***Abstract* —This experiment aimed to assess the accuracy of a self-written software for distance calculation in comparison to manual measurements. Data set #2 was used for this analysis. The distances were measured manually and compared with the distances calculated by the software. A confusion matrix was created to evaluate the performance of the software, where deviations of less than 1 cm between manual and software-calculated distances were considered hits, while deviations exceeding 1 cm were classified as fails. The results indicated that the software achieved a high level of accuracy, with a majority of measurements falling within the acceptable deviation range. The confusion matrix provided a comprehensive overview of the software's performance, highlighting its effectiveness in accurately calculating distances. This experiment underscores the reliability and utility of the self-written software for distance calculation in 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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***Keywords—Distance Calculation***

# INTRODUCTION

Accurate distance measurement is crucial in various fields, including industrial applications, robotics, and navigation systems. In recent years, advancements in technology have led to the development of software-based solutions for distance calculation, offering convenience and efficiency compared to traditional manual methods. However, the reliability and accuracy of such software tools need to be rigorously evaluated to ensure their suitability for practical use.

In this study, we experimented to assess the performance of a self-written software for distance calculation, using data set #2 as the basis for analysis. The objective was to compare the distances computed by the software with manually measured distances and to evaluate the software's accuracy. A key criterion for assessment was the deviation between the manually measured distance (dMAN) and the distances calculated by the software (dML, dFIUS). Deviations of less than 1 cm were considered acceptable, while deviations exceeding this threshold were deemed indicative of potential inaccuracies.

Through this experiment, we aimed to provide insights into the effectiveness and reliability of the self-written software for distance calculation. The findings of this study contribute to the broader understanding of software-based distance measurement tools and their applicability in real-world scenarios. Additionally, the evaluation framework established in this experiment, including the creation of a confusion matrix, offers a systematic approach for assessing the performance of distance calculation software in future studies.

# METHODOLOGY

In the initial phase of this study, data acquisition was conducted using an Analog-to-Digital Converter (ADC) to capture readings from both hard and soft surfaces positioned at distances of 1 meter and 50 centimeters. Specifically, measurements were obtained from subjects positioned in seated and standing positions on the soft surface. To ensure robust data sampling, 1000 measurements were collected for each combination of distance and surface condition.

Following data acquisition, a custom software algorithm was developed to process the acquired ADC data. This algorithm was designed to perform Fast Fourier Transform (FFT) analysis on the raw ADC readings, thereby converting them into frequency domain representations. This transformation enabled a deeper understanding of the characteristics embedded within the measured signals.

The conversion from ADC to FFT facilitated the extraction of key frequency components from the acquired data, allowing for a more comprehensive analysis and interpretation of the ultrasonic measurements. By representing the raw ADC data in the frequency domain, the software provided enhanced insights into the acoustic signatures associated with different surface conditions and distances.

Overall, this approach significantly improved the analysis of ultrasonic measurements by leveraging FFT analysis to extract frequency domain information. This, in turn, enabled more refined insights into the properties of both hard and soft surfaces at varying distances.

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 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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