining the kinematics of the manipulator of the PCR, the workspace of it can be simulated according to the scope of movement of the joints.

Chapter 6 covers the inverse kinematics of the underwater manipulator. It can be considered as the mathematical foundation for the position analysis of serial manipulator. Then the trajectory planning of the manipulator is presented by applying the inverse kinematics.

Chapter 7 provides the fundamental knowledge needed for the Jacobian of the manipulator of the PCR. The Jacobian of the manipulator with respect to the last frame is studied.

Chapter 8 covers the static force analysis of the manipulator. By applying the concept of Jacobian, the torque of each joint is calculated while the end-effector is under a known force and moment.

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DEDICATION

The author wishes to dedicate this thesis to the scope of the Underwater Vehicle-Manipulator System (UVMS), especially to apply the research presented in this thesis to the related area, such as in cleaning swimming pool and water-storage tank. This thesis introduces not only the fundamental theory of UVMS, but also the essential analysis of the designed robot.

In the present market, it exists different kinds of underwater robotic product for cleaning water pool. Some of the robots are controlled by manual and some are controlled automatically, but it is only an underwater mobile robot. It is seldom to be found that any UVMS product in the general market. The reason may be caused by the control of UVMS is relatively professional and the maintenance of UVMS is complicated and expends a lot. This thesis represents a pool cleaning robot in order to indicate an UVMS is more flexible and efficient than an underwater mobile robot. The combinational system of the underwater mobile robot and manipulator is introduced to the readers to let them clarify how an UVMS can assist in our daily work.