Wave Height Estimation Using a Novel Seaweed-Attached Sensor

Masoud Emam, Caroline Press, Hamed Jafarzadeh, Marco Belcastro, Brendan O'Flynn, Joanne Casserly, Frank Kane

By: Masoud Emam, Tyndall National Institute, University College Cork. Email: masoud.emam@tyndall.ie

Tyndall National Institute Institiúid Náisiúnta
IMPAQT Intelligent Management System for Integrated Multi-trophic Aquaculture
IARIA
UCC University College Cork, Ireland Coláiste na hOllscoile Corcaigh
Rialtas na hÉireann Government of Ireland
Tionscadal Éireann Project Ireland 2040
Ireland's European Structural and Investment Funds Programmes 2014-2020 Co-funded by the Irish Government and the European Union
European Union European Structural and Investment Funds

Masoud Emam, M.Eng.Sc.

Current Position:

Since 2020: Research Assistant, Wireless Sensor Network Group (WSN), MNS Centre, Tyndall National Institute, University College Cork (UCC), Cork, Ireland.

Education:

2020: Master of Engineering Science, School of Mechanical and Materials Engineering, University College Dublin (UCD), Dublin, Ireland.

2018: Master of Science in Electrical Engineering, Azad University, Qazvin, Iran.

2014: Bachelor of Science in Electrical Engineering, Azad University, Qazvin, Iran.

Research Background:

2020 – 2021: Embedded Software Developer, IMPAQT Project, WSN, Tyndall National Institute, Ireland.

2019 – 2020: Master by Research Student, First Irish Satellite (EIRSAT-1) Project, University College Dublin (UCD), Ireland.

2013 – 2014: Control System Engineer, Dynamic Control System research lab. (DCSrl), Mechatronics Research Lab. (MRL), Azad University, Iran.

2013: Control System Engineer, flying Robot Research lab., Mechatronics Research Lab. (MRL), Azad University, Iran.

Publications:

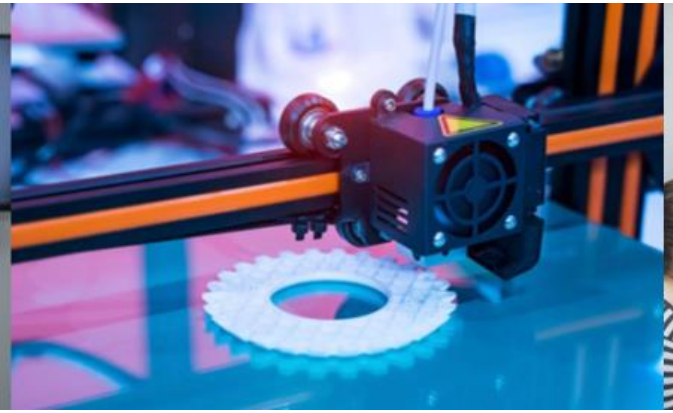
https://scholar.google.com/citations?user=6vwx5MEAAAAJ&hl=en

Wireless Sensor Network Group

Tyndall National Institute
Institiúid Náisiúnta

IMPAQT
Intelligent Management System for Integrated Multi-trophic Aquaculture

In the Wireless Sensor Networks (WSN) we are a group of 34 researchers specialised in carrying out multi-disciplinary research projects associated with Wearable Smart Systems integration, embedded computing, and edge analytics.

Overview

- Introduction
- Methodology
- Pilot Results
- Conclusions and Future Works

Introduction

Motivations:

- The growth rate of seaweed is significantly affected by wave parameters and sea conditions.
- The wave characteristics in an aquaculture farm is normally measured using expensive equipment, which is not affordable for many farmers or researchers
- It is not easily relocated from place to place to evaluate wave conditions in a variety of locations.
- The proposed method will avail many researchers to use wave height data in their study to fill the gap in knowledge of the impact of water motion on aquaculture and maximising of seaweed harvests.

State of the art:

- In this paper, a sensor fusion method is presented which can estimate wave height using the data logged by a multi modal low-cost seaweed-attached sensor system [1].
- This method is based on combination of extended Kalman filter and artificial neural networks.

[1] C. Peres, M. Emam, H. Jafarzadeh, M. Belcastro, and B. O'Flynn, "Development of a Low-Power Underwater NFC-Enabled Sensor Device for Seaweed Monitoring," *Sensors,* vol. 21, no. 14, p. 4649, 2021.

Methodology

- The seaweed attached sensor, has been originally designed to measure ambient parameters relevant to seaweeds, such as light, temperature, depth, and motion [1].
- In this paper, a method is proposed to estimate wave height as the fusion of the readings from the embedded IMU. The embedded IMU sensor consists of a 3-axis accelerometer and a 3-axis gyroscope.
- Motion and displacement of the seaweed-attached sensor is the result of current and wave. Faster motion is the result of stronger wave [2]. Therefore, if we can calculate the motion of the attached sensor, we can estimate the strength of current or wave.
- The proposed method is to feed IMU measurements to an EKF to estimate the orientation of the IMU with respect to an Earth-Fixed coordination Frame (EFF). Using the orientation of the IMU w.r.t. EFF, we will be able to reject the effect of gravity on measurements of accelerometer and estimate the accelerations in EFF.
- An Artificial Neural Network (ANN) is designed and trained to estimate the wave height using the output of extended Kalman filter.

Figure 1. The seaweed attached sensor

[1] C. Peres, M. Emam, H. Jafarzadeh, M. Belcastro, and B. O'Flynn, "Development of a Low-Power Underwater NFC-Enabled Sensor Device for Seaweed Monitoring," *Sensors,* vol. 21, no. 14, p. 4649, 2021.

[2] M. Denny and B. Gaylord, "The mechanics of wave-swept algae," *Journal of Experimental Biology,* vol. 205, no. 10, pp. 1355-1362, 2002.

Pilot Results

- To test the feasibility of the proposed method, data collected in one of the AquaBit deployment in the Marine Institute aquaculture research site (Lehanagh Pool), Galway, Ireland is used. In this deployment, AquaBit units have been attached to artificial seaweeds, as shown in Figure 2.
- The data recorded by the IMU sensor of AquaBit in this deployment have been compared with tilt data recorded by the data buoy of the same site using the Pearson correlation.
- Since these measurements are compared in frequency domain, the Fast Fourier Transformation (FFT) is used to transform tilt and angular velocities into frequency domain.
- As the tilt measured by the buoy is correlated with the angular velocity measured by the sensor device, we conclude that the wave height could be estimated by the angular velocity.
- This supports the expectation that a sensor fusion algorithm for accelerometer and gyroscope could provide good estimates of wave height and energy.

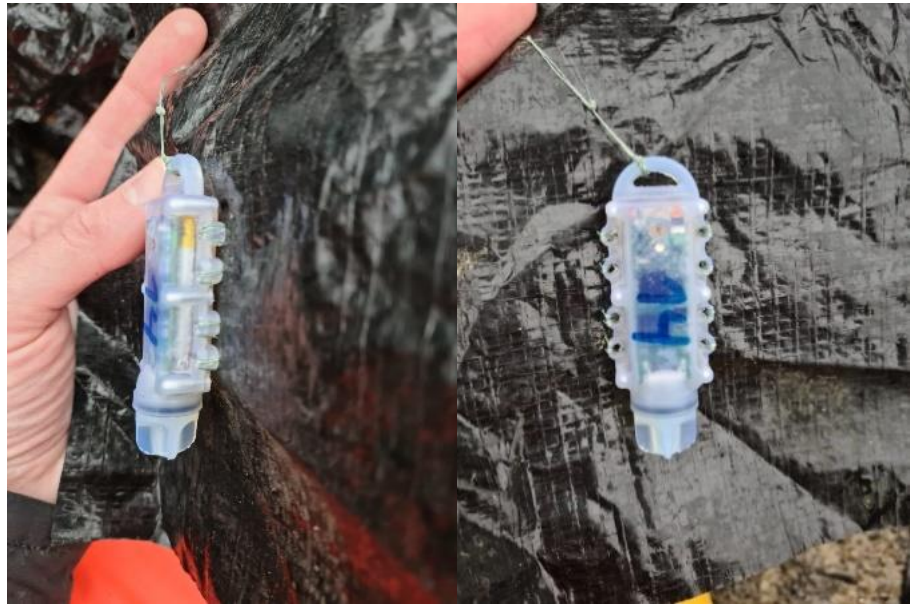


Figure 2. An AquaBit unit attached to artificial seaweed

Conclusions and Future Works

- In the paper, we presented a work in progress, a novel method of estimation of wave height for cost effective research project.
- The method translates the data collected by a 6 Degree of Freedom (DoF) IMU (accelerometer and gyroscope) into wave height by combining EKF and ANN.
- The data analysis of a pilot trial showed that the angular velocity is strongly correlated to tilt values recorded by a wave-rider buoy.
- In other words, wave height or other wave statistical parameters could be estimated using readings from the embedded IMU of AquaBit.
- The next step is to figure out an ANN and train it to estimate the wave height using the data recorded by the embedded IMU of AquaBit.
- The hypothesis will continue to be investigated in Flume Tanks [1] (dedicated infrastructure for wave measurements) and the algorithms developed to establish wave height from IMU readings attached to seaweed lines in aquaculture oriented deployments.

[1] "LiR National Ocean Facility " http://www.lir-notf.com/ (accessed 2021).

Tyndall
National Institute
Institiúid Náisiúnta

Tyndall National Institute,
Lee Maltings,
Dyke Parade,
Cork,
Ireland.
T12 R5CP

t: +353 21 490 4177
e: info@tyndall.ie
tyndall.ie

@tyndall-national-institute
@TyndallInstitut
@tyndall_institute
@TyndallInstitute

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Rialtas na hÉireann Government of Ireland
Tionscadal Éireann Project Ireland 2040
Ireland's European Structural and Investment Funds Programmes 2014-2020
Co-funded by the Irish Government and the European Union
European Union
European Structural and Investment Funds