TUTORIALS OF THE ITSNT2018

Half-day tutorials are organized to make the most out of the presence of international experts at ITSNT. The lectures will be the perfect opportunity to have privileged discussion with them on any topics of their domain of expertise.

The tutorials will take place on **November, 13th 2018**, on the afternoon of the first day of the Symposium. The 3 tutorials will be held in parallel, so you can attend only a single one.

A **registration** is required to attend the tutorials, with a price of 200.00 €. Please follow the instructions available on the "Registration" section of the website: http://www.itsnt.fr/en/registration/11

The topics of the tutorials are:

- **Vision-aided inertial navigation: Enabling accurate positioning in GNSS-denied environments**, by **Jonathan Kelly** (University of Toronto, Canada)
- **Dual-frequency multi-constellation GNSS for Civil Aviation**, by **Todd Walter** (Stanford University, USA)
- **Processing of future GNSS signals**, by **Christophe Macabiau** (ENAC, France)

ITSNT Toulouse www.itsnt.fr
NOV 13/16 2018 International Technical Symposium on Navigation and Timing
Ecole Nationale de l'Aviation Civile in Toulouse, France

VISION-AIDED INERTIAL NAVIGATION: ENABLING ACCURATE POSITIONING IN GNSS-DENIED ENVIRONMENTS

Jonathan Kelly
Assistant Professor, University of Toronto, Canada

Objective: Introduce attendees to the key aspects of vision-aided inertial navigation systems (VINS) for indoor and outdoor positioning applications. Provide details regarding the design and implementation of VINS, and review basic performance characterization.

Prerequisites: General background in engineering (multivariable calculus, matrix algebra). Some knowledge of inertial navigation would be helpful.

Contents:

- **PART 1 — Fundamentals of Visual and Inertial Sensing**
  - Camera models and calibration methods.
  - Image feature detection and tracking.
  - Outlier rejection techniques.
  - Inertial measurement unit components (accelerometers, gyroscopes).
  - IMU models, noise characteristics, and mechanization equations.
  - Dead reckoning using inertial measurements.

- **PART II — Sensor Fusion for VINS**
  - Filtering-based camera-IMU fusion methods (EKF, UKF).
  - Batch and sliding window nonlinear optimization methods.
  - State representation and state parameterization.
  - Simultaneous localization and mapping.
  - Multi-state filtering without mapping.

- **PART III — Online, In-Field Calibration**
  - Camera-IMU spatial calibration in a filtering framework.
  - Camera-IMU temporal (time offset) calibration.
  - Observability of the calibration problem.
  - Accuracy considerations.

- **PART IV — Case Studies and Performance Evaluation**
  - VINS for small unmanned aerial vehicles (quadrotors).
  - VINS for ground robots.
  - VINS for handheld devices (phones, tablets).
  - Evaluating and improving performance.

DUAL-FREQUENCY MULTI-CONSTELLATION GNSS FOR CIVIL AVIATION

Todd Walter
Senior Research Engineer, Stanford University

General Objective: Introduce attendees to the use of GNSS by the civil aviation community, its challenges and solutions and to describe how it is adapting to the variety of new GNSS signals.

Pre-requisite: General background in engineering concepts and GNSS basics

Content:

- **PART I — GNSS for Aviation**
  - Navigation requirements for aviation
  - Traditional navigation aids
  - GNSS and its error sources
  - Augmentation systems
  - ABAS/RAIM
  - GBAS
  - SBAS

- **PART II — GNSS Error Sources and Threat Models**
  - Satellite orbit and clock errors
  - Signal malformation
  - Antenna bias
  - Ionospheric delay
  - Tropospheric delay
  - Multipath

- **PART III — Future Developments**
  - Dual frequency
  - Multi constellation
  - ARAIM
  - RFI sources
  - RFI mitigation

PROCESSING OF FUTURE GNSS SIGNALS

Christophe Macabiau
Head of Telecom Research Team, ENAC, France

General Objective: Introduce attendees to the main characteristics of new GNSS signals and their implications for a GNSS receiver.

Pre-requisite: General background in receiver signal processing for GPS L1 C/A

Content:

- **PART I — Main GNSS Signal Innovations**
  - Reminder on GPS L1 C/A Signal Structure
  - Binary Offset Carrier (BOC)
  - Pilot components
  - Secondary codes
  - Long PRN codes
  - Improvement of Navigation Message

- **PART II — Detailed Description of Concrete Cases**
  - Galileo E1 OS
  - GPS L1C
  - Galileo E5/E5a/E5b
  - GPS L5

- **PART III — Expected GNSS Receiver Performance**
  - Acquisition
  - Carrier Tracking
  - Code Delay Tracking

Biography

Dr. Jonathan Kelly is an Assistant Professor at the University of Toronto Institute for Aerospace Studies (UTIAS), where he directs the Space & Terrestrial Autonomous Robotic Systems (STARS) Laboratory. Before joining UTIAS in 2013, he was a postdoctoral researcher and member of the Robust Robotics Group within the Computer Science and Artificial Intelligence Laboratory at the Massachusetts Institute of Technology, working with Prof. Nicholas Roy. Dr. Kelly received his PhD degree in 2011 from the University of Southern California, under the supervision of Prof. Gaurav Sukhatme. At USC, he was selected as a member of the first class of Annenberg Fellows; the Annenberg award supports prospective leaders in the fields of engineering and media sciences. Prior to graduate school, he was a software engineer in the Space Technologies division of the Canadian Space Agency. He and his group strive to develop robot systems that are *pervasive*, *persistent*, and *perceptive*. His research interests lie primarily in the areas of sensor fusion, estimation theory, and machine learning for navigation and mapping, applied to both robots and human-centred assistive technologies. More information is available on the STARS Laboratory website at http://starslab.ca/.

Dr. Todd Walter is a Senior Research Engineer in the Department of Aeronautics and Astronautics at Stanford University. He received a B.S. in physics from Rensselaer Polytechnic Institute and an M.S. and Ph.D. in Applied Physics from Stanford University. His research focuses on implementing high-integrity air navigation systems. He was one of the principal architects of the Federal Aviation Administration's (FAA) Wide Area Augmentation System (WAAS) safety processing algorithms, including development of the original ionospheric estimation and confidence bounding algorithm. He also advises the FAA on alternate means to exploit satellite navigation signals to provide services more efficiently. He has received the Institute of Navigation's (ION) Thurlow and Kepler awards. He is also a fellow of the ION and has served as its president

Dr. Christophe Macabiau graduated as an electronics engineer in 1992 from the ENAC (Ecole Nationale de l'Aviation Civile) in Toulouse, France. Since 1994, he has been working on the application of satellite navigation techniques to civil aviation. He received his Ph.D. in 1997 and has been in charge of the signal processing lab of the ENAC since 2000, where he also started dealing with navigation techniques for urban navigation. He is currently the head of the TELECOM research team of ENAC, which includes research groups on signal processing and navigation, electromagnetics and data communication networks.