Formation Control Specifications on Multiple Cruising AUVs for Seafloor Topography Mapping

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ABSTRACT

The situation method and its results of NMRI cruising AUVs with a formation control are presented in this paper. The AUV navigation is assumed by a control on leader-follower formation applicable to various underwater measurements. The navigation order is modeled by a graph theory while being easily modified to suit the purpose. In this paper, the effectiveness and impact of the waypoint indication intervals from a leader AUV to a follower AUV are clarified in assuming to conduct a seafloor topography mapping based on the navigational performance of an actual AUV.

KEY WORDS: Cruising AUV; navigation; formation control; graph theory; dynamic waypoint; acoustic communication; seafloor topography mapping.

INTRODUCTION

For conducting efficient seafloor topography mapping and getting detailed maps, the utilization of multiple autonomous underwater vehicles (AUVs) is one of the promising measures. The National Maritime Research Institute (NMRI) has been studying the development of a multi-vehicle operation strategy on cruising AUVs together with an autonomous surface vehicle (ASV) in the 2nd term SIP project (SIP2), "Innovative Technology for Exploration of Deep Sea Resources" in Japan (Fujiwara, 2021, 2022a; Cabinet Office, Japan, 2018; JAMSTEC, 2018). The simple communication from the ASV to the AUVs for formation control, such as automatically increasing or decreasing speed instructions while monitoring the AUVs, was conducted in the present as shown in Fig. 1.

AUVs usually simply navigate along waypoints (WPs) that are determined before they are put into the water. In underwater, acoustic communication devices are normally used for the AUVs at several thousand meters underwater. Communication errors and delays often occur in the real survey. In the positioning from the measurement base, that is a mother ship, a land base for example, measurement error is included in the obtained data, and moreover the data is based on past navigating information of the AUVs due to the slow acoustic communication speed, unlike radio communication in the air. In the operation of multiple AUVs, it is desirable to navigate by communication between AUVs, where there is little communication delay and highly accurate information can be transmitted rather than by instructions from the base. The information sharing among AUVs underwater will be an important measure to promote effective operations on them for seafloor topography mapping etc. in near future. As part of the measure, this paper evaluates the impact of periodically indicated WP, herein referred to as the dynamic WP (DWP) based on navigation instructions given by a leader AUV to a follower AUV.

Fig. 1. Animation figure reproducing the multiple AUVs operation in the sea trial with three AUVs and one ASV (Fujiwara, 2022a)

For general information and an overview of the formation control, Bikramaditya et al. (2016), Sahoo et al. (2019), and González-García et al. (2020) described them in the paper in detail. For leader-follower formation control, for example, Skjetne et al. (2002) for vessels, Soares et al. (2013), Habib et al. (2015), and Indiveri et al. (2016) for semi-submersible vehicles in the WiMUST project were conducted simulations and simple model tests using prototype AUVs. Matsuda et al. (2018) carried out the navigation test using 3 AUVs with communications in the sea. In those studies and trials, no detailed study such as sensitivity analysis of DWP instructions is provided.