Sustainable Water Management

Doctoral Programme (Water4All)

Title of the PhD Project	Perimeter security for underground and surface water basins
Acronym	ELE-2
Research Fields of the Project	Fiber optical sensor systems for sustainable water management
Keywords	Fiber optics, sensors, DAS, advanced signal processing, machine learning algorithms, perimeter security, water basins monitoring
Host Institution, Department and Campus Location	Izmir Institute of Technology, Electrical-Electronics Engineering Department, Urla, Izmir
PhD Awarding Institution and Graduate Programme	Izmir Institute of Technology, Graduate School, PhD in Electronics Engineering
Name and Affiliation of Main Supervisor	Kıvılcım YÜKSEL ALDOĞAN, Associate professor (IZTECH)
Name and Affiliation of Co-Supervisors	Abdurrahman Gümüş, Assistant professor (IZTECH) Yalın Bastanlar, Professsor (IZTECH)
Research Environment and Infrastructure	The Izmir Institute of Technology (IZTECH) has been distinguished as “one of the Top 5 Research Universities” out of 200+ higher education institutions in Türkiye, ranking first in terms of the number of peer-reviewed articles per faculty member. One of the strategic goals of IZTECH is to advance its position to a leading academic institution in water research in European Research Area. IZTECH Campus is in Urla, İzmir and has an area of 232.30 hectares of land (the third largest campus area in Türkiye).

	Being an English medium university, IZTECH currently has Engineering, Science, and Architecture faculties with 19 departments (engineering 10, science 5 and architecture 5), with 18 undergraduate, 29 master's (9 interdisciplinary) and 15 doctorate (4 interdisciplinary) programs in 19 majors. IZTECH has 354 laboratories, 80% of which are for R&D purposes and 20% of which are for educational purposes. All laboratories contain the appropriate technology for education, teaching and research in various fields. Importantly, the Integrated Research Center (IRC) of IZTECH is one of the most-equipped and competent research centers in Türkiye, located on 6,250 m2 area. IRC incorporates eight different Application and Research Centers (ARCs) including Environmental Development ARC, Geothermal Energy ARC, Biotechnology and Bioengineering ARC, National Mass Spectrometry ARC, Wind Energy Meteorology ARC and Continuing Education Center. The equipment and analysis portfolio are accessible through a website that was designed considering online-shopping perspective. Furthermore, the academic supervisors of ELE-2 have their own laboratories, namely FiSENSLAB, MIRALAB and CVRG that will be involved in the project. The Fiber Optic Metrology and Sensor Applications Laboratory (FiSENSLAB, https://eee.iyte.edu.tr/en/fiber-optic-sensors-lab/) was established in 2012 as a complementary part of the ongoing research at the Electrical and Electronics Engineering Department of IZTECH on the photonics domain. Specific research areas focused on at FiSENS-LAB include design and implementation of optical fiber reflectometry techniques, Distributed Optical Fiber Sensors (DOFS), Fiber Bragg Grating sensors (FBG), Passive Optical Networks (PON), and sensor data analysis using machine learning algorithms. The Machine Intelligence Research and Applications Laboratory (MIRALAB) at Izmir Institute of Technology, Türkiye, is dedicated to exploring the frontiers of artificial intelligence, with a particular focus on sequential data analysis and computer vision. MIRALAB is engaged in developing advanced AI methodologies, including transformers, diffusion-based models, and multimodal systems, by focusing on the application areas of optical sensors, biosensors, medical image understanding, facial expression analysis, wearable devices and digital health. The Computer Vision Research Group (CVRG, cvrg.iyte.edu.tr) at Izmir Institute of Technology targets to conduct research on the cutting-edge topics of applying AI and machine learning techniques for visual data such as: Visual object detection/classification, visual localization, vision for autonomous driving and ADAS, 3D reconstruction from images, object tracking, vision for robotics.

Scientific Context of the Project	Perimeter security systems for underground and surface water basins employ a combination of technologies to monitor and protect these critical water resources as well as to safeguard them from potential threats. The specific components and mechanisms used in perimeter security systems can vary according to the requirements of a particular geographic region. Hence, understanding the hydrological and geological characteristics of the water basin area is fundamental. This knowledge helps in determining vulnerabilities, potential pathways for contamination, and areas susceptible to erosion or structural weaknesses. Sensor deployment and geospatial analysis (mapping the terrain, water flow patterns, and potential entry points for security threats) are the main building blocks of these security systems. Various types of sensors (seismic, infrared, acoustic, fiber optic, …) can strategically be deployed along the perimeter of the water basin. Event detection and classification are enhanced using various sensor systems, including deep learning (DL) techniques, catering to a wide array of applications. These systems, combined with DL, effectively address specific challenges in their respective areas. The integration of DL with sensor systems highlights their versatility and effectiveness in dealing with various challenges in event detection and classification. For example, DL algorithms can enhance chemical sensors as early warning systems for hazardous releases, while seismic sensors in environmental monitoring effectively classify earthquakes. The fusion of DL and distributed acoustic sensing has brought new levels of precision and capability in monitoring and interpreting events along fiber-optic lines. Recent studies have utilized DL for enhancing long-distance fiber-optic vibration sensing and threat classification in complex environments, with impressive identification accuracies. In this Project, an extensive multi-disciplinary applied research will be carried out to fulfill the very specific needs of some pre-determined geographic regions.

Brief Workplan	**0 – 2 years:** PhD candidate will take classes from partner universities Analysis of the state of the art Requirement analysis Simulation of the sensor interrogation system Fiber optic lab trainings **0.5 – 2.5 years:** Data collection capability improvement with fiber optic sensors. Noise modelling and analysis. **1.0 – 4 years:** Implementing the fiber optic sensors and tools specific for the corresponding Ph.D. project. Comparison between simulated and experimental data. Secondments visits. Intersectoral mobility (outside plant trials). Congress and article publishing. **1.0 – 4 years:** Developing and implementing artificial intelligence algorithms for the analysis of fiber optic sensors specific for the corresponding Ph.D. project **3.0 – 4 years**: Thesis report, dissemination activities.
Innovative Aspects of the Project	Innovative perimeter security for underground and surface water basins involves the integration of advanced technologies such as sensor networks, acoustic sensors, fiber optic perimeter intrusion detection systems, geospatial technology, and machine learning. These innovations will collectively enhance the overall security, responsiveness, and reliability of water basin protection systems that will be implemented in this Project.

Training Opportunities of the Project	Doctoral schools and courses from the leading academic institutions in Türkiye, namely, Izmir Institute of Technology (IZTECH-beneficiary) in İzmir, İstanbul Technical University (ITU) in İstanbul, Gebze Technical University (GTU) in Kocaeli, and Middle East Technical University (METU) in Ankara. ○ Research Laboratories of the co-advisors (FiSENS, MIRALAB, CVRG) ○ 1 sectoral partnership (SAMM Teknoloji). ○ 3 international academic secondments (UMONS, UPNA, XLIM).
Interdisciplinary Aspects	The main modules of the Water4All project are identified as Environment, Electronics, Planning, Material Science and Energy, and each has different angles of training on research and expected outcomes. In this respect, academic training of PhD student in Water4All is constructed in a modular approach that is interdisciplinary by nature. Perimeter security for water basins is inherently interdisciplinary, drawing from principles of hydrology, geology, physics, engineering, computer science, and environmental science. More particularly, integration of perimeter security systems with geospatial technology in the framework of this thesis (ELE-2) will allow interdisciplinary interaction with PLA (Planning) module of the Water4All project for real-time mapping of the water basin areas.
Intersectoral Mobility ☐ **Short Visit** ☒ **Secondment**	**SAMM technology, Kocaeli premises, Türkiye** SAMM Teknoloji has developed many fiber optic equipment and components for different application areas to date. In addition, in recent years, SAMM Teknoloji has focused on fiber optic-based sensing technologies and aimed to produce value-added products in this regard. SAMM Teknoloji has developed a fiber optic-based sensing system that has been implemented various intrusion detection and perimeter security applications. SAMM Teknoloji will be involved in in the project training, research, and management activities by organizing short-term research activities and trainings both in the R&D center and production facilities of the company. The PhD students involved in the project will be provided by the necessary equipment and infrastructure to get acquainted with fiber sensing concepts.

Intersectoral Mobility ☐ **Short Visit** ☐ **Secondment**	NA
International Academic Secondment	Short-term missions, trainings and laboratory facilities will be offered at the following project secondments: ○ University of Mons, Electromagnetism & Telecommunication Unit, **Belgium** (Host Supervisor: Prof. Marc Wuilpart) ○ Public University of Navarre (UPNA), Optical Communications group, **Spain** (Host Supervisor: Prof. Manuel Lopez-Amo Sainz) ○ XLIM Research Institute, fiber photonics group, **France** (Host Supervisor: Prof. Georges Humbert)

Main Supervisor	
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