Radar based navigation for Autonomous Surface Vehicles*

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I. INTRODUCTION

In this paper we explore the use of radar technology for obstacle detection and avoidance for an Autonomous Surface Vehicle (ASV). ASVs operating in unknown environments can be divided in short-term electric vessels, often utilized for a proof of concept implementation, and long-term gas-powered vehicles which collect data over big areas. In the second case, autonomy requirements include the ability to detect potential hazards such as static or dynamic obstacles. We are currently investigating the use of ASVs for monitoring lake and riverine environments with a special focus on detection of harmful algae and cyanobacteria blooms. One of the primary objectives is the development of affordable technologies that can be utilized by local authorities as well as citizen scientists and civilian associations with limited budgets. In different domains vision and lidar sensors have been the chosen modality for obstacle detection, however, vision-based detection is computationally intensive and lidar sensors are expensive. New developments on mm-wave radars provide an affordable alternative [1]. The marine domain is sparse, where the chance encounter with another vessel needs to be detected, radar waves are absorbed by water but they are reflected by humans and boats, thus providing accurate detections.

II. SYSTEM CONFIGURATION

The target vessel is the Jetyak [2], an ASV developed at the University of South Carolina; see Fig. 1(a) for the ASV operating at Lake Wateree, SC, USA. The ASV is based on a modified Mokai Es-Kape[1] boat. The stock vessel uses an internal combustion engine and reach speeds up to $22.5\,\mathrm{km/h}$, with a deployment duration of over eight hours. The ES-Kape's factory pulse width modulated controlled servo system allows seamless integration with a Pixhawk[2] flight control system and on-board control through a companion Inter UP computer serving to host Robot Operating System (ROS)[3]. The fleet of ASVs at our university has been used for coverage operations [3], riverine exploration [4], and for environmental monitoring for Harmful Algal Blooms [5]. The radar utilized is the Dragonfly mm-wave radar by Perceptin, operating at $77\,\mathrm{GHz}$. The field of view is limited to $60°$ azimuth, $\pm 5°$ elevation, and a range up to $70\,\mathrm{m}$, however, in our field trials the range was limited to $15\,\mathrm{m}$. During test deployment we have mounted the radar together with a camera and a Velodyne LIDAR (Pack 16)[4] and collected timestamped data using the ROS bag[5]; see Fig. 1(b). The synchronized data enable us to observe the accuracy of the radar compared to the more accurate, but (an order of magnitude) more costly, lidar, and also see through the camera the observed scene.


(a) (b)

Fig. 1: (a) ASV operating at Lake Wateree, SC, USA. (b) Closeup of the sensory payload: from the top, Velodyne Pack 16 LIDAR, Camera, and Perceptin Dragonfly radar.

III. OBSTACLE DETECTION AND AVOIDANCE

From preliminary experiments, when the environment is crowded; see first row of Fig. 2 obstacles are detected (Fig. 2(a)) but at a lower resolution compared to lidar (Fig. 2(c)). Clealry, radar technology cannot be used for precise maneuvering in a cluttered space. In contrast, on open water; see second row of Fig. 2, the radar is capable to accurate detect other vessels up to a range of $15\,\mathrm{m}$. It is worth noting that, the lidar sensor provides a lot more information with a wider field of view ($360°$ if mounted without occlusions) and with a range up to $100\,\mathrm{m}$, however, the cost is much higher. Furthermore, the lidar is sensitive, detecting the water splashes at the bow of the ASV in choppy waters. It is worth noting, when partially submerged logs were encountered, the radar was unable to detect them, while the lidar, provided returns.

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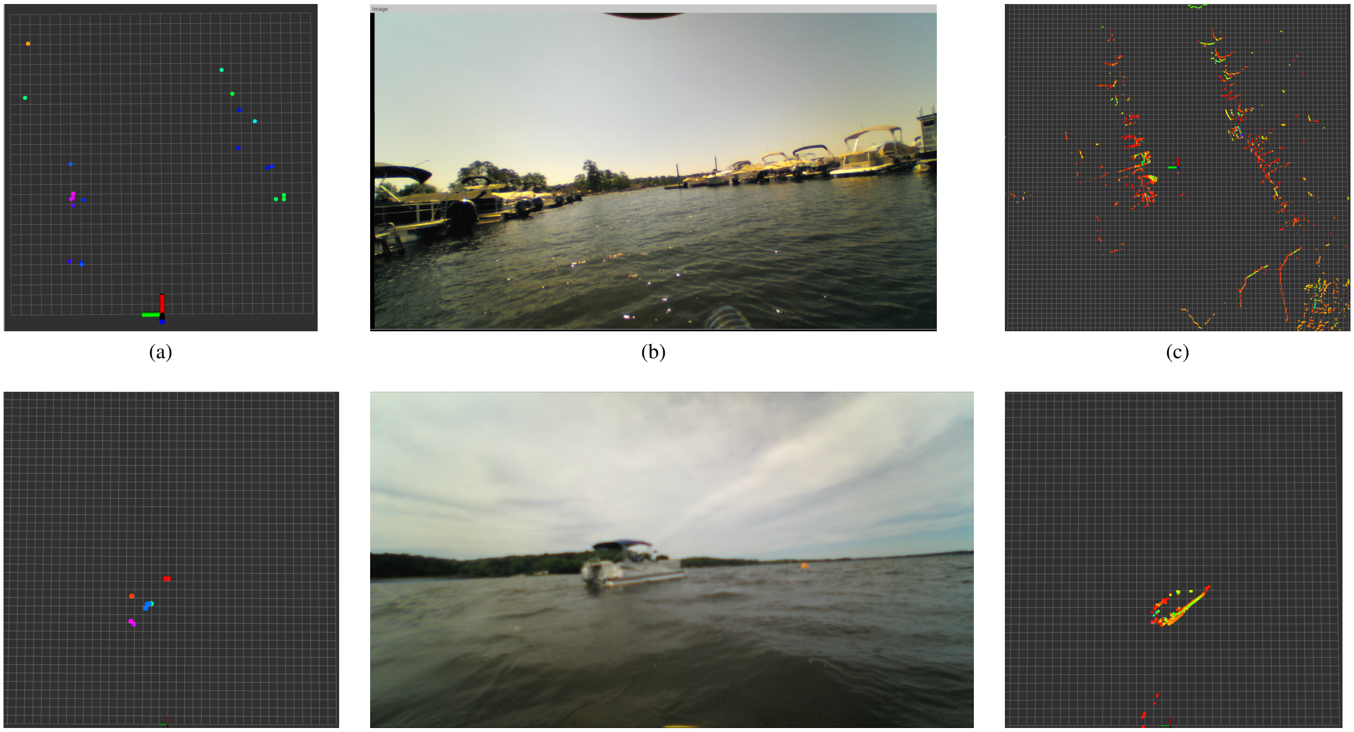
[1] `http://www.mokai.com/mokai-es-kape/`

[2] `https://docs.px4.io/en/flight_controller/mro_pixhawk.html`

[3] `http://wiki.ros.org/`

[4] `https://velodynelidar.com/`

[5] `http://wiki.ros.org/rosbag`


(a) (b) (c)

(d) (e) (f)

Fig. 2: Results from different sensors mounted on the ASV. (top row) Lake Murray, SC, USA: (a) Radar data (crowded); (b) Camera view (crowded); (c) Velodyne LIDAR data (crowded); (second row) Lake Wateree, SC, USA: (d) Radar data (single boat detected); (e) Camera view (single boat detected); (f) Velodyne LIDAR data (single boat detected).

The primary navigation of the ASV is based on a sequence of GPS waypoints which guide the vehicles through the environment. When another vessel is detected, the following options are available, depending one the relative velocity between the two vessels. The ASV can slow down, or even stop, to allow the other vessel to pass, unfortunately the field of view of the radar does not allow detections behind and at the sides of the ASV. The second option is to accelerate (if possible) in order to avoid a collision. Finally, especially if the other vessel is moving towards a heads on collision, the ASV will take evasive actions following the navigation rules of the sea[6].

IV. DISCUSSION

Preliminary experiments demonstrated the utility of the radar sensor for obstacle detection of an ASV. Further processing is required to extract the absolute position and velocity of the detected obstacle using the pose and velocity of the ASV. The placement of the sensors on the mast in conjunction with the instability of the ASV (rolling and pitching) resulted in noisy measurements. First of all, placing the sensors low on the mast will reduce the effect of noise. In addition we are currently implementing an attitude correction based on the IMU measurements from the PixHawk micro-controller.

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