

Estimation of Fishing Net Underwater Geometry with Embedded Deformation Graphs

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Abstract – An innovative proposition to model fishing nets is presented in this paper. The novelty stems from the use of embedded deformation theory to infer the geometry of fishing gear as a graphical problem. The technique developed is proven suitable to solve the task in a practical fishing environment such as purse-seine fisheries, as it considers real-time observations from sparse 6D positioning sensors, which can be easily embedded prior in pre-set pockets in the fishing gear. The effectiveness is validated by simulated experiments of fishing gear deformation scenarios with 12 measurement sensors. Real deployments are also being conducted at the time of writing on a fishing vessel with the equivalent instrumented net and will be readily available for presentation at the time of the conference.

Keywords – Fishing Net, Embedded Deformations Graph, Acoustic Positioning, Distributed Sensor Systems.

I. INTRODUCTION

Traditional approaches to model fishing-gear systems have often relied on mathematical models of the mechanics that govern the movement of the fishing gear, such as mass-spring models of trawling nets [1]. These and other simulated models employed to visualise the dynamics of underwater fishing gear shapes [2] require computationally intensive numerical solvers with abundant parametric assumption about the operating conditions where each particle of a fishing gear should be calculated considering several force vectors (fishing vessel, gear buoyancy, tension of pulling or pursing acting on the flexible netting and ropes, ocean currents, etc.). This work proposes an alternative methodology, whereby the fishing net itself is instrumented with acoustic positioning sensors at known locations in the fishing gear. Driven by the updated 6D pose measurements from the array of sensors, deformation graph theory [3] is suggested as a means to solve the fishing net shape problem given the known physical metrics of the mesh.

II. PROBLEM STATEMENT

Given a 3D fishing net mesh grid of size $m * n * h \in R$, and a small set of sensors that are fixed at certain intervals on the surface of the fishing net, we propose the collection of position plus IMU 6D pose information at fixed time intervals to estimate the shape of the fishing net at any time.

III. EMBEDDED DEFORMATION GRAPHS

An embedded deformation graph (EDG) is proposed for this purpose. An EDG comprises of nodes and edges, defining a mesh. A deformation is defined by a collection of affine transformations. One transformation is associated with each node of a graph embedded in R^3 so that the graph provides spatial organization to the deformation. Each affine transformation induces a localised deformation in the nearby space. Undirected edges connect nodes of overlapping influence to indicate local dependencies. We use the term node to describe an ED node, and vertex to describe a feature point. Each embedded deformation (ED) node j is associated with a position $g_j \in R^3$, $j = 1 \dots m$, an affine matrix $A_j \in R^{3 \times 3}$, a translation vector $t_j \in R^2$, the set $N(j)$ consisting of all connected nodes that share an edge to node j , that is, each vertex v_i in the fish net has a set of neighbouring ED nodes in the deformation graph. For a mesh-based geometry, shape deformation is equivalent to transforming vertices in the EDG. A closed-form energy minimisation function of the affine transformations matrix A_j and translation vector t_j for the whole graph becomes an optimisation problem that can be solved as a Nonlinear Least Squares (NLLS) problem, implemented in this work with an iterative Gauss-Newton algorithm. For more details, the reader is referred to [3].

IV. SIMULATION RESULTS

A fishing net has been fabricated to validate the proposed scheme, as depicted in Figure 1. An illustration of the typical result that this scheme is able to provide is depicted in Figure 2, for two realistic sensor deformation scenarios.

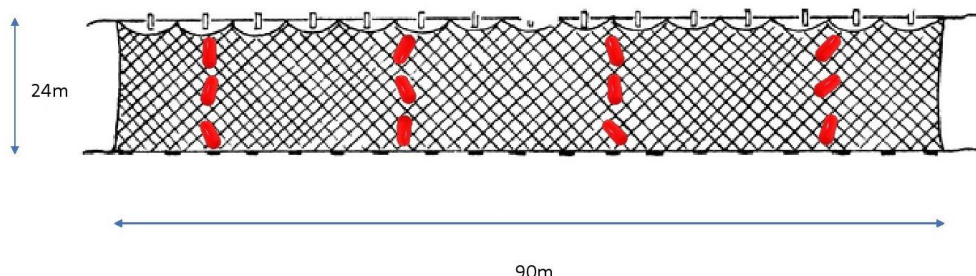


Fig 1. Metrics of the scale purse seine fishing net constructed to validate the proposed scheme.

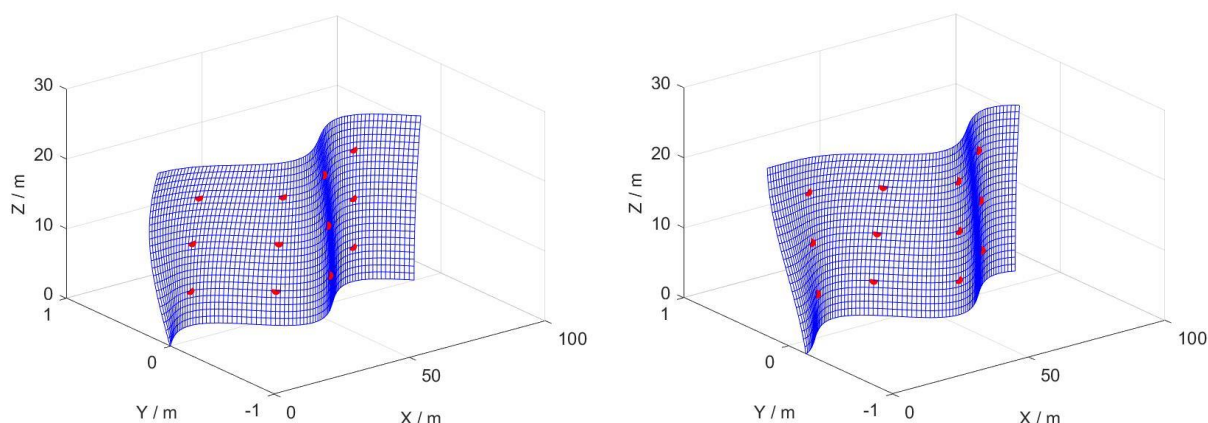


Fig 2. Two simulated examples of fish net deformations with 12 arbitrary control points for sensor locations.

V. CONCLUSIONS

This work demonstrates that the problem of solving for the geometry of an underwater fishing net can be approached as a deformable graph mesh problem, suitable to be efficiently tackled by sparse sensor updates embedded in the fishing gear. Preliminary simulations have shown the feasibility of the approach, that is currently being validate with field trials on a fishing vessel with a scale fishing net constructed and instrumented for that purpose with 12 acoustic 6D positioning tags.

REFERENCES

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