Sensor Fusion and Tracking with MATLAB®

ISIF Fusion 2023 tutorial proposal

Duration

Half day

Presenters

Prashant Arora and Elad Kivelevitch (The MathWorks, Inc.)

Website

https://www.mathworks.com/help/fusion/index.html

Target audience

The tutorial will introduce the audience to the main concepts of sensor fusion and tracking and will use MATLAB to demonstrate tools that enable these concepts in common applications. Therefore, the target audience can range from students new to the field; recent graduates who would like to learn about tracking; practitioners in industry, academia, or government who are looking for tools to simplify their work; and professors who are looking for tools they can use in their courses.

Abstract

Sensor fusion and tracking is at the core of many modern systems that require an understanding of the surrounding environment. These systems include autonomous vehicles, which use a sense-perceive-plan-act loop to safely navigate in unrehearsed situations, as well as surveillance systems, which provide situational awareness in air, space, maritime, and ground applications. Each system typically uses multiple and diverse sensors, for example radar, cameras, infrared sensors, lidars, sonars, etc.

While tracking algorithms have existed in literature since the 1960 (e.g., the Kalman filter), students and practitioners are often required to write code to reimplement these algorithms for their unique use cases, which is time consuming, may lead to errors, and slows the progress into new state-of-the-art algorithms. Moreover, the testing of such algorithms with simulated or real data and the analysis of such testing with state-of-the-art metrics is often time consuming and error prone.

The Sensor Fusion and Tracking Toolbox™ provides tools in MATLAB® and Simulink® to enable researchers and practitioners with a rich set of features:

- Motion and measurement models.
- Tracking filters.
- Assignment algorithms.
- Multi-object trackers.
- Track-to-track fusion for multi-object tracking.
- A simulation environment to define scenarios and common sensor models.
- A set of detailed and score-based metrics to evaluate tracking quality.
- Visualization tools.

These tools are specifically developed to enable researchers and practitioners develop new solutions, evaluate their performance, and generate C/C++ code to run on real hardware.

Outline

The workshop is divided into two main parts. In the first part, we briefly introduce the main concepts in multi-object tracking and show how to use the toolbox. In the second part, we demonstrate the tools with applications that involve camera-based tracking, multi-sensor tracking for autonomous systems, and multi-sensor tracking for wide area surveillance systems.

Part 1: Introduction to tracking with MATLAB®

In this section, we introduce the topics of importing sensor data, single-object estimators, data association, multi-object trackers, scenario simulation, and metrics. The introduction of algorithms focuses on the conceptual level rather than mathematical level and shows the relevant MATLAB code in the toolbox for each concept.

Part 2: Examples

In this section, we cover two to three examples from the toolbox in more detail to show a step-by-step workflow on how the tools can be put together for real world applications. We start with a single camera-based tracking as this is the simplest to visualize and understand. The second example demonstrates multi-sensor extended object tracking and various approaches that the toolbox enables, including centralized and decentralized algorithms. The third example demonstrates tracking for large surveillance areas with both active and passive sensors. In this example, we discuss challenges and practical implementations for heterogeneous use-cases, when some sensors provide full measurements like position and some sensors provide partial measurements like angle-only, range-only, or time-difference-of-arrival.

All the examples show the use of state-of-the-art metrics to quantify the tracking performance. Time permitting, we may cover other documented examples per requests from the audience.

Requirements

Attendees are expected to have a laptop.

Course material will include slides, MATLAB exercises with solutions for interested attendees. Registered attendees will receive a trial license for the toolbox.

Biographical Sketches

Prashant Arora

Prashant joined The MathWorks in 2016 and currently holds the position of a Senior Developer, responsible for creating advanced tools and algorithms for the Sensor Fusion and Tracking Toolbox™. Prashant received his bachelor's degree in mechanical engineering from the Indian Institute of Technology (IIT) Roorkee in 2013 and a master's degree in mechanical engineering from the Pennsylvania State University in 2016. During his bachelors, he was part of the Formula Student team and assumed a leadership role in guiding the design teams to successfully participate in Formula SAE Australasia (2011) and Formula Student UK (2013). At Pennsylvania State University, he was a part of the Intelligent Vehicle and Systems Group (IVSG) where he designed and developed a driving simulator for assessing human behavior in randomly generated, mixed autonomous environments.

Elad Kivelevitch, PhD

Elad is the development manager responsible for the development of the Sensor Fusion and Tracking Toolbox. He has been working for The MathWorks since 2015. Prior to joining The MathWorks, Elad was an Assistant Professor at the Department of Aerospace Engineering at the University of Cincinnati. Prior to joining the University of Cincinnati, he was a Systems Engineer working on data fusion systems for Ness Advanced Technologies (Israel) and a Project Engineer in the Israeli Air Force.

Elad holds a BSc. (1997) and MSc. (2005) in Aerospace Engineering from the Technion – Israel Institute of Technology and a PhD (2012) in Aerospace Engineering from the University of Cincinnati. He is an Associate Fellow of the AIAA and a former chairperson of the AIAA Intelligent Systems Technical Committee.