FIUS Sonar Sensor Project #ML1 and #ML2 (ML standalone) 5 ECTS

Organization: 2 - 4 persons per group

Project supervisors: Prof. Pech
Project coordinator: Mr. J. Umansky

Prj.	Task	Milestone	Date
#ML1	**Reliability test and improvement of a sensor system for object detection** An existing measurement system for detecting the position of the **first** echo (i.e. first reflection) of a pulsed ultrasonic beam shall be assessed and improved.		
	a) Introduction: Getting familiar with the measurement equipment and the measuring methods. Write a short literature review on ultrasonic distance measurement and describe the ML method used for finding the first reflection. The measurement equipment and experimental setup will be provided in room 8-102a or the Robolab.	**MS1**: **Introduction completed and report submitted**	**7 Jan 2024**
	b) Distance measurement data collection (data set #1) using different objects and persons. There are three distances available. First, the FIUS inbuilt distance measurement (d_{FIUS}). Second, the distance that you calculate from the first echo position. The first echo position is detected by the machine learning-driven first echo detection algorithm (d_{ML}). Third, the manually measured distance using a folding meter stick (d_{MAN}). Compare the distances d_{FIUS}, d_{ML}, and d_{MAN}. Data set #1 must consist of at least 1000 measurements. **Store ADC data and all distances.** Record the experimental setup properly, including all environmental conditions and photos of the objects, persons, and the measurement situation. Submit data set #1.	**MS2: Data set #1 & distance comparison submitted**	**20 Jan 2024**
	c) Write software (Python or C++) that automatically calculates and displays the distance d_{ML} between the sensor and the first reflection using the ML first echo detection algorithm given.		
	d) Conduct the same experiment as done in part b), this time with your self-written software for distance calculation (data set #2). Measure the distances manually. Compare the results and create a confusion matrix. If the deviation between the manually measured distance (d_{MAN}) and the automatically created distance (d_{ML}. d_{FIUS}) is less than 1 cm, then it shall be counted as a hit. Otherwise, it's a fail. Submit data set #2 and the confusion matrix.	**MS3: Data set #2 & confusion matrix submitted**	**3 Feb 2024**
	e) Improve the precision of the first echo detection by searching the maximum peak within the time window indicated by the ML-driven automatic search. Then conduct experiment b) again (data set #3). Create a confusion matrix.	**MS4: Data set #3 & confusion matrix submitted**	**24 Feb 2024**

	f) Research on and implementation of improvements such as: - Improve decision speed. Submit the measuring data and the result. - Improve measurement accuracy. Submit the measuring and the result. - Systematically search for and report the limits of the system. - Develop and implement software for cropping the first echo's data. After finding the position of the first echo, the part of the time signal near the echo shall be stored in a file. There should be an opportunity to pre-set the length and the position of the time window that shall be stored. - Develop a GUI for displaying the signal and the results. It shall be used for settings (e.g. length of the time window, position of the time window relative to the first echo position) too. Alternatively, extend the existing GUI. - Analyze systematically results, data, and FFTs, especially of false predictions, and give reasons, e.g. based on research scientific papers and books on ultrasonic physics.	**MS5: Research & improvement finished, data set #4 and report submitted**	**22 March 2024**
	g) Write a report and submit it. The report should contain theory, HW, SW (if applicable), data processing, measurement settings, variations, results, and photos. It also should explain briefly the context of the project to the module.	**MS6: Report & source code submitted**	**31 Mar 2024**
	h) Give a demonstration of your system. The demonstration date will be announced.	**MS7: Demonstration**	**TBA**

Grading: **Tasks a) – e), g), and h) are required to pass the module (grade 4).** Additional achievements such as tasks as of f) improve the grade. Comprehensible result description, staying on schedule, stable and reproducible measurement settings, systematic variations of boundary conditions, a well-structured report, and research of scientific papers about state of the art (SOTA) also contribute to the grade.

Prj.	Task	Milestone	Date
#ML2	**Parameter setting and reliability test of a sensor system <u>for infant carrier car seat sensing</u> in a car using a dashboard sensor**		
	a) Introduction: Getting familiar with the measurement equipment and the measuring methods. Write a short literature review on person detection in the interior of a car. The measurement equipment and experimental setup will be provided.	**<u>MS1</u>: Literature review submitted**	**7 Jan 2024**
	b) Measurement data collection (= data set #1) consisting of at least 1000 events of 40 ultrasonic scans of an infant carrier seat without and with a baby doll thus creating at least 40000 measurement scans. Prove that the baby seat is located in the center of the ultrasonic beam. **Store header and ADC data.** Record the experimental setup properly including all environmental conditions and photos of the clothing. Record the size of the baby doll. Record the distance between the ultrasonic sensor and the infant carrier seat. Take photos of all experimental setups. The classification result of the sensor will be stored automatically. Submit the data set. Create a confusion matrix of the classification results for data set #1.	**<u>MS2</u>: Data set #1 & proof & confusion matrix submitted**	**20 Jan 2024**
	c) Calculate FFT from all measurements of data set #1. Create, train, and test an MLP for classifying empty and occupied infant carrier seats. Input the FFT data to the MLP. Create a confusion matrix. Store the pre-trained MLP for further use.	**<u>MS3</u>: MLP & confusion matrix submitted**	**27 Jan 2024**
	d) Conduct another 40,000 measurements and classify them using the pre-trained MLP from milestone MS3. Submit data set #3 and the confusion matrix.	**<u>MS4</u>: Data set #3 & confusion matrix submit**	**10 Feb 2024**
	e) Create a CNN for classification and train it. Input FFT data from data set #3. Create a confusion matrix. Store the pre-trained CNN for further use.	**<u>MS5</u>: CNN and confusion matrix submitted**	**20 Feb 2024**
	f) Research on and implementation of improvements such as: - Optimize the MLP and CNN. - Test the limits of the classification. Find out how the classifiers (CNN, MLP) can be obfuscated. - Take measurements of the baby doll covered with a blanket. (data set #4) - Take measurements with sun protection mounted. Submit the measuring data. (data set #5)	**<u>MS6</u>: Research & improvement finished, data set #4 & 5 submitted**	**24 Mar 2024**

	-Analyze systematically results, data, and FFTs of false predictions and give reasons, e.g. based on research scientific papers and books on ultrasonic physics. g) Write a report and submit it. The report should contain theory, HW, SW (if applicable), data processing, measurement settings, and variations, results, and photos. It also should explain briefly the context of the project to the module. h) Give a demonstration of your system. The demonstration date will be announced.	**MS7 Report submitted** **MS8 Demonstr.**	**31 Mar 2024** **TBA**

Grading: **Tasks a) – e), g), and h) are required to pass the module (grade 4)**. Additional achievements such as tasks as of f) improve the grade. Comprehensible result description, staying on schedule, stable and reproducible measurement settings, systematic variations of boundary conditions, a well-structured report, and research of scientific papers about state of the art (SOTA) also contribute to the grade.