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Applying the Bisection Search Method to Search the Maximum Environmental Conditions in DPCap Analysis for Marine Vessels

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Dynamic positioning capability (DPCap) analysis can assist in determining the maximum environmental forces that a dynamically positioned (DP) vessel can counteract for given headings. The maximum environmental forces are represented by the maximum wind velocity of the environmental condition, which is generally searched by the incremental search method from 0 to the maximum wind velocity that the vessel cannot counteract if the environmental forces corresponding to the wind velocity increase. Thrust allocation logic is the module by which we check whether the vessel can withstand the aforementioned environmental forces. When the thrust region is nonconvex, the computing effort of the thrust allocation logic generally becomes high. To reduce the computing effort, we employed a bisection search method. Analytically speaking, compared to the incremental search method, the bisection search method can reduce the number of searching steps dramatically. A DPCap analysis for a semisubmersible unit was performed to demonstrate the effectiveness and efficiency of the method. The bisection search method can ensure that the DPCap analysis program performs as a very robust, effective, and efficient marine research tool that gives reliable guidance to the designer of the vessel's dynamic positioning system (DPS). The further utilization of the bisection search method to search the wind gust is also discussed.

INTRODUCTION

A dynamically positioned (DP) vessel is defined by the International Maritime Organization (IMO) and the certifying class societies as a vessel that maintains its position and heading (fixed position or predetermined track) exclusively by means of active thrusters (Sørensen, 2011). Dynamic positioning systems (DPSs) have been widely used in offshore engineering over the last five decades. Brink and Chung (1981) and Chung (2005) have carried out an extensive computer simulation and performance analysis and assessment for the dynamic positioning control of a 300,000-ton ship. Detailed descriptions of DPSs, including their early history, can be found in Fay (1990).

Operational safety is always the first consideration in the design and operation of a new DPS. To plan safe and efficient operation, it is important to know the window of operation and the maximum environmental conditions that a particular DP vessel can withstand. During critical operations such as drilling, oil production, and offloading, the positioning precision requirements are high, regardless of the environmental conditions. It is thus important to know the positioning capability of the vessel in order to plan and execute operations safely, according to Pivano et al. (2012). It is necessary to perform a dynamic positioning capability (DPCap) analysis when designing a new DP vessel.

DPCap analysis can assist in determining the maximum environmental forces (usually represented by wind velocity) that the DP vessel can counteract for a given heading. Mahfouz and El-Tahan (2006) have addressed the importance of DPCap analysis to the selection of thrusters and their configuration and the preliminary investigation of the positioning ability of a newly designed DP vessel. Pivano et al. (2012) have proposed a dynamic station-keeping capability analysis, trying to provide a more detailed study of a vessel's station-keeping capability in realistic dynamic conditions. However, there has been almost no effort devoted to the improvement of the computing efficiency of the DPCap analysis. Generally, the maximum wind velocity is searched by the incremental search method from 0 to the maximum velocity the vessel cannot counteract if the environmental forces corresponding to the wind velocity increase further. Thrust allocation logic is the module by which we check whether the vessel can withstand the aforementioned environmental forces. When the thrust region is nonconvex (e.g., considering the forbidden zones in the thrust region), the computing effort of the thrust allocation logic generally becomes high. Thus, the DPCap analysis is very time-consuming, although the quadratic programming (QP) search is very efficient. To ensure the efficiency of DPCap analysis as a marine research tool, the computing effort must be suppressed.

The main objective of this paper is to propose a bisection search method that can be applied to search the maximum wind velocity in DPCap analysis for marine vessels. The bisection search method in mathematics is a root-finding method that repeatedly bisects an interval and then selects a subinterval in which a root must lie for further processing. A transformation should be made when this method is applied to search the maximum wind velocity. By use of the bisection search method, the number of searching steps (i.e., the number of checks by thrust allocation logic) can be dramatically reduced. Therefore, the computing efficiency can be essentially increased.

A program was developed based on the present study. The effectiveness and efficiency of the newly developed DPCap analysis program adopting the bisection search method was demonstrated by a DPCap analysis for a semisubmersible unit.

For automatic station-keeping control, wind gust is usually larger and a bigger issue than maximum average wind velocity. Wind gust may push the ship outside the watch circle, which is a position criterion to guarantee safe offshore operation. The utilization of the bisection search method for searching the maximum wind gust is also discussed.

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