1. Home

Navigation aims to determine the position, velocity and attitude of platforms, humans and animals. Fusion between several sensors is commonly required, in order to obtain accurate navigation. The Autonomous Navigation and Sensor Fusion Lab (ANSFL) researches problems in the fields of autonomous navigation, inertial navigation systems, and estimation theory, as well as in related fields. Our focus is mainly (but not only) on marine platforms, such as autonomous underwater vehicles, buoys, drifters, and unmanned surface vehicles. The current research goals are to derive unorthodox inertial and sensor fusion algorithms, to hunt for the next inertial navigation system architecture, and to pioneer deep learning based navigation approaches.

1. Research

2.1 Deep Learning Based Navigation

Deep learning (DL) is a machine learning method that takes an input and uses it to predict an output. It is an automated formation of useful representations from data. In the last five years, we have witnessed major breakthroughs in deep learning algorithms in the fields of computer vision, speech recognition, text translation, and autonomous vehicles, amongst others.

In the last year, deep learning was applied to pedestrian dead reckoning (PDR), an indoor navigation approach. Instead of applying traditional algorithms, deep learning frameworks were suggested, both to recognize an activity and to determine a user position. DL-based PDR algorithms provide dramatic improvement in the determination of a user position.

In the proposed research we aim to advance, drive and implement deep learning approaches for marine navigation, particularly for autonomous underwater navigation. This area of research is new and innovative, and we are among the first to pioneer it.

2.2 Enhanced INS/DVL Fusion for AUV Navigation

Fusion between an inertial navigation system (INS) and a Doppler velocity log (DVL) is commonly used in the navigation of autonomous underwater vehicles (AUV). In normal operating scenarios, the navigation accuracy is satisfactory for the AUV to complete its goal. Yet, when operating in complex environments, when passing over fish and other sea creatures, or when the distance between the DVL and seafloor exceeds the DVL range, partial or complete DVL outage situations may occur. In both situations, the navigation solution will depend mainly on the INS solution, which will drift in time.

In this research, we aim to derive algorithms that enable velocity vector estimation for complete DVL outage situations over short time periods. We also intend to derive approaches for handling partial DVL availability conditions, and for circumventing the drift of INS solutions. Currently, several algorithms and theories are being derived and proven via simulations and sea-based experiments.

2.3 Looking for the Next INS Architecture

In general, an inertial navigation system (INS) consists of a navigation computer and an inertial measurement unit (IMU). If the initial conditions and IMU measurements are available, position, velocity, and orientation can all be calculated. The inertial sensors - namely, the accelerometers and gyroscopes - are part of the IMU. A classic IMU architecture has three accelerometers (to measure specific force) and three gyroscopes (to measure angular velocity), arranged in orthogonal triads.

Experimental INSs were first developed in the 1920s; however, the contemporary sensor and computation technology was not good enough for practical application. In February 1953, Draper’s team demonstrated an INS flight on a Boeing B-29. This instigated the INS era, initially for military usage and later (1960s) for civil aviation. Strapdown INS technology was developed during the 1970s. Later, the micro-electro-mechanical system (MEMS) revolution enabled a dramatic reduction in INS size, weight, and power consumption, allowing INS technology to penetrate into new applications and instruments, such as wildlife and livestock tracking, smartphones, and medical instruments. During this time, the greatest effort was put into improving sensor performance and reducing their size. However, the architecture of three orthogonal accelerometers and three orthogonal gyros has survived from the beginning of the modern INS era, and it remains the only architecture available as an off-the-shelf product.

In this research we aim to design new INS architectures, and to build, evaluate and derive relevant theory. Several architectures are at different stages of development, so there is room to develop these further.

2.4 Buoy Height Measurements

A buoy is a floating platform equipped with sensors which measure the self and surrounding physical quantities. Buoys can be classified into two categories: 1) moored buoys, which float on the surface but are secured to the seabed, so that their specific location is relatively fixed; and 2) drifting buoys (often of a Lagrangian type), which can move freely with winds and water currents. Moored buoys are commonly larger and more expensive than drifting buoys. There are currently thousands of buoys deployed worldwide, and the majority are of the second type.

Several applications require buoy data, the main one being weather forecasting. Here, buoy data is crucial, because the buoys can be deployed in remote ocean areas where no other source of valuable data is available. Continuous data from weather forecast buoys is also extremely valuable in tropical storm forecasting, and in preprocessing data during a storm.

One of the important quantities commonly measured by buoys is wave height and period; the parameters which define the sea state. To measure these parameters, either an expensive set of accelerometers/gyroscopes, or other sensors which rely on external sources such as GPS, can be employed. The former is not suitable for drifting buoys, while the latter maybe unavailable in some situations. Our goal is to use only low-cost inertial measurement units, supported by appropriate new algorithms, to determine wave height and period with the necessary accuracy.

1. Team

* Prior to joining the department of marine technologies in October 2019, I was a research fellow at Rafael – Advanced Defense System Ltd (2007-2019), and an adjunct lecturer at the Technion Institute of Technology (2011-present). In July 2014, I was at Prof. Yaakov Bar-Shalom’s Tracking and Fusion Lab, University of Connecticut, for a short sabbatical. I hold B.Sc. (2004) and M.Sc. (2006) degrees in Aerospace Engineering, and a Ph.D. in Mapping and Geo-information Engineering from the Technion (2011).
* Itzik Klein received B.Sc. and M.Sc. degrees in Aerospace Engineering from the Technion Israel Institute of Technology in 2004 and 2007, respectively, and a Ph.D. in Civil Engineering from the Technion Israel Institute of Technology in 2011.

At present, he is an Assistant Professor, heading the Autonomous Navigation and Sensor Fusion Lab at the Department of Marine Technologies, University of Haifa. His research interests include navigation, unorthodox inertial navigation architectures, autonomous underwater vehicles, sensor fusion, and estimation theory.

* Barak received B.Sc. (2016) and M.Sc. (2018) degrees in Aerospace Engineering and also a B.A. (2016) degree in Economics from the Technion Israel Institute of Technology. Prior to starting his Ph.D., Barak was an Algorithm Engineer at Qualcomm, in the fields of ML and DSP.

1. Teaching

* The course focuses on inertial navigation systems theory and applications. It is divided into three parts:

1) Inertial sensors: accelerometers and gyroscopes are addressed, including their principles of operation, different technology implementations, and sensor calibration.

2) Navigation mathematics: mathematical foundations, such as reference and coordinate frames, transformation matrixes and their properties, quaternions, and more.

3) Navigation systems: strapdown navigation kinematics, coarse alignment, and pedestrian dead reckoning.

* The course covers the fundamentals of linear and nonlinear estimation theory, as applied to INS fusion with external sensors and information. The course is divided into three parts:

1) Inertial navigation systems: a brief review of basic navigation mathematics fundamentals and INS kinematic equations.

2) Estimation theory: a presentation is given of optimal state estimation in a Kalman framework - linear Kalman filter, extended Kalman filter (EKF), and unscented Kalman filter (UKF). Two implementations are derived: a total state and an error state.

3) INS fusion with external sensors and information: focusing on fusion between INS and global navigation satellite systems (GNSS), we derive two integration approaches - known variously as loosely coupled and tightly coupled architecture - and examine their usage in vehicle navigation and geodetic applications. We also address topics within the INS fine alignment process, indoor navigation fusion approaches, autonomous road vehicle navigation, and more.

* The course focuses on autonomous underwater vehicle navigation. After a brief review of inertial navigation theory and optimal state estimation in a Kalman framework, external sensors that are commonly used to aid the INS in AUV navigation are presented. We derive relevant theory, principles of operations, error sources and more, for Doppler velocity log (DVL), magnetometer, terrain-referenced navigation, and model-aided INS. Finally, we address several fusion approaches between the sensors and the INS.

1. Open Positions

Postdoctoral research fellow positions are available in navigation, deep learning, and sensor fusion. The positions will provide an opportunity to advance breakthrough scientific discoveries in those fields.

Appointments are for one year, with the possibility of renewal pending satisfactory performance and continued funding. Funds for some conference travel and research expenses will also be provided. Openings are available immediately, but there is flexibility in start dates.

While all candidates will be considered, the ideal candidate will have the following qualifications:

Position Requirements

* Applicants should have a doctorate degree in engineering, computer science, or a related discipline.
* Programming expertise in Python, MATLAB, or another programming language is essential.
* Experience with deep learning frameworks and tools is useful.

Applicants should apply directly for this position by [email](mailto:kitzik@univ.haifa.ac.il), attaching a curriculum vitae (CV) and a list of publications.