The Challenges of Autonomous Sub-Ice Navigation and Field Robotics in Antarctica

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Summary

Europa, Jupiter’s innermost icy moon, has been a major target in the search for another planetary body that can support life. However, currently available off-the-shelf robotic platforms and deployment solutions cannot be used for such a mission due to the unique challenges encountered. Additionally, it is difficult to find a realistically similar environment to Europa on Earth to test any custom solutions developed. Since Europa’s ocean lies beneath a thick ice shell, the ice shelves of Antarctica provide a useful terrestrial test bed for candidate robotic platforms. Moreover, similar technologies enable exploration of the most remote and thus one of the least well characterized parts of Earth’s climate system – the underside of the polar ice shelves. The development of a novel, human-portable, modular, tethered, under-ice unmanned underwater vehicle, named Icefin, is presented here. This vehicle is capable of vertical deployment and recovery through hundreds of meters of ice in a small diameter hole, is capable of withstanding temperatures down to -40 C, and is depth rated to 1500 meters. Human-portability, modularity, and a small vehicle diameter (26 cm) allow the Icefin vehicle to be deployed directly through a hole in the ice shelf for exploration of these harsh, uncharted, under-ice waters. In 2014, the vehicle was deployed along with a support team to McMurdo station in Antarctica to conduct under-ice exploration missions through the McMurdo ice shelf. Video data from the Icefin’s mission contained imagery of locations at the seafloor not previously observed due to its limited accessibility beneath the ice shelf and large distance away from open water access. The design challenges and Antarctic deployment of the Icefin vehicle will be presented.

Methods developed to aid in navigational tasks through these sub-ice environments will also be presented. Specifically, development of computer vision algorithms using acoustic and optical imaging sensors (especially through sensor fusion) is used to help aid in sub-ice UUV navigation. The methods presented utilize low-cost sonar and camera sensors already onboard many UUV platforms, and do not require expensive external infrastructure or setup effort. While pose estimation using either a sonar or camera sensor provides valuable information for autonomous navigation in a UUV, fusion of these two complementary sensors can result in a much stronger and more robust trajectory estimate. A novel sonar and camera sensor fusion approach is presented here which uses a factor graph framework to combine estimates from these noisy but partially redundant sensors. In this case, the camera estimates provide additional degrees of motion not available from the sonar sensor, and the sonar sensor alleviates the scale factor ambiguity inherent to the camera sensor. Fusion of these two sensors can be used to leverage the
strengths of each sensor in order to overcome individual weaknesses, and provide much more robust overall vehicle motion estimates. These algorithms can further the mission capabilities of current under-ice vehicle platforms to enable further exploration of these remote areas of the planet.

Bio

Anthony Spears is a computer vision researcher in the R&D department at Prioria Robotics. Anthony earned his B.S. and M.S. degrees in Electrical and Computer Engineering from the University of Florida in Gainesville. There, he specialized in embedded computing applications. He earned his Ph.D. degree in Electrical and Computer Engineering from the Georgia Institute of Technology in Atlanta as a member of the Human-Automation Systems (HumAnS) laboratory under Dr. Ayanna Howard. There, he specialized in underwater robotics and computer vision applications. His dissertation research addresses sonar and optical sensor fusion for under-ice visual navigation using unmanned underwater vehicles. At Prioria, Dr. Spears is involved in several R&D projects sponsored by the U.S. DoD and NASA. Currently, he is serving as principal investigator for a U.S. Army SBIR program to develop swarming UAS guidance technology. Anthony was also involved in the development of UAS failsafe visual navigation methods as part of a NASA STTR program. This included serving as principal investigator for Phase IIIE portion of the program, researching the applicability of binocular visual navigation technology to UAS systems.