Title: Motion Detection Using FIUS Ultrasonic Sensor and Red Pitaya

Project Type (Topic from the list): ML Project- MOV: Movement detection

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Research Problem/ Hypothesis/ Motivation (Why do I want to do what I will do?)

Motion detection is required in many real-world situations such as safety systems, restricted area monitoring, and smart environments. In many cases, it is only necessary to know whether movement is present, not who or what is moving. Camera-based systems often face problems such as poor lighting conditions, privacy concerns, and high system cost.

This project is motivated by a simple and realistic scenario where a FIUS ultrasonic sensor is placed on a table, and a person walks from a few meters distance towards the sensor. Such a scenario represents real-life applications like intrusion detection and human presence monitoring. Ultrasonic sensors provide a low-cost and privacy-friendly alternative. However, detecting movement using ultrasonic signals is challenging due to noise and reflections. Therefore, this project focuses on improving motion detection using signal processing and machine learning techniques applied to FIUS sensor data acquired using Red Pitaya.

Flow Diagram:

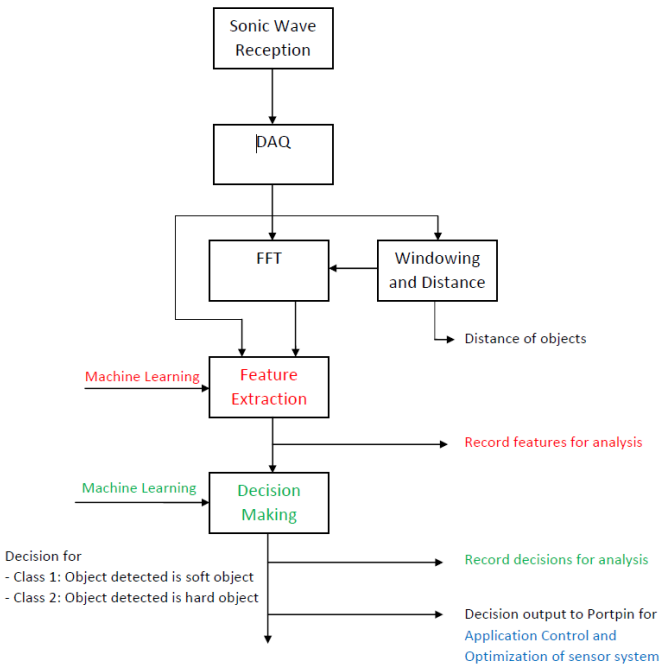

Fig 1: Elementary Functional Diagram of Data Processing of Sensor[1]

Goal/ Objective (What do I want to achieve?)

The goal of this project is to design, implement, and evaluate a motion detection system based on ultrasonic sensor data acquired using the FIUS sensor and the Red Pitaya measurement platform. The system aims to reliably detect human movement in a realistic scenario, where a stationary ultrasonic sensor is placed on a table and a person moves from a few meters distance towards the sensor.

The specific objectives of this work are:

- To acquire and analyse ultrasonic echo signals from the FIUS sensor during static and dynamic scenarios using Red Pitaya
- To extract meaningful time- and frequency-domain features (e.g., using FFT-based analysis) that capture temporal changes caused by motion.
- To develop a machine-learning-based classifier capable of distinguishing between movement and no-movement conditions
- To evaluate the performance of the motion detection system using quantitative metrics such as confusion matrices, accuracy, precision, and recall.
- To assess the robustness and limitations of ultrasonic-based motion detection under realistic environmental conditions

By achieving these objectives, the project aims to demonstrate the feasibility and effectiveness of ultrasonic sensors for reliable motion detection in applications where camera-based solutions are impractical or undesired.

Methodology (How do I want to achieve it?)

The motion detection task will be implemented by following the standard FIUS ultrasonic sensor data processing pipeline and adapting it for movement detection. The overall processing structure is based on established ultrasonic signal acquisition and analysis methods using FIUS sensors and the Red Pitaya embedded system [2]. First, the FIUS ultrasonic sensor will be placed at a fixed position on a table, while the Red Pitaya platform will be used for data acquisition. Ultrasonic pulses emitted by the sensor will be reflected by the surrounding environment. Two experimental scenarios will be considered:

1. a static scene with no movement, and
2. a dynamic scene where a person walks from a few meters distance towards the sensor. The reflected echo signals will be sampled and digitized by Red Pitaya and stored for further processing.

The reflected echo signals will be sampled and digitized by Red Pitaya and stored for further processing, following the sensor control and data acquisition approach described in [2]. Next, the acquired time-domain signals will be processed using signal processing techniques. Windowing will be applied to isolate the relevant echo portions, followed by Fast Fourier Transform (FFT) to analyse the frequency-domain characteristics of the ultrasonic signals. FFT-based analysis is used to make motion-related

variations in the backscattered ultrasonic signal measurable, as demonstrated in prior FIUS-based ultrasonic sensor research [2].

From the processed signals, meaningful features will be extracted that capture temporal variations caused by movement. Typical features include spectral energy, variance, and frame-to-frame differences between consecutive measurements. Similar frequency- and time-domain features have been shown to contain discriminative information in ultrasonic-based detection systems [2].

A supervised machine learning classifier will then be trained using the extracted features to distinguish between two classes:

- No Movement
- Movement Detected

The performance of the classifier will be evaluated using quantitative metrics such as confusion matrices, accuracy, precision, and recall. Both the extracted features and the classification decisions will be recorded to enable systematic analysis and validation of the approach, following the evaluation methodology commonly used in ultrasonic sensor-based classification systems [2].

By following this structured methodology, the project aims to demonstrate a reliable and reproducible approach to motion detection using FIUS ultrasonic sensor data and Red Pitaya.

Deliverables (How will I deliver my results?)

1. Project Report

A structured project report will be submitted, describing the problem formulation, motivation, methodology, experimental setup, signal processing steps, machine learning approach, and evaluation results. The report will follow the KICS (Keep It Clear and Structured) principle and include figures, tables, and quantitative performance metrics.

2. Functional Diagram and Evaluation Tables

A functional diagram of the developed motion detection system, based on the FIUS ultrasonic sensor data processing pipeline, will be provided. In addition, evaluation tables, such as confusion matrices and error tables, will be included to clearly present the performance of the motion detection approach.

3. Conclusion Summary

A concise conclusion summary will be delivered, highlighting the main findings, achieved objectives, limitations of the approach, and potential improvements. This summary will clearly state whether the project goals were met and discuss the relevance of the results for real-world motion detection applications.

References (if already available)

[1] P.Nauth, A.Pech – Introduction to FIUS Sensor (CAMPUAS Portal).

[2] P. M. Nauth, A. H. Pech and R. Michalik, "Research on a new Smart Pedestrian Detection Sensor for Vehicles," 2019 IEEE Sensors Applications Symposium (SAS), Sophia Antipolis, France, 2019, pp. 1–5, doi: 10.1109/SAS.2019.8705978.