Proceedings of 2nd Student Conference on Sensors, Systems and Measurement 2023

15th June

CTU in Prague, Department of Measurement

About the Conference

Organized by the CTU in Prague, Faculty of Electrical Engineering and supported by a group of Universities, Academics and Companies worldwide.

The conference aimed to give students an opportunity to present their research results, improve their presentation skills, provide the floor for discussion, and exchange ideas and experience. Presentation of the best thesis results has raised awareness of topics solved at different laboratories and broadened the horizons for possible exchange and stays abroad.

The main topics of the conference is Sensors, Measurements, Measuring Systems, and Instrumentation divided into the two sections:

- Sensors, Materials and its Application
- Instrumentation and Measurement Systems

Within the conference itself, lectures from the industrial area have been given to help students in deciding on their future professional life.

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Conference Programme

Thursday, 15th June

9:00 - 9:05 Start of the Conference - **Introduction of the Student Conference on Sensors, Systems and Measurment**

9:05 - 11:00 Section A - **Sensors, Materials and its Application**

9:05 - 10:00 **Industry partner I - BTL Medical Technologies s.r.o.**
Jan Kriz: Conquering Challenges in High-End Medical Device Manufacturing

10:00 - 10:15 **Annealing of Nanocrystalline Wires for Magnetic Sensors Application**
Diana Hrakova, Faculty of Electrical Engineering, Czech Technical University in Prague

10:15 - 10:30 **Noise Characteristics of Mems Absolute Pressure Sensors**
Albert Mlcoch, Brno University of Technology

10:30 - 10:45 **System for Acoustic Detection and Localization Based on Two Microphones**
Matej Trnka, Faculty of Electrical Engineering, Czech Technical University in Prague

10:45 - 11:00 **Design, Calibration, Launch, and Data Processing of Sounding Rocket Payload to Measure the Earth's Magnetic Field**
Abigail Mthethwa, University of Johannesburg, South African National Space Agency, South Africa
David Novotny, Faculty of Electrical Engineering, Czech Technical University in Prague

11:00 - 13:00 Conference Lunch

13:00 - 15:00 Section B - **Instrumentation and Measurement Systems**

13:00 - 14:00 **Industry partner II - STMicroelectronics Application GmbH**
Jan Pistulka: Automotive systems, a shift toward tomorrow

14:00 - 14:15 **Statistical Approach for BTT Probes Distribution**
Mohammed Lamine Mekhalfia, Institute of Thermomechanics of the CAS

14:15 - 14:30 **Raspberry Pi Pico Development Kit**
Matej Poncak, Brno University of Technology

14:30 - 14:45 **Exploring the ChatGPT Capabilities for Creating Measuring Applications in LabVIEW**
Vlastimil Mancl, Brno University of Technology, Faculty of Electrical Engineering

14:45 - 15:00 **Measurement of Projectile Position in Dynamic Projected Target**
Vaclav Vesely, Faculty of Electrical Engineering, Czech Technical University in Prague

15:00 - 15:15 **Universal Graphical User Interface for Data Visualization and Control of Custom User-Made Measuring Instruments**
Jiri Maier, Faculty of Electrical Engineering, Czech Technical University in Prague

15:15 - 15:45 Coffee break

15:45 - 16:00 **Awards, Closing of the Conference**

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ANNEALING OF NANOCRYSTALLINE WIRES FOR MAGNETIC SENSORS APPLICATION

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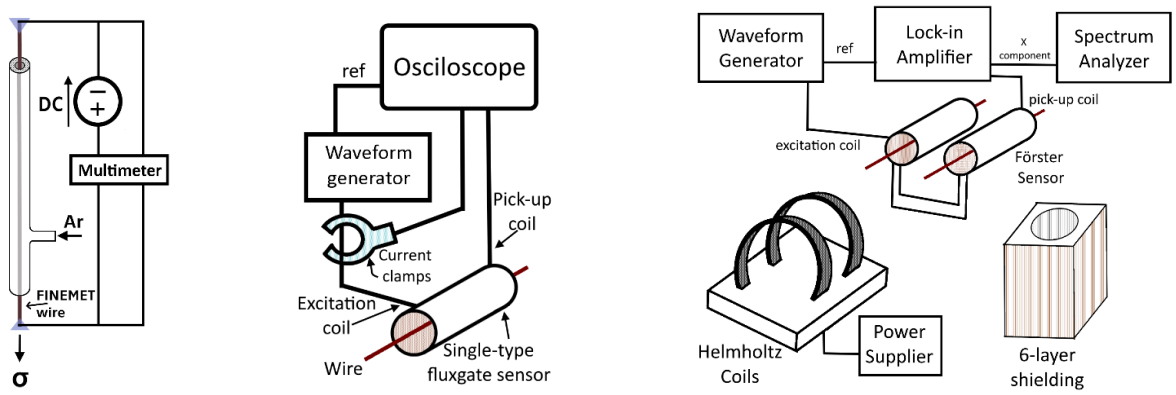
1. INTRODUCTION

One of the most important parts of a fluxgate sensor is a magnetic core. This work is dedicated to studying fluxgate sensors based on a nanocrystalline wire as a core and comparing it to the performance of amorphous wire with chemical composition $(Co_{94}Fe_{06})_{75}Si_{15}B_{10}$ [1]. Both wires were manufactured by the Institute of Technical Physics, Iasi, Romania.

2. METHODS AND RESULTS

For all experiments described in this paper, we have been using amorphous master alloy wires with a nominal composition of $Fe_{73.5}Cu_{l}Nb_{3}Si_{13.5}B_{9}$ manufactured by the Institute of Technical Physics, Iasi, Romania. The wire diameter is 0.12 mm. During the annealing process, we could control such parameters as the gas environment, annealing time, annealing current, and applied tension to control the crystals' growing process. [2] The flash annealing is performed by passing the current through the wire in the Ar atmosphere which prevents oxidation. BH loops were measured at 1 kHz on straight wire samples using an excitation coil (H) with 400 turns, and a secondary (B) coil with 200 turns. Using the annealed wires we built the Forster-type fluxgate sensors. The same sensors were used for studies of amorphous wire as a core. [1] For the measurement of the sensor noise, we have used 6-layer permalloy shielding. The diagrams of the measurement setup are shown in Figure 1.



a) Annealing process **b) Material characterization** **c) Sensor characterization**

Figure 1. Experimental setups and sensors

To reach different temperatures for controlled crystallization it is necessary to apply different currents for different values of applied stress. Figure 2 shows the effect of applying different values of applied current and tensile stress. High tension prevents the fast growth of crystals, however when the temperature reaches a higher value, the crystal growth is uncontrollable, and the impact of tension is negligible. Summarizing the conducted experiments, the optimum annealing conditions for $Fe_{73.5}Cu_{l}Nb_{3}Si_{13.5}B_{9}$ nanocrystalline wires with 0.12 mm diameter are the following: annealing time should be in the range of 15-60 s; annealing current should be in the range of 490-505 mA;

applied stress for the wire 0.12 mm in diameter should be in the range of 8-12 MPa. The measured parameters of the Förster type sensor with the core wires annealed under different tensile stress is shown in Figure 3 and represent how the tensile stress could impact the crystals grown and hence sensitivity. The comparison of fluxgate sensor performance with the amorphous and nanocrystalline core is depicted in Figure 4.

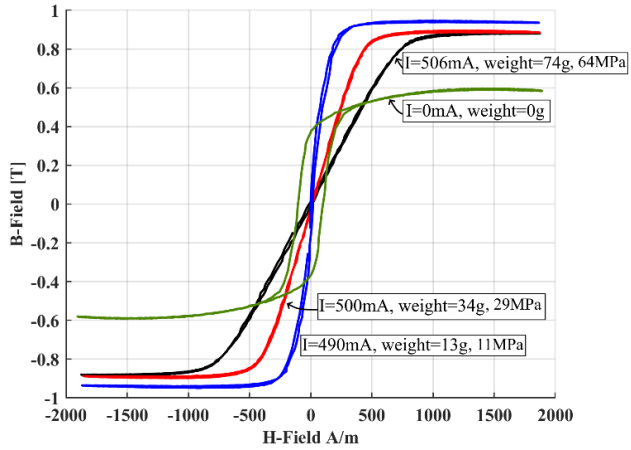


Figure 2. BH loop of the core, 1kHz, 10V

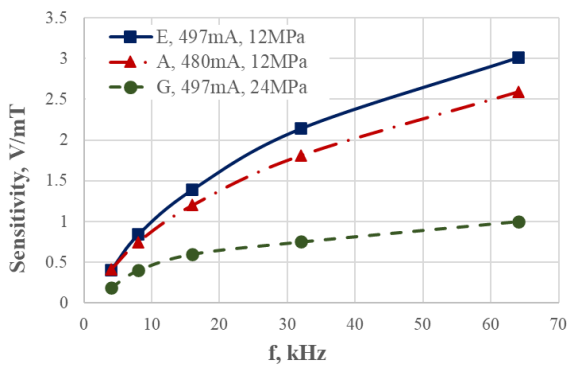


Figure 3. Sensitivity of the Forster-type fluxgate as a function of the frequency with different applied stress and annealing current, 15 s

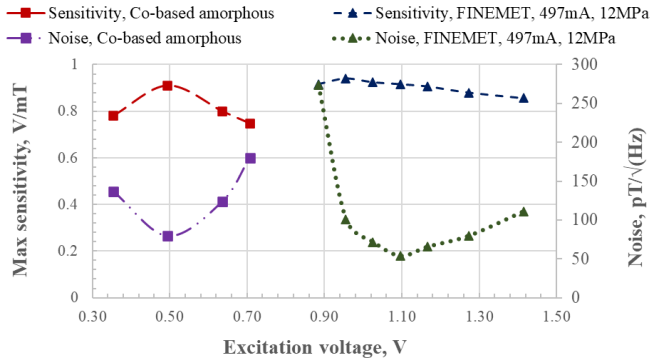


Figure 4. Sensitivity and noise of the Forster-type fluxgate as a function of the excitation voltage with different core materials, fexc = 8kHz

3. CONCLUSION

FINEMET wires annealed under tensional stress show better results as a magnetic core for a fluxgate sensor than Co-based amorphous ones, but the main advantage of using nanocrystalline alloy as a fluxgate core is its better stability under elevated temperatures. We observed the change of coercivity with tension. With plastic deformation, it is possible to form such a finely dispersed structure, which cannot be obtained by conventional heating.

ACKNOWLEDGMENT

This study was supported by the Student Grant of CTU within the Soft magnetic particles project (SGS21/163/OHK3/3T/13).

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NOISE CHARAKTERISTICS OF MEMS ABSOLUTE PRESSURE SENSORS

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1. INTRODUCTION

The resolution and accuracy of Micro-Electro-Mechanical Absolute Pressure Sensors (MEMS pressure sensors) have been steadily improving in recent years. Therefore, today MEMS pressure sensors are a promising solution for measuring not only absolute pressure but also relative pressure.

One of the key parameters for selecting a sensor for a given application is the noise level of the particular sensor. The amount of sensor noise depends mainly on the sensor type and integration time. Longer integration times typically lead to noise suppression. Other influences can be temperature, absolute pressure, sensor age, and others. In the present paper, the effect of integration time on noise suppression will be investigated for several selected sensor types and then the measured results will be evaluated.

2. METHODS AND RESULTS

Commonly, noise is considered a random phenomenon with zero mean. To suppress it, a simple integration of the investigated signal, which has the properties of a low-pass filter, should be used. As has been shown by W. Allan [1], noise also contains slow components with a period comparable to or longer than the measurement period, which degrade the long-term stability of the measurement. A too long integration of such noise leads to a mean shift of the measured signal and thus to an increase of the measurement error. Using Allan variations, the optimal integration time can be determined from the measured data to minimize the sensor noise. In the present study, the following relationship was used to calculate Allan's variation [2]:

$$\sigma(\tau) = \frac{1}{2(N-2n)} \sum_{k=1}^{N-2n} [\bar{\Omega}_{k+1}(\tau) - \bar{\Omega}_k(\tau)]^2 \qquad (1)$$

Where N is the total number of data points, $\bar{\Omega}_k$ is the k-th data cluster, n is the number of data points in the cluster, τ is the cluster length.

For comparison, 10 types of pressure sensors available on the market were selected. Five sensors from each type were mounted, some sensors were damaged during mounting and had to be removed from the measurements. An overview of the selected sensors with the number of commissioned units and the main parameters, including price, are shown in Table 1.

Table 1. List of tested MEMS pressure meters, datasheet information, sample period 20 ms.

SENSOR	NUMBER OF SAMPLES	PRIZE [$/PC]	RANGE [KPA]	RESOLUTION (APPROX.) [PA/DIGIT]	RELATIVE ACCURACY [PA]	NOISE [PA]
ICP-10100	5	3.7	30-110	0.01	±1	0.8
BMP388	3	3.5	30-125	0.016	±8	1.2
WE2511020213301	4	4.0	26-126	0.024	±2.5	0.75
MS5840-02BA01	5	5.8	30-120	1	±50	1.6
LPS27HHWTR	5	8.2	26-126	0.024	±2.5	0.7
MS5839-02BA36	5	13.8	30-120	1	±50	1.6
FXPQ3115BVT1	4	9.1	20-110	0.086	±5	1.5
DPS368XTSA1	5	4.8	30-120	0.06	±6	0.4

DPS422XTSA	3	2.9	30-120	0.06	±6	2.5
2SMPB-02B	5	4.1	30-110	0.06	±4	1.3

All 44 sensors were connected via I2C bus. Address collision was solved by multiplexers controlled also via I2C bus. Data was collected via the NI8452 measurement card into a text file on the PC, and them were processed using LabView programming language and MATLAB scripts. The sampling period was set to T = 3 s due to the large number of sensors being operated at the same time. For comparison, digital filters were disabled on all sensors and the integration time was set lower than 20 ms. The measured noise characteristics of the sensors are shown in Fig. 1.

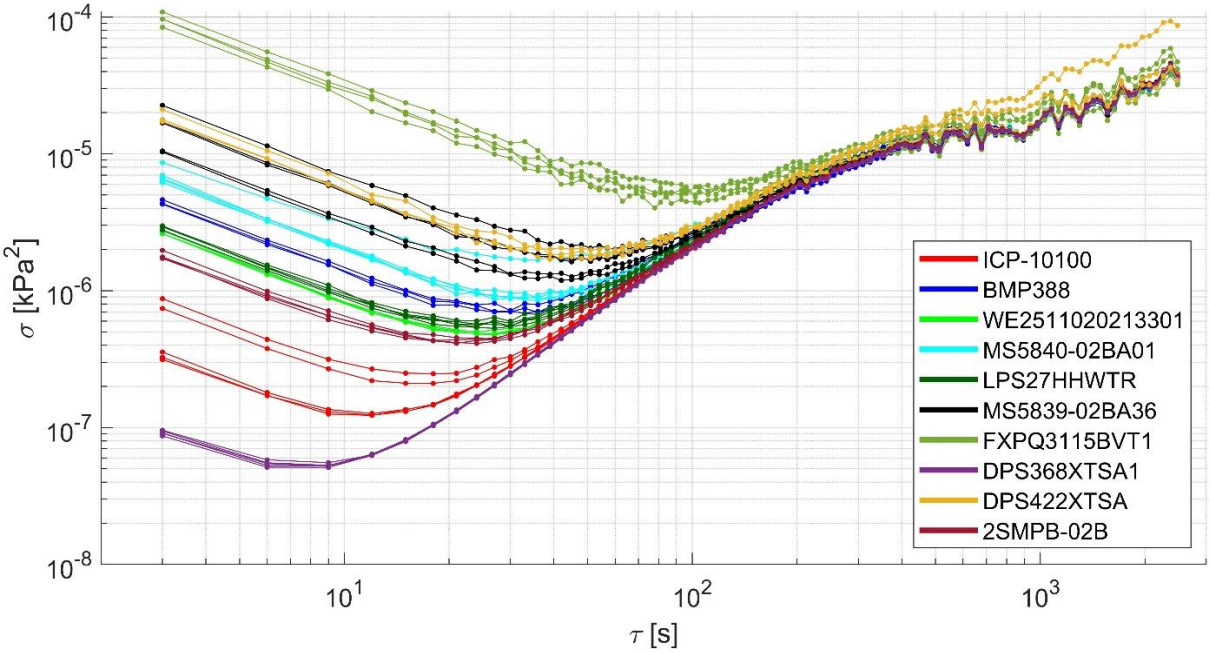

Figure 1. Allan variation functions of tested MEMS pressure sensors

3. CONCLUSION

Due to the large number of sensors measured, it was not possible to measure their behavior at higher sampling periods. Nevertheless, from the data obtained, it is possible to determine the noise levels for all measured sensors in the range from about 10 s to 1000 s. Above 1000 s, fluctuations can be seen in all sensors, probably due to errors caused by the measurement method. The lowest noise level was found with the DPS368XTSA1 sensor, this sensor should be measured at a higher sampling rate to more accurately determine the minimum of the Allan function. The FXPQ3115BVT1 is the worst performing sensor in terms of noise performance. For averaging over hundreds of seconds, all sensors are comparable.

ACKNOWLEDGMENT

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System for Acoustic Detection and Localization Based on Two Microphones

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1 Introduction

Acoustic localization is a task to find the location of the sound source based on acoustic signals. This technology can be used, for example, to detect dangerous situations in public places (e.g., gunshots) [1], military applications, automatic camera steering, or teleconferencing. This work deals with the theory, design, and practical implementation of the system for acoustic detection and localization of acoustic impulse events based on two microphones. The goal is to create a demonstration device for acoustic detection and localization running on low-power IoT devices. The final device can be seen in figure 1.

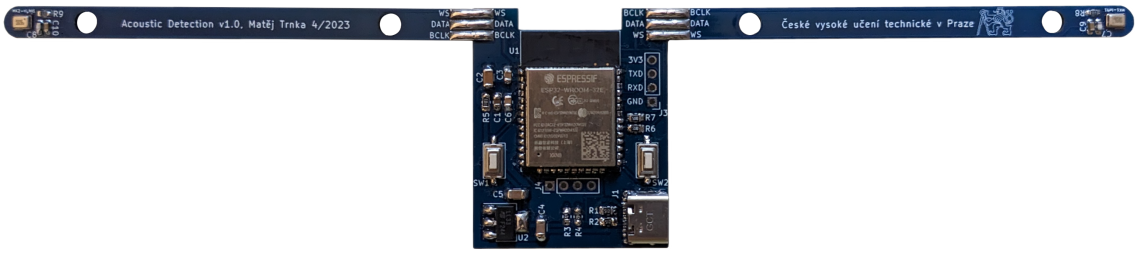

Figure 1: Final device

2 Methods and results

For the detection of acoustic events, many algorithms can be utilized. In work [1] algorithm based on the median filter is used to detect gunshot events. In paper [2] energy level of signal over a time frame with adaptive threshold is used. Since this device aims to detect all acoustic impulse events, there is no need to have special requirements for the detection algorithm. To detect acoustic impulse events following algorithm based on recurrent mean calculation is used

$$\hat{\mu}[n] = \frac{p \cdot |x[n]| + (1-p) \cdot \hat{\mu}[n-1]}{2}\,, \tag{1}$$

where $x[n]$ is current sample, $\hat{\mu}[n-1]$ and $\hat{\mu}[n]$ are estimates of previous and new sum and constant $p = 0.2$. For every audio sample, separate $\hat{\mu}[n]$ is calculated for each channel, and if both $\hat{\mu}[n]$ are greater than experimentally set constant 500, an acoustic impulse event is detected.

Common methods to find delay between microphone signals are cross-correlation, generalized cross-correlation with phase transform (GCC-PHAT) introduced in paper [3] by Knapp and Carter or adaptive filter with least mean square (LMS) algorithm [4]. In this work, biased cross-correlation was chosen, which is defined by the equation

$$R_{xy}[k] = \frac{1}{N} \cdot \sum_{n=0}^{N-1-|k|} x[n+k] \cdot y[n]\,, \quad \text{for } k = 0,\ \pm 1,\ \ldots,\ \pm(N-1)\,, \tag{2}$$

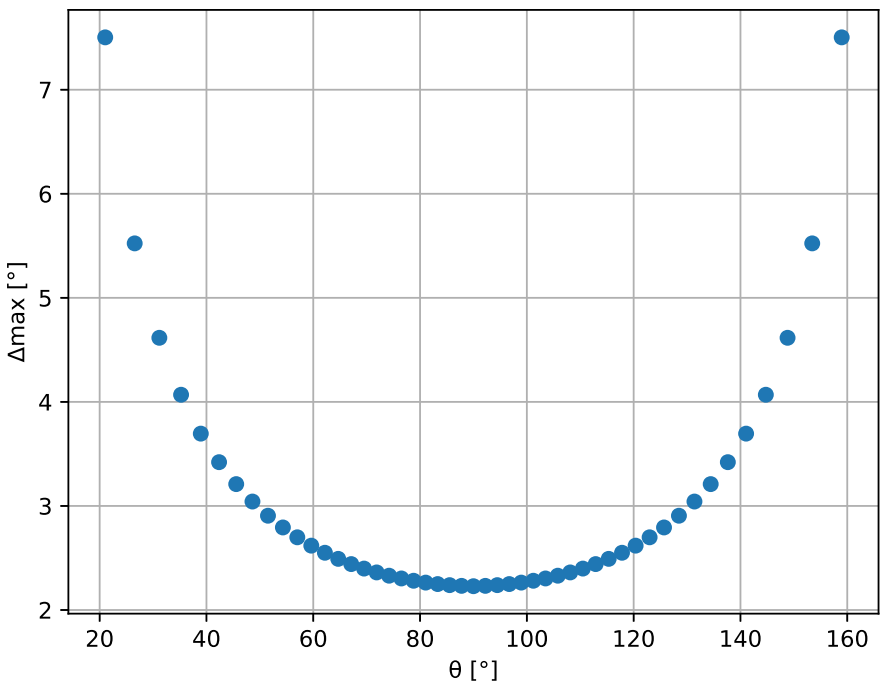

Figure 2: Angle resolution error caused by sampling for $f_s = 44.1\,\mathrm{kHz}$ and $d = 0.2\,\mathrm{m}$

where $x[n]$ and $y[n]$ represent microphone signals and N is number of samples. Estimation of delay between signals is then given by

$$\hat{D} = \underset{k}{\operatorname{argmax}}\, R_{xy}[k]\,, \tag{3}$$

where $k \in \{x \in \mathbb{Z} \mid x \in [-N_{\max}, N_{\max}]\}$ and $N_{\max}$ is sample shift for maximal angle (in this case $N_{\max} = 25$).

To determine angle estimation from time delay, assuming plane-wave incidence, the trigonometric equation is used

$$\theta = \arccos\left(\frac{\tau \cdot c}{d}\right)\,, \tag{4}$$

where c represents speed of sound ($c = 343\,\mathrm{m/s}$), d is distance between microphones (in this case $d = 0.2\,\mathrm{m}$) and $\tau = \hat{D} \cdot \frac{1}{f_s}$, where f_s is sample frequency (in this case $f_s = 44.1\,\mathrm{kHz}$). In figure 2 angle resolution error caused by sampling with a finite sampling rate is visualized.

For practical realization, the microcontroller ESP32 was chosen because of its sufficient computing power, connectivity via Wi-Fi or Bluetooth, hardware support for I^{2}S and PDM processing, and relatively reasonable price and good availability. To capture the sound signal I^{2}S MEMS microphones SPH0645LM4H-B were selected. Software for the ESP32 microcontroller was written in C++ using the Arduino framework with the help of the ESP-IDF framework. Portability was considered to visualize data, and web technology via Wi-Fi was selected. Microcontroller communicates with a client device (e.g., laptop or mobile device) via HTTP and Server-Sent Events (SSE) to send angle information. Web interface (figure 3) was created using Plotly.js library [5] for polar chart and Bootstrap [6] for design. HTTP server for ESP32 was created using library ESPAsyncWebServer [7].

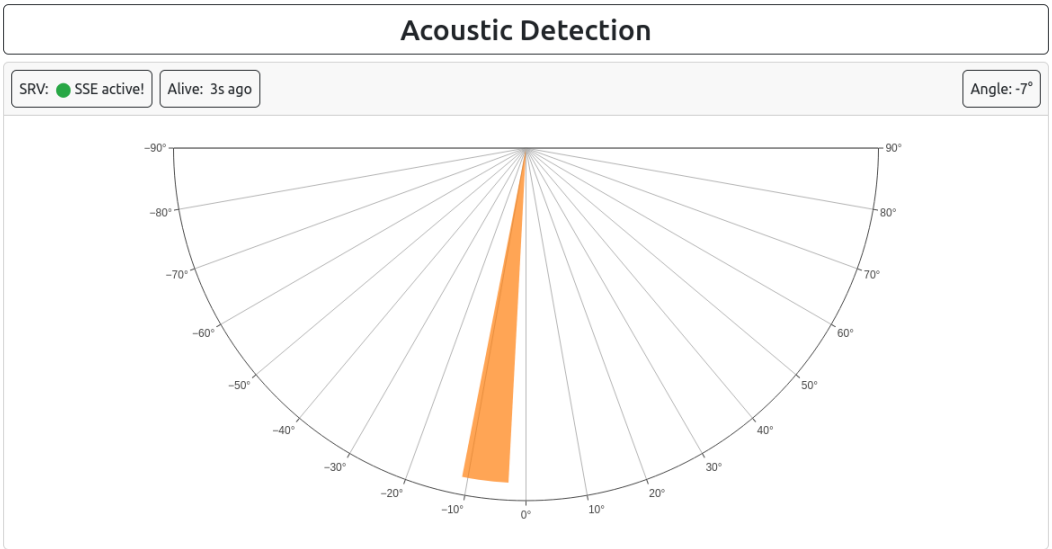

Figure 3: Web interface

3 Conclusion

In this work functional device for acoustic detection and localization was created using an ESP32 microcontroller and SPH0645LM4H-B microphones. Multiple methods for detecting acoustic impulse events were considered, and an algorithm based on recurrent mean calculation was chosen. Biased cross-correlation was used to estimate the time delay of two microphone signals. Web technology was selected to display results due to its good portability and user experience.

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Four Seconds Over South Africa:

Design, calibration, launch, and data processing of sounding rocket payload to measure the Earth's magnetic field.

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INTRODUCTION

The objective of this study was to analyse the Earth's magnetic field as a function of altitude. An instrument was designed and placed on an experimental rocket to collect data during its test flight. Due to unforeseen circumstances, we only retrieved the first four seconds of the entire flight. The instrument was equipped with a high-performance AMR magnetometer developed at CTU MAGLAB, for space applications. There were also two auxiliary magnetometers, gyroscope, accelerometer and thermometer. The purpose of this study was to analyse and calibrate the data obtained from the instrument to visualize the Earth's magnetic field in the first few kilometers above the surface of the Earth. The abstract presents data collected from a rocket instrument measuring the various parameters.

METHODS AND RESULTS

The instrument (Fig. 1) was designed and built at CTU in Prague. Required dimensions were "1U cubesat format" – 10x10x10 cm. Mechanical construction is done by FDM 3D printing. Main PCB contains STM32 microcontroller, power supply unit, 2 auxiliary magnetometers (integrated AMR), gyroscope, accelerometer, FLASH memories, mechanical 2g switch, thermometer and xbee module. Main "scientific" magnetometer is connected externally over UART and also SD card logger is external (open-log). Two different memories were used for redundancy. The onboard sensors were calibrated at the South African National Space Agency (SANSA) in Hermanus, South Africa. The rocket was designed and built by students in the mechanical engineering department of the University of KwaZulu Natal (UKZN) and launched from the Denel Overberg Test Range. The instrument was designed (keeping redundancy in mind) to start recording results once the rocket reached one of conditions: mechanical 2g switch trigger, integrated accelerometer measures more than 2g, thermometer measures less than 10°C or if xbee command to start logging is received. A Yagi antenna was placed on the ground on a certain angle that would allow it to remain aligned with the rocket and capture instrument telemetry for the first few seconds. All the data was written at high cadence to onboard FLASH memory and an SD card for post-flight retrieval. Unfortunately, high winds required the launch direction to be reconfigured to flight over the ocean. The winds also prevented deployment of the parachute and the entire rocket landed at sea and has not been recovered. The only data captured was the telemetry before the rocket moved out of the antenna's field of view.

The data reported by the instrument was in the form of timestamp, angular velocity, acceleration, and magnetic field from all three magnetometers, temperature and battery voltage. A python code was developed to analyse and calibrate the data.

The pre-processing of data was done to remove any noise or outliers, and the calibration process involved the correction of bias, scaling factors, and alignment errors of the sensors. The angular velocity, acceleration, and magnetic field strength data were then plotted as a function of time. The acceleration data recorded by the instrument during the first four seconds of the flight was plotted and compared to that of the acceleration calculated from the ground external cameras which measured the position and velocities of the rocket for the entire flight (Fig. 2) The comparison revealed the following results.

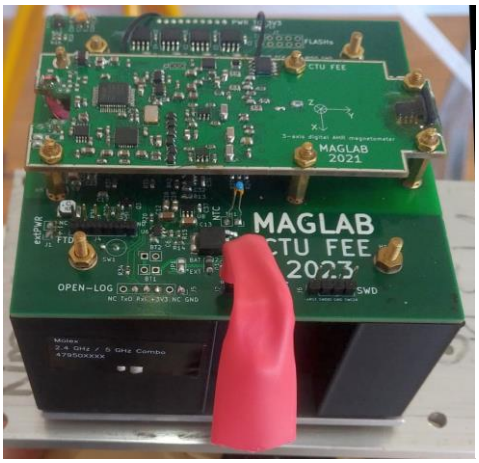

Fig. 1 – Photo of instrument (payload) prepared for flight

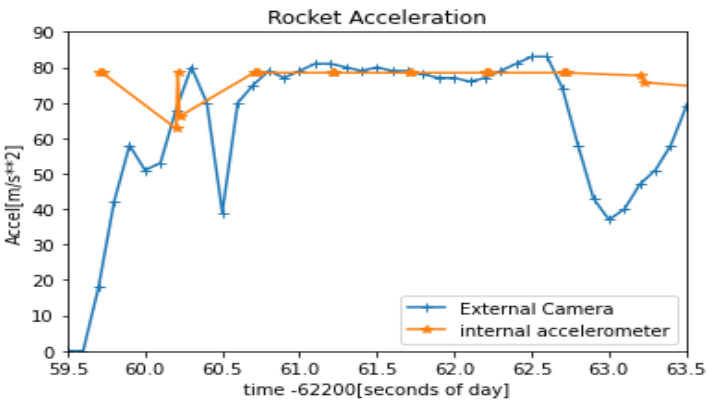

Fig. 2 – preview of onboard data vs external measurement

Analysis of the magnetic field data is ongoing, and we hope to be able to show results at the meeting in June.

CONCLUSION

In conclusion, the instrument designed for this study was successful in recording the motion of the rocket during the first four seconds of the flight. The analysis and calibration of the data provided valuable insights into the rocket's angular velocity, acceleration, and the Earth's magnetic field strength. Overall, the developed instrument and analysis methods can provide valuable data for further research and development in the field of rocket science.

ACKNOWLEDGMENT

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STATISTICAL APPROACH FOR BTT PROBES DISTRIBUTION

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1. BLADE TIP TIMING PRINCIPLE

Blade tip timing (BTT) system is a non-invasive method used for measuring the blade tip timing of rotating machinery. The BTT system typically consists of sensor probes, signal conditioning system, and data acquisition unit. The sensor probes are placed in proximity to the rotating blade tips, Sensors measure the time at which each blade passes by the probe. By measuring the blade tip timing, the BTT system can detect changes in the blade tip vibration, which is an important for the health monitoring and performance optimization of rotating machinery [1]. To ensure accurate measurement of blade tip timing, the probe arrangement is crucial. The placement of the probe relative to the blade tips can affect the measurement accuracy, and thus, several probe arrangement algorithms have been developed to optimize the placement of the probe.

Instead of considering the condition number, we will utilize statistical algorithms to optimize the placement of probes for accurate measurement of blade tip timing in turbo-machinery. The statistical approach will be employed to determine the optimal locations for probes, with the aim of reducing errors in the measurement of blade tip timing [2].

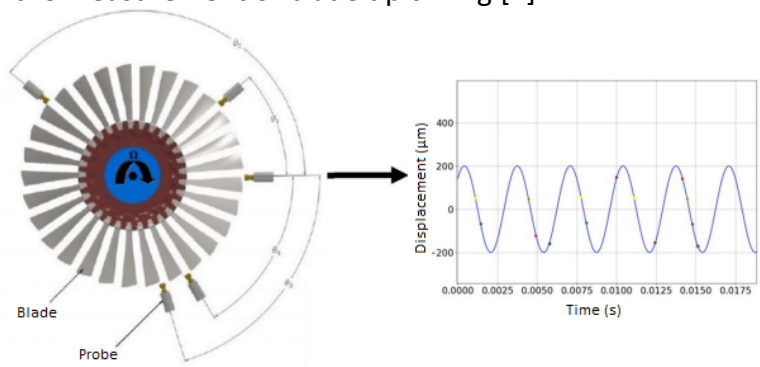

Figure 1: Blade tip timing principle

2. METHODS AND RESULTS

We define a vibration signal $y(\tau)$ as follows: $y(\tau) = x(n/f_0)$. Note that $y(\tau)$ is periodic with a period of $1/f_0$, and its Fourier series can be expressed as follows:

$$y(\tau) = d + \sum k\, \beta_{ks} \sin(2\pi k f_0 \tau) + \beta_{kc} \cos(2\pi k f_0 \tau) \qquad (1)$$

Defining new time variable τ as follows: $\tau = n/f_0$ where d is the DC component of $y(\tau)$, β_{ks} and β_{kc} are the Fourier coefficients of the sine and cosine terms, respectively, and $k = 1, 2, \ldots, \infty$. Note that the Fourier coefficients depend on EO_k and A. To estimate EO_k from $y(\tau)$, we need to identify the frequency components. The identification process depends on prior inputs about the natural frequencies and mode shapes of the blades and the rotation speed.

The statistical optimization method for probe arrangements aims to identify the best locations for probes in turbo-machinery to accurately measure vibration parameters such as amplitude and frequency. The optimization process involves reducing statistical variables such as RMSE and bias to achieve the desired level of precision.

$$\hat{A}_k = \sqrt{\hat{\beta}_{ks}^2 + \hat{\beta}_{kc}^2} \qquad (2)$$

$$bi_k = \frac{\sum_{m=1}^{M} (\hat{A}_{mk} - \hat{A}_k)}{M} \qquad (3)$$

$$std_k = \sqrt{\frac{\sum_{m=1}^{M} \hat{A}_{mk}}{M} - \frac{\sum_{m=1}^{M} \hat{A}_{mk}^2}{M}} \quad (4)$$

$$RMSE_k = \sqrt{\frac{\sum_{m=1}^{M} (\hat{A}_{mk} - \hat{A}_k)^2}{M}} \quad (5)$$

RMSE measures the difference between predicted values and actual values, while bias measures the difference between the expected value and true value. By minimizing these variables, we can obtain the optimal probe placement that will provide the highest quality data and best accuracy of vibration parameters.

Table 1: Probe positioning of the BTT measurement system after the optimization process based on the minimization of the bias, standard deviation, and the RMSE of the amplitude of the frequency of vibration

bi_1 (μm)	std_1 (μm)	$RMSE_1$ (μm)	Configuration
-3.06 x 10^{-4}	3 x 10^{-1}	2.98 x 10^{-1}	(0, 1, 8)
-4.51 x 10^{-4}	2.12 x 10^{-1}	2.16 x 10^{-1}	(3, 5, 8)

Parameter values: T = 3000 s, M = 200, σ = 20 μm

Table 1 reports on the ranking of probe positioning obtained from the optimization process. Each winner probe configuration corresponds to the one with the minimal value of one of the statistical variables. For example, (3, 5, 8) has the smallest value of RMSE and standard deviation, while (0, 1, 8) corresponds to the smallest value in absolute value of bias.

Table 2: Probe positioning of the BTT measurement system after the optimization process based on the minimization of the RMSE of the amplitude of the frequency of vibration

bi_1 (μm)	std_1 (μm)	$RMSE_1$ (μm)	Configuration
−0.005	0.213	0.212	(6, 8, 11)
−0.0178	0.214	0.214	(6, 8, 17)
−0.045	0.212	0.216	(3, 5, 8)
−0.036	0.214	0.216	(2, 6, 11)
1635.37	0.222	0.221	(2, 8, 15)

Parameter values: δ = 20, T = 3000 s, M = 200, σ = 0.1 μm

According to Table 2 which reports on RMSE optimization process, (3, 5, 8) is considered as the optimal probe placement for determining amplitude of vibration with highest accuracy. This means that placing probes at positions 3, 5 and 8 in turbo-machinery will provide more accurate measurements than other probe placements.

3. CONCLUSION

The measurement of blade tip displacement through BTT system is crucial to monitor the blade's dynamics. To do so, the probes need to be placed adequately to record useful blade tip displacement enabling the determination of the vibration parameters. This work has proposed a statistical method of determination of the probe's arrangement, based on the minimization of the RMSE in the case of synchronous vibrations and the combination of synchronous and asynchronous vibrations.

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Raspberry Pi Pico Development Kit

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1. INTRODUCTION

In early 2021, Raspberry Pi Foundation introduced its first microcontroller, the RP2040, along with the Raspberry Pi Pico development board. Its 32-bit architecture allows for use in the simplest of applications, right down to machine learning or video output to a computer monitor. The RPi Pico development kit was created for use in the laboratory exercises of the Embedded Systems course and will be described in this paper.

2. DEVELOPMENT KIT

There are a number of extension development kits for the Raspberry Pi Pico board on the market from various manufacturers such as Arduino, Adafruit, Pimoroni and Waveshare. However, most of them are single-purpose boards that contain only a few specific modules such as an OLED display, Bluetooth and Wi-Fi module, inertial measurement unit, pins for connecting sensors and actuators or a VGA video output. None of these boards include a debugger.

In order for the development kit to contain as many functional units as possible that could be used together, a custom development kit was designed.

2.1 HW Platform Design

The entire wiring of the HW platform is divided into several blocks. The most essential part of the design is the Raspberry Pi Pico development board itself with the RP2040 microcontroller, which is connected to the kit in a modular way via pin headers. The debugger is used to flash a program to the Raspberry Pi Pico and to debug it. Eight LEDs and eight buttons are used for basic interaction with the user. Furthermore, a rotary potentiometer and a rotary encoder are used. The audio output is implemented in three different ways. These are a piezoelectric transducer and audio output generators using PWM and PCM modulation. The simplest visual output is provided by a 0.96" OLED display. Other video outputs are output via VGA and DVI interfaces. The data can be recorded to a 4 kB EEPROM or to an external micro-SD card [1].

2.2 Realization

The design of the printed circuit board (PCB), as well as the schematic, was drawn in KiCad. The result is a 4-layer PCB with dimensions of 100 × 100 mm. Figure 1 shows a 3D model of the designed RPi Pico Development Kit.

For the final implementation, mostly SMD parts were used. The potentiometer, encoder, piezoelectric transducer as well as all connectors including pin headers were left as THT components, in order to maintain better mechanical resistance during handling. Most of the passive components use the 0603 case size. Pin headers use a standard 2.54 mm spacing.

2.3 HW Testing

The fabricated PCB was hand-soldered and tested. Only two faults were found, but these have been corrected. The other components functioned as expected.

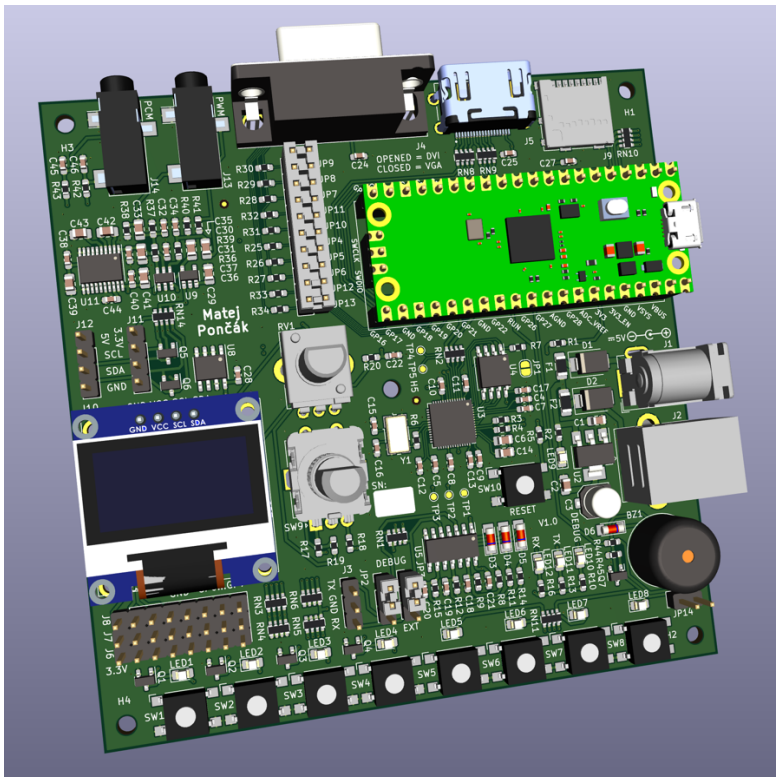

Figure 1. 3D model of the designed RPi Pico Development Kit.

2.4 SW Testing

Testing was carried out one by one on individual HW components, for which short programs were created to test their functionality, which also used to demonstrate their function. Finally, a demonstration program was created.

3. CONCLUSION

The main goal of the work was to create a development kit for Raspberry Pi Pico. The designed development kit contains several components which include a debugger, basic interface for user interaction, video and audio output. The proposed PCB has been manufactured and assembled. The individual units have been successfully tested.

This universally designed board will be used in the laboratory exercises of the course Embedded Systems. In addition, thanks to the availability of all production documentation, anyone will be able to produce the board and then use it for their own needs. The board can also serve as a development kit for assigning semestral projects or other final theses.

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Exploring the ChatGPT capabilities for creating measuring applications in LabVIEW

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1. INTRODUCTION

Automation of measurement and analysis processes is widely used practice. There are several approaches to automate measurement or analysis. First approach is the use of measurement hardware, corresponding drivers and a control station running a control or analysis application. This application can be created using textbased programming languages such as C, C# etc. or visual based, such as LabVIEW environment, developed by National Instruments.

Many different applications have common parts that must always be created. This part of programming is often laborious and tedious. The solution is to build an application from a common base, which is called a template. Some measurement or analysis problems are already solved, and corresponding template already exists, so it is desirable to, create an application with them in mind.

When programming textbased languages, code generators can be used for this purpose. Recently, the use of machine learning models and chatbots such as ChatGPT has also been widely considered [1] The use of ChatGPT has been quite successful in this area. This paper aims to investigate whether ChatGPT can serve as a useful tool in creating a program in a visual based programming environment. A secondary idea was to evaluate the use of ChatGPT by a person who has limited experience with LabVIEW.

2. METHODS AND RESULTS

First, the functionality of the final application had to be specified. It was specified that the application would be based on the "Event driven state machine" template and would continuously measure two analog voltage inputs on the myDAQ card. It was also determined that rectangular signals of the same parameters but different phase would be applied to the inputs. These signals mimic the ideal output of an incremental rotary motion sensor. The resulting application will measure these signals and calculate their frequency simultaneously with the direction of rotation. The state diagram of the resulting application can be seen in figure 1.

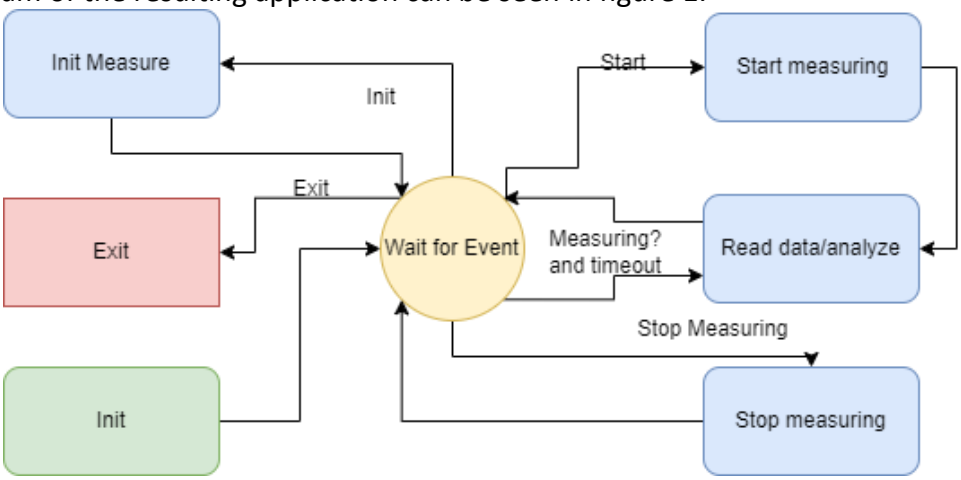

Figure 1. Step Diagram for basic measurement application using “Event driven state machine” template.

2.2 Initial queries with chatbot

The first experiments consisted of queries to create a complete application as described in the previous section. Unlike text-based programming, ChatGPT cannot provide a finished program. It was therefore necessary to ask for step by step instructions. This tutorial had some signs of success, however the scope of the query exceeded the Chatbot capabilities and after a few steps it started to stray into nonsensical advices. Some of the steps guided for the use of non-existent functions or advised odd way of wiring of the functions. In particular, it made the mistake of programming measurement channels. Multiple channel measurements with single card must be within a single "measurement task". The chatbot always suggested using two different tasks.

This approach did not lead to the desired result. An inexperienced person would not be able to program a state machine and thus a working application. However, the use of the chatbot would guide the programmer to the correct functions and principles needed for successful programming when questioning the chatbot in detail.

2.3 Detailed queries

Detailed queries led to a successful analysis of the problem and a guide that the average knowledgeable person could use. The questions had to be asked in the style of "How to create multiple channel measurement task to continuously measure voltage on myDAQ measurement card" or questions on the correct use of the state machine. However, even with this kind of chatbot use, the inconsistency in terminology or ill wiring advice occurred. There were confusing descriptions of feedback loops in the edge detection instructions. However, the dialogue led to proper direction, for the programmer's thoughts and knowledge towards a successful solution of the problem.

One of the queries led to the key function "Treshold detector.vi", which was crucial to successful edge detection. ChatGPT was also able to design the frequency calculation well. In one of the cases, ChatGPT failed when asked to write instructions without using "digital palettes". It ignored the specified query and answered with advice to use the aformentioned palette.

3. CONCLUSION

A measurement application was created using ChatGPT to analyze the measurement data from the incremental sensor. ChatGPT showed potential, however, it was unable to produce a tutorial to solve the complex problem. The problem had to be divided into several sub-problems, in which case ChatGPT served more as a consultant. Detailed inquiries led to a successful solution. However, it was necessary to be knowledgeable in Labview at level above the beginners. For an unknowledgeable programmer, ChatGPT would serve as a source of terminology and concepts, which must be understood before the desired application could be created. ChatGPT excels especially when the programmer does not know where to begin the programming.

Thus, ChatGPT is a limited tool that, in its current state, cannot replace a human programmer. Like any other tool it is possible, if used properly, to be utilized to create great results.

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Measurement of projectile position in dynamic projected target

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1. INTRODUCTION

The safe handling of a pistol is an integral part of most security forces. In order to achieve a high level of confidence when using a handgun in the field, it is necessary to achieve conditions during training that are as close to realistic as possible. One of the available options is to simulate a realistic environment in a closed shooting range using audio-video projection.
A video of a particular situation is projected onto the target area.
When a shooter decides it is necessary he can fire on the projected image. After that fire an evaluation is needed, however it is problematic to evaluate the shot, because the target itself may change immediately after the shot.
This (affordable) evaluation is main topic of this study. Together with a statistical treatment of the results obtained.

2. METHODS AND RESULTS

The main objective for the evaluation of the intervention was to use an available optical sensor. In this project it is a camera with a Sony IMX708 CMOS chip. The whole measurement chain (Figure 1) is based on the principle of machine recognition of dark spots on a white background. Other necessary components are also high-power LEDs in the infrared spectrum, a data-projector, a target with a support structure for paper rewinding and a Raspberry Pi used as an evaluation unit. Nowadays adding of touchscreen display is considered as well.

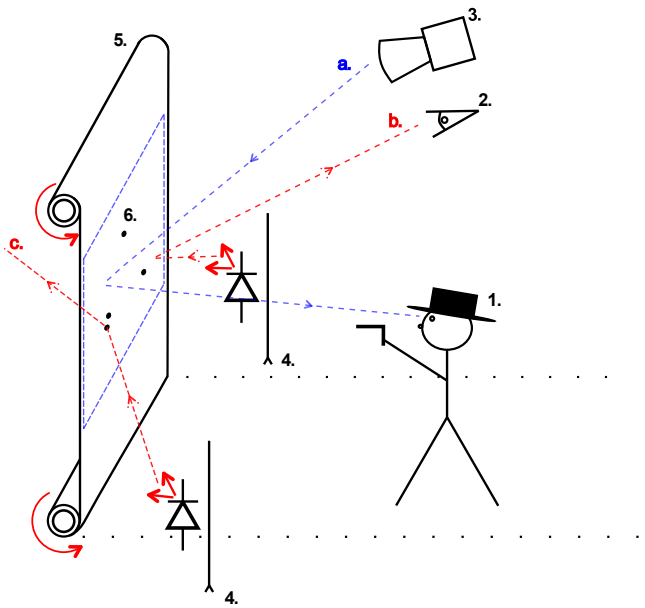

Figure 1. Measuring chain: **1-*shooting position*, 2-*camera (IR light beam-b)*, 3-*projector (image light rays-a)*, 4-*IR light source*, 5-*white paper base*, 6-*bullet hole* (*an IR beam that has passed through a bullet hole-c*).**

An image representing the target is projected onto a white surface by the projector, this image may or may not be time-varying. At the same side, the image is overexposed by an IR source. This over exposition must be optimally balanced – It must be strong enough, so the camera sees only a white surface with bullet holes, while the shooter does not even notice it. It is therefore necessary to set the brightness of the chip firmly to the given conditions.

The *c*amera output is processed by the program in the following steps:

i. Reduce the image size.
ii. Possible use of a Gaussian filter to reduce noise.
iii. Conversion to black and white (binary) image using adaptive thresholding [1].
iv. Finding contours, i.e., dark points.

Next, the coordinates of the bullet holes are recorded, along with the time the event was captured.

Just After the shooting is over, the program resegments the projected video and assigns each coordinate with its own time stamp to appropriate image from the original video.

These coordinates are then transformed into the coordinates of the original image and plotted.

In order for the coordinate transformation to occur correctly, a calibration pattern must be added to the beginning of each video.

To increase accuracy, a microphone which responds only to the fire-shot sound is used. If a fire-shot is registered, the camera image is captured, again with a time stamp. If the detection does not occur immediately, it is possible to evaluate each image separately and thus purposely change the thresholds for a given adjustment.

3. CONCLUSION

The system is not tested in a shooting range environment because it is necessary to wait for a suitable date. Testing so far has been done with an airsoft gun, or with artificially created holes.
However, the system with this concept is functional, but it is necessary to keep the projection area sufficiently stretched so that there is no unwanted distortion during evaluation. Also, bullet holes that are close together can generate problems. This can be counteracted by, for example, a small paper rewind.
The overall accuracy of the position of the plotted hole captured by the camera in the original image is within 12 [mm].

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Universal Graphical User Interface for Data Visualization and Control of Custom User-Made Measuring Instruments

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1. INTRODUCTION

This piece of software, named DataPlotter, is a tool that serves as a user interface for software defined instruments, typically designed by students or enthusiastic using microcontroller boards. The design of the software focuses on versatility and ease-of-use.

The most innovative feature of DataPlotter is a fully customizable GUI for controlling the connected device. While the default functionality is limited to sending text commands, the basic terminal can be replaced at runtime by custom GUI provided by the connected device. This allows the users (designers of measuring device) to insert their custom GUI interface into the application.

2. PLOTTING AND PROCESSING DATA

There are two ways to add data: either in oscilloscope style, where whole dataset is sent at once with uniform sampling rate. Or in rolling mode, where samples are sent continuously one by one, and each is appended after the previous.

Measured data can be further processed in the application. This includes basic mathematical operations, FFT, X-Y mode and calculation of signal parameters (mean, amplitude, RMS, frequency, rise/fall time, etc.). Interpolation can be used to reconstruct signals with sparse sampling.

Figure 1. The Application window displaying two channels of connected oscilloscope (RPi Pico oscilloscope coded by Vít Vaněček). FFT is also shown. ANSI terminal (on right side) is used for configuration of device.

3. COMMUNICATION PROTOCOL

The communication between application and device is done using serial port (typically USB virtual Com port or UART). Basic communication (sending data for plotting) requires only one-way communication. Sending data is therefore as easy as using whatever “print()” function your microcontrollers framework offers. Data can be sent either as text (printf) or in binary.

Communication in the opposite direction (application to device) is very minimalistic, as any predefined messages would be against the concept of universality. Communication specific to particular device (configuration) is handled by the control interface that is fully customizable and thus the message format is fully under user's control.

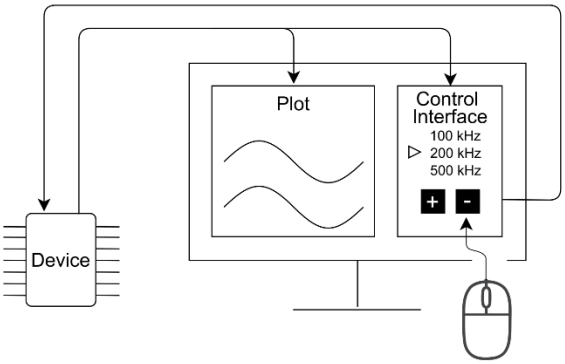

Figure 2. Interaction between the application and the device, while the plot is hardcoded part of the application, the control interface can be customized for use with any device

4. CUSTOM INTERFACE FOR DEVICE CONTROL

Controlling the device using GUI would normally be limited to applications made specifically for the device used. Achieving the same features with universal application seems very difficult and doing so without introducing great complexity may seem almost impossible. However, this application offers such features and, as you may judge yourself, the usage is quite simple.

4.1 Pseudo-Graphical Interface Using ANSI Terminal Emulator with Additional Features

Device can print text into a terminal which supports ANSI escape sequences, which allow changing font and background color of characters and thus creating a pseudo-graphical interface. This terminal is however enhanced by one subtle but very smart feature: Clicking on a character with colored background will send this character to the serial port (so the click can be registered by the device). This allows creation of pushbuttons in the pseudo-graphical interface.

4.2 Truly Graphical Interface Using QML

DataPlotter was created with the use of Qt Framework. Part of this framework is so-called QML: a scripting language used for GUI definition. GUI created using QML is not compiled but rather loaded on runtime by the application. This means that the application can load a QML code from a string sent by the device and use this to display a custom GUI interface.

DataPlotter provides a backend for the custom GUI. It allows sending and receiving data to/from the device using functions defined in the QML code. This allows the user to have full control over the interaction between the device and the control interface.

5. SUMMARY

The ability to load custom GUI definition on runtime gives users full authority over interaction between the application and their own device while maintaining user-friendly GUI. This combination of user-friendliness and high customizability is a unique feature of the DataPlotter application.

ACKNOWLEDGMENT

This project began as a bachelor's thesis[1] supervised by Jan Fischer. I thank him for his advice and guidance, and I appreciate that he motivates students to use my application in their projects.

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