ML and AIS Project

Feature extraction and assessment from FIUS (FRA-UAS stand-alone (!) Intelligent Ultrasonic Sensor) and/or ML for object differentiation, especially for automotive applications with calculation of confidence score.

Distinguishing Between Occupied Car Seats (Soft Object - Passenger) and Unoccupied Car Seats (Hard Object) Using Sensor Parameterization and Reliability Testing

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Project Summary :

Introduction

Feature extraction plays a vital role in numerous machine learning and Autonomous vehicles. It involves selecting and transforming raw data into a set of relevant and informative features that can be used to build predictive models, perform classification, clustering, or other data analysis tasks.

In the context of our title, feature extraction is undoubtedly a foundational element of the procedure for distinguishing objects with the aid of the FIUS sensor and ML techniques in the realm of automotive applications. FIUS sensor, purposefully designed for object recognition and differentiation, plays a central role in this endeavour. The FIUS system is composed of a transducer and a Red Pitaya microcontroller, combining hardware and software components to enable sophisticated ultrasonic data processing for real-world applications. Person or Object detection is required in many different fields including robotics and the autonomous vehicles.

The research initially focuses on utilizing sensor-acquired data to distinguish between hard and soft objects through the analysis of signals and Fast Fourier Transforms (FFTs). This study employs the Region-based Convolutional Neural Network (RCNN) method to discern unique features in signal characteristics, enabling the classification of objects based on their distinct properties.

Implementation & Methodology :

The detection of a passenger in a seat or an empty seat poses significant challenges, particularly concerning safety measures in autonomous vehicles. This detection is crucial not only for ensuring passenger safety but also for activating protective measures in case of pedestrian proximity. Conversely, during potential collisions with other vehicles or obstacles, immediate activation of protective systems for vehicle occupants becomes essential.[2]

To address these shortcomings and develop a preliminary prototype, we propose a sensor system for accurately detecting passengers in seats, utilizing ultrasonic signals.

Comprising an ultrasonic sensor and an embedded system, this prototype offers a cost-effective alternative compared to complex solutions like computer vision. Previous attempts at cost-effective object tracking in the side-near-field using ultrasonic sensor arrays have been proposed. However, our sensor system stands out as it can function both as a single device and within a sensor array. Notably, our method focuses on detecting and classifying objects accurately [2].

In the current phase of research, we aim at a deeper analysis of discriminatory features and at the integration of components in order to develop a detection of infant in baby seats. It consists of three parts [2]:
1.) Ultrasonic Sensor SRF02 with a mean frequency of 40 kHz and a power output of 150 mW (manufacturer's data) for sensing.
2.) Embedded System Red Pitaya with a sampling frequency of 1.95 MS/s and a resolution of 14 bit for controlling the SRF02 and for analog digital conversion of the received signal.
3) A Laptop which supports data analysis software.

The FIUS system incorporates ultrasonic sensors, such as the SRF02, interfaced via I2C, to emit ultrasonic pulses. These sensors receive signals, which are digitized using the Red Pitaya's analog-to-digital conversion input. The captured signals undergo WLAN transmission to a connected laptop for comprehensive signal analysis [2][fig1]

The first in the methodology is to collect data by using the red pitaya[fig2] to acquire multiple measurements from hard objects (empty car seat) and soft objects (i.e., passenger in car seat). The Red Pitaya needs a software to be download from CampUAS and get familiar with the GUI.

The project involves deploying the FIUS sensor in an autonomous car to collect data. We can collect data's of different types like person getting on to the driver seat staying for 2 seconds and similarly getting out of the car and collecting the data. We need to create confusion matrix using the data. The confusion matrix is formed after every type of dataset being added. The sensor-acquired data undergoes thorough pre-processing, including feature extraction and spectral analysis, where FFT is utilized to transform signals into the frequency domain, facilitating the visualization of spectrograms highlighting distinctive characteristics of hard and soft objects. The collected data is systematically segmented into classes representing hard (empty car seat) and soft (passenger in a car seat) objects, carefully annotated for classification purposes. An RCNN architecture tailored for signal processing is designed, considering the dimensions of input data and the nature of signal features. This model is trained using a split dataset comprising training, validation, and testing sets, optimizing it to accurately classify signals from both classes.

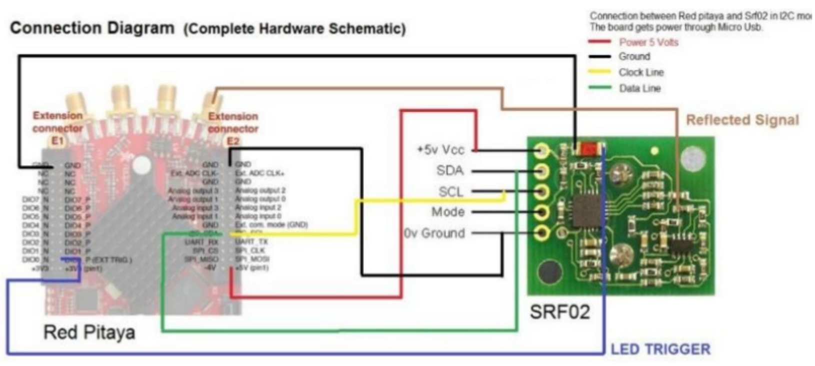

Fig.1Ultrasonic Sensor (Red Pitaya) [1]

Flow chart of Data processing sensor:

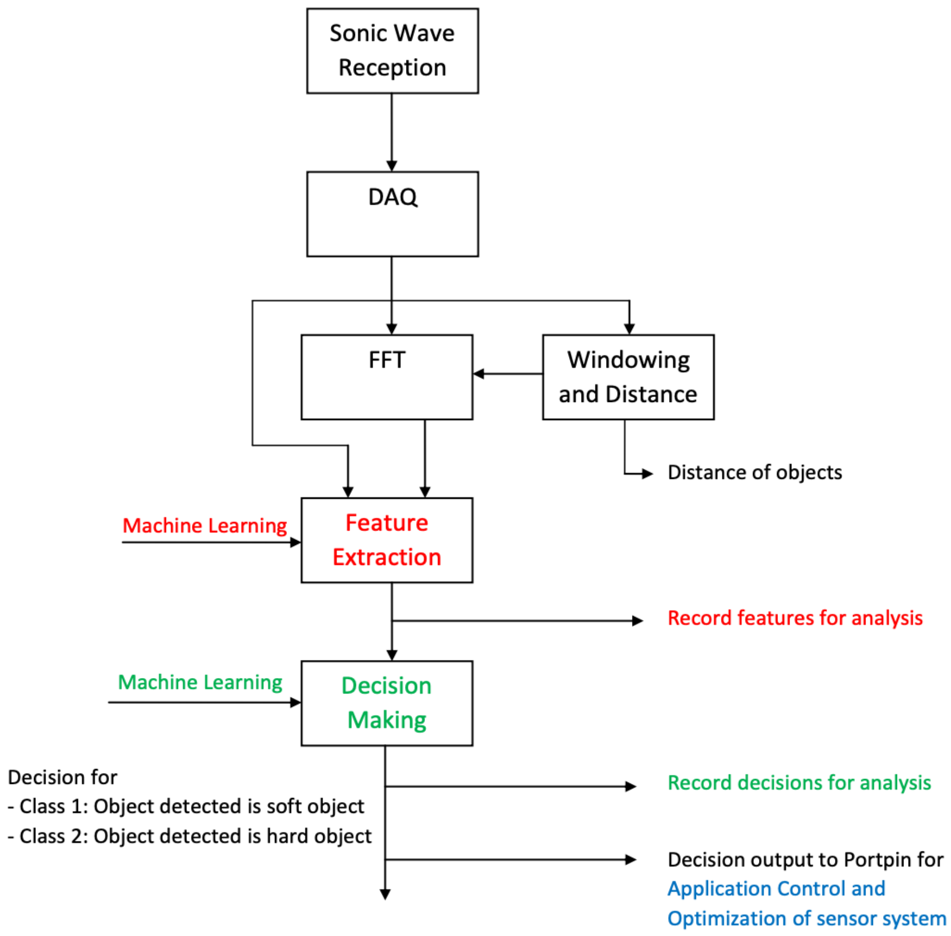

Fig2. Flow Chart of Sensor [1]

System Configuration and Setup:

The ultrasonic sensors, part of the FIUS technology, are strategically placed within the dashboard area to ensure an unobstructed view of the car seat. These sensors emit ultrasonic pulses directed towards the car seat, capturing the surrounding environment and potential occupants.

Hardware for data collection :

To make use of the Red Pitaya, we need to download software from CampUAS and become acquainted with its graphical user interface (GUI). This open-source software serves as a user-friendly example of how to interact with sensors and actuators effectively. Moreover, it offers flexibility for control through Python, and MATLAB, making it an ideal resource for educational purposes.

Approach:

We collect as many as data's sufficient enough to start with our algorithm. Programming is carried simultaneously with the data collection. Collect datasets every week by all varying methods.

Project Objectives:

- **Introduction to Equipment (MS0):**
    - This section aims to provide an initial understanding of the measurement equipment and methodologies used in the experiment.

- **Data Collection and Experimental Setup (MS1-MS2):**
    - Gather a dataset (#1) comprising a minimum of 1000 events with 40 ultrasonic scans to detect whether a seat is occupied (with a passenger) or empty seat in a vehicle thus creating at least 40000 measurement scans.
    - Ensure the correct positioning of the seat within the ultrasonic beam.
    - Measure and document the distance between the ultrasonic sensor and the vehicle seat. Capture images of all experimental setups.
    - Automatically store the sensor's classification results and submit the collected dataset.
    - Create a confusion matrix to evaluate the classification performance of data set #1.

- **Threshold Variations and Confusion Matrix Analysis (MS3-MS4):**
    - The next set of data focuses on different situations. We will collect similar data but with variations in the threshold settings. Then, we will create another confusion matrix using this adjusted dataset #2.

- **Data Collection and Confusion Matrix Analysis for Occupied Seat Detection with Engine Running (MS5-MS6):**
    - The third type involves the car's engine running with different positions of an adult to simulate scenarios with a person seated or an empty seat. We collect datasets in a similar manner for these cases and generate a confusion matrix based on the distinction between a person occupying a seat and an empty seat.

- **Enhancement and Optimization of Ultrasonic Sensor Systems for Car Seat Occupancy Detection (MS7-MS8):**
    - Systematically altering lateral/vertical seat positions, angles of incidence of sonic waves, and distances for additional measurements.
    - Improving sensor mounting methods to ensure stability, reproducibility, and minimize systematic angle of incidence variations.

  - Conducting measurements on diverse objects, including a clothed dummy, to observe and contrast detection outcomes.

- **Analysis, Report, and Demonstration (MS9):**
  - Provide explanations based on research findings from scientific papers and books.
  - Compile a comprehensive report encompassing theoretical aspects, hardware (HW), software (SW), data processing techniques, measurement settings, variations, results, and visual documentation (photos).
  - Conduct a demonstration to showcase the functionality of the developed passenger detection system for vehicle seats.

Tools for the implementation part:

1. **Language: Python**
2. **Libraries:**
   a. OpenCV
   b. TensorFlow/Keras
   c. Scikit-learn.
   d. Matplotlib
3. **IDE**: Visual Studio Code
4. **Model algorithm**: Convolutional Neural Network (CNN)

Project Timeline Overview:

S.no	**Milestones**	**Timeline**
1	MS0	2 weeks
2	MS1-MS2	2 weeks
3	MS3-MS4	2 weeks
4	MS5-MS6	2 weeks
5	MS7-MS8	3 weeks
6	MS9	2 weeks

Benefits and Applications:

Improved Safety Measures: Enhanced car seat occupancy detection ensures better safety by accurately identifying occupants. This information can trigger appropriate safety systems like airbags or seatbelt reminders, potentially reducing injury risks in accidents.

Efficient Resource Utilization: Accurate detection allows for optimized resource usage, such as adjusting air conditioning, which can lead to better fuel efficiency in vehicles by reducing unnecessary energy consumption.

Airbag Deployment: Determining whether a seat is occupied helps in intelligent airbag deployment, avoiding unnecessary airbag activation when the seat is empty, reducing potential injury risks.

Seatbelt Reminders: Alerting occupants to fasten their seatbelts if an occupant is detected, thereby promoting safety measures.

Conclusion:

In the landscape of autonomous vehicles, it's important for them to know the difference between hard objects (empty car seat) and soft objects (i.e., passenger in car seat) through the analysis of sensor-acquired signals and FFTs emerges as a pivotal component for safe and efficient navigation. By employing signal processing techniques like FFT and the Region-based Convolutional Neural Network (RCNN) methodology, this study has underscored the significance of accurate object differentiation. The comparison of signals and FFTs facilitated by the RCNN model has proven instrumental in enhancing safety measures, enabling autonomous systems to respond distinctively to various encountered objects, prioritizing safety protocols.

The successful implementation of this approach not only amplifies safety measures. By being better at telling whether there is a passenger in a seat or it's an empty seat, the car can make smarter choices. As technology gets better, it will keep improving how cars see and understand things, making driving even safer for everyone.

References:

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

[2] P.Nauth, A.Pech, M.Michalik Research on a new Smart Pedestrian Detection Sensor for Vehicles In: IEEE Sensor Application Symposium 2019 (SAS 2019, Sophia Antipolis)