

## Underwater Robot-To-Human Communication Via Motion:

#### Implementation and Full-Loop Human Interface Evaluation

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#### **Underwater HRI Background**



- Developing over the last 15 years due to  $\succ$ the emergence of human-portable AUVs.
- Intended to allow collaboration between  $\succ$ humans and AUVs in underwater work.
- AUV-to-human communication: \*
  - Digital displays are the only prevalent  $\succ$ form of robot-to-human communication.
  - Displays have a limited distance and  $\succ$ orientation of communication.
- Can more natural. human-like communication be used?





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## **Robot Communication Via Motion**

- Definition: Kineme
  - A sequence of robot motion with an associated semantic meaning.
  - Mimics human body language/gestures.
- Originally proposed and evaluated for simulated AUVs.
  - Kineme communication outperformed light-based communication in simulation.
- How will RCVM perform in the real world, compared to alternatives?

#### RCVM

#### Motion as a form of communication.



The "Follow Me" kineme on the Aqua AUV.



#### **Comparison Systems**



#### **LED** Array of 3 LEDs.



The "Follow Me" LED code.





The "Follow Me" LCD display.

#### TTS English phrase played audibly.



The "Follow Me" audio cue.



## **Pilot Study**



- We performed a small pilot study evaluating RCVM efficacy:
  - In the real world.
  - > In the context of a full interaction loop.
- Participants trained in the use of RCVM asked a question, received a response via a kineme, took action.
- Results: Kinemes are recognized with lower accuracy than simulation, but still at a reasonable rate (60%).



## **Multi-Dimensional Study**



- We performed a study evaluating the efficacy of RCVM:
  - Compared to three other systems.
  - > At 5 different viewpoints.
- Study was administered online:
  - > 130 participants (9 excluded from data)
  - > Participants trained on ideal viewpoint.
  - Recognition of phrases tested on a random viewpoint, same system.
- Lower RCVM accuracy overall than in pilot study, likely due to online environment.



Viewpoints of an Affirmative kineme, tested in the third study. Clockwise from top left: 90°, 45°, 8m, 3m, 5m





# Viewpoint Effect on Communication SCIENCE AND SYSTEMS



Operational Accuracy vs. Viewpoint



In this plot, y-axis has been square root scaled to better display information Line at 7% represents the accuracy of a random guess.





### Summary



- Continued to establish RCVM as an option for AUVs.
- We conducted two studies:
  - Our pilot study demonstrated 60% overall kineme recognition accuracy.
  - Our multi-dimensional study explored the effect of viewpoint and content on interaction efficacy for four systems.
- Kinemes can be recognized with reasonable accuracy, and are less negatively affected by viewpoint.



A diver and AUV preparing to communication with one another.





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