Intelligent Robotics and Embedded Systems at the University of Turku

Turku Intelligent Embedded and Robotic Systems (TIERS) Lab
Department of Computing
Faculty of Technology
University of Turku, Finland

https://tiers.utu.fi

The Turku Intelligent Embedded and Robotic Systems (TIERS) Lab was established at the University of Turku in 2018 with the objective of initiating a new research group at the intersection of edge computing, distributed autonomous systems and autonomous robots. These built together towards robust and resilient multi-robot systems. The TIERS Lab works in algorithmic design of autonomous systems, with the constant aim of putting research in action. This is possible with extensive equipment: unmanned aerial, ground and surface vehicles (UAVs, UGVs and USVs), from micro-aerial vehicles (MAVs) to state-of-the-art multirotor platform (e.g., DJI’s Matrice 300). These are supported by a wide array of sensors, including multi-spectral and thermal cameras, 2D and 3D rotating lidars, solid-state 3D lidars, radars and other types of wireless sensors, among others.

Abstract: This report briefly introduces the key research directions and recent developments within the TIERS Lab at the Faculty of Technology, University of Turku, Finland. These areas are, namely, edge computing, autonomous robots and multi-robot systems. Within all this areas, a key focus is on embedding intelligence through lightweight machine learning and dynamic offloading in edge devices and mobile robots. We develop algorithms for collaborative and decentralized decision making, distributed control of multiple mobile robots, and collaborative sensing. Key technologies currently in use are distributed ledger technologies (DLTs), among them blockchain, and ultra-wideband (UWB) wireless communication and ranging. Since it was established, the TIERS lab has initiated research collaboration in three national Finnish projects: AutoSOS, RoboMesh, and Foresail.

Index Terms: Robotics; Autonomous systems; Multi-robot systems (MRS); Edge Computing; Edge AI; Deep learning (DL); Robot learning; Reinforcement learning (RL); Federated learning (FL); Navigation; Mapping; Localization; Search and Rescue (SAR).

1. Introduction

At the TIERS lab we carry out interdisciplinary research in topics ranging from the design of autonomous systems and multi-robot systems to FPGA-based hardware accelerators or the definition of novel edge computing architectures. In multi-robot systems, our main interests are in the areas of decentralized control, collaborative and heterogeneous multi-robot systems, and blockchain for distributed robotic systems. From the perspective of autonomous robotic solutions, our research focuses in localization and mapping in dense urban environments, mapping of unstructured environments, computational offloading techniques, and hardware accelerators for ROS. We work at the edge, with research covering topics from the definition of novel edge computing architectures to the deployment of artificial intelligence at the edge. Our focus is on embedded and distributed intelligence.
2. Autonomous Drones Supporting Maritime Search and Rescue (AutoSOS)

Rescue vessels are the main actors in maritime safety and rescue operations. Aerial drones bring a significant advantage into this scenario. Therefore, AutoSOS develops an autonomous multi-robot search and rescue assistance platform capable of sensor fusion and object detection in embedded devices using novel lightweight AI models. The platform performs reconnaissance missions for initial assessment of the environment using novel adaptive deep learning algorithms that efficiently use the available sensors and computational resources on drones and rescue vessel. When drones find potential objects, they will send their sensor data to the vessel to verify the findings with increased accuracy. The actual rescue and treatment operation are left as the responsibility of the rescue personnel. The drones will autonomously reconfigure their spatial distribution to enable multi-hop communication, when a direct connection between a drone transmitting information and the vessel is unavailable (see Figures 1 and 2).

The AutoSOS project will base its research exploration on the previous work in the development of the world’s first autonomous ferry (Brighthouse Intelligence Oy), research on hybrid aerial-surface-underwater autonomous systems for rescue operations (Tampere University and Alamarin-Jet Oy, aCOLOR project), and algorithms for drones in the areas of formation control and autonomous cooperation in multi-agent systems (University of Turku).

3. Beyond 5G Distributed Ledger Technology driven Mesh for Industrial Robot Collaboration (RoboMesh)

The robotization of industry is one of the key drivers behind the Industry 4.0 revolution. Collaborative robots are becoming a reality across the manufacturing industry, autonomous robots are already a key asset in the logistics sector, and UAVs are being used for inspection and monitoring in diverse domains. Ubiquitous robots with augmented connectivity are merging into the Industrial Internet of Things, enabling higher degrees of intelligence through computational offloading. RoboMesh delves into the design and development of a framework for collaboration and long-term autonomy in distributed and heterogeneous multi-robot systems based on a Beyond-5G wireless mesh network with built-in distributed ledger technology. This framework involves data sharing, collaborative decision making, and dynamic and adaptive computational offloading, while it serves as the basis for interaction between robots and infrastructure with collaborative sensing and multi-modal sensor fusion approaches (see Figure 3).

The multidisciplinary nature and the ambitious targets set by the project requires collaboration between partners having strong know-how and complementary expertise. RoboMesh brings together
the competence and effort of the recognized experts in edge computing and distributed processing for multi-robot systems (TIERS/Univ. Turku), wireless communications (CWC/Univ. of Oulu), and advanced robotic systems and solutions (BISG/Univ. Oulu).

4. Active research areas

Active research areas in TIERS include multi-robot coordination [1], [2], [3], [4], [5], swarm design [6], [7], [8], [9], UWB-based localization [10], [11], [12], [13], [14], [15], localization and navigation in unstructured environments [16], [17], [18], lightweight AI at the edge [19], [20], [21], [22], [23], distributed ledger technologies at the edge [24], [25], [26], [27], [28], [29], edge architectures [30], [31], [32], [33], [34], [35], offloading for mobile robots [36], [37], [38], [39], [40], [41], [42], LPWAN networks [43], [44], [45], [46], sensor fusion algorithms [47], [48], [49], and reinforcement and federated learning for multi-robot systems [50], [51], [52], [53].

References


Tuan Nguyen Gia, Li Qingqing, Jorge Peña Queralta, Zhuo Zou, Hannu Tenhunen, and Tomi Westerlund. Edge AI in smart farming IoT: Cnns at the edge and fog computing with lora. IEEE, 2019.


Jorge Peña Queralta and Tomi Westerlund. Blockchain for mobile edge computing: Consensus mechanisms and scalability. Mobile Edge Computing (Book Chapter), 2020.


Anum Nawaz, Jorge Peña Queralta, Jixin Guan, Muhammad Awas, Tuan Nguyen Gia, Ali Kashif, Haibin Kan, and Tomi Westerlund. Edge computing to secure IoT data ownership and trade with the ethereum blockchain. Sensors, 2020.


[40] Tuan Nguyen Gia, Qingqing Li, Jorge Peña Queralta, Zuo zhou, Hannu Tenhunen, and Tomi Westerlund. Lossless compression techniques in edge computing for mission-critical applications in the IoT. IEEE, 2019.

[41] Jorge Peña Queralta, Fu Yuhong, Lassi Salomaa, Li Qingqing, Tuan Nguyen Gia, Zuo Zhou, Hannu Tenhunen, and Tomi Westerlund. Fpga-based architecture for a low-cost 3D lidar design and implementation from multiple rotating 2D lidars with ROS. IEEE, 2019.


