Oceanographic Survey Design and Error Analysis for a Solar-Powered Autonomous Surface Craft

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ABSTRACT

A solar-powered autonomous surface craft was developed. Survey mission accuracy was evaluated by considering the energy available from its solar panels. This article first briefly mentions the characteristic of components in a solar power system. Then estimation of the solar power generation in a day time and the energy consumption during a survey mission are formulated. The solar energy is regarded as the main power source for implementing survey missions. The survey error is estimated by taking into account of the effect caused by spatial resolution, and the total survey time parameters. The feasibility of the survey error prediction is then demonstrated by random field simulations. Considering the energy consumption during the survey, the range of available survey resolution and total time can be selected. Survey error is evaluated for specific situation with a survey spatial resolution and a total survey time. Experiments were conducted to verify power budget calculation and the survey error prediction.

KEY WORDS: autonomous surface craft; oceanographic survey; solar power; survey sampling; survey error.

INTRODUCTION

Solar energy was acquired from solar photovoltaic array which can convert solar radiation directly into current electricity, and it has applications such as power grids and vehicle power system. However, there are few papers applying solar energy to ocean technology. (Caccia, 2006; Patel, 2005). In the point of view of oceanographic surveys, the survey capabilities of a platform such as a research ship or underwater vehicle are generally restricted by the power of carried battery. Therefore, in order to extend the performance of oceanographic surveys, the utilization of solar energy is the good choice to increase the available power of the vehicle. An autonomous surface craft (ASC) equipped with solar power system is developed in this study. By analyzing the solar energy acquired from the solar panel, and the ASC energy consumption varied with voyage speed, the total operation time can be estimated to ensure the survey mission is available. Combining the theory of survey error analysis, which would be obviously different based on the total survey time and spatial resolution of the survey mission. Finally, the total survey error can be estimated by taking into account the solar energy acquired.

To design a solar power system includes considerations on not only solar cell, but the estimation of power consumption of load and energy storage devices. In terms of the energy storage device, Li-Ion battery is the most used because of the characteristics of high output energy density, high power-to-weight ratio and high efficiency of energy conversion (Silberberg, 2006). And the techniques estimated the state of charge by ampere hour counting (Piller et al., 2001) or Extend Kalman filter (Platt, 2004) had been developed. For the estimation of power consumption, Morales and Martinez (2009) evolved the motion model of a normal mobile robot to calculate the power consumption on rigid terrain. Other platforms which posse the motion model similar to the one of ASC were analyzed including boat or autonomous underwater vehicle (AUV). The power required of AUV is proportional to the square of navigation speed (Bradley et al., 2001). In order to maintain the energy balance of a solar power system, Baldock and Mokhtarzadeh-Dehghan (2006) developed an energy management algorithm for a solar powered AUV was also proposed by Jabbert et al. (1997). A mission oriented technique for managing the energy was proposed in (Willcox et al., 2001) in which a performance metrics for oceanographic surveys, considering the available power of AUV was investigated. It is a technique that uses a fixed spatial resolution and finite energy to survey an area. Additionally, this performance metric can be used to evaluate the total error of survey mission, which contains spatial and temporal survey error. For other survey technique with varied spatial resolution, the adaptive sampling algorithm was also used in robotic surveys (Mysorewala, 2008). The survey resolution can be adjusted based on survey specifications to create maps that are represented in different resolutions.

In this study, an ASC with solar power system which provides energy for vehicle was developed, the energy budget was utilized to design an optimal survey path including its resolution, coverage, and speed according to survey mission. Finally, the total survey error caused by spatial resolution and total survey time was estimated to check this error is acceptable. This article is composed of seven sections. Section 1 serves as an introduction and overview of this work. The ASC hardware configuration including the solar panel, Li-Ion battery and loads are described in section 2. In section 3, the solar power generated