DAUSY

Data fusion for indoor localization system based on UWB technologies

Ph.D. candidate

Olha POHUDINA

Cycle

XXXIX

Tutors

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1. Description of the research program

UWB (ultra-wide band) technology (IEEE 802.15.4a/z) is a technology standard optimized for applications based on microlocalization. Using this technology, it is possible to calculate distance and position indoors or outdoors, with an accuracy of the order of a few centimetres. Distance and position are calculated by measuring the times of flight (ToF) of the radio signal sent by one or more transmitters (tags) towards the receivers (anchors). For the system architecture to be scalable and allow for a greater number of transmitters (tags), one of the main techniques used for localization is the Time Difference of Arrival (TDOA). With such a technique, the quality and accuracy of localization depend on:

• Receiver synchronization accuracy

• Receiver positioning geometry

• Absence of occlusions between the transmitter and the receiver (NLOS)

In complex environments, such as industrial ones, the latter condition is not always verified at the expense of an increase in the mean localization error. To overcome this problem, it is possible to think about sensor fusion solutions, by equipping the tags with an inertial sensor and developing inertial tracking algorithms. In particular, the research activity connected to the PhD scholarship will include the study and design of localization and data fusion techniques relating to the industrial scenario detailed above, aimed at achieving the following objectives:

• Development of algorithms able to provide speed and acceleration, taking into account the low computational capability of embedded systems.

• Robustness analysis of the proposed algorithms in relation to the main criticalities of the system (drifts, environmental noise, etc.).

• Integration of the data obtained from the inertial system with those coming from the UWB localization.

In support of research activity, the most modern inertial sensors incorporating machine learning cores to optimize the computational calculation can also be used. The research will be applied to real scenarios provided by E80 Group SpA, an Italian company specialized in automated solutions for logistics 4.0.

Analytical and simulation models of localization will be prepared. Depending on the number of localization objects and the system architecture, the localization quality parameters will be assessed.

As a parallel related research direction, solutions where stationary anchors may be replaced by movable ones will be investigated. Specifically, methodologies, customized architectures and algorithms will be devised to enable the placement of anchors on mini UAVs, using additional localization tools.

To implement the proposed methods, an UWB swarm protocol will be proposed. One promising possibility will be to implement it on Crazyflies, microdrones with an STM32 microcontroller and DW1000 UWB chip. Extensive real-world experiments will be conducted to validate the proposed protocols. To conduct experiments and study the localization accuracy with moving anchors, it will also be explored (and exploited) the Implemented swarm range detection protocol: open source at https://github.com/SEU-NetSI/crazyflie-firmware.

2. Schedule of the research activities

Insert the research activities that you plan, or you have completed for the three years, including any period abroad.

First academic year

	Description	Period	Activity abroad /At the Company
Literature review on UWB technology	Investigation on the state of the art on the topic of UWB (ultra-wide band) technology and the solutions for microlocalization which are proposed	M01-M04	NO
Literature review on Data fusion for indoor localization system	Literature review and recent advances for indoor localization system. Properties and models of positioning sensors.	M01-M09	NO
Literature review on modeling and theoretical approaches to data fusion for localization	Literature review on modelling and theoretical approaches to data fusion for localization. Development of the simulation scenario.	M09-M12	NO
Research work	Statement of a research problem based on the literature review.	M11-M12	NO

Second academic year

	Description	Period	Activity abroad /At the Company
Research work	Analysing and solving different localization algorithms in terms of scalability, refresh rate, and energy requirements.	M1-M9	NO
Simulation/experimental setup	Evaluation of the proposed solution using simulation techniques such as agent-based modelling	M9-M12	SI
Research work	Individual research activity and preparation of manuscripts.	M3-M12	NO

Third academic year

	Description	Period	Activity abroad /At the Company
Research work	Definition of control architectures and algorithms for indoor localization of intelligent agent based on UWB technologies	M1-M9	YES (partially)
Research work	Individual research activity and preparation of manuscripts.	M6-M12	NO
Preparation for final dissertation	Writing of the PhD dissertation.	M 10- M 12	NO

3. Training and research activities plan

First academic year

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Game Theory for Controlling Autonomous Systems (DAUSY course)	18/06/2024 - 19/07/2024	Yes	2
	Multi-agent and multi-object estimation (DAUSY course)	16/02/2024- 26/02/ 2024	Yes	2
	Data-driven fault diagnosis and fault prognosis (DAUSY course)	June - July 2024	Yes	1
	Intelligent Control Systems (DAUSY course)	January-February 2024	Yes	2
B. Master's degree courses	Data Model Identification and Intelligent Control (DEI course)	01/10/2023 31/01/2024	Yes	6
C. Soft skill courses	CILS – Certificate of Italian as a Foreign Language		Yes	1
D. Participation to seminars	Seminars selected among the available ones			2
E. Participation to international congresses or workshops				4
F. Presentation of research products at international congresses or workshops	IEEE International Conference			
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			20
G. Individual research activity	Research activity with Indoor localization system in Laboratory			35
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals				5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			40
	TOTAL OF ECTS			60

Second academic year

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	PhD courses selected among the available ones	January-February 2024	Yes	5
	Winter or Summer Schools			2
B. Master's degree courses				
C. Soft skill courses	Seminars selected among the available ones			5

	Description	Period	Final Exam	ECTS
D. Participation to seminars				
E. Participation to international congresses or workshops	Participation to an international conference			3
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			15
G. Individual research activity				25
H. Supervision of students				
I. Integrative teaching activities				20
J. Preparation of manuscripts for conferences or journals				
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			45
	TOTAL OF ECTS			**60**

Third academic year

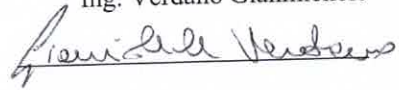|	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Seminars selected among the available ones			4
E. Participation to international congresses or workshops	Participation to an international conference			4
F. Presentation of research products at international congresses or workshops	Presentation of one product at an international conference			4
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			12
G. Individual research activity	Research activity and final dissertation			30
H. Supervision of students				
I. Integrative teaching activities				18
J. Preparation of manuscripts for conferences or journals	Writing and reviewing of academic articles for journal and / or conference publications			
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			48
	TOTAL OF ECTS			**60**

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