Parameter setting and reliability test of a sensor system for infant carrier car seat sensing in a car using a dashboard sensor

Masters of Engineering
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Abstract—**Machine learning methods have been widely used in artificial intelligent systems, robotics and bioinformatics among other fields. Due to the difficulty and cost of these analyses, sophisticated machine learning approaches for this application area have been developed. In this project, we will first go over some basic concepts related to machine learning and classification techniques. Finally, we present some supervised learning methods for building and training an RF model that can classify and provide repeatable results. Our goal is to Parameter setting and reliability test of a sensor system for baby doll in a car seat detection.**

Keywords—ML, FFT, CNN, Confusion Matrix, Ultrasonic Sensors, Red Pitaya.

I. Introduction

In recent years, advancements in sensor technology have paved the way for innovative applications within the automotive industry. One such application is person detection in the interior of a car, which has gained significant attention due to its potential to enhance safety and security. By utilizing advanced sensors, car manufacturers can now implement systems that detect the presence of individuals inside a vehicle. These sensors are designed to accurately identify and track occupants, ensuring their well-being and enabling various safety features. In the European new car assessment programme (Euro NCAP) 2025 roadmap, the child presence detection is mandatory for safety requirements. The United States also mandates that automakers install rear occupant alert systems. Therefore, it becomes increasingly crucial to detect passengers inside the car[1]. Proper monitoring of passengers boarding a car can increase effectiveness, reliability, and safety with proper control of airbags during a crash. Achieving a reliable and low-cost system using machine learning techniques is the main goal.[4].

In general, video cameras, passive infrared (PIR), and ultrasound (US) sensors can be used for occupancy detection[3]. In this project, our focus is on Ultrasonic sensors. The performance capabilities of sensors to identify passengers is crucial. For machine learning models to produce meaningful outputs that autonomous systems can employ to carry out challenging tasks, they need sensor input data.

Pre-processing raw data is essential to raising the precision and dependability of machine learning algorithms. In this context, ultrasonic signals from human and non-human targets are gathered and processed to create the systems' input data. Understanding the importance of pre-processing raw data can help us develop more sophisticated autonomous systems and improve the efficiency and dependability of machine learning algorithms [6].

These are investigated in order to determine a pre-processing method that is efficient for feature extraction. In general, the following parameters are useful in separating humans from nonhumans: maximum amplitude, reflected energy and variation in Fourier transform shape over time[6].

II. Litrature Review

A. *Ultrasonic Sensor*

Ultrasonic Sensors are devices which use ultrasonic sound waves for various applications such as measurement of distance, detection of objects and obstacle avoidance. In general, they use sound waves which have frequencies higher that 20KHz.

Ultrasonic sensors operate by emitting high-frequency sound waves from a transmitter, which propagate through the air until they encounter an object in their path. Upon striking the object, the ultrasonic waves are reflected back to the sensor's receiver. The sensor then measures the time it takes for these waves to make the round trip. Using the speed of sound in the medium (usually air), the sensor calculates the distance to the object. This non-contact distance measurement capability makes ultrasonic sensors invaluable in various applications such as robotics, industrial automation, and parking assistance systems, where accurate proximity detection and obstacle avoidance are essential. Their reliability and simplicity contribute to their widespread use in diverse fields requiring precise distance measurements.

Ultrasonic sensors have the following characteristics:

- They are inexpensive.
- They are discrete and tiny.

- They are able to measure distances across smoke, dust, and humidity.
- They are low maintenance devices.

Because ultrasonic waves propagate slowly and quickly attenuate in air, they present two intrinsic challenges: (i) longer detection distance and (ii) shorter measuring time. An approach to these problems has been suggested: beam-forming with arrayed transmitters. In order to extend the detection distance, a number of research formed narrow beams for output amplification using square arrays. This directivity narrowing method works well for both raising output power and raising the precision of location estimation. To measure a large angular area with a narrow beam, many scans are needed. Without beam scanning, measurement can be done with a limited number of detections to produce a broad beam in relation to the detection plane.[7]

B. *FFT (Fast Fourier Transform)*

An adept understanding of the Fast Fourier Transform is required for understanding the goals of the project. A more accurate depiction of infant presence and activities is possible through the use of Fourier Transform in sensor fusion, which enables a thorough analysis of the combined frequency components. It dissects a signal into its spectral components, yielding frequency data as an output. The utilization of FFTs extends to tasks such as analyzing defects in machines and systems, ensuring quality control, and monitoring overall conditions.

The FFT (Fast Fourier Transform) is the best algorithm for implementing the DFT (Discrete Fourier Transformation). This method involves repeatedly sampling a signal in order to separate it into discrete frequency components, each of which is a single sinusoidal signal with variable amplitude, phase, and frequency [2].

C. *Red Pitaya - The sensor Equipment*

Electrical and electronic engineers use a wide variety of Tests and Measurement (T&M) instruments, which are crucial for projects and many types of engineering labs. Digital multimeters (DMM), oscilloscopes, signal generators, spectrum analyzers, frequency analyzers, and many more are examples of T&M equipment that are commonly used.

The Red Pitaya microchip STEM Lab board provides high bandwidth for the Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC). It is a popular option for radio frequency applications due to its features, especially as a radio receiver and transmitter. The sensor equipment is the Red Pitaya sensor, available in the the Lab for Autonomous System and Intelligent Sensors at Frankfurt University of Applied Sciences. To do the experiment and obtain the ADC data, the device was shipped with a preconfigured Linux system and the Lab's UDP_Client application.

D. *Confusion Matrix*

The confusion matrix, also known as the error matrix, is depicted by a matrix describing the performance of a classification model on a set of test data Fig:1 [3].

Understanding Confusion Matrix:

- True Positives (TP): when the actual value is Positive and predicted is also Positive.
- True negatives (TN): when the actual value is Negative, and prediction is also Negative.
- False positives (FP): When the actual is negative, but prediction is Positive. Also known as the Type 1 error.
- False negatives (FN): When the actual is Positive, but the prediction is Negative. Also known as the Type 2 error.

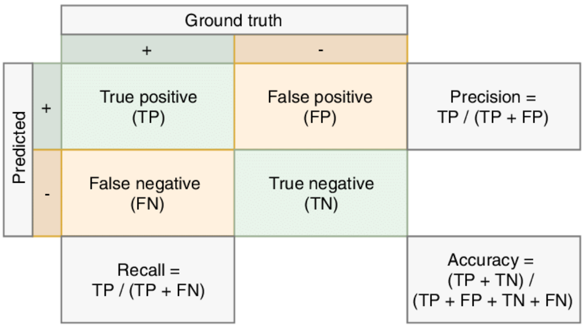

Fig: 1

E. *CNN*

In various domains such as surveillance, robotics, and autonomous vehicles, human detection plays a crucial role. With the advent of machine learning (ML) and deep learning (DL) algorithms, the performance of human detection systems has witnessed significant enhancements. Amongst the various architectures employed for human detection, convolutional neural networks (CNN) have proven to be highly successful, owing to their ability to learn and extract high-level features from images[8].

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