Underwater Gripper using Distributed Network and Adaptive Control

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Abstract Underwater identification and grasping of objects is a major challenge faced by the marine engineers even today. Nowadays, almost all underwater operations are either autonomous or tele-operated. In fact remotely operated vehicles (ROVs) are used to deal with inspection tasks and industrial maintenance whenever there is need for intervention. However, the field of autonomous underwater vehicle (AUV) is a blooming filed with research involving proper moving base control and forces interacting which leads to complicated configuration. Hence the presented work is focused implementation of end-effector with appropriate control and signal processing resulting in autonomous manipulation of movement under water.

Keywords: underwater grasping, autonomous underwater vehicle, remotely operated vehicle, end-effector

1.Introduction

The autonomous manipulation task involves using a form- or force-closed grasping technology with the aid of sensors resulting in advanced grasping capabilities of the gearing system. However, when using the system underwater, the environment offers challenging conditions for the system to operate with accuracy. This has limited the progress of end-effectors over the past few years. The environmental conditions like salt water, ambient pressure, water force and water contact have made the development of conventional solutions as they are available for land-based application only.

2.Literature Survey

There is need for research in the adaptive control for underwater grippers as they deal with mathematical challenges on the grounds of mechanical and electrical foundation. This involves the application of sensor suite and availability of dexterous kinematics. Moreover, there are very limited work presented in the past which deals with underwater gripping system. Hence a brief overview of the gripping system is essential as they are high interest in autonomous manipulation.

In[1], a initial attempt was made in underwater manipulation using multi-fingers. This project dealt with the development of a three-fingered gripper which was made of sensors for slip sensing (made of

polyvinylidene fluoride) and strain gauges used in the measurement of forces. In this work, the bending of finger element was made possible with the use of bellow structure in the fingers that worked on actuation principle. It has been observed that depending on the pose estimation from the pressure created by the below structure, the position control was made. Thus a dynamic behaviour operating at 10Hz was devised using actuation hydraulics. Similarly [2] describes the design of Harbin Engineering University called the HEU Hand II which were used as deep-sea manipulators by the industries. Here the design was built on the three-fingered design with two joints each. Contact sensing was brought about by strain gauge sensors that were integrated with the finger-tip sensors. Along with it, the DC motor actuation torque is also combined and the gripper is made to operate. The control factor was satisfied by controlling the impedance. According to the author, this method of gripping imposed additional challenges since the location of drag, mass, buoyancy and other hydrodynamic terms were not known accurately. In order to cope with this unpredictable condition, [2] proposed a impedance control using position-based neural network. Similarly in [3], tendon-driven three-finger manipulator was designed and implemented in the TRIDENT project. In this work, the author explains the implementation of an electric underwater manipulator in combination with the gripper. Here, the principle of optimal measurement is enforced for contact sensing of the elements. Apart from the actuation of the gripper, position and velocity control were also customised into the motor controllers. The autonomous underwater vehicle which operates at 100 Hz is controlled by a control unit which takes charge of coordinating the gripper and arm system, interfaced with the controllers. The SeeGrip project [4] also involved a three-fingered tripper which involved a multi-modal tactile sensor feedback which was used in place of deep-sea manipulators. The proposed work in [4] involves the use of two limbs and two opposable thumbs of the fingers. A positive control is accomplished based on angular encoders. A sub-miniature servo valve is used by the actuator such that the frequency of operation is 3KHz and 50 bar pressure. Based on the observations made in the recent research work on grippers, it can be concluded that the major application of the robotic grippers were in the ROVs for telemanipulation tasks. However, the state of autonomy requires the ability of the system to react and respond, considering the external factors from various environmental variations. However, one should understand that both damping parameters as well as hydrodynamics need to be well-researched for the objects handled and the gripper [5].

3.Proposed Work

3.1 Touch Sensors

The proposed work uses touch sensors which sense the varying ambient pressure and contact with water. Since the pre-grasp position is crucial in the gripping process, proper measurement of the pose is essential along with identification of the geometric shaped identification of objects that come in the way. However, it is observed that encoder wheels and other traditional approaches do not fall in line with the required task due to limited reliability and pressure housing when the system is submerged in ambient water. During the selection of sensors, it should also be kept in mind that water does not affect magnetic field. Hence hall-effect based sensors prove to be an apt fit to measure angular positions in the presence of water bodies [6]. Moreover, based on research it is found that grippers built so far used

pressure-tolerant force sensors. Hence, in order to improve the sensor feedback quality, it is essential to operate sensors that are unaffected by water and operate independent of water bodies. Moreover, the principle of strain gauge sensors using the Wheatstone Bridge Circuits are used to measure absolute force and are also listed in the MEMs Technology.
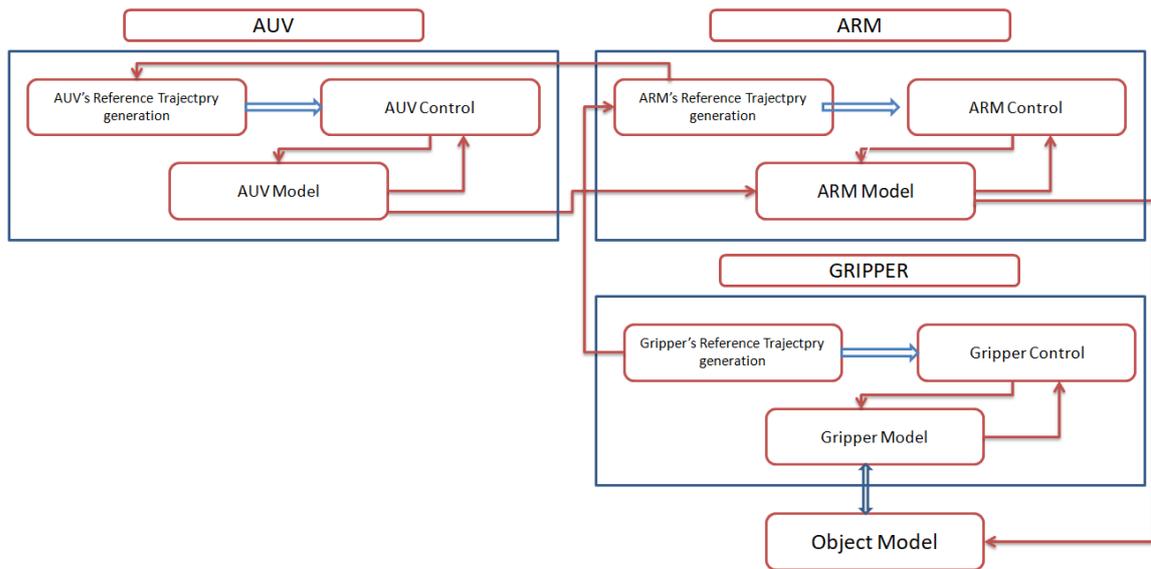

Fig. 1. Block Diagram of the Gripper Interfaced with ARM and AUV

3.2 Nonlinear Optimal Control- A Solution

One of the key feature that is used in different applications in the field of science and industry is nonlinear optimization. The focus in this paper is on choosing the free variable such that the defined objective functions are minimized at the same time maintaining specific constraints. In general, the problem of non-linear optimization can be represented as:

Optimization Vector: $z \in R^n$

Constraint Functions: $h: R^n \in R^{l_e}$

                                                                  $g: R^n \in R^{l_i}$

Objective function: $F: R^n \in R$

Therefore: $\min_{z} F(z)$

This shows that:

$$h_j(z) = 0, where\ j = 1,2,3, \ldots \ldots, l_e$$
$$g_i(z) \leq 0, where\ i = 1,2,3, \ldots \ldots, l_i$$

is referred to as non-linear programming (NLP).

To solve these type of problems, there are many algorithms available. The algorithms were based on Newton's method and WORHP has been designed to solve sparse non-linear optimization problems in large scale. The most preferred NLP solver is the WORHP. This algorithm makes use of either the interior point method at non-linear level or the interior point method for quadratic sub-problem in a sparse sequential quadratic programming (SQP) method. The designed software focuses on application-driven and robust design [7].

3.3 Principle for Distributed Computation

The underlying principle of distributed computation is based on the distributed systems used in computer science field. In general, when many computers that are networked together such that communication between them takes place through message passing, they form a distributed system. The approach of distributed computing is used to solve global issues in a distributed manner. Initially, the problem is first split into multiple sub-problem which is solved using a component. The distributed system using distributed computing has a number of advantages when compared with using a centralized computing system which gathers all data under a single computing centre. The major advantage of using distributed system is that the presence of fault or failure in one system will not affect the entire distributed system as a whole. Further, since the data to be handled is massive and the network components are very large, it helps in congestion prevention. Moreover, the efficiency of the computers can also be improved by distributing the tasks to many computers. However, one should keep in mind that this will require a distributed computing algorithm that will maintain computer efficiency while solving the global problem. Other requirements such as scalability, synchronization, acceptable latency, parallel processing and low communication should be taken into consideration [8].

3.4 Adaptive Control

It is essential to know the use of mathematical model and their influence in understanding the sophisticated numerical optimization software. Because of mutual influences and complex physical phenomena, the tactile exploration under water proves to be a non-linear task which is very complicated. However, simple models of algorithms can be used to simplify this problem with the help of adaptive control of measurements.

- **STEP I:** The primary objective is to find the parameters of the non-linear model which matches the measurements observed (also known as parameter identification). Accordingly, the pre-defined and formulated NLP nonlinear optimization model can be used to identify the parameters in an efficient and robust manner.

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- **STEP II:** On establishing a proper description of the physical influences, it is possible to focus the gripper to move in the optimal direction using the mathematical control algorithm. The problem of optimal control can be comprehended as an infinite-dimensional optimization as the controls and the states at every time point are found to optimal.

There are two approaches commonly used as far as direct methods are considered in order to transform the given problem into finite-dimensional form which will lead to large and sparse or small and dense problems. Hence the second method is more convenient and effective for highly non-linear application due to the nonlinearities and robustness during the process of simulation and evaluation. The control algorithm developed for the gripper using adaptive control will be able to adapt to the presence of natural disturbances, accurately. Hence exact measurement and robustness of the system is an essential component of the gripper algorithm.

3.5 Distributed Sensor Processing

When there is need for handling massive data, a distributed processing system will serve as an efficient and robust way to prevent single point failure and congestion during operation. Since the underwater gripper will require the coordination of many sensors that feed data on temperature, pressure, angle, velocity, position, etc., it is essential to implement the distributed signal processing inside the sensor network. This will further ensure that the sensors do not have access to the sensing capabilities of the other sensors but rather communicate with each other using messages in order to arrive at a global solution. This task can also be addressed as distributed sensor fusion. The distributed solution can be achieved by splitting the global objective function in sub functions which can be summed up along with constraints that every function has a local solution which is further converged into the global solution. However, the drawback with this system is that there might be hidden variables in some cases and there will be inadequate knowledge regarding the dynamic process to proceed with finding the global solution.

4. Results and Discussion

The Tactile exploration of objects is one of the least explored fields. The primary reason is that they cannot be used on land and hence their applications are limited to water-bound experimentation. However, as far as underwater applications are concerned, tactile exploration of objects is a very important criteria which paves way to building an autonomous well-equipped gripper that is able to explore in limited visibility, where manual manipulation is deemed impossible.
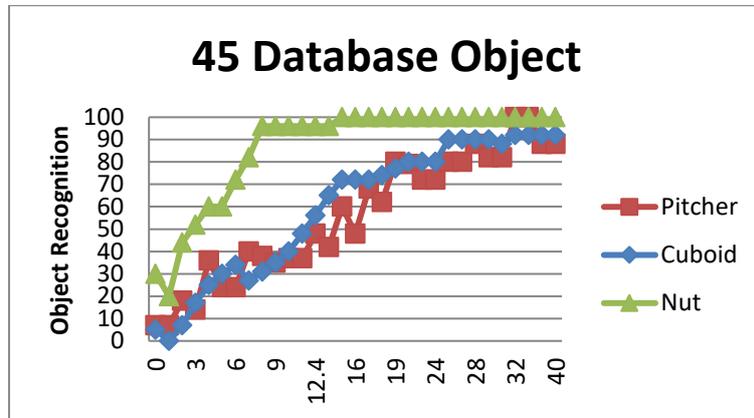
Fig. 2. Underwater Exploration of 45 database object

It was found that object recognition was possible using a set of 45 database object as represented in Figure Fig.2. and similarly the use of 5 database objects is represented in Figure Fig.3.
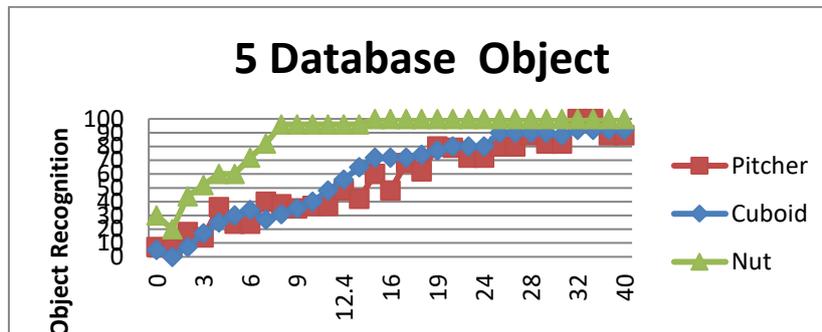

Fig.3. Underwater Exploration of 5 database object

5. Conclusion

In the past few years, there has been serious advancement in robotic systems and their application in numerous fields. However, it has been identified that these advancement in technology suffers ude to limited sensor data and processing capabilities instead of being combined to give a liable and versatile solution. The proposed work demonstrates a gripper system that can be used for operation with the help of adaptive control methodology which estimates the object boundary and controls the gripper to grab the object in the right position. While designing the gripper, the reliability of the system to perform the crucial tasks assigned as well as the robustness of the system need to be considered and uncompromised. Thus, we propose a highly distributed computation and sensing architecture for the

gripper using multimodal sensing that takes into consideration uncertainties identified and dependent on the measurement principle of the sensor feedback. The tractile exploration of the gripper is analyzed and we believe that this integrated robotic end-effector will be the foundation for the future of highly reactive and robust robotic systems in both land and water.

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