Earth Observation Data Intelligence and Knowledge Discovery

Abstract 1

Earth Observation (EO) Data Intelligence is addressing the entire value chain: data processing to extract information, the information analysis to gather knowledge, and knowledge transformation in value. EO technologies have immensely evolved the state of the art sensors deliver a broad variety of images, and have made considerable progress in spatial and radiometric resolution, target acquisition strategies, imaging modes, geographical coverage and data rates. Generally imaging sensors generate an isomorphic representation of the observed scene. This is not the case for EO, the observations are a *doppelgänger* of the scattered field, an indirect signature of the imaged object. EO images are instrument records, i.e. in addition to the spatial information, they are sensing physical parameters, and they are mainly sensing outside of the visual spectrum. This positions the load of EO image understanding, and the outmost challenge of Big EO Data Science, as new and particular challenge of Machine Learning (ML) and Artificial Intelligence (AI). The lecture presents specific solutions for the EO Data Intelligence, introducing methods for physically meaningful features extraction to enable high accuracy characterization of any structure in large volumes of EO images. The theoretical background is introduced, discussing the advancement of the paradigms for stochastic and Bayesian inference, machine learning, and evolving to the methods of Deep Learning and Generative Adversarial Networks. Both unsupervised and supervised learning paradigms are discussed in relation with the semantic meaning extraction and knowledge formalization. The challenge of very limited and high complexity training data sets it is addressed introducing paradigms to minimize the amount of computation and to learn jointly with the amount of known available data using cognitive primitives for grasping the behavior of the observed objects or processes. Since the data sets are organic part of the learning process, the EO dataset biases pose new challenges. The lecture answers open questions on relative data biases, cross-dataset generalization, for very specific EO benchmarking cases for multispectral, SAR observation with a large variability of imaging parameters and semantic content.

The lecture language: English, French, German, Romanian, or Spanish

Artificial Intelligence for Earth Observation

Abstract 2

Artificial Intelligence (AI) for Earth Observation (EO) is largely an interdisciplinary field. The lecture presents selected topics of AI algorithms specific for EO encompassing: orbit, mission, sensor networks, intelligent agents, communication, coding, signal processing, machine learning, deep learning, data indexing, data bases, network theories, simulation, modeling, inverse problem, model assimilation, or parameters retrieval.

Recently the quantum resources are evolving and a paradigm shift is at the horizons of next few years. EO starts with the mission intelligence. Orbit determines the acquisition time therefore latently includes physical parameters of the Erath surface, illumination, atmospheric effects. Orbit is the key for Satellite Image Time Series, and for multimission observations. It becomes a hidden parameter of sensor fusion. All these are influencing parameter retrieval, model assimilation and the related EO methods. The mission intelligence, i.e. satellite constellations with intelligent orbits can enhance overall the EO performance. And formation flying is boosting the performance with the sensor intelligence, as new configurations of apertures, supported by advanced signal processing and resulting in completely new instruments. To practically implement the Artificial Intelligence techniques, a current trend in Big Data processing is to bring the algorithms to the data on the cloud, instead of downloading large datasets and running algorithms on local servers. EO instead, is demanding more advanced paradigms, as: *bring the algorithms to the sensor*. The sensor is the source of the Big Data, and the lecture is analyzing the methods of computational imaging to optimize the EO information sensing. The presentation is focusing on the most advanced methods in synthetic aperture, coded aperture, compressive sensing, ghost imaging, and also the basics of quantum sensing. The overall theoretical trends are summarized in the perspective of practical applications.

The lecture language: English, French, German, Romanian, or Spanish

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Mihai Datcu, received the M.S. and Ph.D. degrees in Electronics and Telecommunications from the University *Politechnica* Bucharest UPB, Romania, in 1978 and 1986. In 1999 he received the title *Habilitation diriger des recherches* in Computer Science from University Louis Pasteur, Strasbourg, France. Since 1981 he has been Professor with the Department of Applied Electronics and Information Engineering, Faculty of Electronics, Telecommunications and Information Technology (ETTI), UPB, working in image processing and Electronic Speckle Interferometry. Since 1993, he has been a scientist with the German Aerospace Center (DLR), Oberpfaffenhofen. He is developing algorithms for model-based information retrieval from high complexity signals and methods for scene understanding from Very High Resolution Synthetic Aperture Radar (SAR) and Interferometric SAR data. He is engaged in research related to information theoretical aspects and semantic representations in advanced communication systems. Currently he is Senior Scientist and Data Intelligence and Knowledge Discovery research group leader with the Remote Sensing Technology Institute (IMF) of DLR, Oberpfaffenhofen. Since 2011 he is also leading the Immersive Visual Information Mining research lab at the Munich Aerospace Faculty and he is director of the Research Center for Spatial Information at UPB. His interests are in Bayesian inference, information and complexity theory, stochastic processes, machine learning and artificial

intelligence, for applications in information retrieval and understanding of high resolution SAR and optical observations. He has held Visiting Professor appointments with the University of Oviedo, Spain, the University Louis Pasteur and the International Space University, both in Strasbourg, France, University of Siegen, Germany, University of Innsbruck, Austria, University of Alcala, Spain, University Tor Vergata, Rome, Italy, Universidad Pontificia de Salamanca, campus de Madrid, Spain, University of Camerino, Italy, the Swiss Center for Scientific Computing (CSCS), Manno, Switzerland, From 1992 to 2002 he had a longer Invited Professor assignment with the Swiss Federal Institute of Technology, ETH Zurich. Since 2001 he has initiated and leaded the Competence Centre on Information Extraction and Image Understanding for Earth Observation, at ParisTech, Paris Institute of Technology, Telecom Paris, a collaboration of DLR with the French Space Agency (CNES). He has been Professor holder of the DLR-CNES Chair at ParisTech, Paris Institute of Technology, Telecom Paris. He initiated the European frame of projects for Image Information Mining (IIM) and is involved in research programs for information extraction, data mining and knowledge discovery and data understanding with the European Space Agency (ESA), NASA, and in a variety of national and European projects. He is a member of the European Big Data from Space Coordination Group (BiDS). He and his team have developed the Data Mining and KDD processor in the Payload Ground Segment systems for the German missions TerraSAR-X, TanDEM-X, and the ESA Sentinel 1 and 2. He is the author of more than 500 scientific publications, among them about 100 journal papers, and a book on number theory. He has served as a co-organizer of International Conferences and workshops, and as guest editor of special issue of the IEEE and other journals. He received in 2006 the Best Paper Award, IEEE Geoscience and Remote Sensing Society Prize, in 2008 the National Order of Merit with the rank of Knight, for outstanding international research results, awarded by the President of Romania, and in 1987 the Romanian Academy Prize Traian Vuia for the development of SAADI image analysis system and activity in image processing. In 2017 he was awarded a *Chair Blaise Pascal* for international recognition in the field of Earth Observation Data Science, with the *Centre d'Etudes et de Recherche en Informatique* (CEDRIC) at the *Conservatoire National des Arts et Métiers* (CNAM) in Paris. He is IEEE Fellow.

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