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Technical Review Paper

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Navigation and Obstacle Avoidance in an Autonomous Robotic Sailboat System

Introduction

An autonomous sailboat robot is a boat that only uses the wind on its sail as the propelling force, without remote control or human assistance to achieve its mission. Robotic sailing offers the potential of long range and long term autonomous wind propelled, solar or wave-powered carbon neutral devices. Robotic sailboats could contribute to monitoring of environmental, ecological, meteorological, hydrographic and oceanographic data. These devices can also be used by the military for activities such as border surveillance, security, assistance and rescue [1]. This technical review paper briefly summarizes the role of navigation and obstacle avoidance in an autonomous robotic sailboat system.

Navigation

For a robotic sailboat, navigation is considered as the procedure where an optimum track is determined for the sailboat on a particular run based on external factors such as water currents and wind [2]. Navigation also involves determining an optimum heading along which the sailboat is to move. For motorized vehicles in isotropic, stationary environments, where a straight line is the shortest way to a target both in terms of distance and time, the identification of this heading is trivial. However, this is significantly different for sailboats, where a straight line route to the target may not even be navigable if the target is located upwind, in which case a zig-zag route is required [3].

Most existing navigation methods are almost entirely weather-dependent. This means that they all require certain weather predictions and a description of the boat's behavior under certain wind conditions, which is determined from a boat-specific polar diagram. The polar diagram determines the maximum speed attainable by a particular sailboat by taking under consideration wind speed and duration [4]. However, these methods are unreliable as the weather and wind conditions are unlikely to be constant over any given period of time.

Other potential methods for navigation have been researched and written about. One such method involves dependence on winds, by periodically recalculating the heading in reaction to changes in wind conditions. Since short-term weather is unpredictable, the approach takes under consideration only locally determined weather [3]. Another method, based on artificial potential fields, involves building a ‘local potential’ around the boat location to take upwind and downwind sailing constraints into account. Moreover, a ‘hysteresis potential’ relative to the cost of tacking (navigating into the wind) and jibing (navigating away from the wind) is also proposed, making this method easy to tune according to the sailboat specifications [5, 6]. This approach is decomposed into two parts, a global potential field and a local potential field. The global potential field is relative to the target and to the obstacles while the local potential field is relative to the boat kinematics, the wind direction and the latest tack [6]. A third method, which is what is likely to be worked on, involves the use of Google’s Project Tango. In this method, a Kinect sensor will be used for navigation on the robot. Project Tango technology gives a mobile device the ability to navigate the physical world similar to how we do as humans. Project Tango brings a new kind of spatial perception to the Android device platform by adding advanced computer vision, image processing, and special vision sensors [7].

Obstacle Avoidance

An important problem to be solved for long-term unmanned and autonomous missions on sea is reliable obstacle detection and avoidance. Static obstacles such as landmasses can be predefined on the sea map as a basis for the routing system. A combination of multiple techniques, such as thermal imaging, radar, camera, and automatic identification system can be used to detect dynamic obstacles. Research in this field has been carried out for autonomous underwater vehicles and motorized autonomous surface vehicles. However, sailboats rely on wind for navigation, and thus a more sophisticated means of obstacle avoidance is required [8]. Studying a suitable obstacle avoidance technique that works well with the navigation technique selected is of paramount importance in this project.

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