Assessing the Utility of Haptic Feedback when Teleoperating an ROV

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Abstract— **This work-in-progress project investigates the use of haptic feedback when teleoperating an underwater robot through a dangerous cross-current. Haptic feedback provides statistically significant improvement in task accuracy.**

Teleoperated ROVs are used for deep sea exploration, underwater biosurveys and structure inspection. These tasks require significant precision in some of the most hostile conditions that a modern robot will encounter. Limited visibility [1], floating debris, complex environmental geometry [2] and invisible water currents [3] are among the hazards that an ROV may encounter when operating in open water. To address these and other challenges posed by ROVs in difficult environments, researchers are beginning to consider haptic feedback as an approach to conveying additional state and environmental information captured from a robot's sensor suite.

This **project aims** to investigate how haptic feedback delivered through a soft haptic touchpad [4] can improve performance and workload when teleoperating an ROV in a hazardous environment - specifically a strong cross-current.

An experiment was devised in which eight participants were asked to teleoperate an ROV and reach a target 4m ahead of their starting position. The ROV was controlled using a soft haptic touchpad such that moving the finger left-right would steer the robot left to right, and pressing down harder would increase the forward velocity. The touchpad was selected for it's ability to render both hardness and vibration (oriented in the same direction as a cross-current). A strong cross-current was generated by a fixed underwater thruster halfway between the start position and the target which would push the robot approximately 1m to the right of where participants intended to go. Visual feedback was provided at all times using the view from the robot's 720p forward facing camera. The study received ethics approval from York University (certificate e2022-266).

Three conditions were involved in the study - control (no current, visual feedback only), cross-current (with a left-right cross-current in the path of the robot) and current+haptics (where the cross-current was running, and haptic feedback was provided through the touchpad). Five trials were conducted in each condition in a 'familiarisation' phase, followed by a further five trials in each condition in an 'experienced' phase which allowed the results to be analysed in terms of user experience with the task and robot. Participants were asked to complete the NASA TLX survey after each block of five trials. Haptic feedback was provided to indicate the cross-current via an asymmetric (left-right) vibration on the surface of the touchpad, as demonstrated in [5]. The distance to the target (within 0.5m) was indicated by the touchpad becoming physically harder and more difficult to press down on.

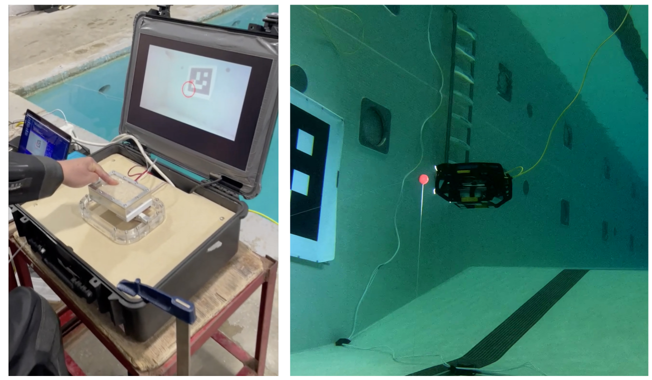

Fig. 1. **Left:** A participant using the soft haptic touchpad to control the robot. **Right:** The robot close to the target ball.

Preliminary results demonstrated statistically significant improvements in accuracy (final displacement from target), average speed and deviation from an ideal path. Cognitive workload was only significantly improved in the familiarisation phase (for novice participants). Improvement in maximal lateral displacement in the water column was significantly improved using haptics once participants had gained experience with the ROV.

Future work will further interrogate the properties of the haptic effects presented here, for example to determine whether the direction of vibration (consistent, opposed or orthogonal to the cross-current) affects operator performance.

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