IMPROVING THE OPERABILITY OF REMOTELY OPERATED VEHICLES

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ABSTRACT

Underwater Remotely Operated Vehicles (ROVs) have a significant support role to play in offshore petroleum production facilities. The extent to which ROVs can replace diver-based operations depends significantly on ROV capacity and the relative costs of mobilising and implementing the two modes of underwater operation. This paper presents work directed at two aspects of ROV operability: the quality of visual information presented to the ROV pilots and the degree of station keeping control exhibited by the vehicle.

Significant improvement in pilot performance of selected maintenance-type tasks has been achieved by the use of a purpose built underwater stereoscopic video camera and associated ship-based stereoscopic display unit. Two generations of cameras have now been built and used on a Perry Triton vehicle in use at the North Rankin A platform on the North West Shelf.

In a related program, stereoscopic images of the platform structure are processed to determine the relative position of the ROV. Changes in position are used as inputs to thruster control algorithms, with a view to enabling the vehicle to hold position in fluctuating current fields. The position data from the processed 3D images are linked to output from an on-board inertial system to enable position to be maintained despite periodic loss of visual information.

First trials of the combined vision-inertial system indicated some success, notably using the vision system, but indicated difficulties with the inertial package and its integration into the control process. An extension of this project is now being supported by the Australian Maritime Engineering Cooperative Research Centre (AME CRC).

INTRODUCTION

Underwater Remotely Operated Vehicles (ROVs) have a significant support role to play in offshore petroleum production facilities. The extent to which ROVs can replace diver-based operations depends significantly on ROV capacity and the relative costs of mobilising and implementing the two modes of underwater operation. Work undertaken by the Centre for Marine Science & Technology (CMST) at Curtin University in Perth, for Woodside Offshore Petroleum Pty Ltd, has been directed to two aspects of ROV operability: the quality of visual information presented to the ROV pilots and the degree of station keeping control exhibited by the vehicle.

Woodside Offshore Petroleum operates three underwater ROVs at its offshore gas production platforms, North Rankin A and Goodwyn A, on the North West Shelf. Its main ROV is a Triton ROV manufactured by Perry Tritech Inc (Florida, USA) (Figure 1). The Triton is used to perform a range of inspection and maintenance tasks on the underwater sections of the platforms. All of the ROV operations are conducted from the Shelf Supporter support vessel .

It is generally significantly harder to perform underwater tasks with ROVs than it is with divers. There are several reasons why this is so. The first reason is the lack of visual fidelity provided by an ROV’s conventional video system. The resolution of a conventional video system is significantly less than that of the human eye. A diver can also see his or her environment with stereoscopic vision

Figure 1: The Triton ROV at the North Rankin A gas production platform

whereas a conventional ROV's video system only provides the operator with a monoscopic view, therefore reducing depth perception. The second reason is the lack of dexterity and control of the manipulator arm as compared to the diver's two hands and arms. The use of the manipulator arm is even more difficult if the vehicle moves while trying to perform a particular task since the manipulator arm must continually be adjusted to counteract the vehicle's movement.

Two systems (one developed and the other in development) offer opportunities to improve the operability of ROVs. The Stereoscopic Video System discussed below uses a maturing technology which provides ROV operators with a stereoscopic view of the ROV's environment, thereby increasing depth perception and task performance. The Station Keeping System discussed below is a system currently in development which aims to reduce the motion of the ROV in fluctuating current fields. It is planned that this will enable the ROV to be used in a greater range of sea conditions, particularly near the sea surface.

STEREOSCOPIC VIDEO

Stereoscopic video is the process whereby video technology is used to capture and display stereoscopic images. A stereoscopic video system has been developed at CMST for use with underwater ROVs. The system consists of a compact underwater stereoscopic video camera which is mounted on the ROV (Figure 2) and a stereoscopic display which is installed in the ROV control room (Figure 3).

The stereoscopic video camera contains a pair of video cameras mounted side-by-side in a single underwater housing. The left and right perspective views captured by the camera effectively simulate the operation of the two human eyes. The 3D video signal from the stereoscopic video camera is displayed on the stereoscopic display in such a way that when the operator views the screen, while wearing the specially polarised glasses, a full-colour flicker-free stereoscopic image is seen (Woods 1997).

ROV STATION KEEPING

In 1992, the Centre for Marine Science and Technology embarked on a project to develop a Station Keeping System for Woodside Offshore Petroleum's Triton work-class ROV. The design concept of the system is that it senses movement of the ROV and controls the thrusters to counteract any unwanted movement. The system senses information from a range of different sources to obtain an accurate measure of the position of the ROV. The primary source of position information is the Stereoscopic Ranging System (SRS) which is discussed in more detail below. The secondary data source is a gyro-stabilised accelerometer platform which provides acceleration data in three linear axes and tilt in two axes (pitch and roll). Position data is also obtained from an Acoustic Tracking System (ATS) (Nautronix, Fremantle) which tracks the ROV in three dimensions with the use of an acoustic beacon on the ROV and a multi-element hydrophone attached to the hull of the Shelf Supporter. The remaining data sources are two depth sensors, a heading sensor and two tilt sensors on the ROV. The layout of the system is shown in Figure 4.

Figure 2: The Compact Underwater Stereoscopic Video Camera

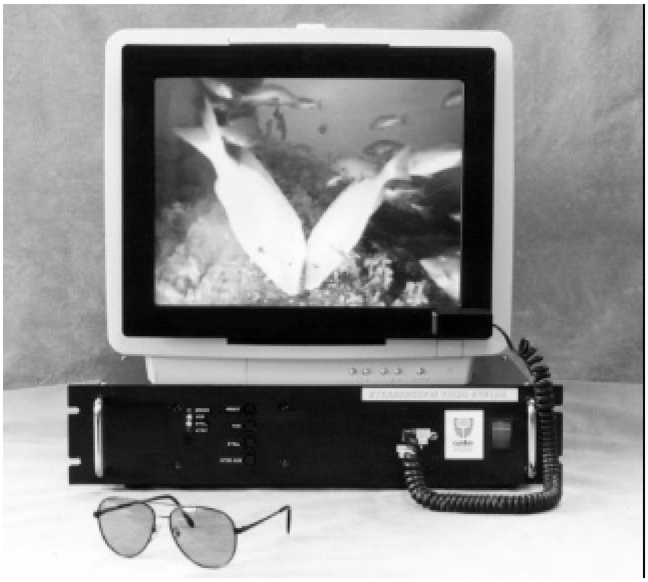

Figure 3: The Stereoscopic Display

The various data sources all vary in their quality, accuracy and long-term stability. For example, the SRS can provide high accuracy position fixes (accurate to within a few centimetres) which are not subject to long-term drift. However, if a fish or some debris drifts in front of the cameras, ranging data from the SRS may be lost completely. In contrast, data from the gyro-stabilised accelerometer platform is highly reliable (no drop-outs occur), however, the measurement of relative position from the accelerometer readings is subject to long term drift. The Station Keeping System software (contained in the Station Keeping Core)

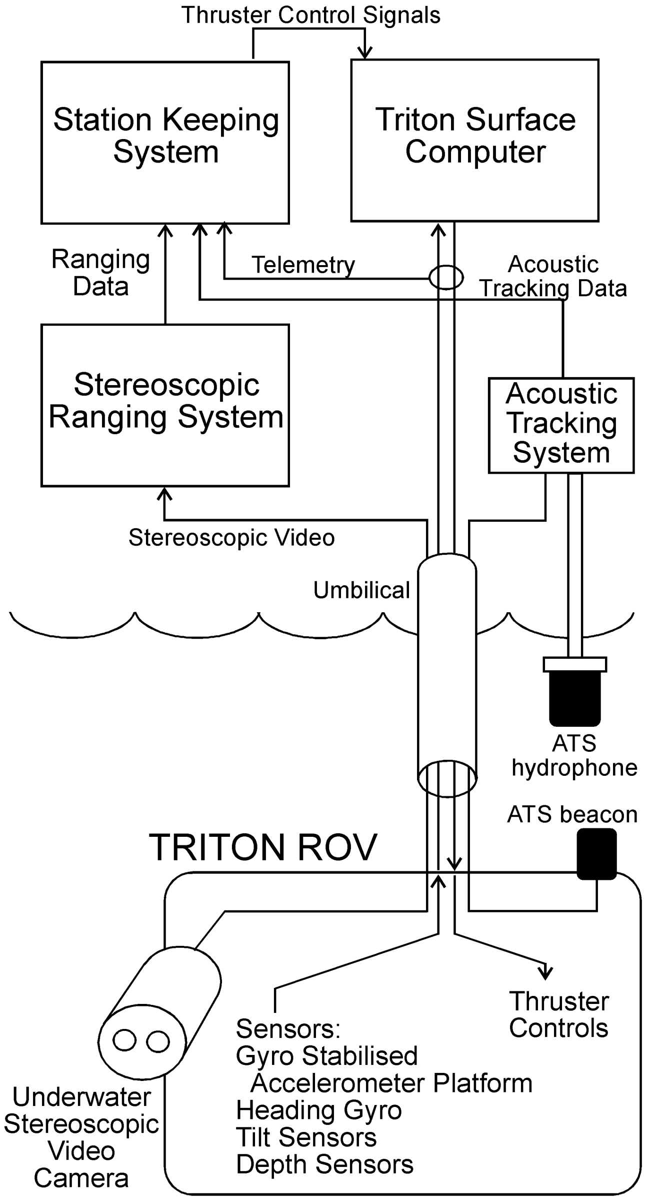

Figure 4: System schematic of the Triton Station Keeping System

therefore combines all these data sources to obtain the best estimation of the ROV's actual position. This process is known as sensor fusion.

The Station Keeping Core is based on a PC with several analog and digital interface cards and custom written real-time software. The key components of the Station Keeping Core are illustrated in Figure 5. It consists of two main blocks: the position estimator and the control algorithm. The purpose of the position estimator is to determine the best estimate of the ROV's position from the available data. The position estimator itself consists of two main blocks: data preparation and the Kalman Filter. The data preparation section converts the data from its various raw formats into physical measurements with appropriate error estimates. As each sensor works in its own local coordinate system the data preparation section must also convert all the data to the same coordinate system before it can be combined. A Kalman filter is used generate the single unified position estimate from the various data sources. Kalman filtering provides a very good way of combining data of varying accuracies into a single output.

The output of the position estimator is compared with the desired position of the ROV (the set point) and passed to a control algorithm which generates a control signal to be applied to the ROV's thrusters. The design of the control algorithm is based upon a software model of the dynamics of the Triton ROV. This model was developed using a process called System Identification (SI) whereby the vehicle's responses to known thruster signals are measured (Goheen and Jefferys 1990).

STEREOSCOPIC RANGING

The Stereoscopic Ranging System was developed as the key source of position information for the Station Keeping System in a related program at Murdoch University and builds upon the successful development of the Stereoscopic Video System discussed previously. The Stereoscopic Ranging System is based around a PC with a special video image processing card and custom-written stereoscopic image tracking software.

Stereoscopic ranging is started by the operator selecting a feature to track which is in the view of the stereoscopic video camera. This feature should be a fixed item (e.g. a part of the platform structure) so that the system can use it as a position reference. Once the feature has been selected, the Stereoscopic Ranging System will track this feature as it moves in the view of the stereoscopic video camera. The three-dimensional position of the feature is determined essentially using the principles of photogrammetry.

Since the location of the feature is fixed (assuming an appropriate feature has been selected), any movement of the feature in the view of the camera must be due to the

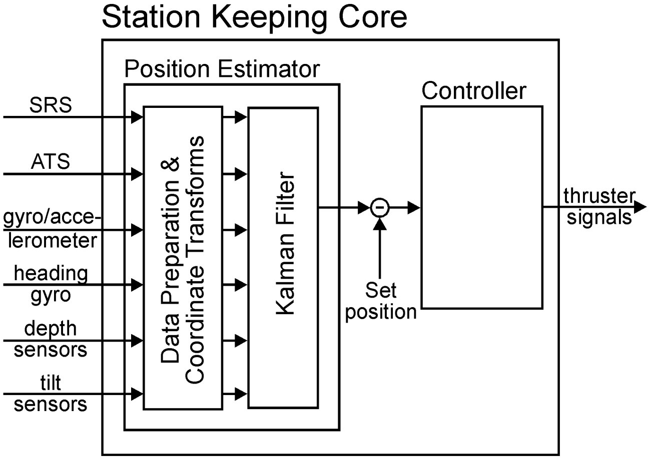

Figure 5: Operation of the Station Keeping Core

movement of the camera. The movement of the ROV can therefore be inferred from the tracking data and fed into the Station Keeping System for use in controlling the ROV.

The Stereoscopic Ranging System can also be used to perform various forms of non-contact measurement. A stereoscopic cursor can be moved around in the stereoscopic image to measure range from the stereoscopic camera or, if two stereoscopic cursors are used, measurements of distance or length can be made.

DISCUSSION

Stereoscopic Video

Stereoscopic video has been found to offer many benefits to the operation of underwater ROVs. The most obvious benefit is the increase in depth perception. When using the manipulator arm, object placement and alignment are easier because the three-dimensional position of the arm can be easily seen. Stereoscopic viewing also provides the operator with a better knowledge of the work-site layout and also helps the operator identify unfamiliar or complex scenes. Stereoscopic viewing also improves the visual quality of the image by improving the operator's ability to see through suspended matter (fine particles) in the water.

In 1991 we performed some field time trials with the Stereoscopic Video System to compare task performance between 2D and 3D operation (Woods et al 1994). The task consisted of using the ROV's manipulator arm to insert a pin through the two eyes of a shackle and then to replace the pin in its home position. The task was repeated a number of times by several ROV operators in 2D and 3D viewing modes. The results of this trial indicated that 3D task performance was considerably better than 2D task performance for the same video image quality and camera field-of-view. The mean times for the two viewing conditions were 3D: 2.6 minutes and 2D: 6.8 minutes. It is not expected that this degree of task performance improvement will always be seen because the specific nature of this task meant that it was highly depth dependent. In general, the degree of task performance improvement will depend upon the particular task being performed. It is also interesting to note that by hand, in air, the task was completed in only 4.5 seconds.

Station Keeping

First trials of the Station Keeping System on the Triton ROV using combined vision and inertial data indicated some success, notably using the vision system. The trial was performed in open water to avoid the possibility of collision damage. To provide the Stereoscopic Ranging System with a stable visual target to track, a test target was mounted mid-water between an anchor and a sub-surface float. The Stereoscopic Ranging System performed well and was capable of tracking the test target for sustained periods of time (several minutes) and successfully fed position data to the Station Keeping System. The trial also confirmed the correct operation of the hardware interfacing of the Station Keeping System to the Triton ROV. Unfortunately, there were difficulties within the core software of the Station Keeping System. When the control loop was closed, excessive control signals were sent to the thrusters and the Stereoscopic Ranging System soon lost view of the test target. Review of the data generated during the trial indicated a fault within the position estimator - specifically with the integration of the inertial data.

The next phase of the Station Keeping Project is to confirm the correct operation of a number of key components of the Station Keeping System: coordinate transformations and data flow, the Kalman Filter's operation within the Position Estimator and the control algorithm. Another important phase is the thorough laboratory testing of the system before field trials are conducted with the Triton ROV. ROV time is expensive and Woodside's Triton ROV invariably has a busy schedule, therefore it is important that as much as possible of the Station Keeping System be tested in closed loop mode before field trials take place. Centre staff will be constructing a test rig which will operate within the Centre's test tank. The Station Keeping System will be interfaced to the test rig in a manner which is similar to the way in which it interfaces with the Triton ROV. This will allow real-time closed loop trials of the operation of the system to be performed in a manner which was not possible in previous phases of the project.

CONCLUSION

Stereoscopic video is a maturing technology and is being used in an increasing number of applications. For example, stereoscopic video is also being applied to underground mining applications, with Mount Isa Mines using a stereoscopic video system from CMST on a remotely controlled front-end loader in their copper smelter. We expect the use of remote control technology to become more wide spread and stereoscopic video provides many advantages to increase the operability of this equipment.

Further work on the Station Keeping System is underway. The Australian Maritime Engineering CRC has approved funding for an extension of the Station Keeping System Project which will implement closed loop position control of the vehicle. The project is part of a larger underwater vehicle research program within AMECRC and is also linked with the TUUV2 (Technology for Unmanned Underwater Vehicles) research program in the UK. It is expected that the further development of this system will offer many operational advantages to the operation of the Triton ROV.

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REFERENCES

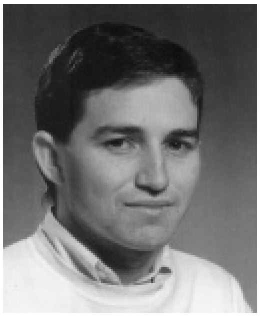
GOHEEN, K.R. AND JEFFERYS, E.R. 1990 - The Application of Alternative Modelling Techniques to ROV Dynamics. In: Proceedings of the 1990 IEEE Conference on Robotics and Automation, Cincinnati, USA, May 1990, 1302-1309.

WOODS, A.J. 1997 - The Application of Stereoscopic Video to Underwater Remotely Operated Vehicles. In: The APPEA Journal, volume 37, 797-800.

WOODS, A.J., DOCHERTY, T. AND KOCH, R. 1994 - Field Trials of Stereoscopic Video with an Underwater Remotely Operated Vehicle. In: Stereoscopic Displays and Applications V, Proceedings of the SPIE (International Society for Optical Engineering) Volume 2177, February 1994, 203-210.

Authors' biographies over page.

THE AUTHORS



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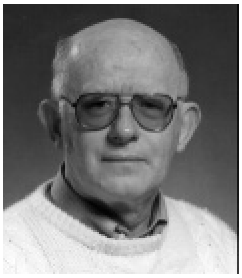

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