1. Home

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

1. Research

2.1 Deep Learning Based Navigation

Deep learning is a machine learning method that takes in 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 are witnessing major breakthroughs in deep learning algorithms in the fields of computer vision, speech recognition, text translation, autonomous vehicles and more.

In the last year, deep learning (DL) was applied to pedestrian dead reckoning (PDR), an indoor navigation approach. There, instead of applying traditional algorithms, deep learning frameworks were suggested both for the activity recognition and user position determination. DL based PDR algorithms show dramatic improvement in the determination of the 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 ones to pioneer it.

2.2 Enhanced INS/DVL Fusion for AUV Navigation

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

In this research, we aim to derive algorithms enabling the velocity vector estimation in situations of complete DVL outages for short time period scenarios. Also, we intend to derive approaches to handle conditions of partial DVL availability and manage to circumvent the INS solution drift. Currently, several algorithms and theory were derived and proven by simulations and sea 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). Given initial conditions and IMU measurements, the position, velocity, and orientation can be calculated. The inertial sensors, namely, the accelerometers and gyroscopes, are part of the IMU. A classical IMU architecture has three accelerometers (to measure specific force) and three gyros (to measure angular velocity) arranged in orthogonal triads.

Experimental INSs were first developed in the 1920s; however, the sensor and computation technology of that time were not good enough for practical applications. In February 1953, Draper's team demonstrated an INS flight on a Boeing B-29. This opened the INS era, first for military usages and later (1960s) for civil aviation. Strapdown INS technology was developed during the 1970s. Later, 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. Most effort during those years was made in improving sensor performance and reducing their size. Yet, the architecture of three orthogonal accelerometers and three orthogonal gyros survived from the beginning of the modern INS era and is still the only architecture available as an off-the-shelf product.

In this research we aim to design new INS architectures, build, evaluate and derive relevant theory. Several architectures are in different stages of development and there is still room for more.

2.4 Buoy Height Measurements

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

There are several applications that require buoy data. The main one is weather forecasts. There, buoy data is crucial because the buoys can be deployed in remote ocean areas where no other source of valuable data is available. Besides, continuous weather forecasts buoys data is extremely valuable in tropical storms forecast and in preprocessing data during the storm.

One of the important quantities commonly measured by buoys is the waves height and period, parameters which define sea state. To measure these parameters, an expensive set of accelerometers/gyroscopes can be employed or other sensors which rely on external sources such as GPS. 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 waves 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 a 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 the B.Sc. and M.Sc. 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 the B.Sc. (2016) and M.Sc. (2018) degrees in Aerospace Engineering and also the B.A. (2016) degree in Economics from the Technion Israel Institute of Technology. Prior to starting his PhD, 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 coordinates frames, transformation matrixes and their properties, quaternions and more.

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

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

1) inertial navigation systems: basic navigation mathematics fundamentals and INS kinematic equations are briefly reviewed

2) estimation theory: Optimal state estimation in a Kalman framework is presented: linear Kalman filter, extended Kalman filter (EKF) and unscented Kalman filter (UKF). Two implementations are derived: total state and 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 as the loosely and tightly coupled architectures and examine their usage in vehicle navigation and geodetic applications. Also, we address topics in 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 those 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 to this positing by email with the submission of a Curriculum Vitae (CV) and a list of publications.