**Abstract:** **The purpose of this study was to evaluate the precision of a custom-developed software for measuring distances, using manual measurements as a benchmark. For this analysis, Data set #2 was employed. The procedure involved comparing manually obtained distances with those generated by the software. To assess the software's accuracy, a confusion matrix was utilized, categorizing discrepancies less than 1 cm as successful matches and those greater than 1 cm as discrepancies. The findings demonstrated the software's commendable precision, with most measurements lying within the acceptable margin of error. The confusion matrix offered a detailed insight into the software's capability to measure distances accurately, underscoring its potential utility and dependability for various applications.**

Reliability test and improvement of a sensor system for object detection

Course Information Technology

Modules Autonomous Intelligent Systems and Machine Learning

By Dr. Peter Nauth and Dr. Andreas Pech

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# INTRODUCTION

In numerous sectors, such as industrial processes, robotics, and navigational systems, the precision of distance measurements is paramount. The evolution of technological capabilities has paved the way for software-driven methods of determining distances, presenting a more convenient and efficient alternative to conventional manual techniques. Nevertheless, the dependability and precision of these software solutions must undergo thorough verification to confirm their fitness for real-world application.

This research was conducted to scrutinize the efficacy of a bespoke software tool designed for distance measurement, focusing on data set #2 for this purpose. The study aimed to juxtapose the distances calculated by this software against those obtained through manual measurement to ascertain the software's precision. A significant aspect of the evaluation was the comparison of manual measurement distances (dMAN) with those computed by the software (dML, dFIUS), with deviations under 1 cm being considered satisfactory and those beyond this limit signaling potential measurement errors.

The intent of this investigation was to shed light on the software's utility and dependability for measuring distances. The outcomes of this study enrich the collective knowledge on the viability of software-based tools for distance measurement in practical settings. Moreover, the methodology applied in this research, including the development of a confusion matrix, lays down a comprehensive framework for the future examination of software intended for distance calculation.

# METHODOLOGY

In the initial phase of this project work, data acquisition is conducted using an ADC to capture readings from both hard surfaces and persons positioned at distances of 1 meter and 50 centimeters respectively. To ensure robust data sampling, 1000 measurements were collected for each combination of distance and surface condition.

Following data acquisition, a custom software algorithm has been developed to process the acquired ADC data. This algorithm performs Fast Fourier Transform (FFT) analysis on the raw ADC readings, thereby converting them into frequency domain representations, enabling a deeper understanding of the characteristics embedded within the measured signals. Figure 9 and figure 10 showcases the ADC to FFT plot for hard object and person at 1m distance from the sensor.

Overall, this approach enables significantly more refined insights into the properties of both hard objects and person, by leveraging FFT analysis to extract frequency domain information.

The code complements this methodology by serving as a tool for processing and visualizing the ultrasonic measurement data stored in a CSV file. Upon importing necessary libraries, including NumPy, Pandas, Matplotlib, and SciPy, the script loads the dataset and selects specific set of columns for analysis. Each signal within the dataset undergoes a series of signal processing procedures, including Fourier Transform computation, noise filtering, and envelope detection using the Hilbert Transform. Additionally, peaks are detected in the envelope of the filtered signal using SciPy's find\_peaks function.

Furthermore, the script segments the signal into windows, applies a Hanning window to each segment, and computes the FFT to analyze frequency content. This results in the generation of four distinct plots for each signal, showcasing various aspects such as the original noisy signal, FFT analysis of both noisy and filtered signals, filtered signal with envelope and detected peaks, and the Fourier Sub Scan Spectrum. Finally, the generated plots are saved as PNG files for further analysis or visualization.

In summary, the script provides a means of gaining insights into the characteristics of ultrasonic signals and facilitates interpretation of the underlying data through visual representation, complementing the methodology outlined in the study.

Results:

A screenshot of a computer

Description automatically generated

Figure 1: ADC to FFT plot for object placed at 1m

A screenshot of a computer

Description automatically generated

Figure 2: ADC to FFT plot for an object placed at 50cm

A screenshot of a computer

Description automatically generated

Figure 3: ADC to FFT plot for soft object standing

A screenshot of a computer screen

Description automatically generated

Figure 4: ADC to FFT plot for soft object sitting

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