ISSN 2278-3091
Volume 9, No.1.3, 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse3491.32020.pdf
https://doi.org/10.30534/ijatcse/2020/3491.32020

Rendering ROV Rolling Motion on a Handheld Haptic Device

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ABSTRACT

While most ROV controlled by varying its motion, it is very helpful to be able to control the orientation directly through a handheld device. This offers opportunity to provide haptic feedback on such handheld device. Haptic device provides force feedback to as a cue signal to a user. The motivation of this work is to give the sensation of rolling object to a user when an ROV, controlled through the handheld device, rolling on the x-axis. The challenge of delivering actual force feedback, instead of a pseudo force, on a handheld device was tackled by using a pair of thrusters, made by brushless DC motors. This device successfully provides up to 168 g (1.65 N) of thrust at it full capacity from each thrusters which gave effective 336 g (3.3N) of thrust in total. While more work can be done to improve user experience utilising the device, this device had managed to provide small but enough force feedback for the user to receive the necessary cue. This paper discussed the approach, some testing results and future work for this study.

Key words: Haptic Feedback, Rolling Motion, ROV, Wave Force.

1. INTRODUCTION

The dream of liberating remote underwater activities, either for social activities, research, economics or recreational, had move our research group, UTeM Underwater Technology Research Group (UTeRG), to continuously work on its many aspect; development of ROV and glider [1], visual feedback [2], multi-sensory system [3], fuzzy based ROV control [4]and recently haptic feedback [5].

This paper presented a study to provide one degree of freedom (DOF) haptic feedback in direction of rolling motion. The motivation is to allow an ROV pilot to realize the current orientation and motion of an ROV through a force feedback from a handheld device. The device is expected to control the orientation of ROV by changing the orientation of the handheld device.

The idea behind this project had been discussed before [5]. Previous works done in providing haptic feedback for handheld devices were mostly limited to the illusion of force through tactile feedback [6], skin surface sheer force [7] or mild electrocution [8]. However, in many of these researches, unlike grounded haptic devices, no kinaesthetic force feedback available and limit it efficiency to convey haptic feedback cues in the form of actual force.

While haptic devices connected to ground capable of producing kinaesthetic feedback through series of junctions and links with reference to ground [9] [10] [11] [12] [13], handheld devices are limited to exploit torque feedback using the gyroscopic effect (GE) [14] and vibration as tactile feedback [15] produced by several actuators, such as motors and thin film [16]. While these pseudo-force feedbacks, as summarized in Table 1, managed to achieve their objectives, none of them could provide kinaesthetic feedback in a form of force available for a grounded device.

However, all these feedbacks had no or limited illustration of force vector direction and could not create net forces on a limb, which is required to provide kinaesthetic feedback. Hence, requiring the feedback, which is usually only an illusion of power, to be processed and interpreted by the person before it affects the change in their physical behaviour. [17]

The handheld haptic devices mainly tackle these problems by stimulating skin, providing cutaneous or tactile feedback by using vibration [18] [6] or differential skin-stretching feedback (SSF). This would delivers the illusion of angular force and translation to the haptic device user [7], allowing small, lightweight and portable or handheld devices. Although these approaches manage to provide a perception of force in a horizontal direction [19], this approach, however, did not produce any perception of force in the antigravity direction [18].

The linear oscillatory actuator (LOA) that uses an asymmetric drive was proposed as haptic feedback [11], creating the illusion of being pushed and pushed, as well as the weight, achieved by a device based on an oscillatory actuator of 2 DOF that was significantly smaller and more practical [26]. GE had been used to produce torque feedback. iTorqU, a hand-held torsion feedback device for haptic applications [21] built to generate torsion feedback without grounding using a gimbal-controlled gyroscope.

Table 1 Leading Approach for Handheld Haptic Device

Criteria	Leading Approaches			
	Linear Oscillatory Actuator (LOA)	Gyro Effect (GE)	Electrical Muscle Stimulation (EMS)	Skin Stretch Feedback (SSF)
Force Feedback	Pull, push, and downward vertical force/weight. No upward vertical cue available [19]	No	Deliver the illusion of movement through electrical stimulation without actually moving. [18]	Variable speed and size of the movements of the tractor to drive the power / torque movements can generate different tactile effects.[7]
Torque	No	Directional torque with more than 360° workspace. [14]	Not explored.	Torque illusion
Tactile Feedback	Simple vibration on horizontal plain	No	Possible	Yes
Bimanual Operation	It is possible but not a specially design device developed for a bimanual operation	It is possible but requires some change in the controller to perform a two-way operation.	Possible but not tested for bimanual operation yet.	Yes.
Accuracy	Good for direction cue, but limited precision of force direction perception. 2 DOF, 2 axes.	Great for directional torque with an anchoring effect.	There is no consistency and calibration required for different users, especially for force feedback [19]. An operation without visual feedback is reported to be disturbing / annoying [8] but have better result with vision feedback. [20]	Good for torque and inertia direction cue, but not for the precise and sharp perception of force in horizontal direction. 2 DOF

This investigation was performed with a gyroscopic actuator for TorqueScreen [27], a powered steering wheel that imposed an angular moment for a handheld tablet, creating the haptic sensation of turning in a direction towards the tablet. However, this approach is limited to 1 DOF, since the device only has one hand wheel. Recently, visual feedback was introduced to improve the haptic feedback provided through electrical muscle stimulation (EMS) [18], motivated by the unsatisfactory haptic sense induced by EMS across the spectrum of a haptic event.

GE did not show any feedback of the translation force and was limited only to the 2-axis torque feedback, which is not available in LOA. However, the SSF technique manages to provide both torsion and the feeling of translational force. The EMS, on the other hand, provided the illusion of movement through electrical stimulation, but was limited to the force caused by the movement of the hand instead of the force from the outside that is applied to an object. All this approach, although it had managed to provide a good feedback of strength and torque, not being connected to ground, none of this approach had provided the user with a visual sense of orientation that users of haptic devices connected to ground had enjoyed.

Both LOA and SSF had the capability to deliver tactile feedback with LOA producing a simple vibration in a horizontal plane. Other than the GE devices, none of the above, as well as any of the approaches for handheld haptic devices described or mentioned before, offered feedback of the kinaesthetic force. They are mostly based on the illusion created with tactile feedback, which cannot be sufficiently comparable to a multi-DOF connected to ground. It was also known that prolonged vibration may cause perceptual fatigue [29].

All this leads to the possibility of creating continuous directional force for a kinaesthetic feedback system through ejecting material approach. This must be done safely without disturbing the driver of the vehicle.

2. METHODOLOGY

A new handheld haptic device, named The handler, was designed to complement a handheld steering device that controls the orientation, rather than the speed, of an ROV. This design had a pair of propellers as its actuators. Each propeller is composed of a BDC motor controlled through a pulse width modulation (PWM) signal. The device, as shown in Figure 1, will provide the force feedback for a rolling motion of an ROV.

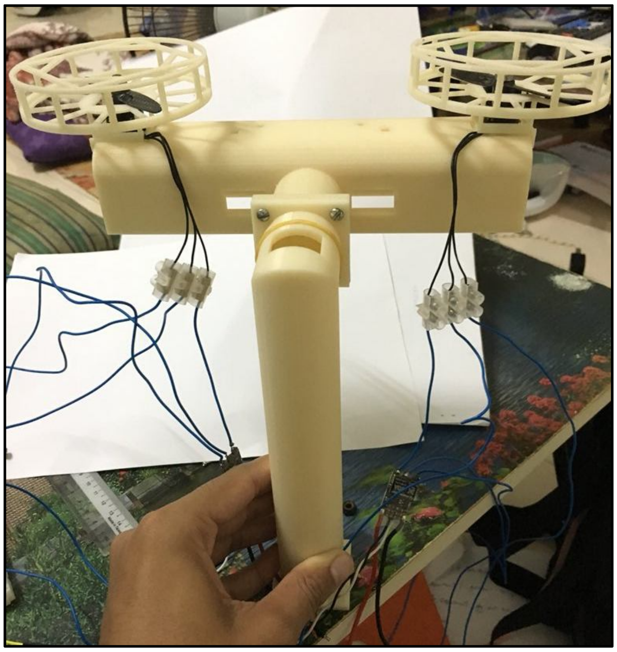

Figure 1: The Handler

As a steering device, the orientation of the device will be captured using a gyro sensor and will be used as a reference angle position for the ROV driving system. This device, The Handler (TH), had two different but integrated systems; (1) ROV steering system and (2) Haptic feedback system. The first part have the user desired orientation as the input and control reference of the ROV as the output, while the second one would have the orientation of the ROV and the haptic device as the input and the haptic feedback as the output, as detailed in Table 2. This paper, however, would describes the later.

Table 2: The Handler's Requirement

Items	Requirements	Parameters	Resolution
Inputs	Workspace		
	Roll	$-90^\circ<\theta<90^\circ$	
	Pitch	$-90^\circ<\theta<90^\circ$	
	Yaw	$-90^\circ<\theta<90^\circ$	
	Force Rotation	<120N.m, [12]	
Outputs	Workspace		
	Roll	$-90^\circ<\theta<90^\circ$	
	Pitch	$-90^\circ<\theta<90^\circ$	
	Yaw	$-90^\circ<\theta<90^\circ$	
	Force Rotation	0N. m<M<11N.m, [16]	2.25N 1N.m

Before the control system was built to control the output force of the device, the thrusters' thrust rate was measured to obtain the linear connection rate between the speed of the motor speed and the force provided by the thruster. A test is made with a wire connection made as shown in Figure 2. Thruster is then placed on a weighing scale to measure the thrust force provided by the thruster proportional to the velocity varies from 0% to 100% of its maximum capacity thruster motor.

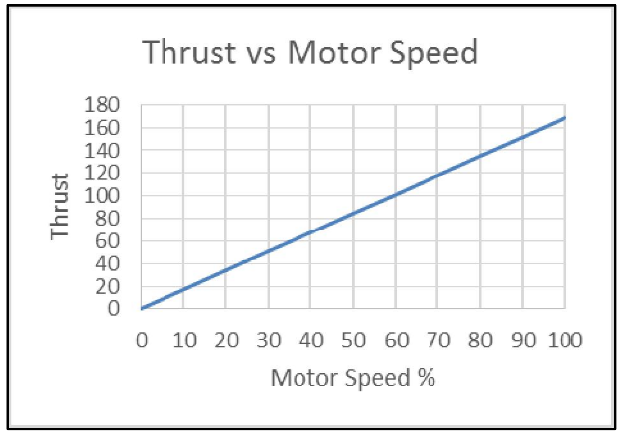

Figure 2: The Thrust Test Result

The result, as shown in Figure 3, had found a linear relation between thruster's thrust in gram and the thruster's motor speed at the rate of 1.66 times of its maximum speed. This finding allow a direct control of the device force output by varying its thruster's speed.

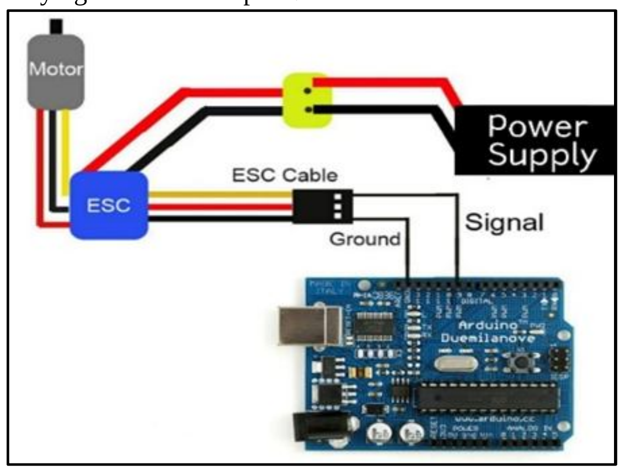

Figure 3: The Thrust Test Wiring Configuration

After full installation was made, the operational test was conducted to see if the device response and working as expected, which is to provide a cue in the form of force at the same direction an ROV motion. The studies made in two phase. For the initial test, a set of LED, with different colours, were used as an indicator of the up thrust and down thrust to make it easier for observation. On the later phase, an actual thrusters used with it speed set at its maximum.

3. RESULTS AND DISCUSSION

Observation was made as both motors of the thrusters were set to rotate at the same rotation since the propeller used are one clockwise and one counter-clockwise. If the motor with clockwise propeller run in clockwise rotation, it will produce up thrust and vice versa. If the motor with counter clockwise propeller run in clockwise rotation, it will produce down thrust. By placing the thruster with clockwise propeller on the left side of the device, the haptic feedback would deliver the illusion of clockwise rotation when rotating clockwise and the other way around when it turns counter clockwise.

Table 3 shows the result of the rotation of both motors. The three conditions which have been programmed in the code as shown in Figure 4.14. Motor 1 was mounted at the left while motor 2 was mounted on the right. The clockwise rotation of the motor will produce up thrust force while the counter clockwise rotation of the motor will produce down thrust force. In condition 2, the motor 1 is clockwise rotation while motor 2 is counter clockwise rotation thus the device should be rolled clockwise. In condition 3, the motor 1 is counter clockwise rotation while motor 2 is clockwise rotation thus the device should be rolled counter clockwise.

Table3: The Handler's Input and Output Requirement

1st MPU (°)	2nd MPU (°)	Condition	Motor 1 (Clockwise)	Motor 2 (Counter Clockwise)
-20	-13	Condition 1		
0	-3	MPU1 <	Stop	Stop
2	12	MPU2+10° And MPU1 > MPU2-10°		
20	10	Condition 2		Down
30	-27	MPU1>MPU2+10°	Upthrust	Thrust
-4	-20			
15	30	Condition 3	Down	
23	50	MPU1<MPU2-10°	thrust	Upthrust
-16	10			

As the device would be handheld by the user, the device will not roll. The user, however, would enjoy the rolling sensation which mirror the ROV motion in control of the user. This would allow user to recognize both drag force as well as the wave acted on the ROV. The nature of a moving body, such as ROV, against wave or water current underwater would allow the user to determine the direction of the wave as the wave impact is at maximum on the direction of the ROV motion against the direction of the wave [17].

By sensing the growing frequency as well as the magnitude of wave hitting the ROV, the user could identify the direction of the wave try to avoid or incorporate the wave into their flight plan of the ROV[22].

4. CONCLUSION

This article discussed the force feedback for an ROV control interface. Since it is difficult to directly measure the force applied underwater, the haptic force vector was derived from the output of a pair of gyro sensor.

On the next stage of the investigation, a study will be carried out on the effect of kinaesthetic force feedback output on a handheld device. Without a base, a handheld device will be the user's hand as the basis of its relative movements. While the ground coordinate system will refer to the adjustment of a grounded device, a handheld device will not have the rigidity of a grounded device. This will allow, depending on how the user responds to kinaesthetic feedback, a significant effect on its orientation control.

ACKNOWLEDGEMENT

Authors are grateful to Universiti Teknikal Malaysia Melaka for the financial support through research grant PJP/2018/FKE(5D)/S01606.

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