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Octopus arm kinematic analysis
for use in multi-arm underwater robotic swimmers

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***Abstract*— The extraction of accurate kinematic information of animal appendages is of great importance for many biologically-inspired robotic applications. Octopus arm trajectories during a two-stroke arm-swimming motion have been initially analyzed through a vision-based 3D process, that reconstructs the arm spatial configurations and captures their 3D motion; this work is presented in [Kazakidi et al, ICRA 2015, Paper WeA2T9.9]. However, these results cannot be directly applied in multi-arm robotic swimmers. To that end, we analyze further the biological arm trajectories and extract related reduced models, exploiting multi-segment arm models with spherical joints between the arms. We, thus, obtain arm joint trajectory data, which could be directly applicable to the control of octopus-inspired multi-arm robotic swimmers. In this poster, we present recent related results and their applicability to our octopus-inspired compliant underwater robotic swimmer [Sfakiotakis et al, IROS 2014, pp. 302-308]. We will also discuss possible biological implications of these results for the octopus arm-swimming behavior and its propulsive capability.**

***Index Terms*— Biologically-Inspired Robots, Soft Robots, Underwater Robots, Octopus, Computer Vision, Kinematics.**

I. MOTIVATION

Our work in [1] presents a robust vision-based method to extract the 3D trajectories of the medial axes of octopus arms, during arm swimming motion, from a video sequence of a live octopus (Fig. 1). The work includes a complete 3D swimming motion sequence of all eight individual octopus arms. Our current aim is to analyze this sequence further and extract a kinematic description of the motion for direct use in multi-arm robotic swimmers.

II. METHODS AND RESULTS

The main software framework of the developed kinematic tools is the SIMUUN simulation environment [2], which is based on the SimMechanics toolbox of Matlab/Simulink, and provides computational models for mechanical, control, neural control and sensory aspects of undulatory locomotion. The SIMUUN libraries have been expanded to support simulations of serially-connected modules capable of 3D movements in an aquatic environment.

These tools are supplemented by a computational module for approximating a continuous, finite-length 3D curve with a piecewise linear one (Fig. 2), based on the algorithm presented in [3]. The module provides a means of solving the inverse kinematics (in terms of joint angles) of a hyper-redundant segmented robot arm, with 2-dof torsion-free spherical joints between the body segments (Fig. 3), so that the arm assumes a given shape, specified as a 3D curve. In the present study, these 3D curves are obtained from our reconstructed biological data [1], to provide the corresponding joint trajectories for reproducing the arm swimming motion via the reduced model of a compliant octopus-like arm.

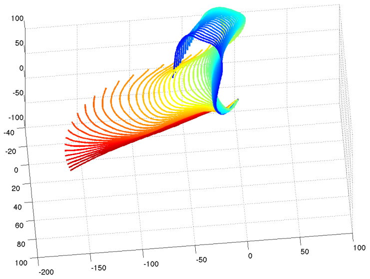

Fig. 1: The trajectory of an individual octopus arm, reconstructed from a video of arm-swimming motion, for a zero starting point [1]. Dark blue color refers to initial (open) positions while red colors to final (closed) positions. Dimensions are in mm.

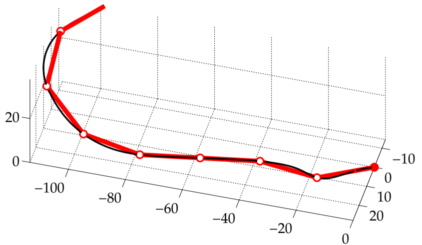

Fig. 2: Discretization in 8 segments (red lines) of the continuous 3D shape (black line) of an individual arm. Dimensions are in mm.

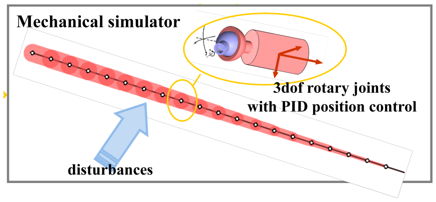

Fig. 3: A multi-segment octopus-like robot arm, with torsion-free spherical joints.

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