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Optical-Based Lane-Assist System for Rowing Boats

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Abstract : Rowing boats (shells) are often steered by a small rudder operated by one of the backward-facing rowers; the attention required of that athlete then slightly decreases the power that that athlete can provide. Reducing the steering distraction would then increase the overall boat speed. Races are straight 2000 m courses with each boat in a 13.5 m wide lane marked by small (~15 cm) widely-spaced (~10 m) buoys, and the boat trajectory is affected by both cross-currents and winds. An optical buoy recognition and tracking system has been developed that provides the boat's location and orientation with respect to the lane edges. This information is provided to the steering athlete as either: a simple overlay on a video display, or fed to a simplified autopilot system giving steering directions to the athlete or directly controlling the rudder. The system is then effectively a "lane-assist" device but with small, widely-spaced lane markers viewed from a very shallow angle due to constraints on camera height. The image is captured with a lightweight 1080p webcam, and most of the image analysis is done in OpenCV. The colour RGB-image is converted to a grayscale using the difference of the red and blue channels, which provides good contrast between the red/yellow buoys and the water, sky, land background and white reflections and noise. Buoy detection is done with thresholding within a tight mask applied to the image. Robust linear regression using Tukey's biweight estimator of the previously detected buoy locations is used to develop the mask; this avoids the false detection of noise such as waves (reflections) and, in particular, buoys in other lanes. The robust regression also provides the current lane edges in the camera frame that are used to calculate the displacement of the boat from the lane centre (lane location), and its yaw angle. The interception of the detected lane edges provides a lane vanishing point, and yaw angle can be calculated simply based on the displacement of this vanishing point from the camera axis and the image plane distance. Lane location is simply based on the lateral displacement of the vanishing point from any horizontal cut through the lane edges. The boat lane position and yaw are currently fed what is essentially a stripped down marine auto-pilot system. Currently, only the lane location is used in a PID controller of a rudder actuator with integrator anti-windup to deal with saturation of the rudder angle. Low Kp and Kd values decrease unnecessarily fast return to lane centrelines and response to noise, and limiters can be used to avoid lane departure and disqualification. Yaw is not used as a control input, as cross-winds and currents can cause a straight course with considerable yaw or crab angle. Mapping of the controller with rudder angle "overall effectiveness" has not been finalized - very large rudder angles stall and have decreased turning moments, but at less extreme angles the increased rudder drag slows the boat and upsets boat balance. The full system has many features similar to automotive lane-assist systems, but with the added constraints of the lane markers, camera positioning, control response and noise increasing the challenge.

Keywords : auto-pilot, lane-assist, marine, optical, rowing
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