Real-Time on-Water Estimation of a Sprint Canoe Paddle Path

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Understanding complete paddle stroke trajectories with a real-time system can yield better coaching through athlete feedback and offline analysis, as well as furthering research possibilities such as the correlation of boat speed with technique changes. While research has been done which measures the load on a sprint canoe paddle throughout its path on water [1], the paddle position and orientation (pose) have not been simultaneously tracked. Our research combines real-time pose estimation of a sprint canoe paddle with other systems to fully track the path of a paddle with respect to the canoe, while simultaneously recording the canoe's velocity and the load on the blade of the paddle.

The hardware needed to implement this system is mounted to a sprint canoe and can be used on the water to collect and analyze data in a training scenario. The output from an Optical Image System (OIS), consisting of a stereo camera with markers attached to the paddle and an image processing algorithm, is fused with output from an orientation sensor mounted to the paddle. These two systems complement each other. The OIS provides direct pose measurements at a slow rate, while the orientation sensor, using a higher sampling rate, can, by dead reckoning, fill in the changing pose between OIS measurements. The measurements are combined using a Manifold Extended Kalman Filter (MEKF) based on the work of Bernal-Polo [2]. The method described here can be used alongside existing on-water instrumentation [1] to monitor load and pose in real-time.

A stereo camera (Intel RealSense D415) is mounted facing backwards near the bow of the canoe and orange marker balls are affixed to the paddle via 3D-printed mounting hardware. A Python algorithm was developed to take the color image and depth map from the stereo camera and remove the background by applying a minimum depth. Hue-Saturation-Value (HSV) thresholding is then used to create a binary mask representing the location of the orange markers. After performing morphological opening on the mask to remove extraneous signals, contours are generated and used to determine the depth of the marker from the camera, as well as the three-dimensional position of the marker. An Iterative Closest Point (ICP) approach is then used to find the pose that best aligns the known layout of the markers with the markers identified from the image (see Figure 1).

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(a) (b) (c)

Fig. 1: OIS algorithm visualized: (a) depth map, (b) HSV mask after morphological opening (d) overlay with contour centroids in red, centers and radii as yellow circles, ICP fit in green and output of the filter in blue.

A USFSMAX AHRS orientation sensor is used, which consists of a motion co-processor and IMU sensors. Combining the orientation sensor and OIS measurements (see Figure 2) through the MEKF algorithm results in a paddle path that can be recorded or used in real-time and paired with load and boat speed measurements for further analysis.

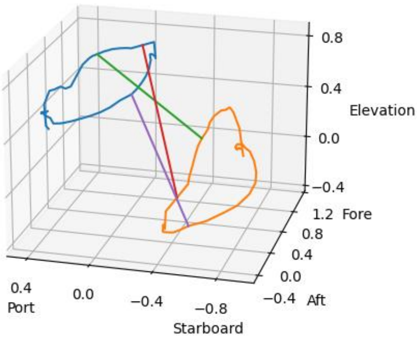

Fig. 2: Tracked paddle path: blue shows the top of shaft handle position; orange the blade tip position; green, red and purple lines show the paddle position at the catch, mid-drive and extraction phases of the stroke respectively. Units are in meters.

This paddle path estimation method uses a novel fusion algorithm and demonstrates the potential for a low-cost paddle tracking system that can work on water, faciliting athlete training and further studies.

1. Stephen Tullis, Cameron Galipeau, Dana Morgoch (2018) Detailed On-Water Measurements of Blade Forces and Stroke Efficiencies in Sprint Canoe. ISEA Proceedings, 2(6):306
2. Pablo Bernal-Polo, Humberto Martinez-Barberá (2019) Kalman Filtering for Attitude Estimation with Quaternions and Concepts from Manifold Theory. Sensors, 19(1):149

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