Industrial PhD Position: Real-Time Data Assimilation of Sensor Time Series and Digital Imagery with Unknown Uncertainty

Summary

In this industrial PhD sponsored by Estonian firm DefSecIntel, we will explore, develop, test and validate new data assimilation methods for integrated autonomous situation awareness urgently needed for monitoring and surveillance systems. Combining sensor data time series with digital imagery remains theoretically challenging as the spatial and temporal scales, measurement sensitivities, detection range and noise from each type of sensing system typically have little overlap. A promising method to address these challenges is data assimilation, which has strong theoretical underpinnings based on optimal filters and is commonly used to update large-scale numerical model forecasts in the geosciences. Outside of this largely specialist academic community however, data assimilation remains underutilized as a powerful tool for combining sensor time series measurements with grid-based data such as digital imagery and numerical model results. To address this lack of suitable methods for a wider number of use-cases, the TalTech Environmental Sensing and Intelligence group has pioneered the development of lightweight data assimilation algorithms capable of estimating unknown uncertainty, and which can be deployed on real-time systems based on microcontrollers.

Research field:	Information and communication technology
Supervisor:	Jeffrey Andrew Tuhtan
Availability:	This position is available.
Offered by:	School of Information Technologies Department of Computer Systems
Application deadline:	Applications are accepted between October 01, 2024 00:00 and October 25, 2024 23:59 (Europe/Zurich)

Description

Summary

Data assimilation combines two or more sources of data using dynamic weighting algorithms which require uncertainty estimates at each time step. The main objective of this project is to develop, test and implement one or more real-time data assimilation algorithms which combine sensor time series (e.g. surface detection or distance as measured using radar or radio frequency with digital imagery (e.g. remote sensing satellites, UAVs or fixed station cameras). Specifically, the project addresses two research questions, and one question to guide and inform future works:

1. Which methods are suitable for estimating time series and imaging sensor uncertainty in real-time?
2. What are the advantages, disadvantages and best performing observation operators for data assimilation from time series and digital imagery collected in field applications?
3. What are the hardware (high performance desktop vs. embedded), software, environmental, human resource and financial requirements to develop real-time time series and digital imagery assimilation systems based on the best available technologies?

Background on the need for this research

Combining sensor data time series with digital imagery remains theoretically challenging as the spatial and temporal scales, measurement sensitivities, detection range and noise from each type of sensing system typically have little overlap. A promising method to address these challenges is data assimilation, which has strong theoretical underpinnings based on optimal filters and is commonly used to update large-scale numerical model forecasts in the geosciences. Outside of this largely specialist academic community however, data assimilation remains underutilized as a powerful tool for combining sensor time series measurements with grid-based data such as digital imagery and numerical model results. To address this lack of suitable methods for a wider number of use-cases, the TalTech Environmental Sensing and Intelligence group has pioneered the development of lightweight data assimilation algorithms capable of estimating unknown uncertainty, and which can be deployed on real-time systems based on microcontrollers.

Gap 1: lack of lightweight data assimilation methods based on digital imagery

Currently, the largest gap in real-time data assimilation is that it has been developed for large-scale numerical models, and thus computationally efficient methods are not of particular interest to the geoscience community from which data assimilation originates. The main reason why data assimilation is not widespread is because it requires both measured quantities as well as estimates of the measurement uncertainty. This is a substantial bottleneck for the broad range of researchers, governmental agencies and industrial users who work outside of the geosciences who could substantially benefit from lightweight, real-time data assimilation methods, without the need of high-performance computers.

Gap 2: need for flexible and dynamic observation operators for novel data assimilation applications

In most cases, assimilation is carried out using a sensor with high precision, rapid sampling rates (e.g. 1-100 Hz) and localized spatial coverage (e.g. 1 cm-1 m) with geospatial, gridded data with lower precision, lower sampling rates (e.g. 1 min – 1 hr) and broad spatial coverage (e.g. 10 m to 25 km). To accomplish this, empirical equations, known as observation operators are needed to up- and downscale data from one measurement system to the other before data assimilation algorithms are applied. Classes of well-known operators exist in fields such as sea surface temperature mapping, oceanography, meteorology and models of atmospheric chemical processes. However, to operationalize data assimilation for new applications, it will be necessary to investigate which types of observation operators may be suitable for lightweight data assimilation, and to develop, test and validate bespoke operators for tailored sensor and imaging system applications.

Responsibilities and main tasks of this PhD position

- Perform a literature review of data assimilation methods on embedded systems, to be published as a Q1 journal article
- Test and evaluate state-of-the-art lightweight data assimilation algorithms using low-powered hardware capable of recording both digital imagery and at least one complimentary sensor modality.
- Collaborating with junior and senior researchers to learn how to prepare news articles, press releases and open house events disseminating the research outcomes from this PhD.
- Aid in the preparation of research proposals related to lightweight data assimilation.
- Participate in workshops, conferences and public events as a representative of the Tallinn University of Technology to share, improve and grow your knowledge on the topics of embedded sensing and data assimilation.

Applicants should fulfil the following requirements:

- a master’s degree in computer science, with an emphasis on computer vision / embedded systems
- a clear and related interest in the topic of the position based on their previous experience
- excellent command of English
- strong and demonstrable software development, writing and analytical skills
- capacity to work both as an independent researcher and as part of an international team
- capacity and willingness to provide assistance in organizational tasks relevant to the project
- be able to travel at least two weeks per year for field work, collaboration and training events

The following experience is beneficial:

- Programming in Python
- Experience in training, testing and validation of machine learning models
- Solid foundation in frequentist & Bayesian statistics
- Working knowledge of video and image annotation processes for classification
- Demonstrated skill in convolutional neural networks applied to image classification tasks
- Code documentation and the use of shared repositories
- Basic understanding of digital signal processing (e.g. filters, Fourier transform)

To be considered for evaluation, a candidate must submit a one-page research plan for the topic, including the overall research strategy. Here it is strongly encouraged to elaborate on their choices of suitable computer vision methods, based on those available in the literature. The format of the research plan is up to the candidate, but should include references to relevant books, journal and conference publications to highlight the candidate’s ability to independently source references.

We offer:

- 4-year PhD position in the leading environmental sensing research center in Estonia with a large portfolio of ongoing pan-European, regional, national and local projects.
- The chance to do high-level research in a leading international group on outdoor sensing
- Opportunities for conference, research stays and networking with globally leading universities and research centers in the fields of computer vision and outdoor sensing.

About the research group

The Centre for Environmental Sensing and Intelligence is an internationally-recognized and highly interdisciplinary research group at the Tallinn University of Technology focusing on environmentally relevant and future-oriented research and teaching topics:

- Data-driven modelling of large-scale environmental sensing networks
- Computer vision applications for underwater monitoring in freshwater environments
- Development of rugged and robust underwater sensors for extreme physical environments
- Human kinematic measurement systems for underwater and microgravity environments
- Environmental technology innovation with small to medium enterprises
- Teaching large-scale environmental sensor development (MSc) and academic writing (PhD)

Additional information

For further information, please contact:

Assoc. Prof. Jeffrey A. Tuhtan

Email: jetuht@taltech.ee

To get more information or to apply online, visit https://taltech.glowbase.com/positions/872 or scan the the code on the left with your smartphone.