AIoTwin

Twinning action for spreading excellence in Artificial Intelligence of Things

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REPORT ON THE AIOTWIN SUMMER SCHOOLS

(1)

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Executive Summary

The 1st AIoTwin Summer School was a 3-day event held at the historic St. John's Fortress in Šibenik, Croatia, from 4 to 7 September 2023. The event brought together participants from academia, both renowned experienced researchers and PhD students, to exchange ideas and learn about the latest advances at the intersection of AI and IoT. The summer school was organised by the AIoTwin consortium, a Horizon Europe project that aims to strengthen research and innovation excellence in Artificial Intelligence of Things (AIoT) in Croatia and other EU Member States. The event was organised with a full three-day programme (from 5 to 7 September, reception on 4 September) specifically tailored for PhD students interested in IoT and AI. In addition to cutting-edge lectures by prominent speakers from academia on the latest developments and biggest challenges in the field of AIoT, the event also included hands-on technical training and coaching sessions to develop skills for a successful PhD and orientation on the Horizon Europe funding programme.

Key highlights from the Summer School include:

- **Keynotes** by Petar Šolić on alternative sensing, Danh Le Phuoc on using knowledge graphs to build perceptual IoT systems, Thiemo Voigt on the road to in body and battery-free IoT, and Alexander Artikis on complex event recognition.
- **Tutorials** on Low-Power Wide-Area Network (LPWAN) protocols, the IMUNES[1] network emulator for performance evaluation of edge deployments, orchestration aspects in distributed computing continuum systems, decentralized graph mining, successful PhD journey, and proposal writing and evaluation of collaborative Horizon Europe projects.
- **Hands-on sessions** on federated learning for IoT edge devices using a small cluster of Jetson Nano and Xavier devices (specially transported from Berlin to Šibenik) to jointly train models without sharing raw data, and on the framework for creating high-level Service Level Objectives (SLOs) to enforce them in cloud and edge environments.
- **PhD poster and pitch session** where PhD students presented their research on a variety of innovative topics.

The total number of participants was 36, including 3 invited speakers and 33 participants from the four AIoTwin partner institutions (10 top grade/senior researchers, 3 recognised researchers, 18 PhD students, 4 MSc students and 1 administrator). The total number of participants per institution is the following: 18 from UNIZG-FER, 7 from RISE, 5 from TUW, 3 from TUB and 3 external. The event provided a valuable opportunity for participants to network with other experts in the field and get inspired for a career in AIoT research and development.

The presentations and extended abstracts of all sessions are available on the project website https://www.aiotwin.eu/aiotwin/activities/1st_summer_school.

[1] Integrated Multiprotocol Network Emulator/Simulator, http://imunes.net/

1 Introduction

This deliverable presents the report on the first AIoTwin Summer School, which took place from 4 to 7 September in Šibenik, Croatia. The main goal of the AIoTwin Summer School is to bring together PhD students interested in IoT and AI and to expand their knowledge around the latest developments and biggest challenges in these research fields. The programme included numerous keynotes, tutorials and hands-on training sessions tailored to spark participants' interest in the AIoT research field and stimulate discussion between them that should lead to new research ideas and future collaborations. The event also included tutorials aimed at helping PhD students to approach their doctoral research more effectively and introducing them to the preparation and evaluation process of Horizon Europe projects in order to advance their scientific careers. In addition to the aforementioned presentations by prominent speakers from academia, participants had the opportunity to present their research contributions and challenges in our first PhD forum that was organised as part of this summer school.

This document is organised as follows. Section 2 presents the general information about the first AIoTwin Summer School, followed by the official programme overview. In Section 3, we present the programme of the first PhD Forum that took place in the framework of the first AIoTwin Summer School. An overview and comments of the feedback survey conducted after the event is given in Section 4. We conclude the report in Section 5. Detailed programme, abstracts of all talks and the results of the feedback survey are given in the corresponding appendix sections.

2 First AIoTwin Summer School

The 1st AIoTwin Summer School was a 4-day event held at the historic St. John's Fortress in Šibenik, Croatia, from 4 to 7 September 2023. The event brought together participants from academia, both renowned experienced researchers and PhD students, to exchange ideas and learn about the latest advances at the intersection of AI and IoT.

The Summer School was organized by the AIoTwin consortium, a Horizon Europe project that aims to strengthen research and innovation excellence in AIoT in Croatia and other EU Member States. The project's four research domains are:

- Edge Computing and Orchestration
- Federated and Decentralised Machine Learning
- AI for Robust and Energy Efficient IoT
- Distributed Ledger Technology (DLT) for IoT

The Summer School covered all four research domains, with a higher emphasis on the first two research domains. The event featured a mixture of keynotes, hands-on sessions and tutorials delivered by leading experts from the scientific community. The Summer School also included the first AIoTwin PhD Forum, where participating PhD students had the opportunity to present their research topics with short pitch talks and then discuss their ideas and contributions with other participants and senior researchers from the AIoTwin consortium in a poster session.

The total number of participants was 36, including 3 invited speakers and 33 participants from the four AIoTwin partner institutions (10 top grade/senior researchers, 3 recognised researchers, 18 PhD students, 4 MSc students and 1 administrator). The total number of participants per institution is the following: 18 from UNIZG-FER, 7 from RISE, 5 from TUW, 3 from TUB and 3 external (invited speakers). The distribution of participants per institution is given in Table 1.

Table 1. Distribution of participants per institution

	UNIZG-FER	RISE	TUW	TUB	External	Total
Top Grade/Senior Researchers	4	2	0	1	3	10
Recognised Researchers	1	1	1	0	0	3
PhD students	8	4	4	2	0	18
MSc students	4	0	0	0	0	4
Administrators	1	0	0	0	0	1
	18	7	5	3	3	**36**

2.1 Overview of the 1st AIoTwin Summer School Programme

Dates: 4th of September - 7th of September, 2023

Venue: Educational campus of St. John's Fortress, Šibenik, Croatia

The event offered a full three-day programme (from 5 to 7 September, with a welcome reception on 4 September) specifically tailored to PhD students interested in IoT and AI. In addition to cutting-edge lectures by prominent speakers from academia on the latest developments and biggest challenges in AIoT, the event also included hands-on technical training and coaching sessions to develop skills for a successful PhD and orientation on the Horizon Europe funding programme.

The 1st AIoTwin Summer School served as a meeting point for prominent experts and PhD students to address the following research areas relevant to AI for IoT: Edge Computing and Orchestration, Federated and Decentralised Machine Learning, and AI for Robust and Energy Efficient IoT.

Aims of the summer school are the following:

- To introduce participants to the latest research and cutting-edge technology in the field of AIoT;
- To promote interactions and networking with peers working in the field;
- To help participants, especially PhD students, to build their skills for a successful research career and to establish contacts for possible future research collaborations; and
- To offer PhD students the opportunity to present their research and receive feedback from academics and highly qualified professionals in the AIoT field.

Figure 1. Summer school participants during the keynote talk by Thiemo Voigt

2.2 Programme Overview

To meet the desired outcomes, the programme included four keynote talks as well as four tutorials reflecting emerging topics from the area of IoT and AI.

On the first day of the Summer School, Prof. Petar Šolić gave a keynote speech on alternative sensing, followed by tutorials on LPWA protocols, the IMUNES network emulator for performance evaluation of edge deployments, a workshop analysing the skills and the path to a successful PhD, and orchestration aspects in distributed computing continuum systems.

The second day of the Summer School began with a keynote address by Dr Danh Le Phuoc on using knowledge graphs to build perceptual IoT systems, followed by hands-on workshops on federated learning for IoT edge devices and TUW SLO management framework. The day also included a PhD pitch session where PhD students presented their research on a variety of innovative topics.

The third and final day of the Summer School featured a keynote address by Prof. Thiemo Voigt on the journey towards in-body and battery-free IoT, followed by a keynote address by Alexander Artikis on complex event recognition. The day also included a tutorial on decentralized graph mining and a tutorial on proposal writing and the evaluation of collaborative Horizon Europe projects. The Summer School concluded with a boat trip to visit the stunning St. Nicholas Fortress, followed by a farewell dinner.

The full programme in available in APPENDIX 1: Detailed programme of the 1st AIoTwin Summer School. Note that on each day of the workshop, we posted a summary of the day on LinkedIn to promote the event to a wider audience and potentially attract interest for future events. Here are the links to the posts:

1. DAY 1, https://www.linkedin.com/feed/update/urn:li:activity:7105096800901971968,
2. DAY 2, https://www.linkedin.com/feed/update/urn:li:activity:7105517110453239812,
3. DAY 3, https://www.linkedin.com/feed/update/urn:li:activity:7106947026126274560.

The following keynote talks were held at the event:

- Keynote by Prof. Alexander Artikis (University of Piraeus): Can computers understand what is happening? A Tutorial on Complex Event Recognition
- Keynote by Dr. Danh Le-Phuoc (Technische Universität Berlin): Knowledge in Building Perception Systems
- Keynote by Prof. Petar Šolić (University of Split): IoT Implementation and Alternative Sensing
- Keynote by Prof. Thiemo Voigt (Research Institutes of Sweden RISE): Towards In-body and Battery-free Internet of Things

Abstracts of keynote talks are listed in APPENDIX 2: Keynote talk abstracts. Both the abstracts and presentations of the four keynote talks in pdf format can be found at https://www.aiotwin.eu/aiotwin/activities/1st_summer_school/keynote.

Figure 2. Keynote speakers

The list of tutorials is the following:

- Tutorial by Dr. Lodovico Giaretta (Research Institutes of Sweden RISE): Tutorial on Decentralized Graph Mining (Gossip Protocols + Graph Representation Learning)
- Tutorial by Dr. Pantelis Frangoudis, Dr. Ilir Murturi (Technische Universität Wien): Orchestration Aspects in Distributed Computing Continuum Systems
- Tutorial by Prof. Mario Kušek (University of Zagreb - Faculty of Electrical Engineering and Computing): The landscape of IoT protocols - practitioner's view
- Tutorial by Ivan Čilić and Dr Petar Krivić (University of Zagreb - Faculty of Electrical Engineering and Computing): Network emulator IMUNES and edge performance evaluation

Additionally, Edvin Listo Zec, a PhD student from RISE, reviewed the current challenges within the field of federated and decentralized learning, which is currently highly relevant for the AIoT field.

Abstracts of all tutorials are listed in APPENDIX 3: Tutorial abstracts. Both the abstracts and presentations of the four tutorials and Edvin's presentation in pdf format can be found at https://www.aiotwin.eu/aiotwin/activities/1st_summer_school/tutorials.

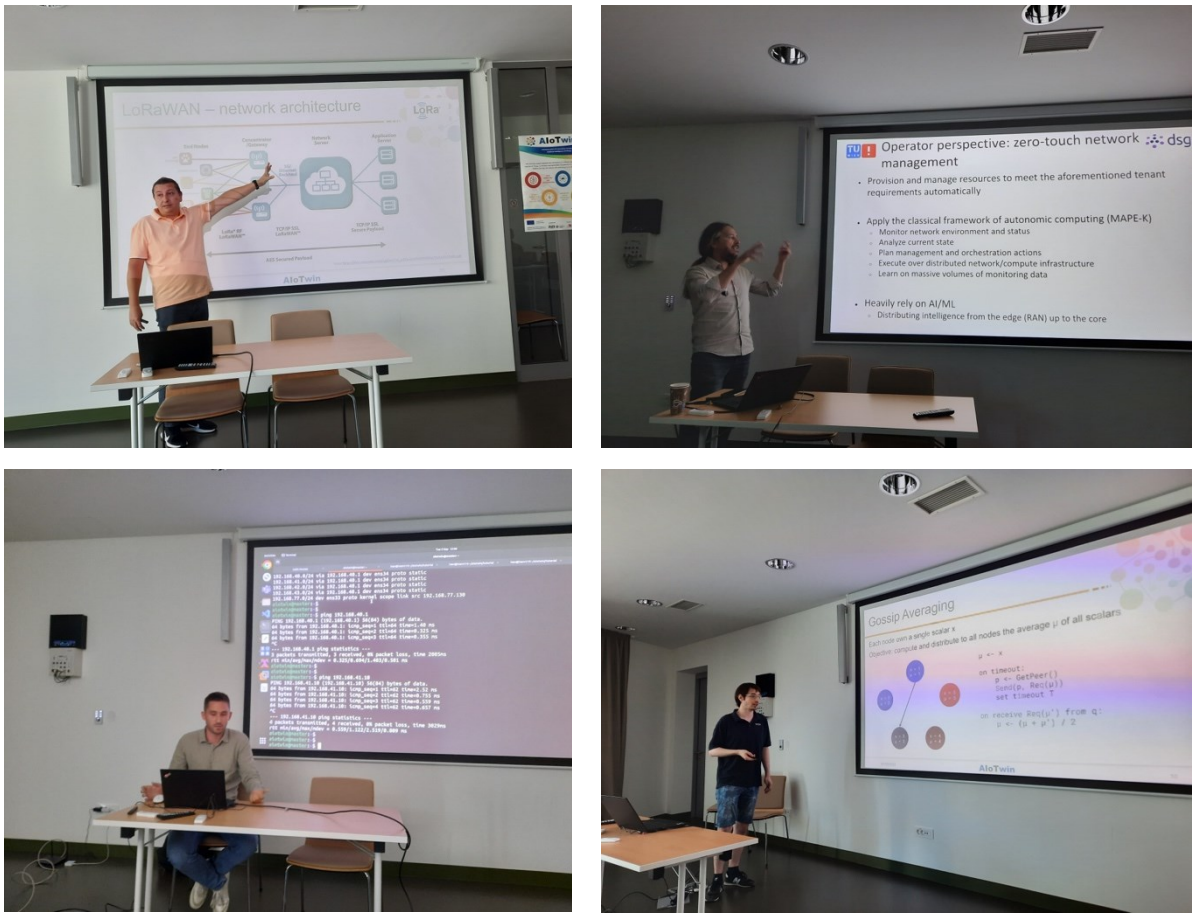


Figure 3. Tutorial sessions

In addition to the keynote talks and tutorials already mentioned, the programme also included two additional tutorials to develop general skills required for successful completion of the doctoral programme and a future academic career.

- Tutorial by Prof. Martin Gaedke (Chemnitz University of Technology): The 5 Steps of the PhD Journey - A coaching session for greater clarity, effectiveness, and fulfilment
- Tutorial by Prof. Ivana Podnar Žarko and Prof. Maja Matijašević (University of Zagreb - Faculty of Electrical Engineering and Computing): Proposal writing and evaluation of collaborative Horizon Europe projects

The PhD students particularly enjoyed Prof. Martin Gaedke's coaching session, which aimed to equip students with the essential understanding of the PhD lifecycle and tools they need to excel in their research careers. Martin explained the 5 steps for a successful PhD completion and specifically motivated them to pursue their goals and maintain interest and passion for their research.

Abstracts of the two tutorials for development of skills are available in APPENDIX 3: Tutorial abstracts. Both the abstracts and presentations in pdf format can be found at https://www.aiotwin.eu/aiotwin/activities/1st_summer_school/tutorials.

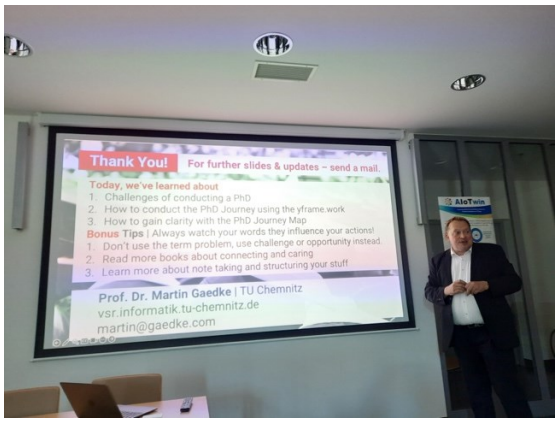
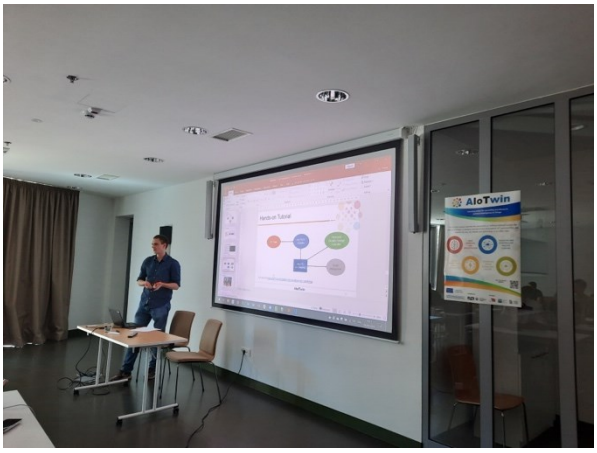


Figure 4. Coaching and skill-development sessions

Finally, the participants had the opportunity to take part in two hands-on workshops in which they could try out the application of modern technologies for federated learning and edge orchestration in practise. These sessions were highly interactive and led to many questions among the attendees.

- Hands-on workshop by Thomas Pusztai (Technische Universität Wien, TUW): TUW SLO management framework
- Hands-on workshop by Jicheng Yuan and Duc Manh Nguyen (Technische Universität Berlin, TUB): Federated Learning for IoT Edge devices

Abstracts of the two hands-on sessions are available in APPENDIX 4: Hands-on workshop abstracts. Both the abstracts and presentations in pdf format can be found at https://www.aiotwin.eu/aiotwin/activities/1st_summer_school/hands-on_workshops.

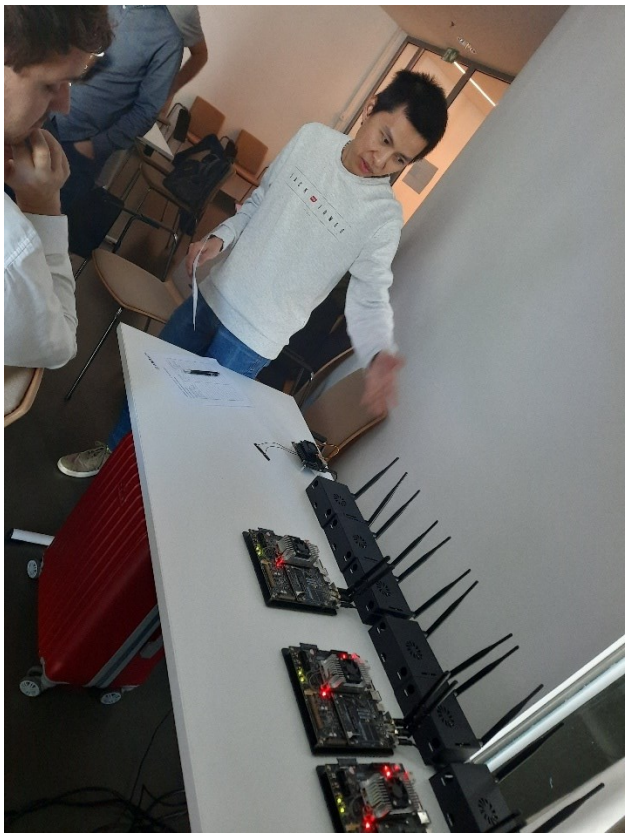


Figure 5. Hands-on sessions

3 PhD Forum

The PhD Forum was organised as part of the 1st AIoTwin Summer School to give PhD students the opportunity to present their work and discuss the details of their research questions and original contributions with top academics – professors and senior researchers working in the field of IoT and AI - from leading European universities. The aim was also to encourage interaction and networking between PhD students from different universities.

PhD students were invited to submit a two-page extended abstract to participate in the PhD Forum. Each submitted extended abstract was reviewed by at least two experts, professors and senior scientists from the AIoTwin consortium and invited speakers from the Summer School. During the event, the participating PhD students had the opportunity to first present their research to the audience in a pitch talk presentation and then discuss it with the audience and the dedicated reviewers of the AIoTwin consortium in the poster session.

Eleven PhD students from three AIoTwin institutions (UNIZG-FER, RISE and TUB) actively participated and presented their research topics and the results achieved in their doctoral studies through the short pitch talk presentations:

- Dalibor Fonović (UNIZG-FER): "Using reactive paradigm with COAP protocol"
- Daniel Perez (RISE): "Machine Learning for Combinatorial Resource Allocation"
- Dora Kreković (UNIZG-FER): "Optimizing Data Transfer in IoT: Strategies for Reducing Data Volume"

- Duc Manh Nguyen (TUB): "Cooperative Sensing with Semantic Stream Processing"
- Ivan Čilić (UNIZG-FER): "Runtime Model for Distributed Workload in the Edge-to-Cloud Continuum"
- Ivan Kralj (UNIZG-FER): "Collaboration between IoT-devices in Edge Computing hierarchical structure using TinyML"
- Katarina Mandarić (UNIZG-FER): "Negotiation-Enabled Multi-Agent System for Service Provisioning in Multi-User Scenarios"
- Marko Križmančić (UNIZG-FER): "Distributed topology control in networked multi-agent systems based on consensus protocol and graph neural networks"
- Saptarshi Hazra (RISE): "Data-Driven Approaches for Battery-Free IoT Networks"
- Shuai Zhu (RISE): "On-device Learning for Secure Internet of Things"
- Jicheng Yuan (TUB): "VisionKG: Unified Access for Integrated Visual Datasets"

The abstracts of all PhD Forum submissions are listed in APPENDIX 5: PhD forum abstracts. The submitted two-page extended abstracts in pdf format can be found at https://www.aiotwin.eu/aiotwin/activities/1st_summer_school/phd_forum.

Figure 6. Poster session and discussion during the PhD Forum

4 Summary of the feedback survey

A feedback survey was carried out after the event, which was completed by eight participants. The number of responses was rather low, but nevertheless informative. We formulated 16 questions and also asked for recommendations to help us improve future events.

It is interesting to note that all 8 participants rated their satisfaction with the event as 5.00 overall. 6 of the 8 participants stated that overall the summer school exceeded their expectations (the remaining 2 stated that it met their expectations).

The content of the workshop was predominantly rated as very clear and useful. The keynote presentations were rated as either excellent (50%) or very good (50%). Most participants (5) felt that the tutorials were both informative and effective in expanding their knowledge, while 3 said they could have been more engaging and 2 wished for more in-depth information. These are the points for improvement for the following events. For hands-on sessions, the majority indicated that they were (very) effective (6) in acquiring new skills (1 somewhat effective and 1 not applicable). The majority (6 out of 8) indicated that the balance between technical and skill sessions was just right and that there were plenty of networking opportunities.

In terms of the organisation of the PhD Forum, participants also found the structure overwhelmingly positive and indicated that they were able to communicate their research ideas effectively. Five out of six stated that the comments they received during the poster session were valuable and constructive, while one would have preferred to receive them in written form. Seven out of eight participants said they would consider participating in future PhD Forum AIoTwin summer schools. They would also be most likely to recommend the event to a friend or colleague.

The sessions and topics that were rated as most valuable are as follows: Hands on workshop; Federated learning, real life IoT applications, scenarios and research areas (among others); Knowledge Graphs for Building Perception Systems; Federated and decentralized learning. We also obtained a comment from a PhD student who is not closely involved in the AIoT field: “Considering that the topic of the summer school itself was not in my field, I was very surprised that I learned many interesting things. I think that all the lessons were more than useful and interesting, and so were the lecturers.”

All participants stated that they were very happy with the logistics and organisation overall, while the quality of the food and the excursion could be improved (50% were very happy). Most of the surveyed participants were also very happy with the venue, although one of the participants commented that the venue, being on a hill, is a bit remote from the city and other amenities. These are the points to consider when planning the venue for the next edition of the summer school.

All results of the feedback survey are included in APPENDIX 6: Results of the feedback survey.

5 Conclusion

This deliverable reports on the programme and outcomes of the first AIoTwin Summer School. The event brought together experienced researchers and PhD students from all AIoTwin partner institutions to exchange knowledge, discuss open challenges in the AIoT research field and network with fellows from other institutions. The event comprised a full three-day programme including a PhD Forum and was attended by a total of 36 participants, 18 of whom were PhD students. All PhD students received a certificate of participation indicating the equivalent of ECTS credits for their participation and engagement in the specific summer school activities.

To summarize the impressions, we can conclude that the targeted objectives were successfully met, including:

- Providing participants with a comprehensive overview of the latest advances in AIoTwin technology.
- Promoting collaboration and networking between participants as well as opening up additional opportunities for collaboration within the scope of AIoTwin project.
- Inspiring participants to pursue careers in AIoTwin research and development.

The AIoTwin Summer School was a successful event that provided a valuable opportunity for participants to network with other experts in the field and to be inspired to pursue careers in AIoTwin research and development. The Summer School also helped to raise awareness of the AIoTwin project and its goals.

APPENDIX 1: Detailed programme of the 1st AIoTwin Summer School

September 4	
7:00 pm to 9:00 pm	Welcome reception
September 5	
08:00 – 09:00	Breakfast
09:00 – 10:00	Opening Keynote talk 1 **Prof. Petar Šolić** (University of Split)**:** IoT Implementation and Alternative Sensing
10:00 – 11:00	Tutorial 1 **Prof. Mario Kušek** (University of Zagreb - Faculty of Electrical Engineering and Computing): The landscape of IoT protocols - practitioner's view
11:00 – 11:30	Coffee break
11:30 – 12:30	Tutorial 2 Ivan Čilić, Petar Krivić (University of Zagreb - Faculty of Electrical Engineering and Computing): Network emulator IMUNES and edge performance evaluation
12:30 – 14:00	Lunch break
14:00 – 15:30	Tutorial 3 **Prof. Martin Gaedke** (Chemnitz University of Technology): The 5 Steps of the PhD Journey - A coaching session for greater clarity, effectiveness, and fulfilment
15:30 – 16:00	**Coffee break**
16:00 – 17:30	**Tutorial 4** **Dr. Pantelis Frangoudis**, **Dr. Ilir Murturi** (Technische Universität Wien): Orchestration Aspects in Distributed Computing Continuum Systems
19:30 – 21:30	Dinner
September 6	
08:00 – 09:00	Breakfast
09:00 – 09:45	Keynote talk 2 Dr. Danh Le-Phuoc (Technische Universität Berlin): Knowledge Graphs for Building Perception Systems
09:45 – 10:30	Hands-on Workshop 1

	Jicheng Yuan and **Duc Manh Nguyen** (Technische Universität Berlin): Federated Learning for IoT Edge devices
10:30 – 11:00	Coffee break
11:00 – 11:45	Hands-on Workshop 1 (continued) Jicheng Yuan and Duc Manh Nguyen (Technische Universität Berlin): Federated Learning for IoT Edge devices
11:45 – 12:15	Hands-on Workshop 2 **Thomas Pusztai (Technische Universität Wien, TUW): TUW SLO management framework**
12:15 – 13:45	Lunch break
13:45 – 14:45	Hands-on Workshop 2 (continued) **Thomas Pusztai (Technische Universität Wien, TUW): TUW SLO management framework**
14:45 – 15:15	**PhD presentation** **Edvin Listo Zec** (Research Institutes of Sweden RISE): Current challenges within federated and decentralized learning
15:30 – 18:00	**PhD Forum** **PhD presentations and pitch talks** **Poster session**
September 7	
08:00 – 09:00	Breakfast
09:00 – 09:45	Keynote talk 3 Prof. Thiemo Voigt **(Research Institutes of Sweden RISE):** Towards In-body and Battery-free Internet of Things
09:45 – 10:30	Keynote talk 4 **Prof. Alexander Artikis** (University of Piraeus): Can computers understand what is happening? A Tutorial on Complex Event Recognition
10:30 – 11:00	Coffee break
11:00 – 12:30	Tutorial 5 Dr. Lodovico Giaretta (Research Institutes of Sweden RISE): Tutorial on Decentralized Graph Mining (Gossip Protocols + Graph Representation Learning)
12:30 – 14:00	Lunch break
14:00 – 15:30	Tutorial 6

	Prof. Ivana Podnar Žarko and **Prof. Maja Matijašević** (University of Zagreb - Faculty of Electrical Engineering and Computing): Proposal writing and evaluation of collaborative Horizon Europe projects
15:30 – 16:00	**Closing**
18:00 – 22:00	**Excursion and Farewell Dinner**
September 8	
08:00 – 09:00	Breakfast
09:00 – 15:00	AIoTwin Consortium meeting (only for project partners) – detailed agenda TBD Working lunch

APPENDIX 2: Keynote talk abstracts

Alexander Artikis: ***Can computers understand what is happening? A Tutorial on Complex Event Recognition***

Complex Event Recognition (CER) refers to the activity of detecting patterns in streams of continuously arriving "event" data over (geographically) distributed sources. CER is a key ingredient of many contemporary Big Data applications that require the processing of such event streams in order to obtain timely insights and implement reactive and proactive measures. Examples of such applications include the recognition of attacks in computer network nodes, human activities on video content, emerging stories and trends on the Social Web, traffic and transport incidents in smart cities, error conditions in smart energy grids, violations of maritime regulations, cardiac arrhythmias and epidemic spread. In each application, CER allows to make sense of streaming data, react accordingly, and prepare for counter-measures. In this tutorial, we will present the formal methods for CER, as they have been developed in the artificial intelligence community. To illustrate the reviewed approaches, we will use the domain of maritime situational awareness.

Danh Le-Phuoc: ***Knowledge Graphs for Building Perception Systems***

Semantic memory and episodic memory play a critical role in human perception. The semantic memory refers to our brain's repository of general world knowledge and episodic memory refers to our "episodic memory system", which encodes, stores, and allows access to "episodic memories", e.g. recollection of personally experienced events situated within a unique spatial and temporal contexts. This inspired us to introduce the semantic stream, a dynamic knowledge graph, wherein semantic and episodic memories are represented as interconnected graphs. This presentation allows integration and fusion of various kinds of sensory observations, e.g, images, videos and point clouds, into interlinked sub-symbolic and symbolic data streams at different levels of semantic abstractions.

The talk will delve into the fundamental elements of perception systems, from sensory inputs to high-level cognition, providing a comprehensive overview of how different knowledge types contribute to the whole process of building these systems. Special attention will be given to dynamic knowledge representation, semantic-driven learning, the fusion of sensory data, and the integration of contextual knowledge. Furthermore, I will share my experiences in building perception pipelines for autonomous vehicles and robots via a declarative programming model based on semantic streams. This programming

model enables developers to write semantic stream fusion programs, composed of if-then rules associated with stream data fusion operations for both reasoning and learning tasks.

Petar Šolić: ***IoT implementation and Alternative Sensing***

In this talk, an overview of IoT lab (University of Split, FESB) activities is to be provided. This involves an overview of practical full-stack implementation scenarios in different IoT use-cases. In addition, an overview of alternative sensing methodologies is to be provided aiming at reducing implementation costs and energy requirements.

Thiemo Voigt: ***Towards In-body and Battery-free Internet of Things***

In this talk, I present Fat-IBC, a novel approach for in-body communication that uses the human body's adipose (fat) tissue as a communication channel for radio-frequency based communication. Situated between layers of skin and muscle that act as a wave guide, the fat tissue allows for energy-efficient communication inside the body. Fat-IBC enables multi-hop Internet of Things (IoT) networks inside the body that allow to transfer data from deeply embedded places in the body to a place where it is easy to couple signals in and out. The relatively high bandwidth Fat-IBC enables supports interesting applications such as bionic arms and exoskeletons without cables. I further present some recent work on backscatter communication. Backscatter communication enables a drastic reduction of the energy consumption by outsourcing the energy-hungry task of generating the radio wave. This reduction of energy usage enables devices to run on harvested energy rather than on batteries. However, to ensure application progress also when there is no energy to harvest, state must be saved on non-volatile memory. I show how the combination of these two approaches enables a high data yield for sensing applications even when energy and a carrier wave are not always present. We believe that these technologies will also pave the way for battery-free IoT inside the body.

APPENDIX 3: Tutorial abstracts

Mario Kušek: ***The landscape of IoT protocols - practitioner's view***

This talk gives an overview of the typical architecture of IoT systems and the IoT protocol stack. We then address the requirements for wireless device communication in terms of range, frequency spectrum, network topology and energy consumption. We analyse and compare protocols belonging to the family of low-power and mid-range protocols (IEEE 802.15.4, ZigBee, Z-Wave, IEEE 802.11ah) and Low Power Wide Area Network (LPWAN) protocols such as LoRaWAN, NB-IoT and Sigfox. We report on our experiences with the use of LoRa and LoRaWAN for precision agriculture applications.

Ivan Čilić, Petar Krivić: ***Network emulator IMUNES and edge performance evaluation***

In this tutorial, we demonstrate the use of the Imunes network emulator/simulator and the applicability of the tool for conducting experiments in edge computing research. In the first part of the tutorial, we show the features of Imunes and how we used it to evaluate our dynamic scheduling algorithm for edge computing. In the second part, we perform a live demonstration of the tool and a step-by-step setup to test a simple service placement algorithm implemented within the K3s container orchestration tool.

Martin Gaedke: ***The 5 Steps of the PhD Journey - A coaching session for greater clarity, effectiveness, and fulfilment***

In this high-impact coaching session, we will embark on a deep exploration of the PhD journey, aimed at empowering students with the knowledge and tools they need to excel in their research careers. The core objective is to cultivate a holistic, strategic, and high-performance approach to the doctoral process, ensuring each student gains the maximum benefit from this critical period in their academic life.

The session's centerpiece is the innovative approach known as "The 5 Steps of the PhD Journey." This comprehensive roadmap demystifies the doctoral process by breaking it down into five manageable stages, including: onboarding with clarity and the right mind set, becoming an expert, structuring the research process in a smart way, developing contributions effectively, and mastering the final step of thesis writing and defense. By understanding these steps and their interconnections, students can navigate their PhD journey with greater clarity, confidence, and direction.

A central theme throughout the session is the concept of a "High Performance PhD." We'll explore this paradigm, emphasizing the importance of effectiveness, resilience, and personal well-being in academic research. We aim to instill a proactive mindset, where students learn to manage their workload effectively, cope with the typical challenges, and maintain well-being and relationships while still delivering exceptional research output.

Finally, we'll delve into an arsenal of proven strategies, tactics, and practical tools that will amplify the students' research skills and productivity. From the PhD Journey Map for clear and efficient strategic decision making to techniques for structuring you activities on what really matters most, this session will equip students with awareness and the right focus for every stage of their PhD journey. Overall, this coaching session promises to provide a blend of conceptual understanding, practical skills, and motivation, aiming to enhance the students' overall PhD experience, promoting clarity, effectiveness, and fulfilment in their research endeavours.

Pantelis Frangoudis: ***Orchestration Aspects in Distributed Computing Continuum Systems***

This tutorial begins by a definition of the emerging device-to-cloud computing continuum, and provides an overview of its distinctive features. We then clarify the meaning of orchestration in this context both from an infrastructure and an application service view. This dual perspective is a central theme in this tutorial. We then delve into the details of the infrastructure technologies that compose the continuum, both regarding connectivity and computation. The continuum is a complex computation environment, and managing it more efficiently calls for intelligent mechanisms. At the same time, next-generation IoT applications that run on top of it rely more and more on AI/ML processes. We thus focus on the nascent research field of "edge intelligence," which is at the intersection of edge computing and AI. The tutorial concludes with remarks on what we consider necessary for the management and orchestration of future distributed computing continuum systems.

Lodovico Giaretta: ***Tutorial on Decentralized Graph Mining (Gossip Protocols + Graph Representation Learning)***

This tutorial introduced the topic of deep learning on decentralized graph structures, including the motivation for fully decentralized learning, its potential use cases involving decentralized graphs, the problems faced in efficiently performing these learning tasks, and ongoing research into their optimization. In order to properly understand these aspects, the tutorial first provided the necessary background in Gossip Learning and Graph Neural Networks (GNNs). Gossip Learning was introduced as an efficient technique to perform fully decentralized aggregation tasks, and in particular ML model averaging.

GNNs were presented as the most effective approach for deep learning on graph-structured data.

Ivana Podnar Žarko, Maja Matijašević: ***Proposal writing and evaluation of collaborative Horizon Europe projects***

This is an introductory tutorial which provides essential information on the Horizon Europe R&I programme, covering the following topics:

- How to find information on call topics
- Requirements for defining a collaborative project
- Proposal preparation process
- Proposal evaluation steps
- Details of the application form (Part A and Part B) with examples
- Evaluation criteria (excellence, impact, and quality and efficiency of implementation)

Edvin Listo Zec: ***Current challenges within federated and decentralized learning***

Federated learning has received attention for its efficiency and privacy benefits, in settings where data is distributed among devices. Although federated learning shows significant promise as a key approach when data cannot be shared or centralized, current incarnations show limited privacy properties and have shortcomings when applied to common real-world scenarios. One such scenario is heterogeneous data among devices, where data may come from different generating distributions.

In this presentation we will go through federated learning and challenges associated with it, with a focus on heterogeneous data.

Mario Kušek: ***The landscape of IoT protocols - practitioner's view***

The architecture of Internet of Things (IoT) systems relies on a protocol stack that governs communication between devices. The physical and data link layers play a crucial role, exhibiting essential properties such as low power consumption. Standards like IEEE 802.15.4, ZigBee, and Z-Wave cater to mid-range IoT applications, while Sigfox, LoRa, LoRaWAN, LTE-M, and NB-IoT address long-range communication needs. The diversity of these standards reflects the flexibility required to support a wide range of IoT applications, from short-range, low-power scenarios to long-range, wide-coverage deployments. In this presentation, we will provide an overview of the currently available standards that are the most common choice in IoT, with reference to their advantages and disadvantages.

APPENDIX 4: Hands-on workshop abstracts

Jicheng Yuan, Duc Manh Nguyen: ***Federated Learning for IoT Edge devices***

The hands-on workshop "*Federated Learning for IoT Edge Devices*" explores the application of federated learning in the context of Internet of Things (IoT). It focuses on a decentralized machine learning paradigm in a Federated Learning manner, allowing edge devices, such as Jetson Nano and Jetson Xavier to collaboratively train models without sharing raw data. This approach enhances privacy and efficiency by conducting model training locally on devices, minimizing the need for centralized data storage. The

workshop highlights the potential of federated learning to empower IoT edge devices with intelligent decision-making capabilities while preserving data security and privacy.

Thomas Pusztai: ***FTUW SLO management framework***

This workshop first introduced the concepts of the open-source Polaris SLO Framework. This orchestrator-independent framework is designed for creating high-level Service Level Objectives (SLOs) and enforcing them using either generic or application-specific elasticity strategies in cloud and edge environments. The hands-on part guided participants through the creation of a custom horizontal elasticity strategy and an average CPU usage SLO for scaling a demo application.

APPENDIX 5: PhD forum abstracts

Dalibor Fonović: "Using reactive paradigm with COAP protocol"

The Constrained Application Protocol (COAP) is a lightweight communication protocol designed for efficient data exchange in resource-constrained environments and intended for use in IoT applications. However, the functionality of the COAP protocol is limited. By incorporating reactive program- ming concepts into COAP, its ability to manage dynamic and asynchronous communication can be improved to better meet the needs of modern IoT applications. The goal of this research is to investigate the integration of the reactive paradigm with the COAP protocol, which will be used in the dissertation as a mechanism to improve energy efficiency and reduce network congestion.

Daniel Perez: "Machine Learning for Combinatorial Resource Allocation"

This project investigates the potential of machine learning methods for optimizing resource allocation problems of combinatorial nature in large, heterogeneous networked systems. Traditional heuristic algorithms, while computationally less in- tensive, often result in sub-optimal solutions that lead to resource wastage and increased energy consumption. As a milestone in the project we introduce DeepGANTT, a novel learning-based sched- uler that leverages Graph Neural Networks and Transformers to solve an NP-hard combinatorial resource allocation problem for IoT networks with battery-free sensor tags. DeepGANTT offers up to 50% reduction in resource consumption compared to the state-of-the-art heuristic, and is capable of scaling to networks significantly larger than those used for training without the need to be retrained. The scheduler is designed for generalizability and elasticity, adapting to varied network sizes and conditions while maintaining efficient runtimes. Our findings pave the way for future research in applying machine learning techniques to enhance resource allocation in diverse networked systems.

Dora Kreković: "Optimizing Data Transfer in IoT: Strategies for Reducing Data Volume"

The rapid proliferation of Internet of Things (IoT) devices has led to a significant increase in data generation and transmission. However, the limitations of IoT devices, including constrained processing power, memory, and battery capacity, along with restricted network technologies, necessitate effective data management. This study offers an overview of various techniques proposed to reduce the volume of data transferred within IoT contexts. These techniques encompass approaches like data compression, aggregation, and selective transmission. By exploring the advantages, constraints, and suitable deployment contexts of these methods, this research aims to contribute to the evolving field of data reduction in the IoT environment. This contribution aims to improve network efficiency, reduce energy

consumption, and optimize data usage, thereby enhancing the overall landscape of data management in the IoT domain.

Duc Manh Nguyen: "Cooperative Sensing with Semantic Stream Processing"

This thesis is motivated by the challenge of effectively uti- lizing real-time sensor data in the IoT. The imbalance between vast data volumes and users' time-sensitive needs necessitates a shift from simplistic cloud-based approaches. The rise of IoT expose this issue, prompting the exploration of Fog/Edge Computing paradigms. This thesis seeks to leverage semantic technologies to enable autonomous, cooperative sensing at network edges, enhancing data discovery and exchange amidst sensor data heterogeneity. The fusion of Fog/Edge computing and semantics holds the promise of optimizing information processing in dynamic sensor environments.

Ivan Čilić: "Runtime Model for Distributed Workload in the Edge-to-Cloud Continuum"

Edge-to-Cloud Continuum (ECC) optimizes IoT data processing by executing it closer to the data sources. The hierarchical structure of ECC spans from resource-constrained IoT devices to high-performance cloud servers, providing a distributed IoT environment with lower network congestion, improved response times and enhanced security compared to cloud-based IoT solutions. Despite its advantages, ECC faces challenges due to its heterogeneous and dynamic nature that has to deal with uneven distribution of data sources. To address these challenges, in this doctoral research, we propose a runtime model for distributed workload in ECC. The model describes the behavior of data sources in ECC, the services required to process the generated data, and the underlying topology of ECC that hosts these services. This model serves as the basis for the implementation of the ECC workload simulator which provides insight into the data dynamics within the edge computing nodes and the ability of the processing services to handle the incoming workload. By simulating the workload and processing in a distributed ECC environment, the simulator can help optimize topology design, service scheduling, and data routing decisions.

Ivan Kralj: "Collaboration between IoT-devices in Edge Computing hierarchical structure using TinyML"

The coordinated integration of heterogeneous TinyML-enabled elements in highly distributed Internet of Things (IoT) environments paves the way for the development of truly intelligent and context-aware applications. Edge computing has emerged during the last years as a ground-breaking solution that permits to enrich regular IoT deployments with novel ser- vices and possibilities. Under this paradigm, the processing and storage capabilities of end-devices and edge-nodes are exploited in order to reduce their cloud-dependency by adding a new layer in the network architecture in charge of data aggregation, filtering, processing, and storage. On the other hand, TinyML is a recently-emerged paradigm that proposes to embed optimized Machine Learning (ML) models in units with limited computing resources, such as those powered by micro-controllers. Our goal in this doctoral research is to optimize traffic control systems through the integration of IoT-devices within an Edge Computing hierarchical structure. Specifically, the focus is on leveraging TinyML techniques in the context of IoT for traffic control applications.

Katarina Mandarić: "Negotiation-Enabled Multi-Agent System for Service Provisioning in Multi-User Scenarios"

Smart Homes and Environments have been the focus of research for many decades. From connecting devices, to simple automation rules, now Smart Homes are on another level. By introducing cognitive

capabilities with Internet of Things, it has become possible to create truly smart systems which offer services that cater to the wishes and needs of users. Researchers proposed very advanced Smart Home systems over the years, but mostly focus on single user scenarios. Scenarios involving multiple users with individual needs and desires that are often opposed to each other are largely neglected. In this paper, we discuss the possibility of the application of software agents, i.e. a multi- agent system in which users are represented by user agents who, knowing the preferences of their users, negotiate with each other to reach a joint decision that best satisfies all users.

Marko Križmančić: "Distributed topology control in networked multi-agent systems based on consensus protocol and graph neural networks"

This research aims to develop a distributed, adap- tive, and scalable method for controlling communication topology in networked multi-agent systems. The method uses algebraic connectivity tracking and resilience optimization, using a con- sensus protocol for estimating the global topology through local communication. Agents converge to a common state and collec- tively select the best link(s) to add or remove using a heuristic or novel graph neural network (GNN) method. Additionally, a new GNN model will enhance system resilience without compromising desired connectivity.

Saptarshi Hazra: "Data-Driven Approaches for Battery-Free IoT Networks"

The constant requirement for battery replacements is a significant barrier in the world of the Internet of Things (IoT), with concerns about battery sustainability and effective recycling. These critical challenges motivate the need for the growth of battery-free IoT, in which devices use ambient energy from sources such as photovoltaic or piezoelectric harvesters. However, due to the unpredictable and sporadic availability of ambient energy, there are obstacles in the design and implementation of such devices. The unpredictability of ambient energy emphasizes the requirement for methods that allow for frequent communication with efficient data transmission. Furthermore, because these devices have limited processing capabilities and must balance energy usage for computation with communication, securing them is partic- ularly difficult. In this abstract, we present three pertinent challenges and our data-driven approaches to these challenges.

Shuai Zhu: "On-device Learning for Secure Internet of Things"

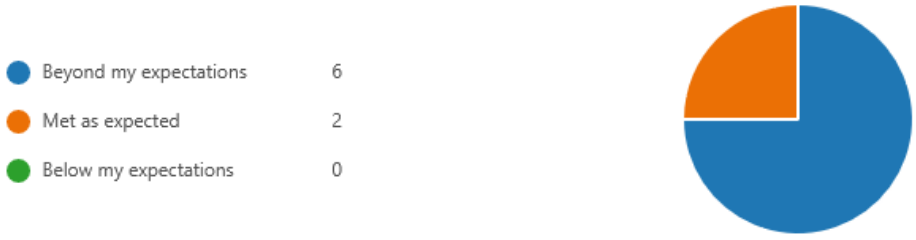
The recent breakthroughs in machine learning (ML) and deep learning (DL) have catalyzed the design and de- velopment of various intelligent systems over wide application domains. While most existing machine learning models require large memory and computing power, ML/DL applications on edge devices have been extensively studied in recent years. Most early systems exploit the inference capabilities of ML and DL models that are already trained on data captured from different mobile and embedded sensing components for specific application goals, such as classification and segmentation. More recently, on-device learning (ODL) has gained attention, which refers to using resource-constrained devices, such as mobile phones and embedded systems, for ML/DL model training. The reason is that ODL makes ML-based systems smarter and more robust, for example, ODL can help to cope with data drift problems by tuning deployed models according to deployed environments on the fly. However, most state-of-the-art ODL systems are designed for less resource-constrained devices, such as smartphones. This research project aims to enable ODL on devices with extremely limited hardware resources, for example, low-power IoT devices. A potential use case is to apply ODL to IoT security, for instance, jamming attack detection and classification for low- power wireless networks.

Jicheng Yuan: "VisionKG: Unified Access for Integrated Visual Datasets"

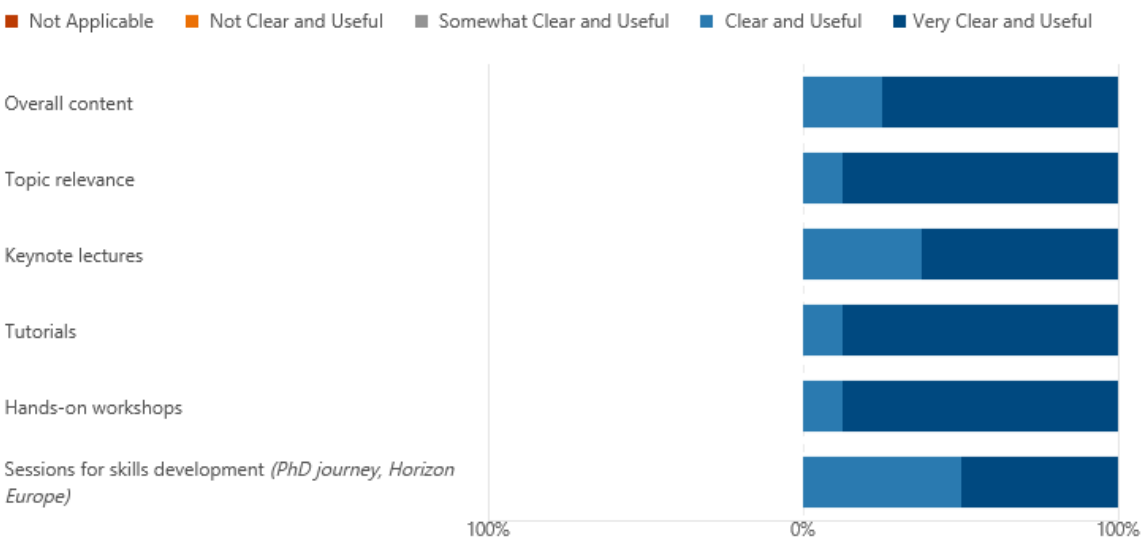
Large-scale datasets play a key role in the success of modern computer vision. However, most are narrowly tailored for specific tasks, with restricted image data distributions. There is no unified approach to organizing and accessing them across diverse sources, tasks, and taxonomies. Hence, models can only perform well in specific domains. This not only creates unnecessary over- heads when building robust visual recognition systems but also introduces biases into learning systems and limits the capabilities of data-centric AI. Addressing these problems, Vision Knowledge Graph (VisionKG) is a novel framework that interlinks and organizes visual datasets via knowledge graphs. As real-world scenarios encompass diverse weather conditions and imbalanced class distributions, we will introduce a semi-supervised domain adaptive object detection architecture empowered by VisionKG to navigate these challenges. Additionally, drawing on data enriched with semantically rich descriptions in VisionKG, we will evaluate VisionKG's efficacy in boosting transparency, ensuring traceability of data sources, and fostering trust in AI systems.

APPENDIX 6: Results of the feedback survey

1. Did the Summer School content meet your expectations?



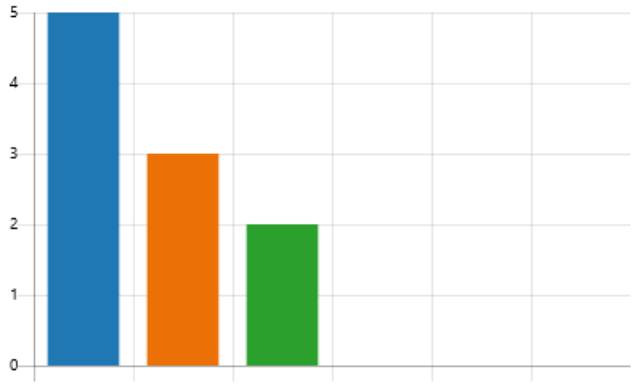
2. How did you find the following aspects of the event?



3. Rate the **keynote lectures** in terms of their significance or impact.

4. Did you find the tutorials both informative, offering interesting topics, and effective in expanding your knowledge?

Yes, the tutorials were both inf...	5
Yes, they were informative, th...	3
Yes, they were interesting, but...	2
No, they didn't fully capture m...	0
Not Applicable/Did Not Atten...	0
Ostalo	0



5. Rate the **hands-on workshops** in terms of their effectiveness in helping you acquire new skills

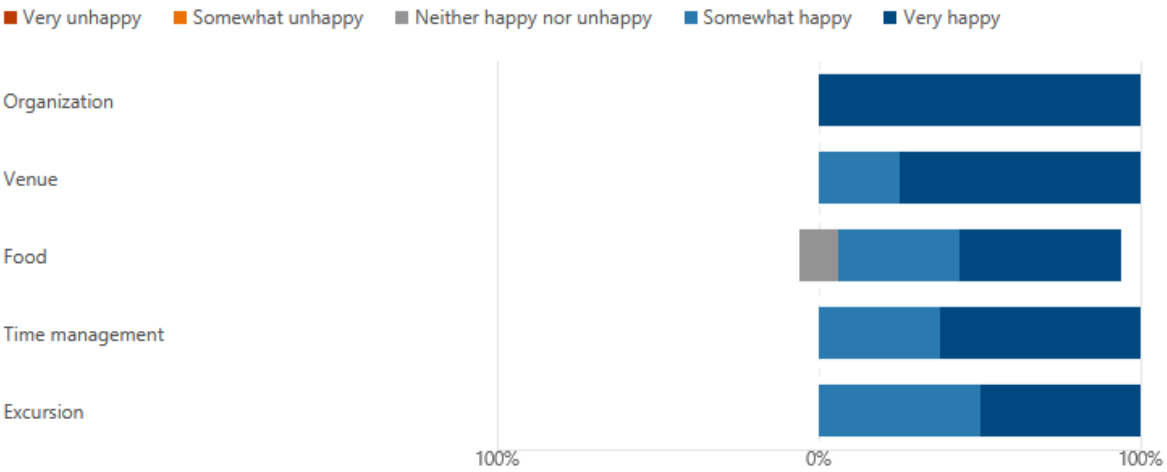
Not Applicable	1
Not Effective	0
Somewhat Effective	1
Effective	3
Very Effective	3

6. Balance Between Technical and Skill Sessions

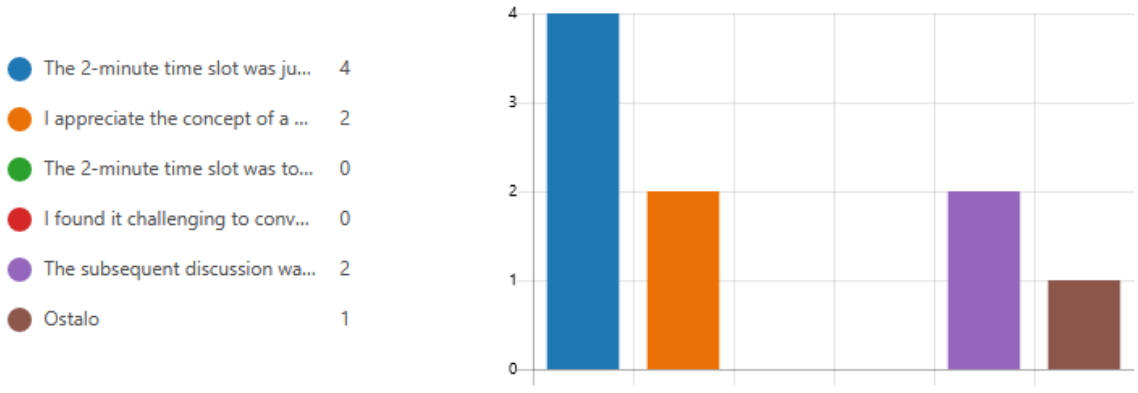
Yes, the balance was just right	6
There were too many technica...	0
There were too many skill sess...	1
I would have liked more techn...	1
I would have liked more skill s...	0
Ostalo	0

7. Networking Opportunities

8. How satisfied are you with the overall logistics and organization of the Summer School (e.g., registration, schedule, communication)?



9. Did you find the structure of the PhD presentations and pitch talks clear and organized?



10. Did the presenters effectively communicate their research or ideas?

Very Effective	3
Effective	5
Somewhat effective	0

11. For PhD Forum participants: Were the comments and reviewers provided during the PhD forum valuable and constructive?

Yes, the comments and review...	5
I would prefer written comme...	1
No, the comments and review...	0
Not Applicable/I did not recei...	1
Ostalo	0

12. Would you consider participating in or attending future PhD presentations and pitch talk sessions?

Yes	7
No	0
Maybe	1

13. Overall, how satisfied are you with the event?

8
Odgovori

★★★★★
5.00 Prosječna ocjena

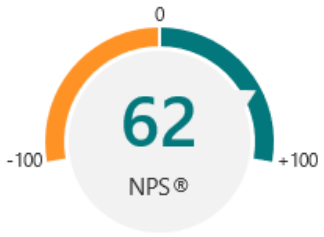
14. Which specific session topics did you find most valuable or interesting?

5
Odgovori

Najnoviji odgovori
""

15. How likely are you to recommend the event to a friend or colleague?

Zagovornici	6
Ravnodušni	1
Kritičari	1



16. Would you consider participating in future AIOTWIN Summer School events?

Yes	7
No	0
Maybe	1

17. If you have any particular recommendations to enhance the upcoming AIOTWIN Summer School events, kindly provide them here. Additionally, please don't hesitate to share any extra comments, suggestions, or feedback you may have regarding the Summer School.

3
Odgovori

Najnoviji odgovori

6 Acronyms

AI	Artificial Intelligence
AIoT	Artificial Intelligence of Things
IoT	Internet of Things
LPWAN	Low-Power Wide-Area Network

7 List of Figures

