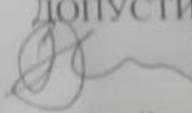


МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
КАФЕДРА АВІАЦІЙНИХ КОМП'ЮТЕРНО-ІНТЕГРОВАНИХ
КОМПЛЕКСІВ

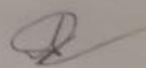
ДОПУСТИТИ ДО ЗАХИСТУ
 Завідувач кафедри
В.М. Синєглазов
" 21 " // 2020 р.

ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬО-КВАЛІФІКАЦІЙНОГО РІВНЯ
"МАГІСТР"

Тема: Індивідуальна мобільна навігаційна система числення шляху

Виконавець:



Лазаревський О.А.

Керівник:



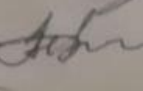
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Консультант з екологічної безпеки:



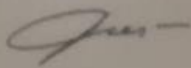
к.т.н., доцент Явнюк А.А.

Консультант з охорони праці:



старший викладач Козлітін О.О.

Нормоконтролер:



к.т.н., професор Філяшкін М.К.

Київ 2022

EDUCATION AND SCIENCE MINISTRY OF UKRAINE
NATIONAL AVIATION UNIVERSITY
DEPARTMENT OF AVIATION COMPUTER INTEGRATED
COMPLEXES

ADMITTED TO DEFENSE
Head of department
Viktor M. Sineglazov
" 21 " // 2022

MASTER'S THESIS
(EXPLANATORY NOTE)

GRADUATE OF EDUCATION AND QUALIFICATION LEVEL
"MASTER"

THEME: Individual Mobile Navigation System of Way Counting

Executor: Lazarevskiy O.A.
Supervisor: Vasylenko M.P.
Advisor on environmental protection: Iavniuk A.A.
Advisor on labor protection: Kozlitin O.O.
Norms inspector: Filyashkin M.K.

Kyiv 2022

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет аеронавігації, електроніки та телекомунікацій
Кафедра авіаційних комп'ютерно - інтегрованих комплексів

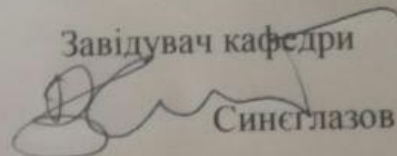
Освітній ступінь: магістр

Спеціальність 151 "Автоматизація та комп'ютерно-інтегровані технології"

Освітньо-професійна програма "Комп'ютерно-інтегровані технологічні процеси і виробництва"

ЗАТВЕРДЖУЮ

Завідувач кафедри



Синєглазов В.М.

" 21 " // 2022 р.

ЗАВДАННЯ

на виконання дипломної роботи студента

Лазаревський Олександр Андрійович

1. **Тема роботи:** «Індивідуальна мобільна навігаційна система числення шляху».

2. **Термін виконання роботи:** з 19.09.2022р. до 15.11.2022р.

3. **Вихідні дані до проекту (роботи):** числення шляху на основі мобільного телефону, навігаційна система, алгоритм пошуку шагів, середовище Matlab.

4. **Зміст пояснювальної записки (перелік питань, що підлягають розробці):**

1.Актуальність навігаційна система числення шляху на основі мобільного телефону; 2. Огляд існуючих методів; 3. Огляд теоретичної інформації з приводу рішення задачі пошуку шагів; 4. Розробка навігаційної системи числення шляху на основі мобільного телефону.

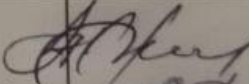
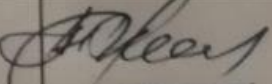

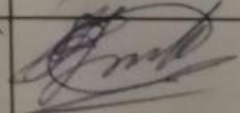
5. **Перелік обов'язкового графічного матеріалу:**

1. Блок-схема числення шляху пішохода 2. Положення мобільного телефону у просторі; 2. Вікно розробленої системи пошуку пройденого шляху; 3. Фазу ходи людини; 4. Таблиця порівняння кількості шагів щодо реального та виміряної кількості за алгоритм пошуку шагів; 5. Структурна схема розробленої програми.

6. Календарний план-графік

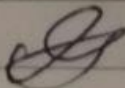
№ п/п	Завдання	Термін виконання	Відмітка про виконання
1	Отримання завдання	22.08.2022-23.08.2022	Виконано
2	Формування мети та основних завдань дослідження	24.08.2022-26.08.2022	Виконано
3	Аналіз існуючих методів	27.08.2022-31.08.2022	Виконано
4	Теоретичний розгляд рішення задачі	01.09.2022-08.09.2022	Виконано
5	Розробка структури навігаційної системи числення шляху	09.09.2022-15.09.2022	Виконано
6	Розробка програмного забезпечення навігаційної системи числення шляху з різними патерами шляху	16.09.2022-30.09.2022	Виконано
7	Оформлення пояснювальної записки	01.10.2022-30.10.2022	Виконано
8	Підготовка презентації та роздаткового матеріалу	01.11.2022-15.11.2022	Виконано

7. Консультанти зі спеціальних розділів

Розділ	Консультант (посада, П. І. Б.)	Дата, підпис	
		Завдання видав	Завдання прийняв
Охорона праці	Старший викладач, Козлітін О.О.		
Охорона навколишнього середовища	к.б.н., доцент, Явнюк А.А.		

8. Дата видачі завдання 22.08.2022

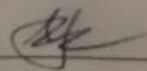
Керівник:
М.П.



Василенко

(підпис)

Завдання прийняв до виконання:



Лазаревський О.А.

(підпис)

NATIONAL AVIATION UNIVERSITY
Faculty of aeronavigation, electronics and telecommunications
Department of Aviation Computer Integrated Complexes

Educational level: master

Specialty 151 "Automation and computer-integrated technologies"

Educational and professional program "Computer-integrated technological processes and production"

APPROVED BY

Head of department

Victor M. Sineglazov

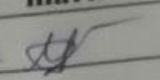
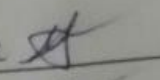
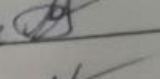
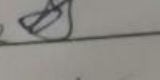
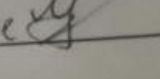
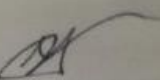
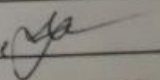
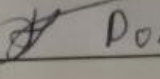
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Graduate Student's Diploma Thesis Assignment

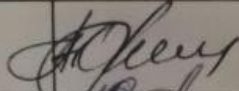
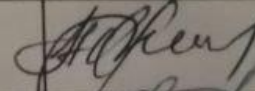
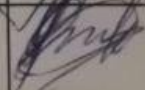
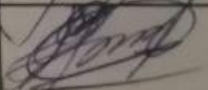
Lazarevskiy Oleksandr Andreyovich

1. **The thesis title:** « Individual mobile navigation system of way counting».
2. **The thesis to be completed between:** from 19.09.2022 to 15.11.2022.
3. **Output data for the thesis:** mobile phone-based route calculation, navigation system, step search algorithm, Matlab environment.
4. **The content of the explanatory note (the list of problems to be considered):**
 1. The relevance of a mobile phone-based navigation route counting system;
 2. Review of existing methods;
 3. Review of theoretical information regarding the solution to the task of finding steps;
 4. Development of a mobile phone-based way counting navigation system.
5. **List of compulsory graphic material:**
 1. Block diagram of counting the path of a pedestrian
 2. Position of a mobile phone in space;
 2. Window of the developed path search system;
 3. Phases of human gait;
 4. Table of comparison of the number of steps in relation to the real and measured number according to the step search algorithm;
 5. Structural

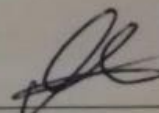
6. Planned schedule:

No	Task	Execution term	Execution mark
1	Receiving the task	22.08.2022-23.08.2022	Done 
2	Formation of the goal and main tasks of the research	24.08.2022-26.08.2022	Done 
3	Analysis of existing methods	27.08.2022-31.08.2022	Done 
4	Theoretical consideration of problem solving	01.09.2022-08.09.2022	Done 
5	Development of the structure of the navigation system of way counting	09.09.2022-15.09.2022	Done 
6	Development of software for a navigation system of path counting with different path patterns	16.09.2022-30.09.2022	Done 
7	Issuance of an explanatory note	01.10.2022-30.10.2022	Done 
8	Preparation of presentation and handout	01.11.2022-15.11.2022	 Done

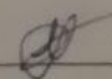
7. Special chapters' advisors

Chapter	Advisor (position, name)	Date, signature	
		Assignment issue date	Assignment accepted
Labor protection	Senior lecturer, Kozlitin O. O.		
Environmental protection	Ph.D, Associate Professor, Iavniuk V.F.		

8. Date of task receiving: 22.08.2022

Diploma thesis supervisor: 
(signature)

Vasilenko M.P.

Issued task accepted: 
(signature)

Lazarevskiy O.A.

РЕФЕРАТ

Пояснювальна записка до дипломної роботи «Індивідуальна мобільна навігаційна система числення шляху»:

с., рис., табл., графіків, літературних джерела.

Об'єкт дослідження: система числення шляху пішохода.

Методи дослідження: теоретична фізика, теорія коливань, теорія обробки даних з магнітометра.

Мета роботи: вдосконалення методів пошуку шагів та розробки нової системи, що здатна з порівняно невеликими обчислювальними затратами здійснювати побудову шляху.

Для досягнення цієї мети необхідно розв'язати наступні завдання:

- проаналізувати існуючі методи пошуку шагів;
- проаналізувати існуючі апаратні засоби, придатні для реалізації розглянутих методів;
- на основі проведеного аналізу здійснити вибір методу який би дозволив здійснювати розрахунок маршруту з мінімальними обчислювальними затратами;
- розробити програмне та апаратне забезпечення реалізації обраного методу;
- провести експериментальне дослідження роботи розробленої системи.
- розробка методу навігаційної системи числення шляху на основі мобільного телефону.
- теоретична фізика, теорія коливань, теорія обробки даних з магнітометра.

ІНЕРЦІАЛЬНА НАВІГАЦІЯ; ЗНАХОДЖЕННЯ ПІКІВ КРОКУ ЛЮДИНИ;
МОДУЛЬ ВЕКТОРА ПРИСКОРЕННЯ; ФІЛЬТРАЦІЯ; ТРИАНГУЛЯЦІЯ;
ГЛОБАЛЬНИЙ МАРШРУТ.

ABSTRACT

Explanatory note to the thesis «Individual mobile navigation system of way counting»:

p., figures, tables, graph, literary resources.

The object of research: pedestrian path counting system.

Methods of research: theoretical physics, theory of oscillations, theory of magnetometer data processing.

The purpose of the work: improvement of methods of finding steps and development of a new system capable of constructing a path with relatively low computational costs.

To achieve this goal, the following tasks must be solved:

- analyze the existing methods of finding steps;
- analyze the existing hardware suitable for the implementation of the considered methods;
 - on the basis of the conducted analysis, select a method that would allow calculating the route with minimal computational costs;
- develop software and hardware for implementing the chosen method;
- conduct an experimental study of the operation of the developed system.
- development of a mobile phone-based navigation system method for calculating the route.
- theoretical physics, theory of oscillations, theory of magnetometer data processing.

INERTIAL NAVIGATION; FINDING PEAKS OF PEOPLE'S STEP;
ACCELERATION VECTOR MODULE; FILTRATION; TRIANGULATION;
GLOBAL ROUTE.

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2.3. Conclusion.....

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3.1.2. Loading data into the processing environment.....

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3.4. Software development.....

3.5. Conclusions.....

4. Development tools.....

4.1. Programs used in development.....

4.1.1. Application package MATLAB.....

4.1.2. Integrated software for creating applications App Designer.....

4.1.3. Application for removing data from the phone Physics Toolbox Sensor Suite.....

4.1.4. Program used for database tables Microsoft Excel.....

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4.2. The system used in the development.....

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GLOSSARY

PDR – Pedestrian dead reckoning

LCS – Local coordinate system

GLCS – Global coordinate system

MEMS – Microelectromechanical sensor

IFR – Inertial frame of reference

CMO – Center of mass of an object

GCS – Geographic coordinate system

CS – Coordinate system

GLONASS – Global Navigation Satellite System

GPS – Global Positioning System

ZC – Zero-crossing

ACF – Autocorrelation function

IMU – Inertial measurement unit

GUI – Graphical user interface

DS – Double support

SS – Single support



INTRODUCTION

The market for sophisticated automated integrated systems of businesses and business institutions of various profiles, as well as for devices that provide communication and must always be close at hand, is growing in the modern, dynamically developing world, where a person occupies a leading position.

There are more than just the developer's basic programs on the gadgets that are all around us. For instance, many who utilize typical GPS navigation techniques have never considered how to go around a mall, a store, or an establishment.

These organizations can all range in size from small businesses with a few dozen employees to large corporations with tens of thousands of workers, and they can all be built in a variety of ways.

Such issues are resolved by the inertial individual navigation system, which is built to address issues at both the enterprise and individual level.

The goal of this work was to create an inertial pedestrian system for tracking steps taken and space orientation without the use of outside data.

The significance of the dead reckoning problem for pedestrians and its characteristics are discussed in the first section of the explanation note.

The note's second section examines the methods' efficacy and describes the methods' range.

The third section, which describes the algorithm of the created program, contains details on the individual methods that made up the algorithm.

The software's documentation is contained in the fourth section. It provides details on how software components interact with one another and describes how users should interact with the software system.

CHAPTER 1. RELEVANCE OF THE PROBLEM OF INDIVIDUAL MOBILE NAVIGATION SYSTEM

A pedestrian may not always be able to receive a satellite signal; on occasion, it may be intentionally blocked or lost because of obstacles in urban areas, a lack of satellite coverage in a particular area, or improper signal triangulation.

1.1. The dead reckoning issue

PDR, or pedestrian dead reckoning, is a type of individual navigation job [1]. Utilizing satellite navigation is a typical mobile phone fix (GPS, GLONASS, Galileo etc.). But as GPS signals can also be suppressed, the PDR issue is important for user orientation in settings like huge shops, urban shopping malls, etc.



Fig 1.1. Muted GPS signal

A standard set of inertial measuring units (IMU)—accelerometers, gyroscopes, magnetometers, and pressure sensors—are integrated into the internal hardware of all contemporary smartphones.

ACIC DEPARTMENT			NAU 22 0492 000 EN		
Performed	Lazarevskiy O.A.		INDIVIDUAL MOBILE NAVIGATION SYSTEM OF WAY COUNTING		
Supervisor	Vasylenko M.P.				
Consultant					
S. controller	Filyashkin M.K.				
Dep. head	Sineglazov V.M.				
			N.	Page	Pages
			15	120	
			225 151		

Measurements made with a magnet will be off. One of two categories—hard iron or soft iron—is thought to apply to these errors. Solid iron distortion is caused by things that create a magnetic field. For instance, harsh iron distortion will be brought on by a loudspeaker or a piece of magnetic iron.

This kind of hard iron distortion will result in a constant bias at the sensor output if a piece of magnetic material is physically attached to the same frame of reference as the sensor. Soft iron distortions are regarded as anomalies or modifications to the current magnetic field.

Depending on the direction the magnetic field is acting in relation to the sensor, these distortions will stretch or distort the magnetic field. Metals like nickel and iron are frequently responsible for this kind of deformation. Hard iron distortion will often add significantly more than soft iron to the overall uncorrected inaccuracy.

On the magnetometer's outputs, distortions of both hard and soft iron can be completely disregarded. Correcting the distortion of both hard and soft iron using the calibration model [3].

1.3. Block diagram of pedestrian dead reckoning

Nowadays, tasks can be solved without inertial pedestrian navigation thanks to the quality of inertial sensors built into smartphones.

A generic structure diagram [4] for dead reckoning for pedestrians is displayed in Fig. 1. 2. New methods to eliminate sensor errors utilizing flexible signals, along with the most recent MEMS performance enhancements, push the limits of current inertial pedestrian navigation systems.

The heading orientation angles in the pedestrian dead reckoning technique are calculated by integrating the angular velocities measured by the gyroscope. Gyroscope errors spread at a cubic rate using this method. The ability to lower sensor deflection and noise is limited in low-cost handheld devices.



Because the Earth's magnetic field is severely disturbed by the nearby artificial fields, updating the geomagnetic heading cannot be done easily or frequently in urban and interior spaces.

The parameterization of the rotation between the mobile device and the navigation frame is a further source of error.

This issue frequently arises because the hand moves quickly through three-dimensional space without indicating any direction.

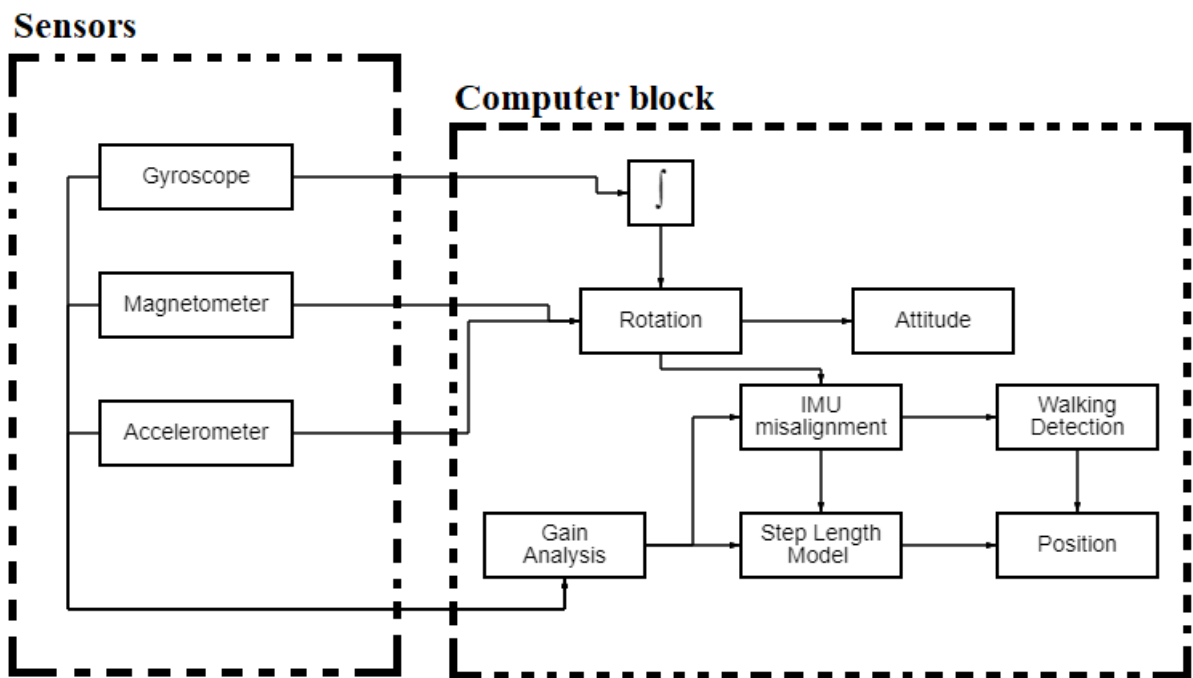


Fig. 1.2. Block diagram of PDR

1.4. Mathematical model of pedestrian dead reckoning

A nonlinear particle filter serves as the foundation for the mathematical model of a pedestrian's state [5]. The process of the equation of state is explained in such a nonlinear form that moving the user has a state vector s_k that estimates the parameters contained in the state vector:

$$s_k = [x^T \ V^T \ q^T \ \varepsilon_a^T \ \varepsilon_\omega^T]^T \quad (1.1)$$

Where x - coordinate, V - velocity, q - rotation quaternion, ε - displacement of readings of accelerometer and gyroscope.

$$x_k = x_{k-1} + V_{k-1} + C(q_{k-1})(\varepsilon_{a_{k-1}}) \frac{T^2}{2} \quad (1.2)$$

$$V_k = V_{k-1} + C(q_{k-1})(\varepsilon_{a_{k-1}})T \quad (1.3)$$

$$C(q) = \begin{bmatrix} q_1^2 + q_2^2 - q_3^2 - q_4^2 & 2(q_2q_3 - q_1q_4) & 2(q_1q_3 + q_2q_4) \\ 2(q_2q_3 + q_1q_4) & q_1^2 + q_3^2 - q_2^2 - q_4^2 & 2(q_3q_4 - q_1q_2) \\ 2(q_2q_4 - q_1q_3) & 2(q_1q_2 + q_3q_4) & q_1^2 + q_4^2 - q_2^2 - q_3^2 \end{bmatrix} \quad (1.4)$$

Dynamic models are based on a model of human movement.

The idea is that, by imagining a uniform movement within it, one can identify the basic harmonic property of the coordinates of every point on the human body, which is timed to the steps. Additional data to enhance the precision of systems that restrict the movement of body parts, such as maintaining an upright posture.

1.5. Human step model

Typically [6] a corresponding change in acceleration occurs as the phases of walking in Fig. 1.3 change. As a result, the majority of techniques for identifying and counting steps rely on processing the size of the acceleration vector.

Figure 1.2 is a schematic for analyzing the gait cycle, which has been extensively used to analyze and model human gait. As a result, the subject walks while switching between a double support (DS) phase and a single support (SS), as seen below:

- DS: the time when both feet are on the ground. The stance phase's start and finish are both regarded as double support periods
- SS: When the opposing leg is raised for the swing phase, the period begins

For comparison, DS normally makes up 20% of the average gait cycle in healthy persons whereas SS makes up 80%. As walking pace rises, the time required to maintain the two limbs falls. Running differs from walking since it doesn't have the DS period.

The simulation of walking motion in Figure 1.2 can be done by looking at the changes between the DS and SS states. Consequently, a number of gait parameters can be obtained:

- Step length: The action taken to move from one Single Support State to another Single Support State is referred to as a step. Calculate the duration of each step, the subject's movement's distance traveled, and the arm swing range (the arm swing is an intriguing parameter to research in the gait assessment).
- Stride length: The movement from one Double Support State to another Double Support State is known as a stride. Calculate the time and distance traveled by the subject for each step.
- Velocity: Knowing the speed of each step and stride is possible with the help of the timestamp and distance information.
- Walking rate, also known as cadence, is measured in steps per minute.

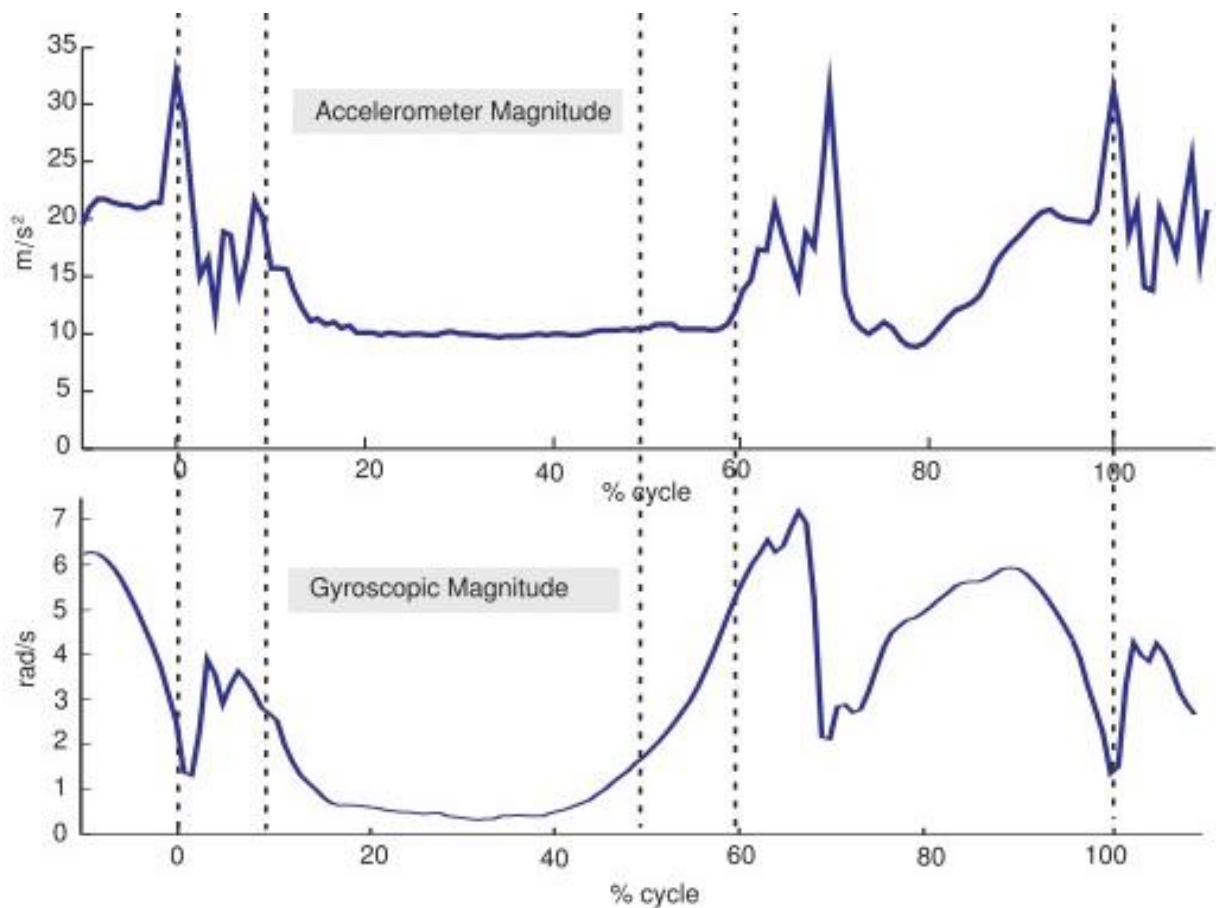


Fig. 1.3. Phases of walking

1.6. Coordinate systems

Numerous coordinate systems exist. Inertial frame of reference (IFR) and geographic coordinates were both used for the diploma.

1.6.1. Inertial reference system

All free bodies move rectilinearly and uniformly or are at rest in an inertial frame of reference [7].

Space is homogenous, isotropic, and time is homogeneous with respect to IRS.

With Earth as the IFR Despite being imprecise, Fig. 1.4 is frequently used in navigation. The following algorithm was used to compile the IFR. According to its chosen model, the earth's center is chosen as point O, the origin of coordinates. The rotational axis of the earth and the z-axis are parallel. The equatorial plane contains

the x and y axes. It should be noted that such a system is not involved in the Earth's rotation.

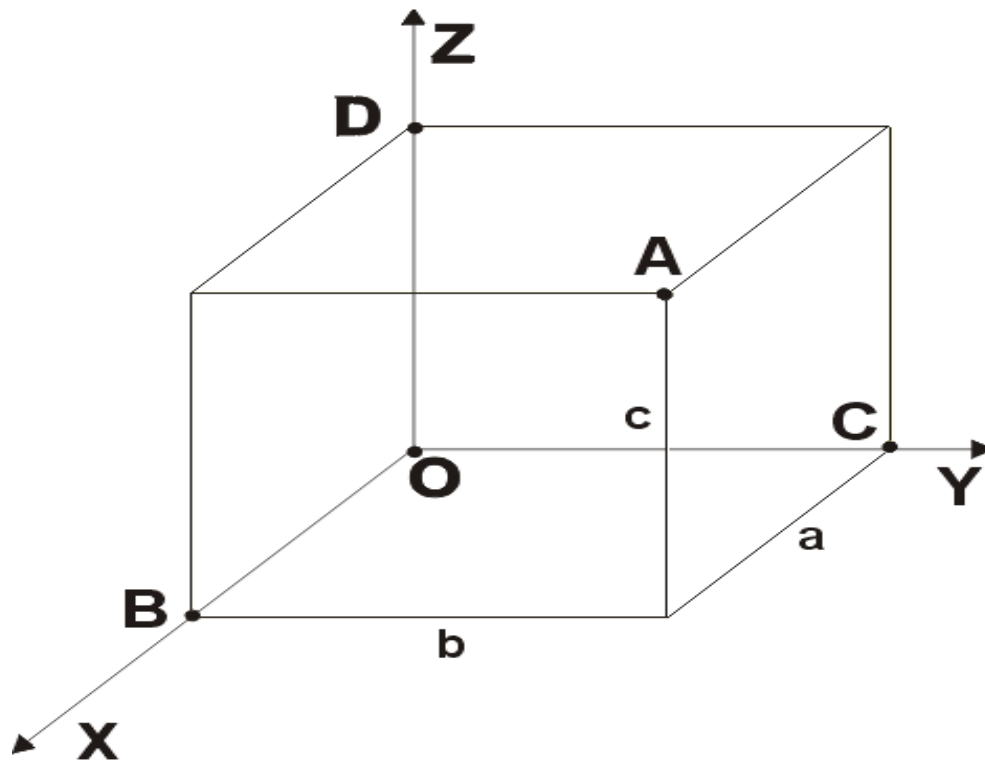


Fig. 1.4. Inertial rectangular coordinate system in space

1.6.2. Geographical coordinates

When the displacement of the plumb line is not taken into account, geographic coordinates are a broader notion of geodetic and astronomical coordinates [8]. In other words, the Earth is treated as a sphere for obtaining the geographic coordinates. Not an ellipsoid of revolution, Fig. 1.5. Geographic coordinates specify a point's location on the surface of the planet or, more generally, inside a geographic envelope. The spherical concept is the foundation of geographic coordinates. On the celestial sphere and for other planets, comparable coordinates are used.

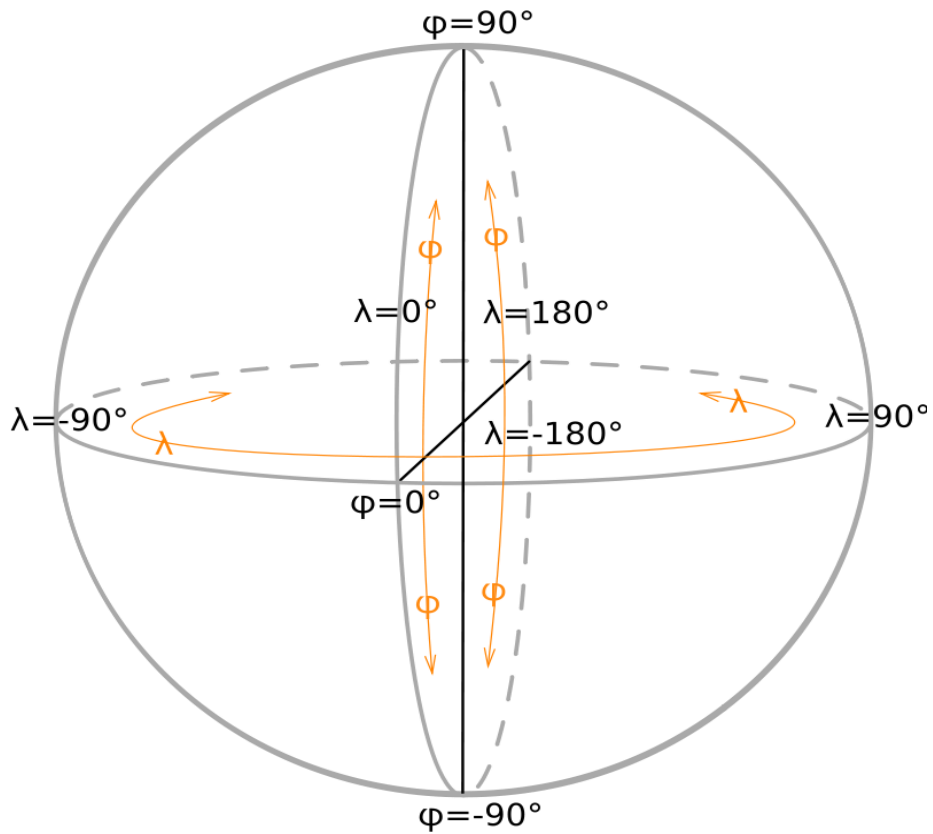


Fig. 1.5. Geographic coordinates on a sphere

The center of mass of the object (CMO) is chosen as the coordinate system's origin in navigation. The values of latitude and longitude are used to determine how to change the origin of coordinates from an inertial coordinate system to a geographic one (from O_i in O_g). When computing using the Earth's spherical model, the center coordinates of the geographic coordinate system (O_g) assume values:

$$\begin{aligned}
 X_{og} &= (D/2 + h) \cos(\varphi) \cos(Ut + \lambda) \\
 Y_{og} &= (D/2 + h) \cos(\varphi) \sin(Ut + \lambda) \\
 Z_{og} &= (D/2 + h) \sin(\varphi)
 \end{aligned}
 \tag{1.5}$$

where D — Earth's diameter, U — rotational angular speed of the earth, h — above-sea level elevation, φ — latitude, λ — longitude, t — time.

The scheme is used to determine the axes' orientation in the geographic coordinate system (GCS):



X-axis (also known as E-axis) - east-facing axis.

Y-axis (another designation - N-axis) - axis pointing north.

Z-axis (another designation is the Up-axis) - the axis directed vertically upwards.

The huge values of the angular velocity of this system at high latitudes, which increases up to infinity at the pole, is its primary drawback in the practical use of GCS in navigation. Consequently, a semi-free in azimuth CS is utilized rather than GCS.

A semi-free azimuth coordinate system is used in practice; all calculations are performed in this system, and the results are then output using the Global Coordinate System (GCS).

As a result, the system also has an initial position and operates using the formula:

$$\begin{aligned} N &= Y_w \cos(\varepsilon) + X_w \sin(\varepsilon) \\ E &= -Y_w \sin(\varepsilon) + X_w \cos(\varepsilon). \end{aligned} \tag{1.6}$$

CHAPTER 2. OVERVIEW OF TECHNIQUES FOR COUNTING STEPS AND DETERMINING THE DIRECTION OF PEDESTRIANS

Inertial navigation systems are now less common among regular users because it is possible to use GPS, with businesses being the main exceptions.

Both large, custom systems and typical systems are available for purchase, typically through subscription. Additionally, their source code is restricted, so if there are errors, it may be necessary to contact the support team, which will take a long time, or to modify and add something to the system, which will be nearly impossible.





Due to the system's independent implementation, the developer has complete control over all operations and can select the right tools for the job at hand as well as update and expand the application.

2.1. Smartphone-based method of pedestrian dead reckoning

Several approaches to step detection and course calculation were taken into consideration when developing the project to ascertain the user's location and position.

There are numerous ways to determine the steps at the moment, but Table 2.1 lists the five most popular ones:

- Threshold detection method
- Threshold dynamic detection method
- Zero-crossing method
- Peak detection method
- Autocorrelation

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Supervisor	Vasylenko M.P.				25	120
Consultant				225 151		
S. controller	Filyashkin M.K.					
Dep. head	Sineglazov V.M.					

Additionally, there are several techniques for calculating the course, including using a magnetometer and a gyroscope (Table 2.2):

- Component of vertical angular velocity
- Signed magnitude angular velocity
- Calculation of the course based on the magnetometer

Table 2.1 Existing methods for finding a step

	Extensibility	The need for filtration	Performance
Threshold detection	-	-	+
Threshold dynamic detection	+	+	+
Zero-crossing	+	+	+
Peak detection	+	+	+
Autocorrelation	+	-	-

Table 2.2 Existing methods of finding a course

	Extensibility	Accumulation of error	Performance
Component of vertical angular velocity	+	+	+
Signed magnitude angular velocity	+	+	-
Calculation of the course based on the magnetometer	+	-	+



2.1.1. Step counting method based on threshold detection

The most straightforward way for identifying steps in a time series of data obtained from accelerometer sensors is the threshold detection method, which is the approach employing thresholds [9]. The waveform of the signal that is received from the sensors is used to assess if it satisfies certain criteria. Which needs to be adjusted depending on the device being used, the person's speed when walking or running, and other factors. Then, if testing this method with numerous users, there are numerous options.

The frequency of readings will also be crucial because thresholds differ significantly amongst devices. There is no assurance that another person's walking will be identified when employing a constant frequency that recognizes one person walking normally. Additionally, the phone may be held in many ways in the hands, in a pocket of shorts or pants, or attached to a belt. This provides little information and a lot of duplicate data. Software that functions on one phone may not function on another, even one of the same models, because manufacturers use [10] different versions of accelerometers.

Even though the approach based on thresholds is the most straightforward, it can be very challenging to select a single optimal threshold for all circumstances, especially when using a smartphone without any space limitations.



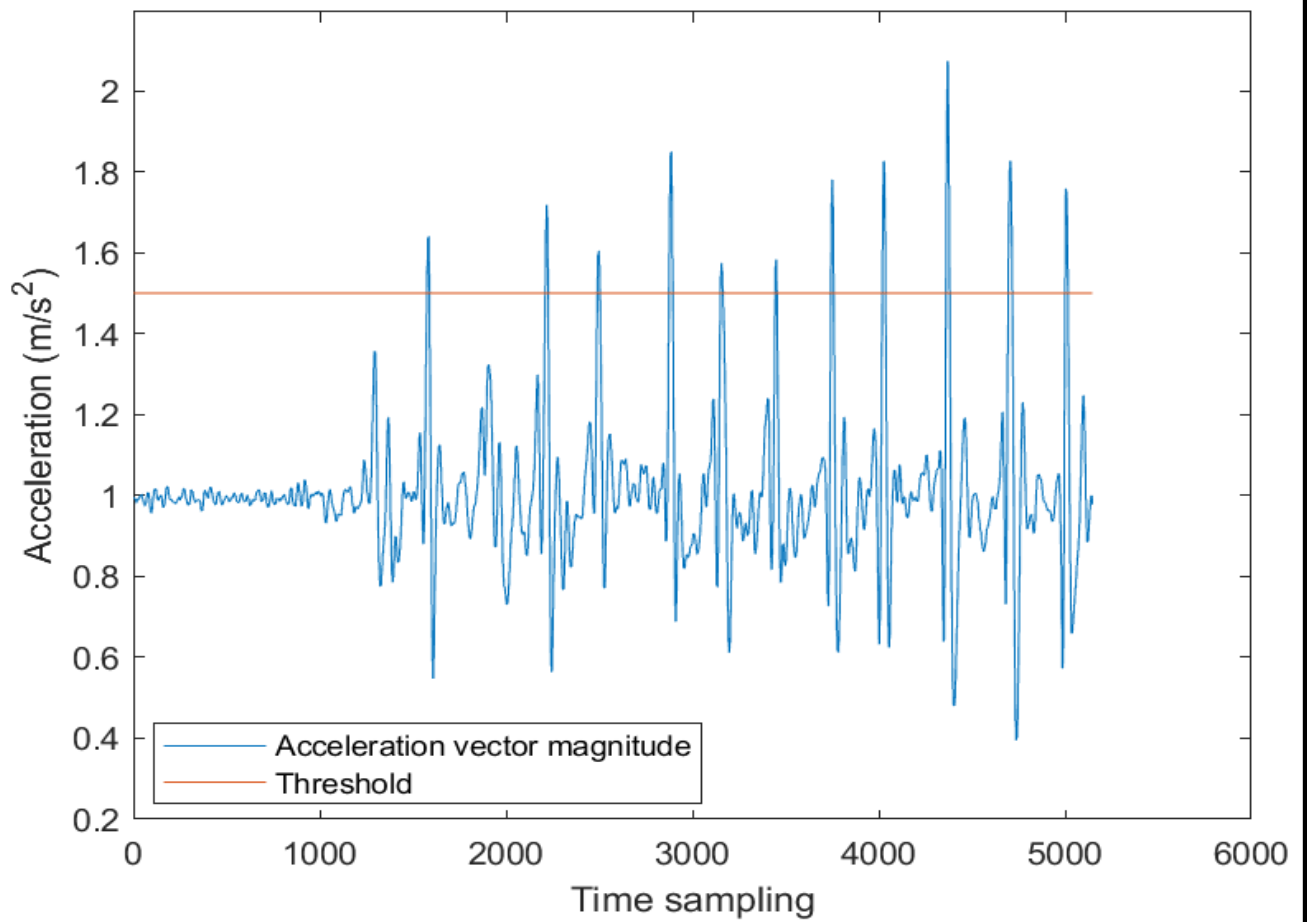


Fig. 2.1. Evaluation threshold for counting steps

Disadvantages:

- Pace of walking
- Frequency of data recording
- Sensor model
- Being in a fixed plane
- Constant threshold

Advantages:

- Simple algorithm
- Works fast

2.1.2. Step counting method based on dynamic detection threshold

An approach using a threshold dynamic step detection method [16], a more sophisticated version of the threshold method, is known as the "dynamic detection threshold method".

The method is made to accommodate the fact that a person can alter his walking pace, switch to running, and make abrupt stops, so a dynamic change in the threshold allows for a more accurate recording of a person's steps.

To determine the step, there are various steps:

- Smoothing
- Dynamic threshold detection
- Algorithm for detecting steps
- Periodicity

Smoothing: Due to inaccurate data acquisition and signal digitization, the signal does not always appear smooth and often contains additional oscillations and noise. This issue will be improved by signal smoothing.

Smooth signal: This is a quick approach to average data that are close together and reduce some of the noise. For instance, the mean of the current sample, the sample before it, and the sample after it might be used to replace each sample. Eliminate unnecessary signal zones using noise. It is required to utilize multiple anti-aliasing windows in order to see the effects differently. The signal will appear cleaner and more aesthetically pleasing as the smoothing window widens, but caution must be exercised when using a window that is too big to smooth out the steps that must be detected first.

Dynamic detection threshold: After smoothing the data, the next challenge is figuring out when a step takes place. One can, for instance, just count the steps by determining the highest point of each step. However, as the threshold relies on the orientation of the user's phone and the accelerometer in it, there is no set

threshold that can be employed. Therefore, a dynamic threshold detection approach must be used for step detection.

Tracking the axis (x, y, or z) along which the largest acceleration occurs is the initial step in this technique. Even though gravity only exerts its pull along one axis, this algorithm may disregard the others and just pay attention to that one axis. This axis displays the selection window's minimum and maximum acceleration values. In other words, continuous measurements of the maximum and minimum triaxial acceleration are made every 50 counts. The dynamic threshold is the average value. This threshold level is used to assess if actions have been done for the subsequent 50 samples. The threshold is dynamic and is changed every 50 samples. The z-maximum, axis's minimum, and (dynamic) threshold values are displayed in Fig 2.2.

Step detection algorithm: The step detection algorithm can function by looking for threshold crossings in the downstream (or upstream) direction given the dynamic detection threshold. For instance, it is evident from Figure 2.2 that each step entails passing through the threshold (purple line) in a descending direction with a noticeable change in acceleration in the opposite direction.

In other words, a step is considered to have occurred if the acceleration curve has a negative slope when it crosses below the dynamic threshold. Improvements that might be made to the step detection method.

Periodicity: Depending on whatever axis experiences the largest change in acceleration, the step counter will compute steps along the x, y, or z axes. The step counter will toss out acceleration changes that are too tiny. With this algorithm, the step counter can function well, but occasionally it seems overly sensitive. The step counter will also count when the pedometer vibrates very quickly or very slowly for an activity other than walking or running. In order to identify the true rhythmic steps, such undesirable vibrations must be eliminated.

It is vital to consider the amount of time that separates any two stages in order to prevent this. assuming that individuals can walk at one step every second and sprint at five steps per second. Therefore, to reduce the number of error sources, all steps with intervals outside the time window can be discarded. The distance between two permissible steps is therefore in the range [0.2 to 1.0 s].

Disadvantages:

- Smoothing required, possible loss of signal data
- Being in a fixed plane
- More time consuming

Advantages:

- Dynamic threshold
- Ability to change the pace
- Ability to change the speed of data writing
- Extensibility of the step detection algorithm

The algorithm is slower than the traditional thresholding method but is more accurate.



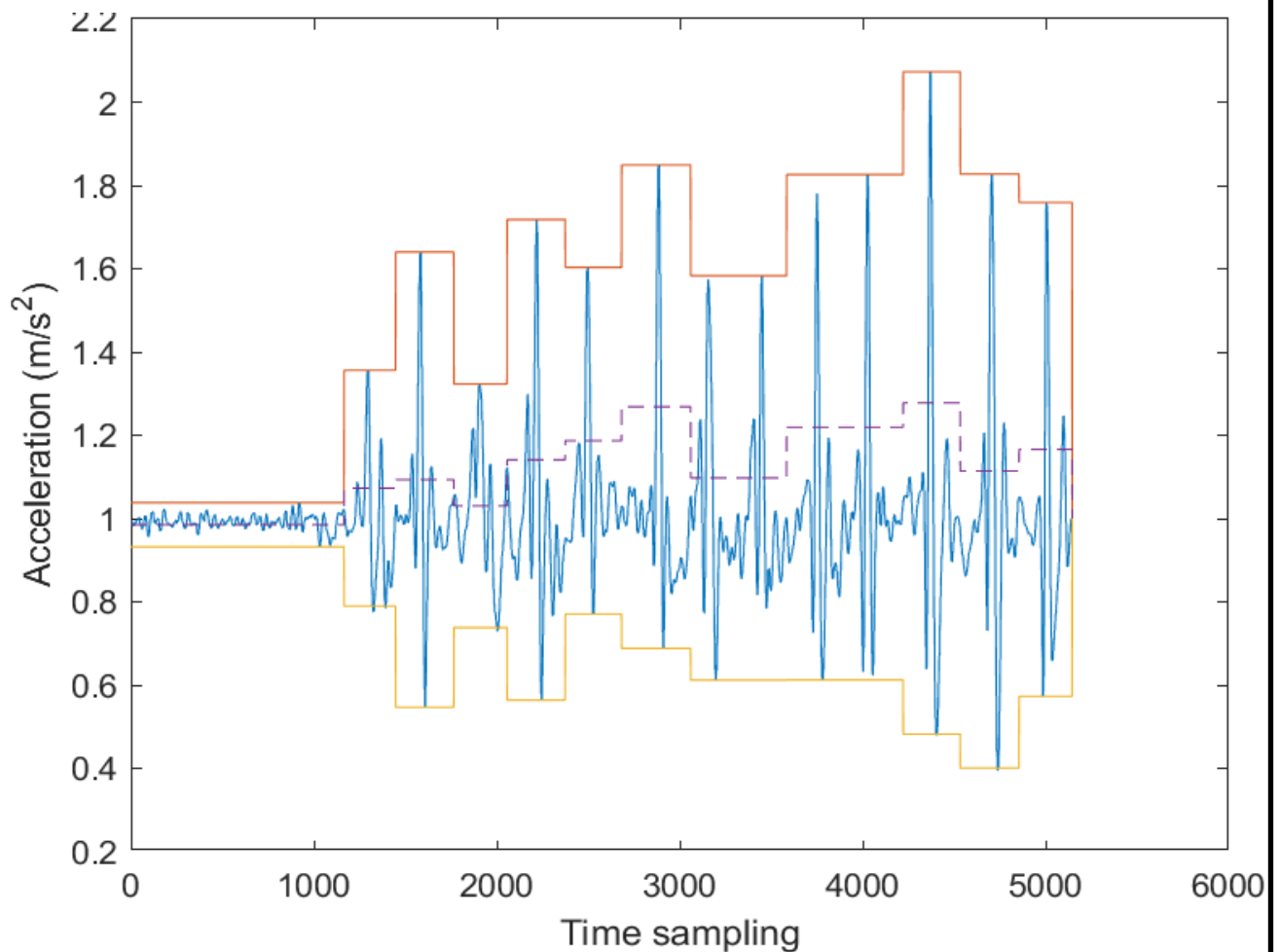


Fig. 2.2. Dynamic detection threshold

2.1.3. Step counting method based on zero-crossing

Zero-crossing (ZC) - This method counts the steps [9], identifying the number of zero points that are vulnerable to sensory corruption and typically call for pre-filtering and anti-aliasing of the original sensory data.

Figure 2.3's zero-crossing displays the acceleration module's data after the user resumed walking following a brief halt. A repeating pattern, consisting of a signal crossing the zero mark once in a negative direction, followed by the same action but in a positive direction, may be seen as soon as the user starts to walk. ZC is a phenomenon that may be utilized to count steps [17]. When employing ZC, there is one significant problem, though. Even after using the noise reduction procedure, the raw acceleration data still has noise, as was previously described. Even while the user is at rest, this noise might exceed zero in the signal register.

To resolve this issue, the zero-crossing boundary is utilized. Boundary zero-crossing can be viewed as a filtering mechanism that enables the system to only take into account zero crossings caused by actual body movement.

This is accomplished by placing fictitious limits, known as ranges, on each side of the zero point. BZC range is indicated in Fig. 2.3 by red lines. Only if the signal originated from outside of this range is zero-crossing taken into account; otherwise, it is ignored. The points in Fig. 2.3 where the zero crossing is taken into consideration are depicted in green.

The zero-crossing approach, which uses acceleration values or angular velocities to look for periods inherent in the cyclical nature of walking, can improve performance, for instance with vertical accelerations, but suffers if the smartphone is not tightly fastened to the user's body.

Disadvantages:

- Smoothing required, possible loss of signal data
- Being in a fixed plane
- Constant detection limit
- Additional data processing required

Advantages:

- Ability to change the pace
- Ability to change the frequency of data recording
- Extensibility of the step detection algorithm

This algorithm gives a significant measurement error when used alone, so it is best used in conjunction with other algorithms to improve their accuracy.



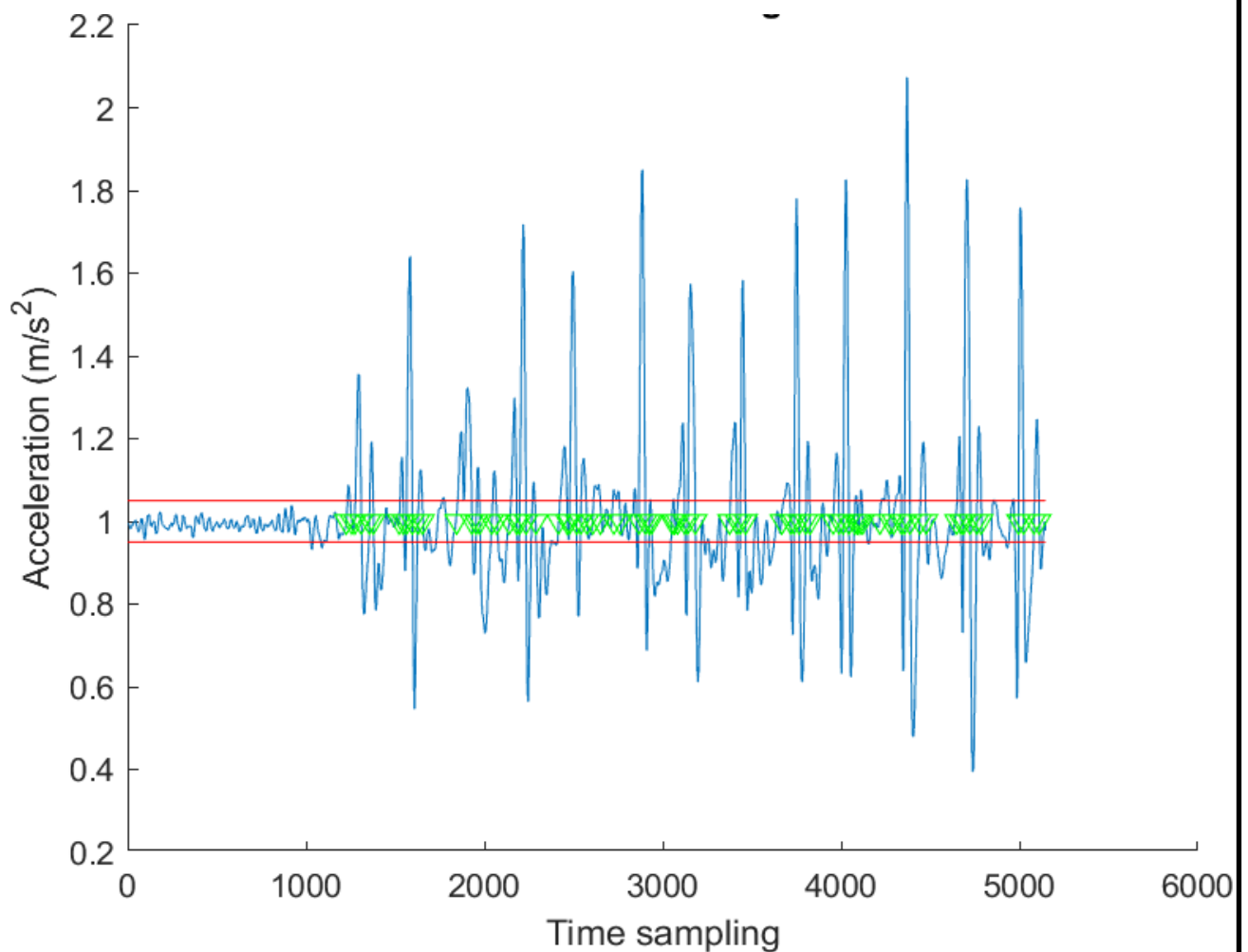


Fig. 2.3. Zero-crossing method

2.1.4. Step counting method based on peak detection

Peak identification is a job in signal processing and time series analysis [9]. Smoothing and matching a known peak form to a time series are two common methods for peak identification. The peak detection approach, which does not rely on predetermined thresholds and estimates steps based on the number of peaks provided by the sequence of captured data, suffers from interference peaks caused by random interference and environmental noise. Low-pass filtering must be used to reduce interference in order to eliminate noise and noise from the surroundings [18].

By calculating the growth and decrease of the acceleration modulus vector, the boundaries of the peaks are sought. As a result, all potential peak spots are identified and will then be processed. In order to prevent this, it is also required to

consider the time interval between any two steps in order to restrict the times between two peaks in line with the model of human behavior and in the frequency of dynamic threshold detection.

If there are multiple peaks in the time interval, the main one is highlighted using the acceleration vector module, or the peak's magnitude. This is done by comparing how far apart the peaks are from one another and assuming that when the gap is overcome, there are already two or more peaks that need to be processed.

Assuming that individuals can walk at one step every second and sprint at five steps per second. In order to limit sources of mistake and erroneous judgment, any steps at intervals outside the time window can be disregarded. With a time, sample of 100 Hertz, the gap between two permissible steps is thus in the range [from 0.2 to 1.0 s]; this value will be [from 20 to 100-time samples]. The vector module is used for acceleration along three axes, thus identifying the device does not have to be done in a certain plane. This allows for freedom of movement when using a device for which acceleration data is measured.

The peak detection is acquired via the application of the approach, allowing for the discovery of more precise information regarding a person's step. As opposed to the intersection ZC, where both the border and the range are situated close to noisy regions. The peak detection approach in Fig. 2.4 eliminates the majority of the drawbacks of other methods but falls short of them in terms of speed of data processing. Applying more filters, such as a filter to lessen jitter during acceleration or the vertical acceleration data used to determine the steps needed to combine sensors, could improve this algorithm.

Disadvantages:

- Additional data processing required
- Necessary filtering of false peaks

Advantages:

- Ability to change the pace

- 3-axis freedom
- Smoothing does not lead to data loss
- Ability to change the frequency of data recording
- Extensibility of the step detection algorithm
- Speed

In compared to other algorithms, this one has proven to be the most dependable, user-friendly, and accurate. This algorithm has the benefit of not requiring continuous detection bounds, unlike threshold values, dynamic detection thresholds, and ZC approaches. It also processes data quickly and its algorithm and application techniques are very extensible.

Combining them with other techniques also helps to fully realize their potential.

Due to its speed and accuracy in counting steps—both of which are crucial for the subsequent construction of the route—this specific algorithm for finding steps was used during the work. It effectively counts steps even when using the phone haphazardly while walking. The benefits of the procedure totally outweigh the drawbacks.



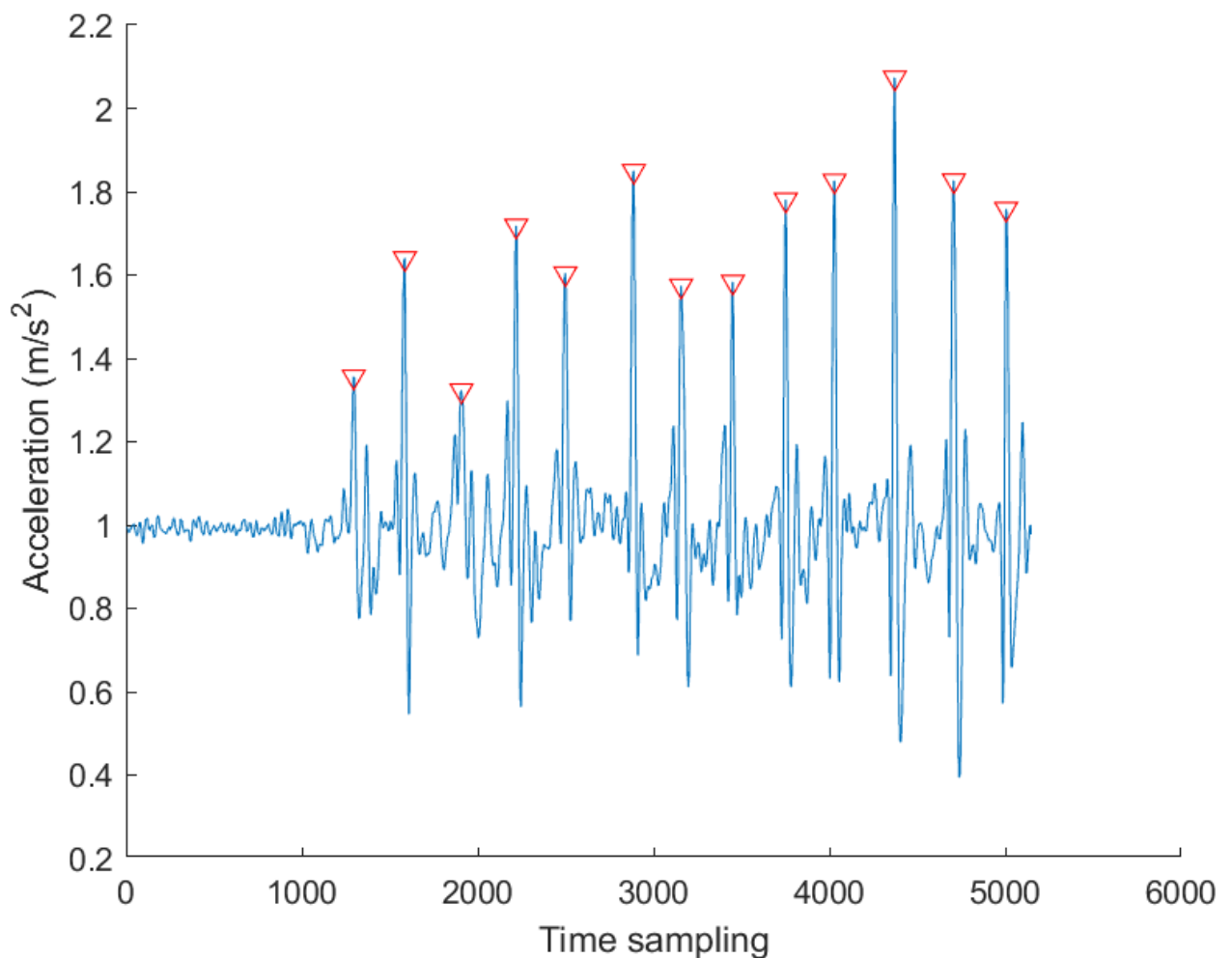


Fig. 2.4. Peak detection

2.1.5. Step counting method based on autocorrelation

Autocorrelation is a method that, in contrast to frequency domain approaches, provides for high performance at a very cheap cost and explicitly identifies cyclical periods in the time domain [9]. By looking at the pattern of the accelerometer signal, which repeats each time the user makes a new step, it is possible to determine that the user's movement is repeated. Autocorrelation may therefore be used to gauge the degree of similarity between a particular time interval and its inverse counterpart in succeeding time intervals by taking into account an accelerometer signal in the time domain [19]. This idea allows for the detection of steps through the analysis of the operation's maximum outcomes.

a correlation-based autocorrelation algorithm for counting steps on mobile devices.

Model used:

$$y_t = \varepsilon_t - 0.5\varepsilon_{t-1} + 0.4\varepsilon_{t-2} \quad (2.1)$$

where ε_t is Gaussian with mean 0 and variance 1, y_t - random process.

The autocorrelation function measures the correlation between y_t and y_{t+k} , where $k = 0, \dots, K$.

According to [20], autocorrelation for lag k is equal to

$$r_k = \frac{c_k}{c_0} \quad (2.2)$$

Where

$$c_k = \frac{1}{T} \sum_{t=1}^{T-k} (y_t - \bar{y})(y_{t+k} - \bar{y}) \quad (2.3)$$

c_0 - sample variance of a time series.

Assume for the moment that the theoretical autocorrelation function (ACF) is equal to zero at q , the lag beyond which the ACF actually equals zero.

Consequently, $k > q$ equals the estimated standard error of autocorrelation at lag.

$$SE(r_k) = \sqrt{\frac{1}{T} \left(1 + 2 \sum_{j=1}^q r_j^2 \right)} \quad (2.4)$$

The standard error drops if the series is random to $\frac{1}{\sqrt{T}}$

An illustration of the autocorrelation of an acceleration signal is shown in Fig. 2.5. The bottom graph displays the autocorrelation of the same signal while the top graph displays the sensor's raw acceleration data.

Purely linear acceleration in Y and Z is used. Since X linear acceleration is more significantly impacted by phone shaking, it is not counted. Data is gathered in the first step in order to determine the horizontal components of the observed linear acceleration values and to look for potential periodic oscillation triggers. Correlation is utilized to find potential correlated segments in the second stage. You can consider these correlated segments to be user steps.

Disadvantages:

- Additional data processing required
- Possible data loss during correlation
- Speed

Advantages:

- Ability to change the pace
- Ability to change the speed of data writing
- Extensibility of the step detection algorithm
- Repeatability of the step pattern

Although this approach produces one of the fewest mistakes in measuring the number of steps, this algorithm is overly difficult for a future system owing to its complexity and non-linearity.

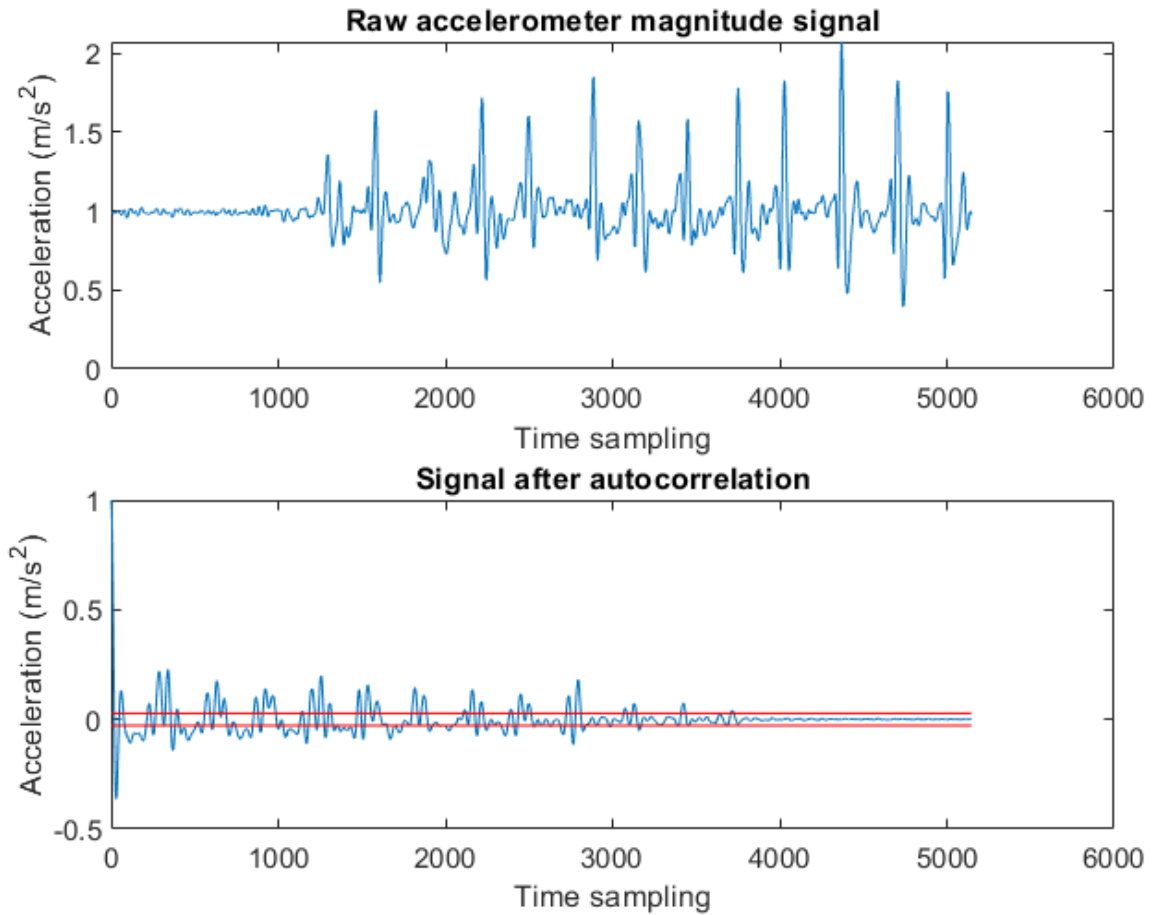


Fig. 2.5. Step detection based on autocorrelation

2.1.6. Method of determining direction based on the vertical angular velocity component

Using a gyroscope and the vertical component of the angular velocity vector [24], which can be derived using the predicted direction of gravity, this approach uses the vertical component to determine the heading. This gyroscope's vertical projection is denoted by the symbol ω_v , and its computation may be done at any moment as follows:

$$\omega_v(t) = \hat{\gamma}(t)^T \omega(t) \quad (2.5)$$

where $\omega(t)$, After the original gyroscope measurements have undergone the proper filtering to remove high frequency interference and random noise, a three-

dimensional vector of angular velocities should be obtained. The right-hand rule dictates, ω_v measures the horizontal turning speed of a pedestrian; positive (negative) speeds denote a turn to the right. So, direct integration is one method for calculating the course change $\omega_v(t)$.

$$\psi(t) - \psi_s = \int_{t_s}^{t_f} \omega_v(\tau) d\tau \quad (2.6)$$

where $[t_s, t_f]$ - time interval of interest (e.g. start and end of data recording), and $\psi(t) - \psi_s$ - relative to its initial value, heading angle in radians over time (i.e., cumulative heading change).

Disadvantages:

- Additional data processing required
- Filtration required
- Strict fixation to avoid unnecessary hesitation

Advantages:

- Simple method
- Speed

The fastest way to find directions has many disadvantages and a cumulative error that has a negative impact on the data over time.

2.1.7. Method of determining direction based on the signed magnitude angular velocity

Another solution to this problem is to use the magnitude of the angular velocity vector, which is known as signed magnitude angular velocity [24].

$$\omega_m(t) = \sqrt{\omega_x^2(t) + \omega_y^2(t) + \omega_z^2(t)} \quad (2.7)$$

The magnitude of the vectors does not rely on the frames in which they are measured when measurement errors are taken into account, hence ω_m is independent of sensor orientation. In actuality, bias and other systematic mistakes cause the measured value ω_m to have some orientation dependency.

Although other angular rates caused by pedestrian movement disturb the rate of interest, it is anticipated that the corresponding $\omega(t)$ will most of these be eliminated, so the filtered measurement should be close to the true horizontal rate of turn.

Determine the sign in order to distinguish between left and right turns $\omega_m(t)$ for every instant of time. This can be done by identifying the accelerometer's dominant axis—either x, y, or z—and using that axis' gyroscope sign to determine the rotation's direction. When two opposing axes are equally dominant (for instance, when a smartphone is tilted), this method may not be accurate 45 °, the Both on their axis and on the z-axis, the force of gravity is manifested in the same manner. Taking a different approach and identifying the difference between a turn to the left and right by looking at the sign will help you avoid this $\omega_v(t)$.

$$\omega_{sm}(t) \equiv \text{sgn}(\omega_v(t)) * \omega_m(t) \quad (2.8)$$

Where $\text{sgn}(\cdot)$ defined as ± 1 for positive / negative inputs and 0 otherwise. Finally, the calculation of the heading using this approach is performed as in the equation (6), but with replacement ω_v on ω_{sm} .

Disadvantages:

- Additional data processing required

- Filtration required
- Accumulation errors

Advantages:

- 3-axis freedom

Compared to the vertical angular velocity component, it is more sophisticated, but it also has a cumulative error that will inevitably grow over time.

2.1.8. Method of determining the course based on the calculation of data from a magnetometer

Calculation of the heading using a magnetometer - A magnetometer is a three-axis sensor used to measure the external magnetic field, which is made up of both the geomagnetic field of the Earth and any nearby magnetic disturbances (due, for example, to the presence of ferromagnetic materials).

The hard-iron and soft-iron distortions of the magnetometer are its defining features. Hard-iron distortion [23] is a result of the measurement field being combined with a DC component. This might be caused by the operation of a permanent magnet or the sensor's own zero offset, for instance. A multiplicative effect called soft-iron distortion reflects a shift in the magnetic induction vector's direction and/or a weakening of the vector.

This effect can be brought on by the presence of a metal object right next to the magnetometer or by inherent flaws in the sensor, such as scale factor errors or sags in the sensitivity axis.

It is possible to calculate the direction using the four-quadrant arctangent from the data from the sensor, converting the force into an angle in radians corresponding to the coordinates of the person's walking direction. This method uses data collected on the strength of the earth's magnetic field in three axes. finally changed to a degree measure $[0,360]$.

4-quadrant arctangent, returns values in a closed range $[-\pi, \pi]$ based on the values of the earth's magnetic force.

Disadvantages:

- Hard-iron and soft-iron
- The earth's magnetic field can change over time

Advantages:

- 3-axis freedom
- Has no cumulative error
- More accurate
- Fast method

The development of a pedestrian's dead reckoning system is best suited for this technique. Due to the fact that its application does not necessitate a thorough understanding of quaternions and rotation matrices, which simplifies the course's calculation and also does not have a cumulative error.

2.2. Description of data collection

To gather data, sensors like an accelerometer were employed (accelerometer bmi160) 3-axis sensor with low power consumption [21] is a low noise 16-bit IMU made for mobile applications like augmented reality or indoor navigation, and it offers extremely accurate sensor data and real-time sensor data. low current requirements BMI160 enables battery-powered gadgets to run continuously. This sensor has a programmable on-chip interrupt engine that offers contextual awareness and motion-based gesture recognition.

Table 2.3 Technical characteristics of the accelerometer

Parameter	Technical data
Dimensions	2,5x3,0x0,8 mm ³
Temperature range	-40 ... + 85 ° C
Supply voltage	1.2 ... 3.6 V
Consumption current	20 mkA
Sensitivity	± 2 г: 16384 μT / g

For data collecting, a 3-axis magnetometer was also employed. A three-axis electronic compass IC with an extremely sensitive Hall sensor is called AK09918 (magnetometer mag-akm09918) [22]. A sensor control circuit, a signal amplifier circuit, and an arithmetic circuit are all included in the small body AK09918 in addition to magnetic sensors for measuring terrestrial magnetism along the X, Y, and Z axes. Additionally, there is a self-test feature. It can be used in smartphones to navigate the map and implement the pedestrian navigation function due to its small size and thin packaging.

Table 2.4 Technical characteristics of the magnetometer

Parameter	Technical data
Dimensions	0,76x0,76x0,76 mm ³
Temperature range	-30 ... + 85 ° C
Supply voltage	1.65 ... 1.95 V
Consumption current	4 mA
Sensitivity	0,15 μT

The average acceleration vector is almost equivalent to the gravitational acceleration vector since gravitational acceleration is a factor in the data. Therefore, it is possible to determine the direction of the Z-axis of a moving person in the coordinate system of a phone by discarding acceleration vectors that are too large

and too small in magnitude in order to reduce the number of vectors responsible for the acceleration of a moving person, and then taking the average vector from the remaining. After that, a rotation matrix was applied such that the Z-axis of the person in Fig. 2.7 and the Z-axis of the phone in Fig. 2.6 were aligned. and modify the accelerometer and magnetometer data. When writing data, the Z axes lined up, so there was no need to finish the rotation matrix.

The data were recorded in a time sample with a data collection frequency close to 100 Hertz [Hz], that is, if the sample length was 60000, its approximate time can be easily calculated using the formula $t = \frac{N}{f}$, which equals 600 seconds or 10 minutes.

Where t — this time is in seconds, N – sample length, f – data recording frequency.

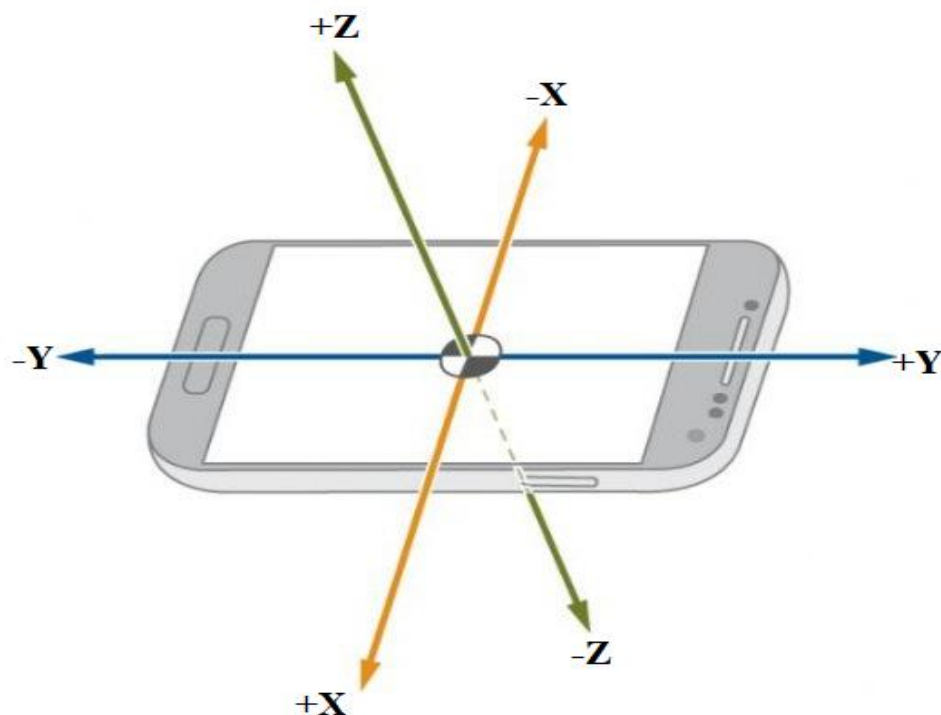


Fig. 2.6. Spatial axes of sensors in the phone

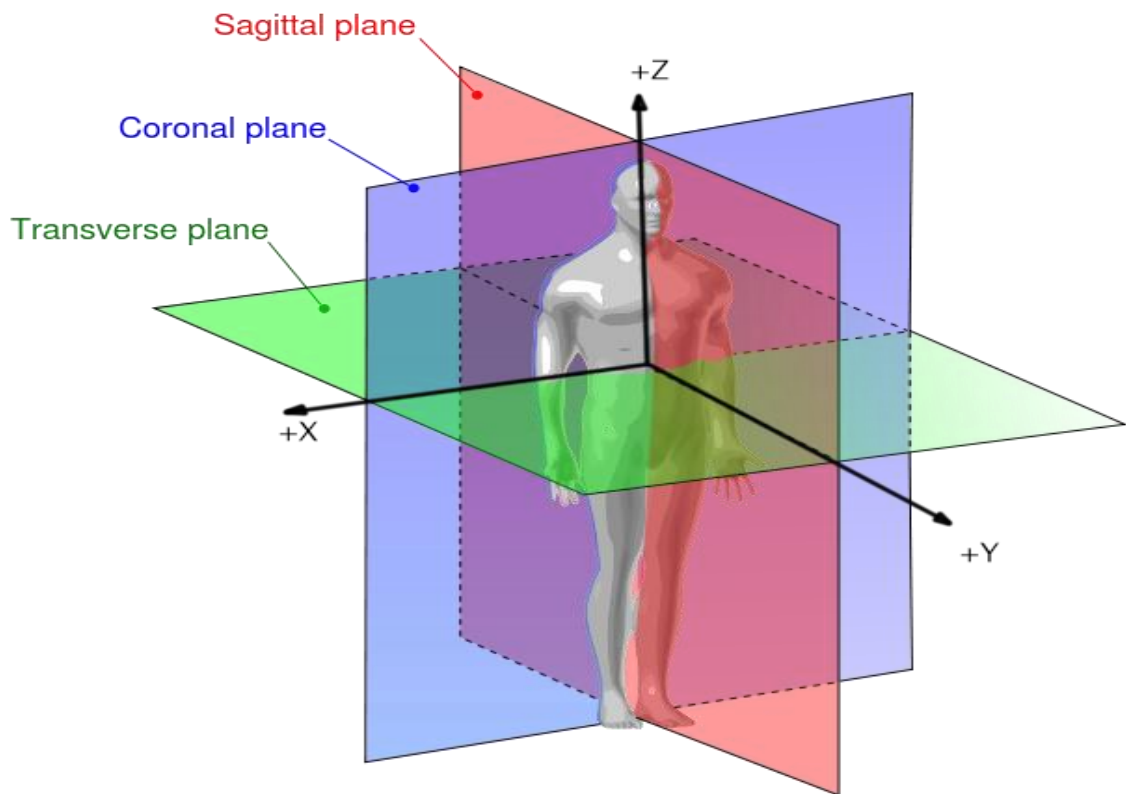


Fig. 2.7. Human axes in space

2.3. Conclusion

For this work, techniques for detecting a person's step were taken into consideration. For each technique, a pro and con were discussed. Finding the step peaks was the method that was selected because it is more appropriate for this job than the other methods mentioned.

Direction-finding strategies are also taken into account. The calculation of the course using a magnetometer was chosen because it has a significant advantage over the others in that it does not have a cumulative error.

Considered are the programs that will be required to implement algorithms and create an application.

CHAPTER 3. OPERATING ALGORITHM FOR MAGNETOMETER- BASED PEDESTRIAN DIRECTION ESTIMATION AND PEAK DETECTION STEP COUNTING

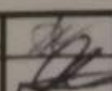
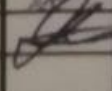
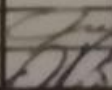
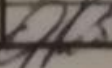
3.1. Data processing algorithm

The algorithm created to determine the pedestrian's steps and direction:

1. Writing data to the device
2. Loading data into the processing environment
 - a. Processing of the received data
 - b. Accelerometer
 - c. Magnetometer
3. Calculation of the magnitude of the acceleration vector
4. Filtration of low peak acceleration fluctuations
5. Determination of all possible peaks
6. Finding groups of peaks and false peaks
7. Determination of the main peaks in groups
8. Dividing peaks into steps
9. Detect pattern
10. Calculation direction
11. Route calculation
12. Layering the route on the global map
13. Comparison of GPS pedestrian path and pedestrian path using the phone's internal sensors

3.1.1. Writing data to the device

Data is obtained from the phone's internal MEMS sensors: magnetometer, GPS, and accelerometer.

ACIC DEPARTMENT			NAU 22 0492 000 EN			
Performed	Lazarevskiy O.A.		INDIVIDUAL MOBILE NAVIGATION SYSTEM OF WAY COUNTING	N	Page	Pages
Supervisor	Vasylenko M.P.				44	120
Consultant				225 151		
S. controller	Filyashkin M.K.					
Exp. head	Sineglazov V.M.					

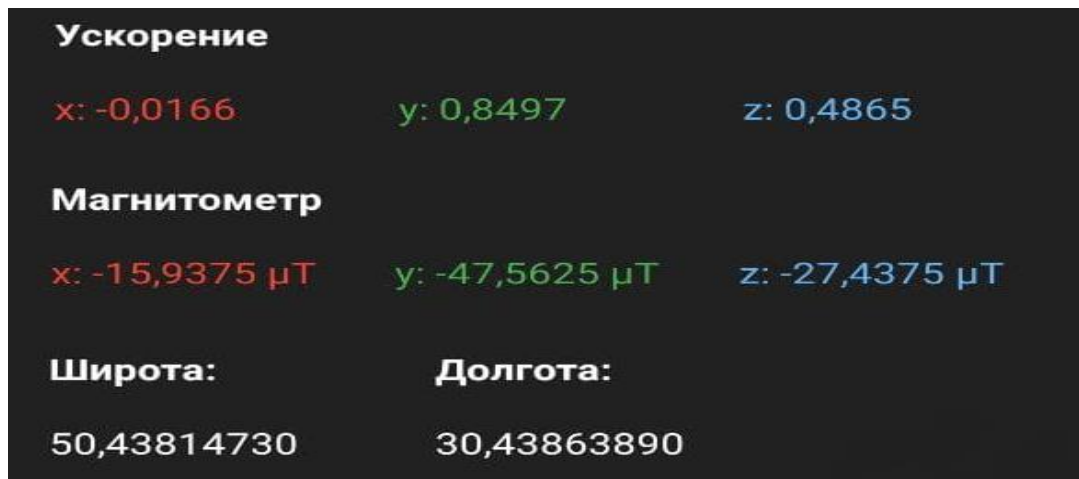


Fig. 3.1. Data recording

The 3-axis digital sensors are used for all data collection, and accelerometers are used to monitor changes in linear motion in accordance with the capacitive detection principle. This method of detection involves observing changes in capacitance between sensitive components. The 3-axis digital magnetometer geomagnetic sensor fits the criteria for compass applications. provides spatial orientation and motion vectors using sensor fusion software that is hardware-adapted.

It is possible to ascertain a pedestrian's path by using it in conjunction with an inertial measurement device. GPS sensors count the number of GPS satellites that are visible at the moment of recording while also measuring position, latitude, and longitude. This is done with at least four satellites so that the phone can locate itself from multiple angles and determine its x, y coordinates on the surface of the earth.

3.1.2. Loading data into the processing environment

After the data has been collected, it must be processed further, which requires loading the data into the processing environment. utilizing the MATLAB environment, whose built-in features enable data loading and processing. Details about Fig. 3.2, in the Appendix A.

time	gFx	gFy	gFz	wx	wy	wz	Bx	By	Bz	Latitude	Longitude	Speedms
Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
time	gFx	gFy	gFz	wx	wy	wz	Bx	By	Bz	Latitude	Longitude	Speed (m/s)
3.8180	0.0202	0.1829	0.9541	-0.0820	-0.0564	-0.0277	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8210	0.0145	0.1840	0.9649	-0.0820	-0.0564	-0.0277	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8230	0.0145	0.1840	0.9649	-0.0703	-0.0724	-0.0170	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8270	0.0145	0.1840	0.9649	-0.0703	-0.0724	-0.0170	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8280	0.0183	0.1860	0.9636	-0.0703	-0.0724	-0.0170	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8280	0.0183	0.1860	0.9636	-0.0490	-0.0852	0.0053	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8290	0.0183	0.1860	0.9636	-0.0490	-0.0852	0.0053	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0

Fig. 3.2. Loading data

It is necessary to distribute each piece of data separately, into its own variable, after loading it all into an array. To perform pathfinding, step counting, filtering, and post-processing.

3.1.3. Processing of incoming data

a) Since the accelerometer sensor moves constantly while walking and gravity constantly acts on one of its three axes, it is first necessary to calculate the module of the acceleration vector for a complete display of the data taken from the phone. Additionally, filters are added to the calculations to make them simpler, such as filtering low peak fluctuations and acceleration. And the MATLAB environment will show all data.

b) It is required to determine the pedestrian's movement's heading in order to determine the direction. The intensity of the magnetic field used in a magnetometer is what causes the earth's magnetic field to be induced on these sensors. Next, calculate the direction matrix to be used later to determine the pedestrian's path.

3.1.4. Calculation of the magnitude of the acceleration vector

For a general understanding of the human step, it is necessary to locate the module of the acceleration vector for all time-related data. Use the following formula to determine the magnitude acceleration vector.

$$A_m = \sqrt{A_x^2 + A_y^2 + A_z^2} \quad (3.1)$$

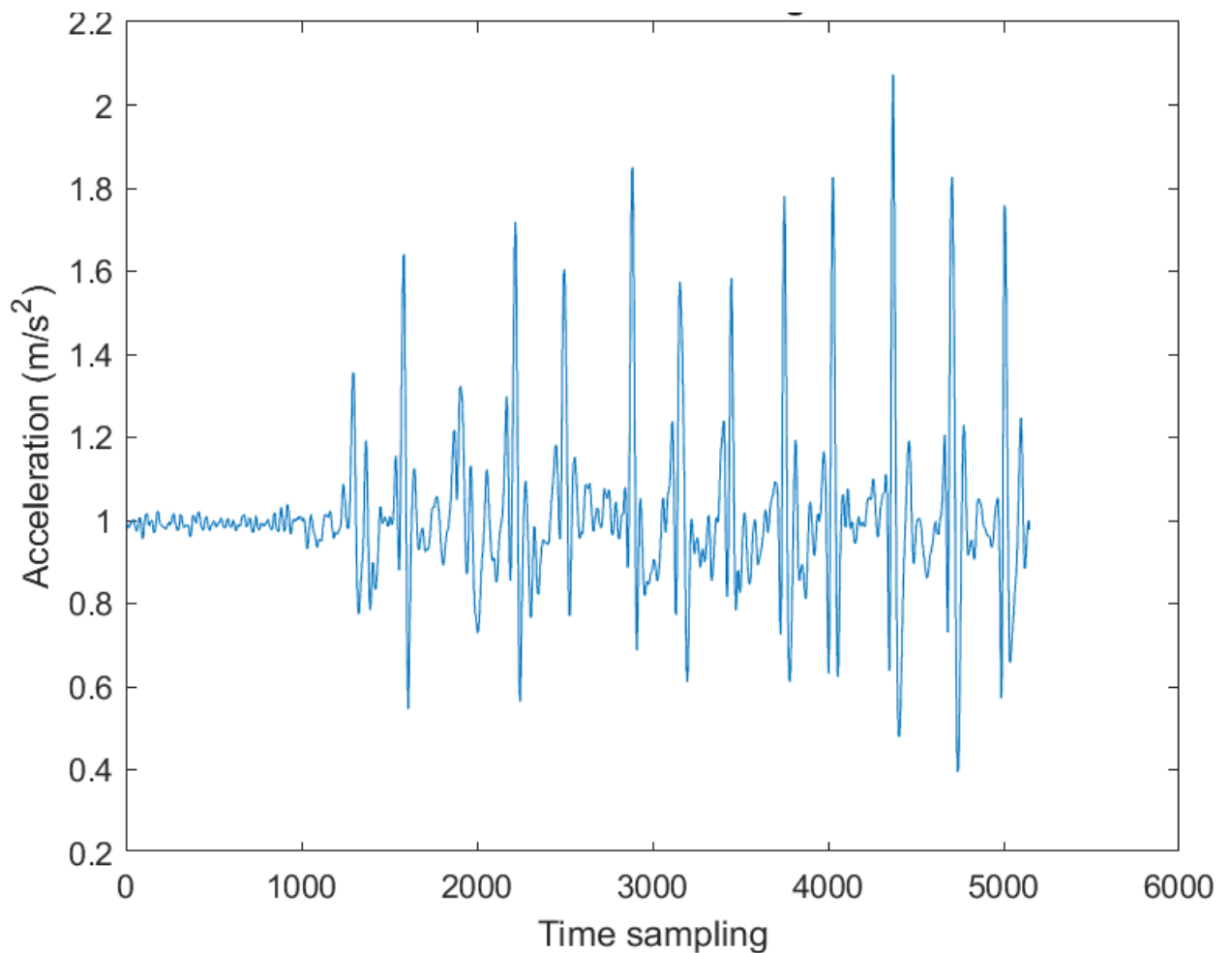


Fig. 3.3. The magnitude of the acceleration vector

3.1.5. Filtering low peak fluctuations Acceleration

The minimal acceleration peaks must be eliminated in order to streamline the step reckoning process. Data from 0 steps, or when the phone is on a flat surface without hesitating at rest, can be used to determine the minimum threshold that needs to be filtered. In the course of the research, it was discovered through experimentation that the necessary filtration height is in the range up to $A_{filter} = 1.2 \frac{m}{s^2}$.

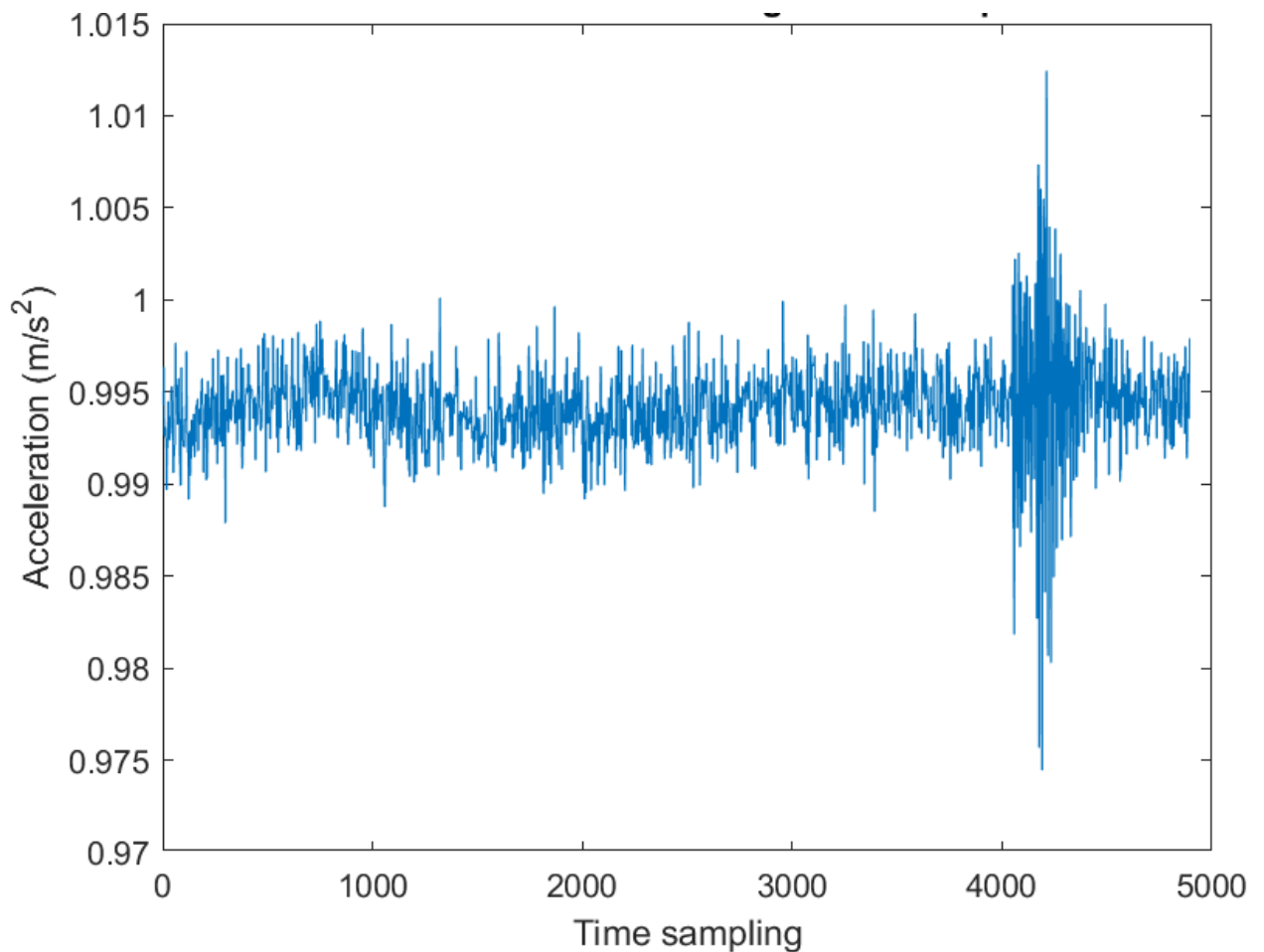


Fig. 3.4. Acceleration vector magnitude 0 step

If $A_m(i) \leq A_{filter}$ this condition is satisfied then $A_m(i) = 1$ after which the acceleration magnitude vector takes the form of a truncated vector, since this algorithm uses a detector that determines the peaks of the step, then do not need the bottom of the truncated vector, as for example, for the ZC algorithm.

Since the vectors were cured through 0 while employing the procedure, the informative content vanishes after cutting the bottom border. The acceleration vector data after applying filters has the appearance seen in Fig. 3.5.

In Fig. 3.5. All peaks of a person's future steps that fall under 2 filtering are displayed. The first step is to identify all potential peaks, and the second is to identify the major peaks in groups.

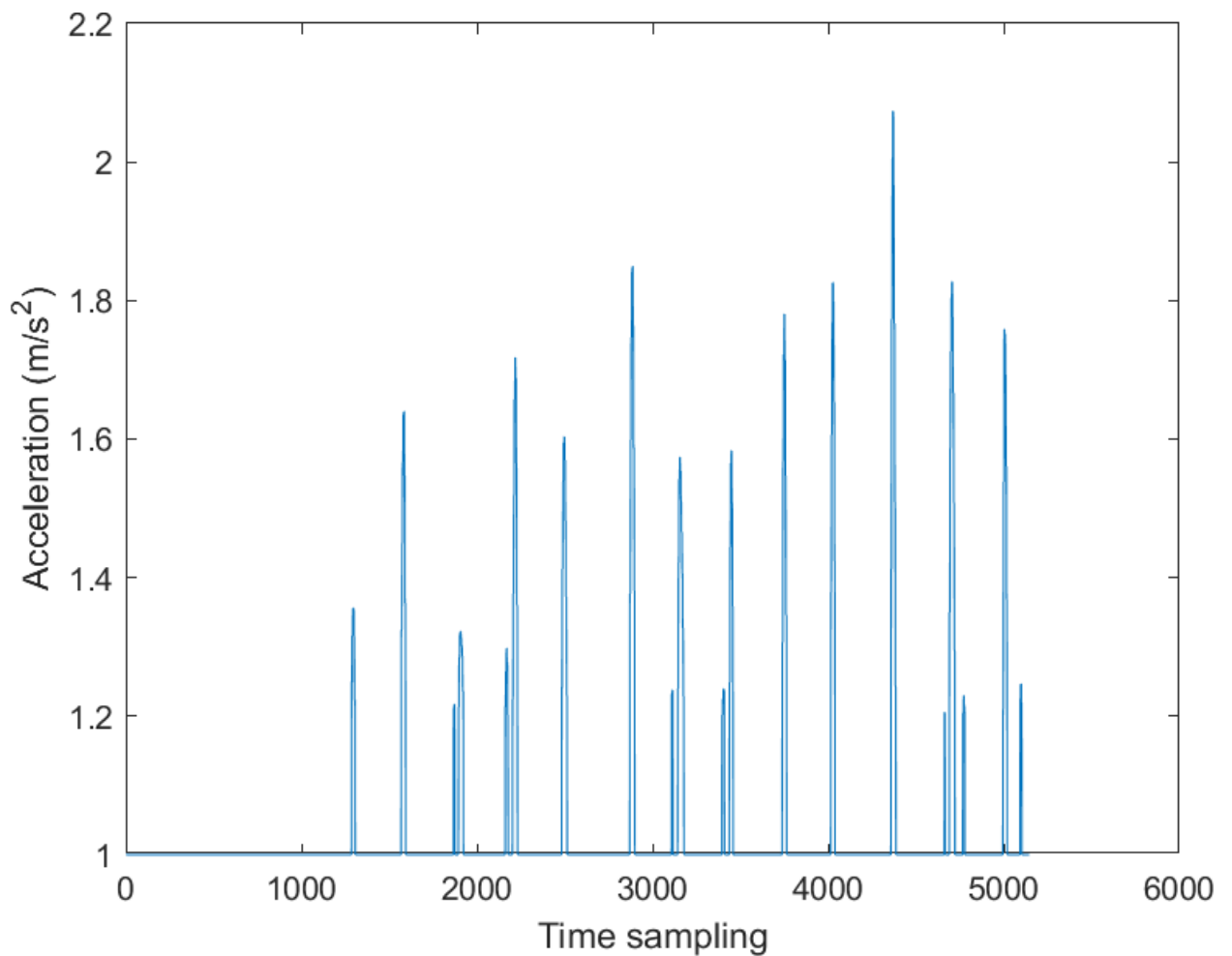


Fig. 3.5 Minimum Peak Threshold

3.1.6. Determination of all possible peaks

At this stage, it is necessary to find all possible peaks and their location in the timeline if the condition, $A_m(i + 1) - A_m(i) < 0$ this means that the current value is the end of the peak. Once all potential peak locations have been identified, it is necessary to enter the peak data into a peak height data matrix and locate the peak in time for further processing of the data and simplification of related actions.

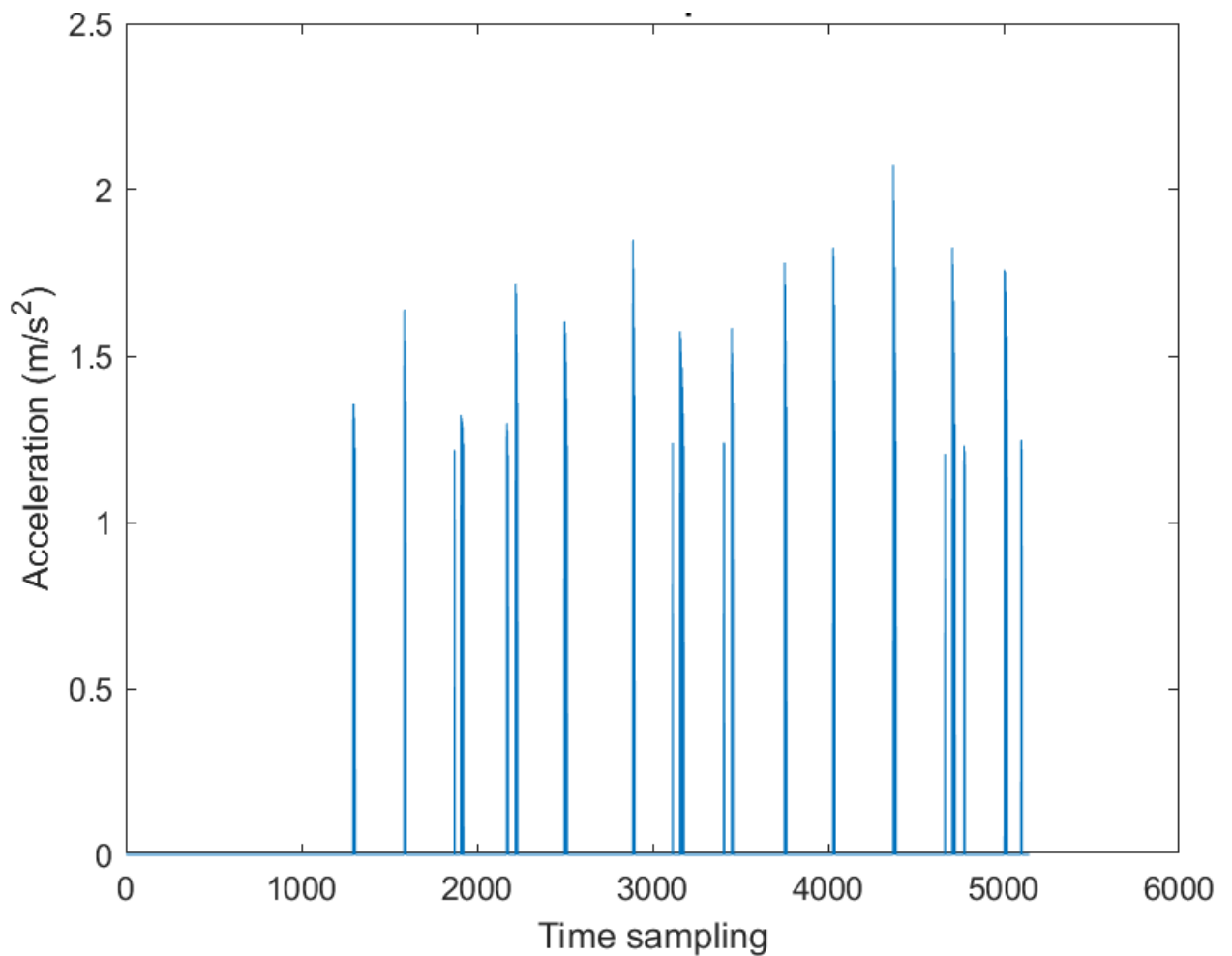


Fig. 3.6. All found peaks

3.1.7. Finding groups of peaks and false peaks

A peak distance filter is then employed to locate regions where the peaks are separated based on their distance from one another and to help identify false peaks that are a component of the step. If the distance between the discovered peaks exceeds the predetermined filtering threshold described in sentence **3.2**, $A_{Local\ Peaks\ Step}$, it splits into different peaks of steps.

From the group of peaks in one step, the remaining peaks must also be filtered, and its main peak must be chosen.

Regarding the pops that make up the data, it is necessary for this data filtering.

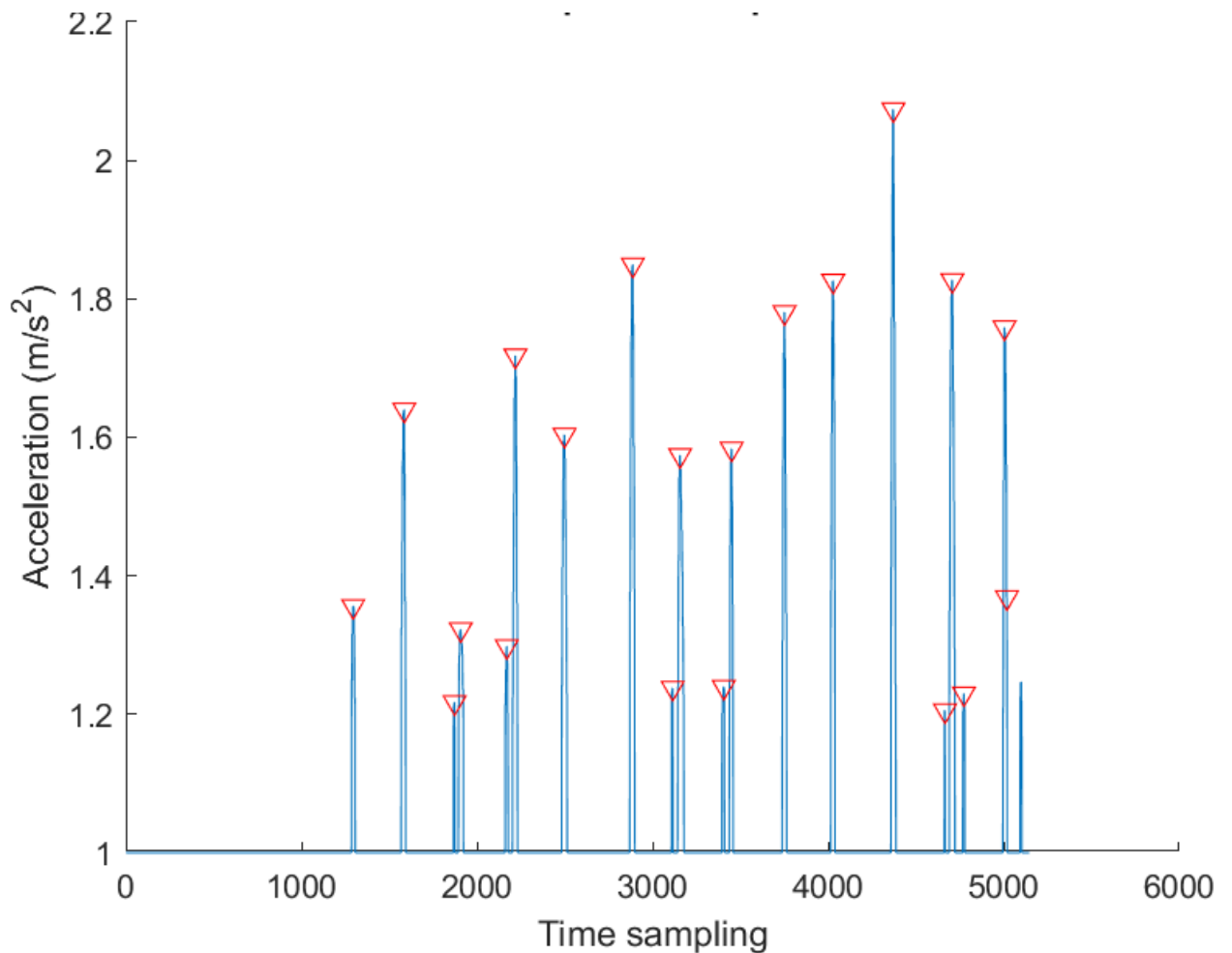


Fig. 3.7. Found unprocessed peaks

3.1.8. Determination of the main peaks in groups

As can be seen in Fig. 3.7, some peaks have false peaks that are close to the main peaks but do not fall under filtering 5 because their height is much higher than the filtering threshold. Therefore, in order to eliminate unneeded false under peaks, the main peak within these peak subgroups must be located.

In other words, if a group of peaks contains one or more peaks that are significantly smaller in amplitude than another peak, that peak is not included in the general data, indicating that it is only a part of the step and not the step itself. As a result, stop considering that peak to be the peak of the step. The grouping is also accomplished by the filtering criterion. **3.2**, $A_{Local\ Distance\ Peaks}$ at a distance of peaks located at a certain distance from each other.

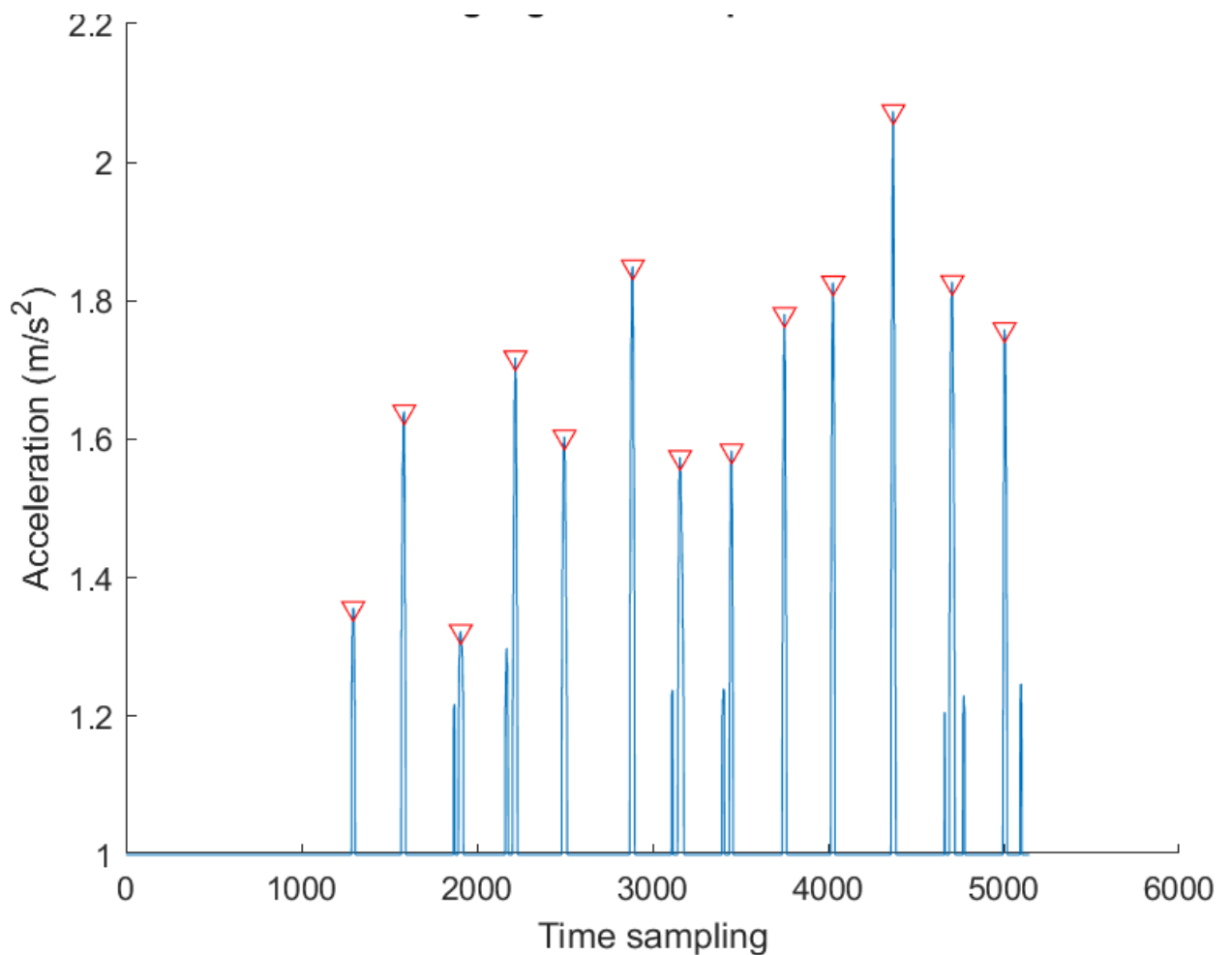


Fig. 3.8. Highlighted main peaks

3.1.9. Splitting peaks into steps

Only the peaks of the steps that were filtered in the earlier phases are left in the last step of the search for the total number of steps. Additionally, since the next step will be superimposed on the current course and a route map of the distance traveled will be drawn, it is necessary to record the positions of the peaks found in order to incorrectly calculate the direction of the course.

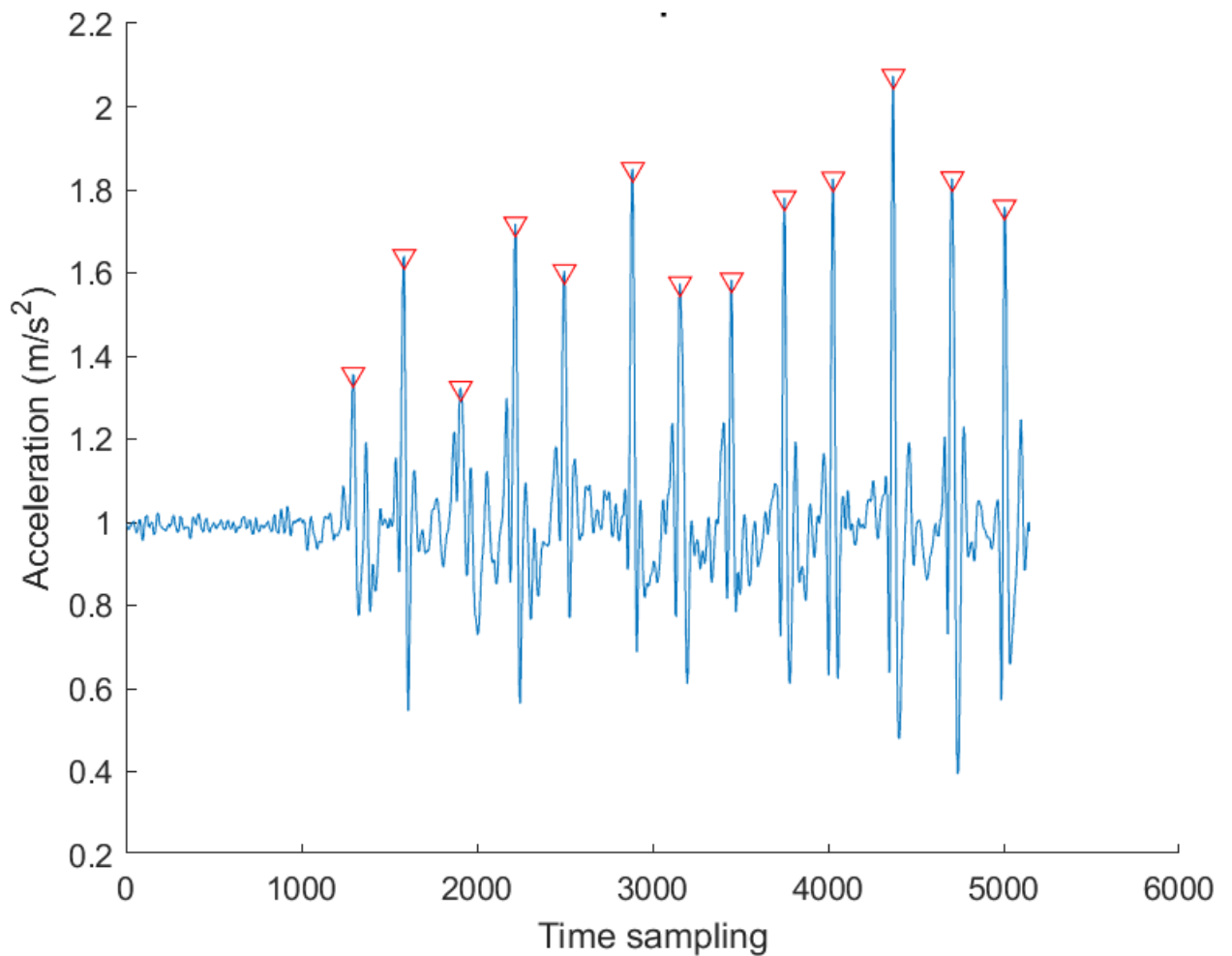


Fig. 3.9. All steps

3.1.10. Calculation direction

Calculation of direction, i.e. angle θ the direction can be determined using the four-quadrant arctangent from the data from the sensor, converting the force into an angle in radians corresponding to the coordinates of the direction a person is walking, taking into account the data gathered from the magnetometer integrated into the device and knowing the magnetic force of the earth along two axes. finally changed to a degree measure $[0,360]$.

4-quadrant arctangent, returns values in the closed interval $[-\pi, \pi]$ based on the earth's magnetic force values.

If the device can calculate the direction using its internal sensors, the advantage of this data is transmitted.

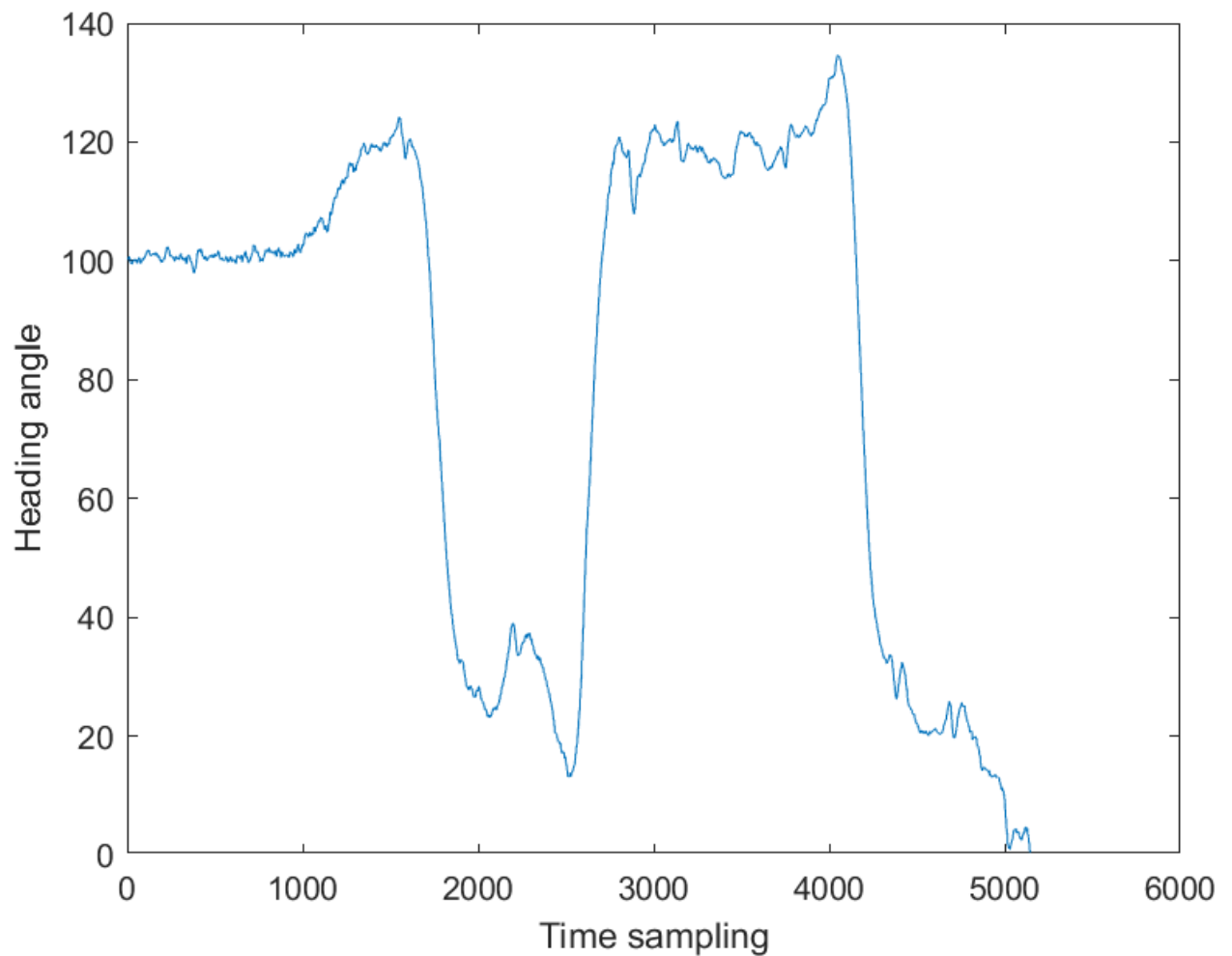


Fig. 3.10. Heading angle

3.1.11. Heading calculation

The path taken by the pedestrian while the data was being recorded is constructed using the angles, the direction, the predetermined number of steps, and their placement in relation to the timeline. By switching from a rectangular to a great circle coordinate system and altering the lengths of parallels depending on the latitude where the test object is located, as per the standards, the display accuracy is greatly increased.

Since the inertial system only displays the distance traveled relative to the initial reference point in meters, and the world direction is preserved relative to the coordinate axes where the positive X-axis is the East direction and the positive Y-axis is the North, West, and South directions, respectively, opposite each other, the

user has the option to provide his approximate coordinates if he is unable to receive a GPS signal.

$$\begin{aligned} X(i + 1) &= \cos(\theta(i) + 90) * l + X(i) \\ Y(i + 1) &= \sin(\theta(i) + 90) * l + Y(i) \end{aligned} \quad (3.2)$$

Where l – this is the step length, θ – angle direction, (X, Y) – coordinates.

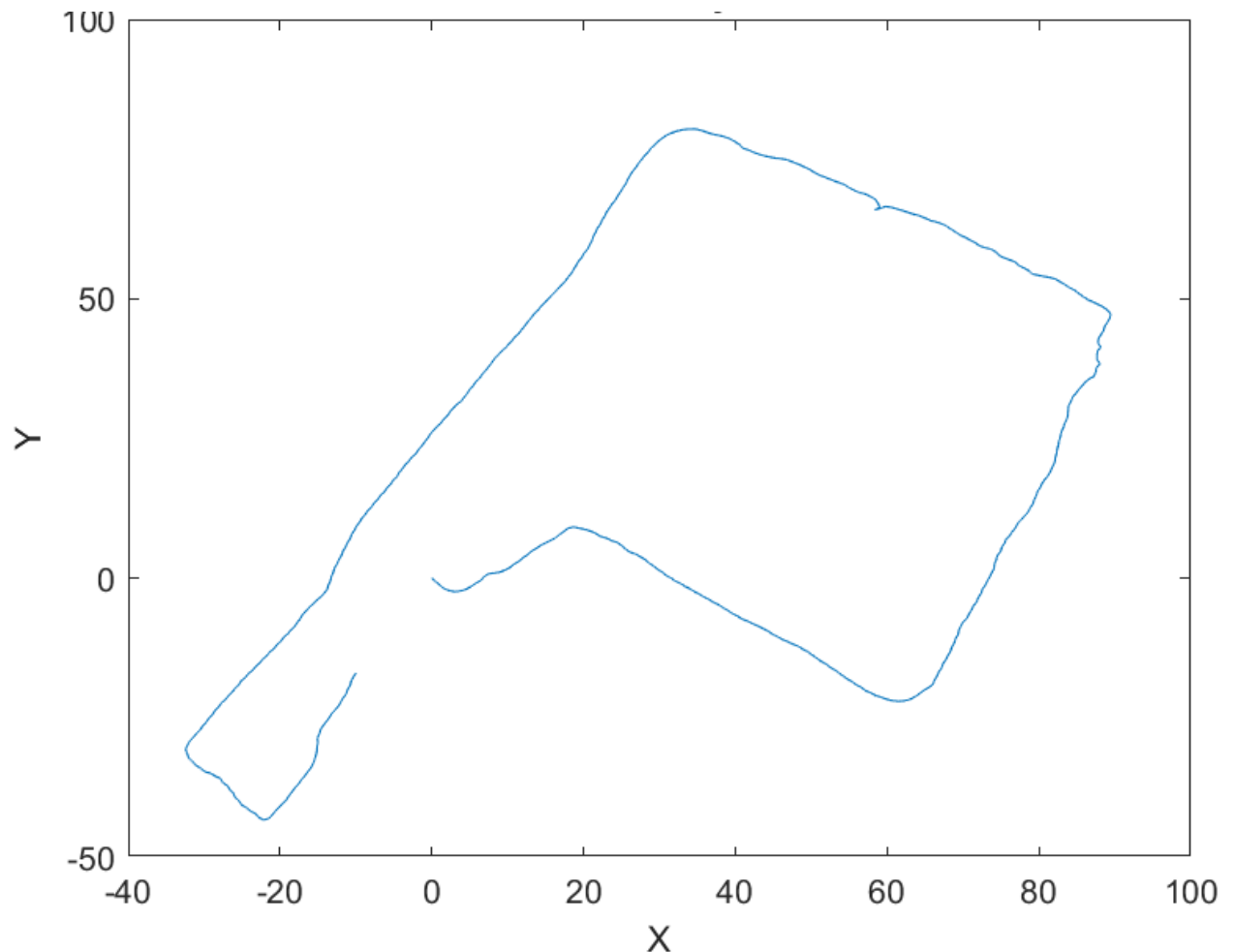


Fig. 3.11 Pathway

3.1.12. Layering a route onto a global map

In order for the pedestrian to traverse the landscape, the generated path must be superimposed on a map of the world. Given the geographic coordinate system and the shift to it from the conventional coordinate system, this needs GPS coordinates from the beginning of data recording or manual input from the user.

To get the most precise numbers, latitude must be adjusted based on longitude because it is not constant.

$$\begin{aligned} lat(i + 1) &= lat(i) + \frac{\cos(\theta(i)) * l * 360}{40000000} \\ lon(i + 1) &= lon(i) + \frac{-\sin(\theta(i)) * l * 360}{40075696 * \cos(lat(i))} \end{aligned} \quad (3.3)$$

Where (lat, lon) – geographical coordinates.

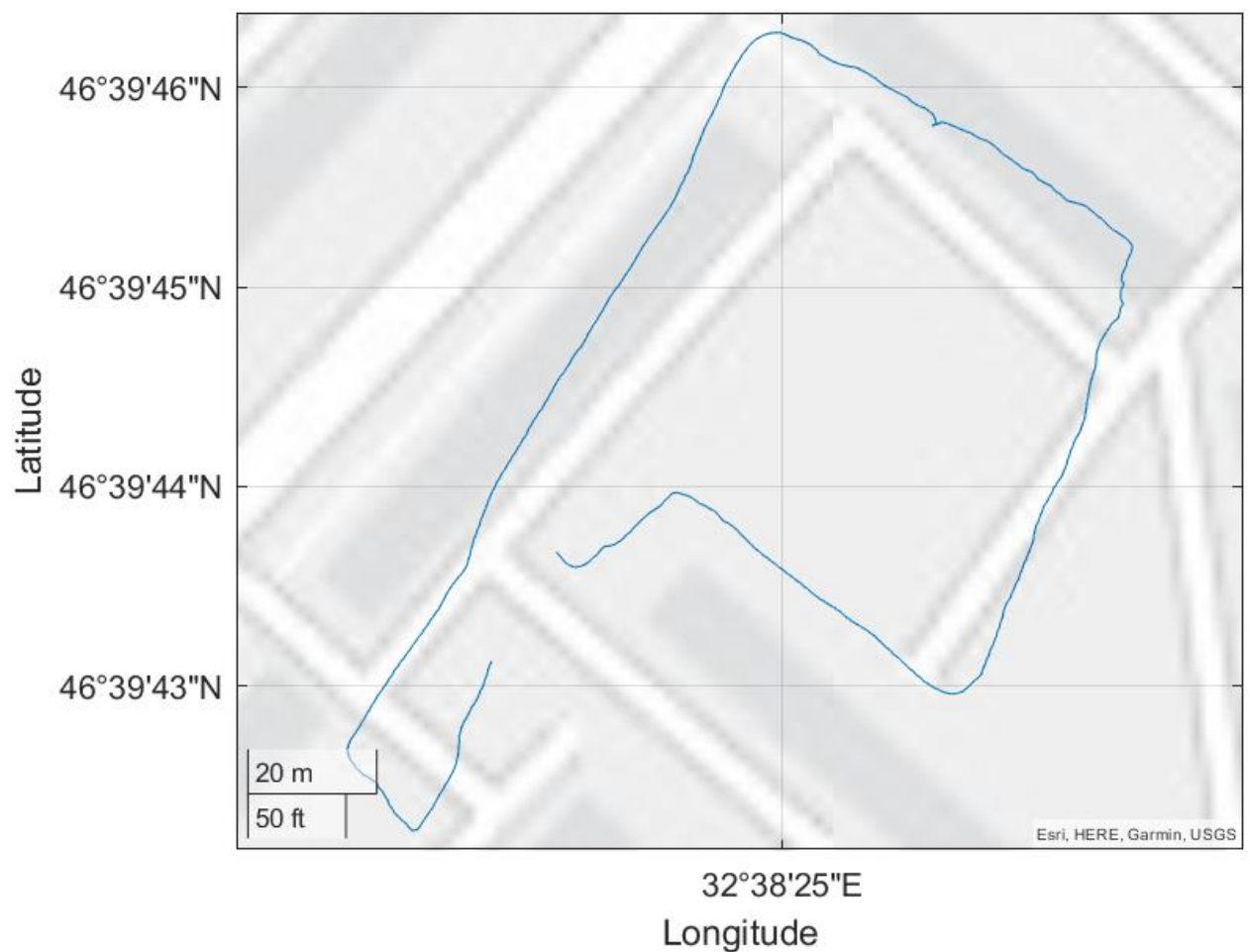


Fig. 3.12. The plotted route on the earth map

3.1.13. Comparison of GPS pedestrian path and pedestrian path using internal phone sensors

It is vital to verify the precision and validity of the route after receiving it using inertial sensors in respect to GPS data. Since the GPS data can have a 15-

meter inaccuracy with the best satellite connection, the route constant provided by inertial sensors should have roughly the same precision. The GPS signal's route is shown in blue in Fig. 3.13, and the path constructed using the phone's sensors is shown in red. As seen in Fig. 3.13, error is within the range of what is acceptable.

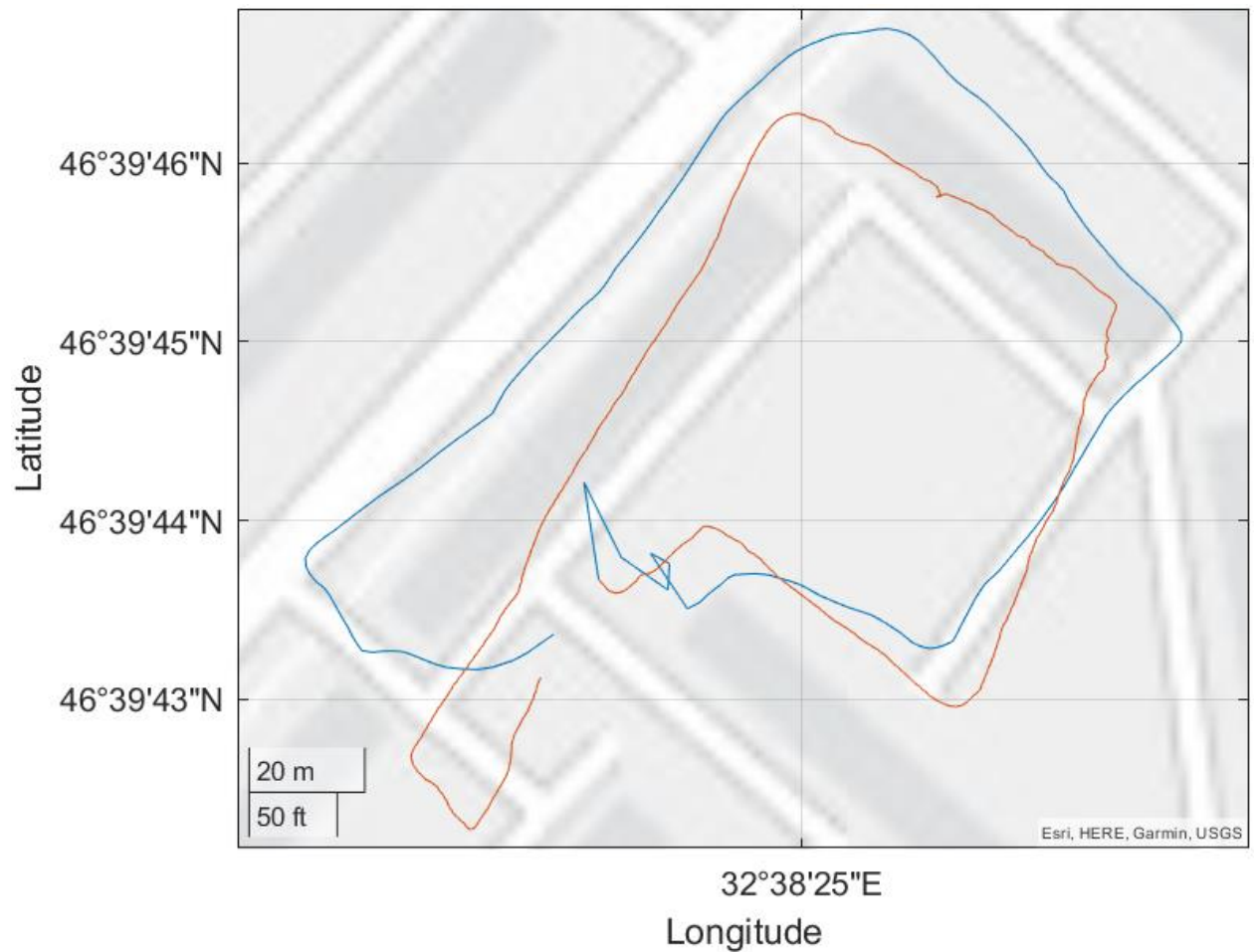


Fig. 3.13. Comparison of the pedestrian path

3.2. Filtration coefficients

It was discovered via the process of studying various time periods that the frequency of data collection for each recorded value varies based on the system load, the parameters of the data collecting program, and the device the pedestrian used to read the values.

The process of finding steps by peaks was used to pinpoint the exact moment that a person made a step. The sensors that pick up the signal must always operate at the same frequency in order for this to happen, but after tests it was discovered that this is not always possible. For this, one of the filtering coefficients is how far the steps are from one another in the time scale, or more specifically in the frequency scale, i.e., the total amount of all data over time. The scale of the factor is determined by the step's characteristics, the intervals between steps, and the step's actual duration.

There is also a filtration coefficient A_{filter} which serves as a criterion for filtering out the minimum peaks to simplify the counting of steps, the minimum threshold that needs to be filtered can be obtained by analyzing data with 0 steps, that is, when the phone is on a flat surface without hesitation at rest. In the process of research, it was experimentally obtained that the required filtration height is in the range up to $A_{filter} = 1.2 \frac{m}{s^2}$.

The coefficients for finding the peaks of steps themselves, as well as the distance between them $A_{Local Peaks Step}$ and $A_{Local Distance Peaks}$ respectively. They are located in relation to the length of the peak relative to Fig 3.14, as well as the distance between the peaks in Fig 3.15, for each specific case, different values of these coefficients are used, which makes it possible to achieve high accuracy in counting in steps, as well as building a route that depends on steps.

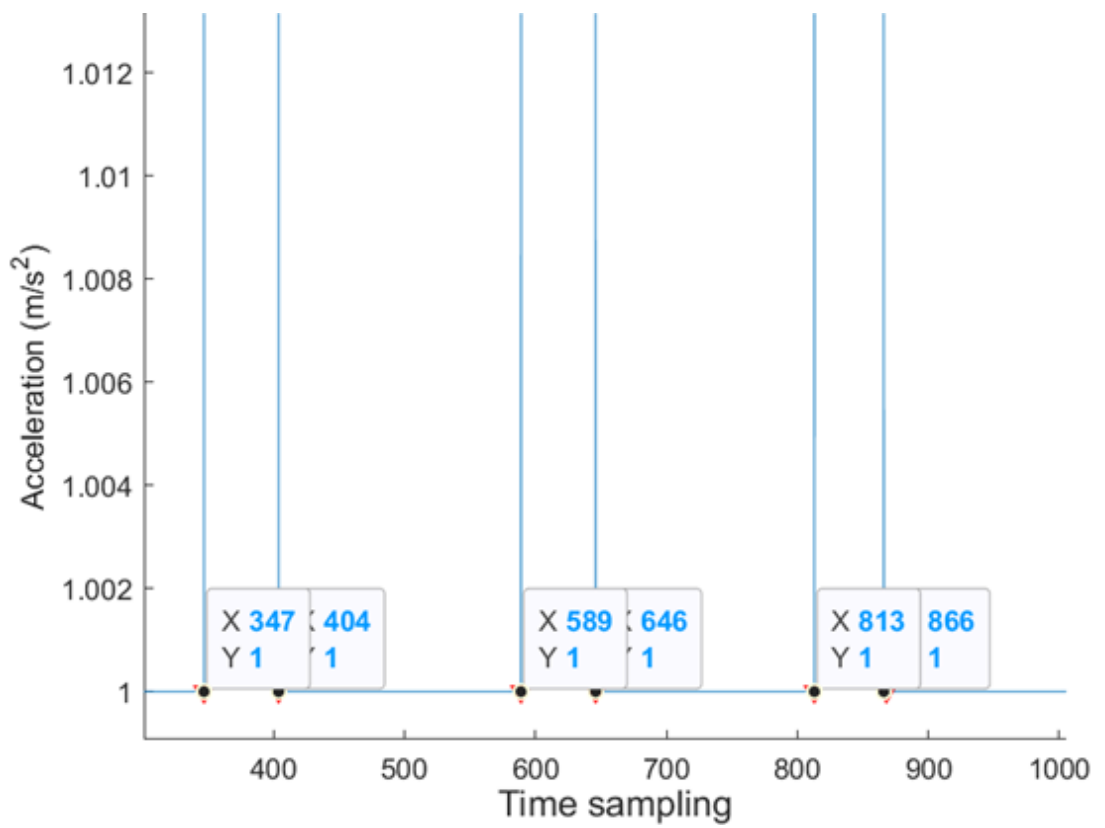


Figure 3.14. Time step period

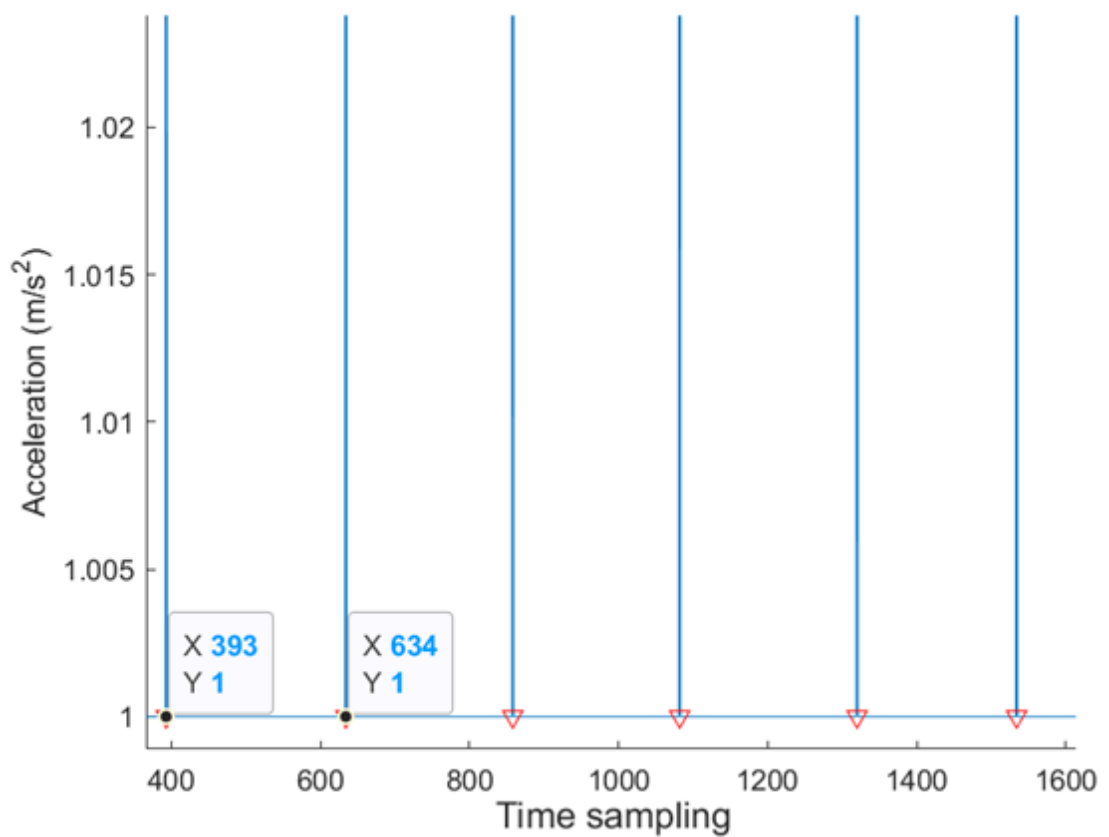


Fig 3.15. Length of time between steps

3.3. Comparison of results

Data from a number of individuals of various genders were gathered as part of the study, and they can now be compared to the data produced after applying the filters and the actual readings of the number of steps. The table includes information on the phone's manufacturer, the individual who measured the data's gender, and the amount of steps he took. The data gained through computations is then input, and the measurement error is then taken into consideration.

Table 3.1 Calculated number of steps and measurement error

Nº	Phone Brand	Gender (M / F)	Actual number of steps	Calculated number of steps	Error, %
1	Honor 8X	M	0	0	0
2	Honor 8X	M	13	13	0
3	Honor 8X	M	80	80	0
4	Honor 8X	M	130	128	1.5385
5	Honor 8X	M	150	149	0.6666
6	Honor 8X	M	198	199	0.5050
7	Honor 8X	M	208	209	0.4807
8	Honor 8X	M	506	502	0.7905
9	Honor 8X	M	1053	1056	0.2849
10	Iphone	F	100	98	2
11	Iphone	F	200	197	1.5
12	Iphone	F	300	296	1.3333
13	Iphone	F	400	404	1

The actual number of steps and the estimated number of steps are shown in Figure 3.16. Since the step pattern is essentially the same while walking, it can be argued that this method of finding steps does not have a cumulative error, which is to say, it does not accumulate error over time. As can be seen, the discrepancies are almost insignificant, even for long distances. The method will also work when a person is resting, or finding him at a traffic light is not mobile as it will be active A_{filter} filtration.

As can be seen in Figure 3.17, the algorithm's calculated error does not exceed 2% of the actual values, which is a positive sign for inertial calculations.

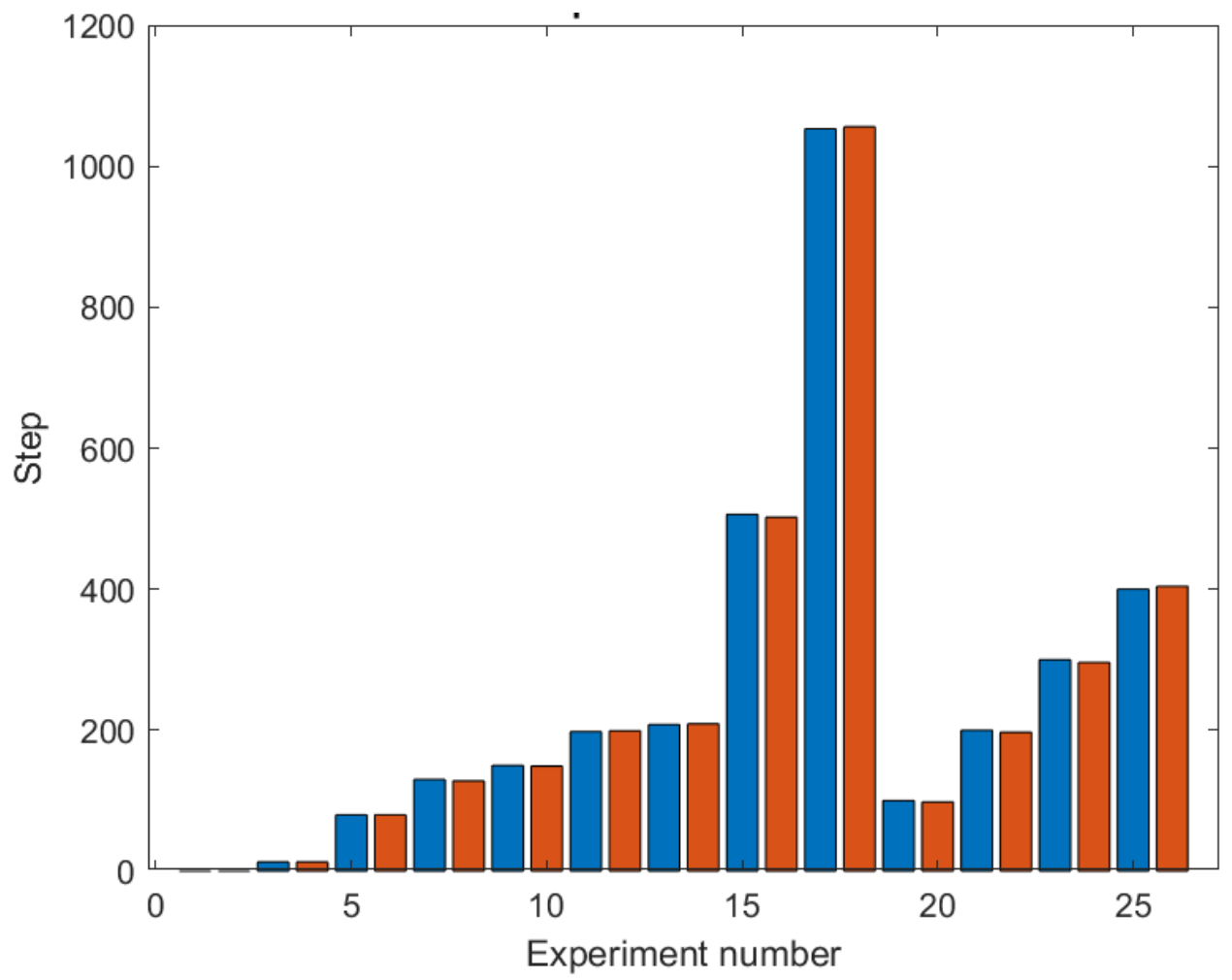


Figure 3.16. Comparison of results

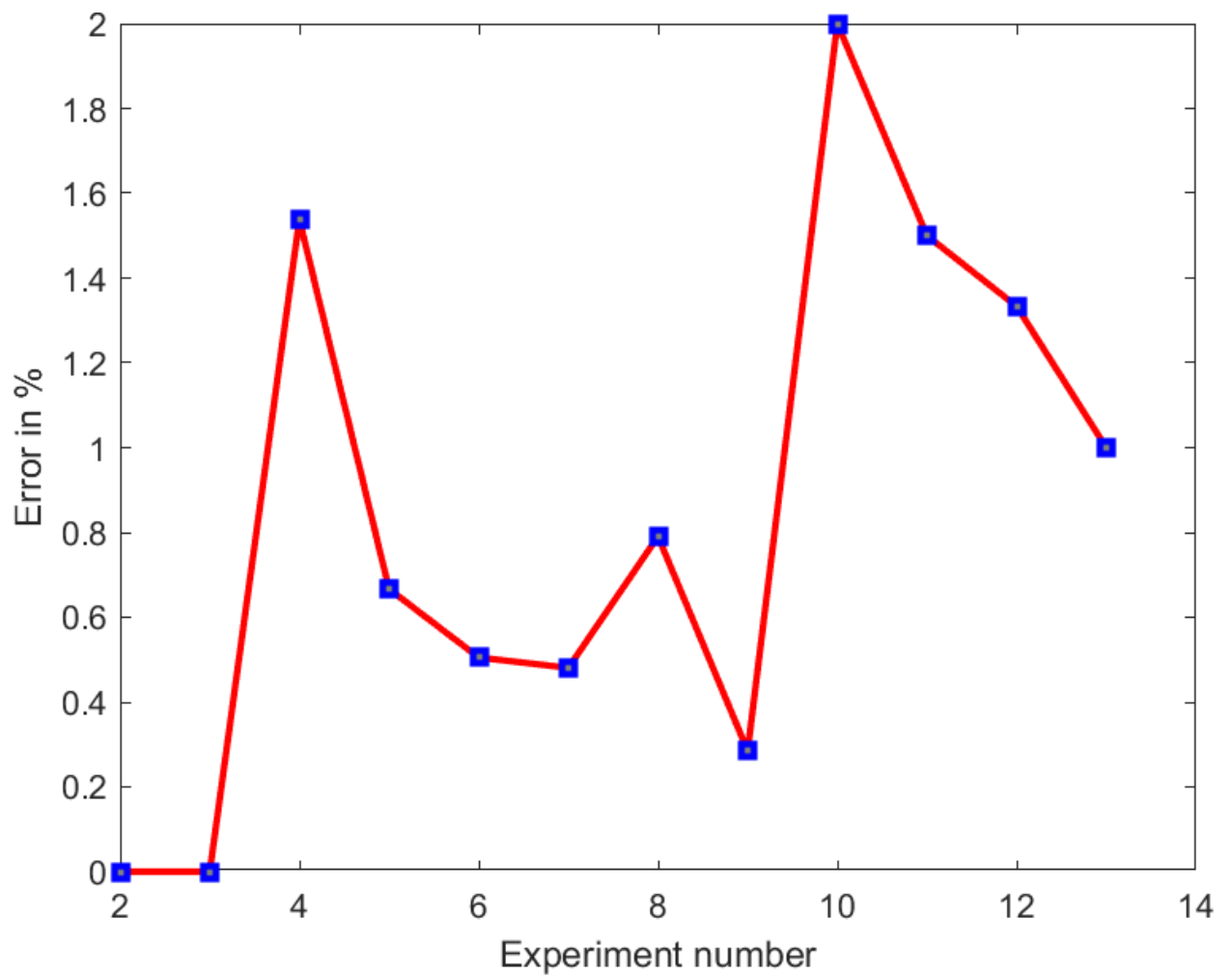


Fig 3.17. Calculation error

3.4. Software development

An algorithm-based 3.1 GUI program called App PDR was created using MATLAB. The software adheres to each of the following algorithms, from 1 to 13. The system depicted in Fig. 3.18 consists of a mobile phone from which data is obtained, a computer on which the bulk of the processing occurs, and the App PDR application, which processes all data and additionally displays information about the user's location.

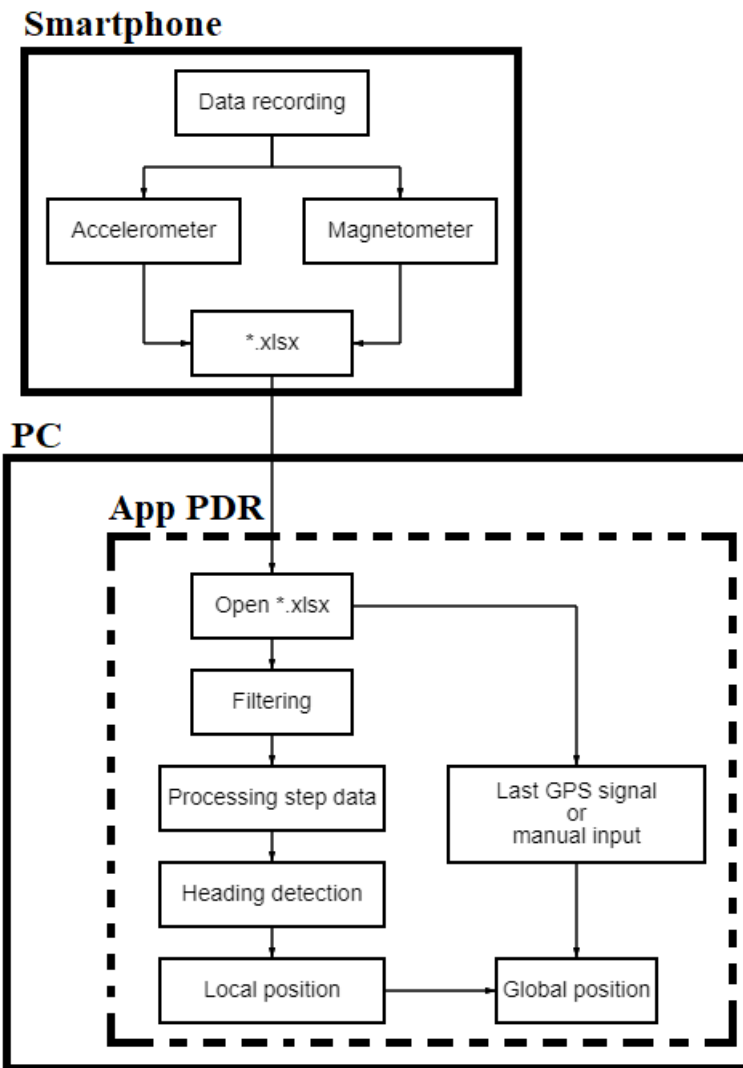


Fig. 3.18. Inertial navigation system diagram ☺

In Fig. 3.19 1-2 points of the algorithm are shown, loading data into the application for its next processing.

To download data, users need to click the “Loading data” button and select the file in the pop-up window and click “Open”.

In the absence of data or the wrong format, the program will display an error in the “Name.xlsx” window and ask to enter correct data from the user.

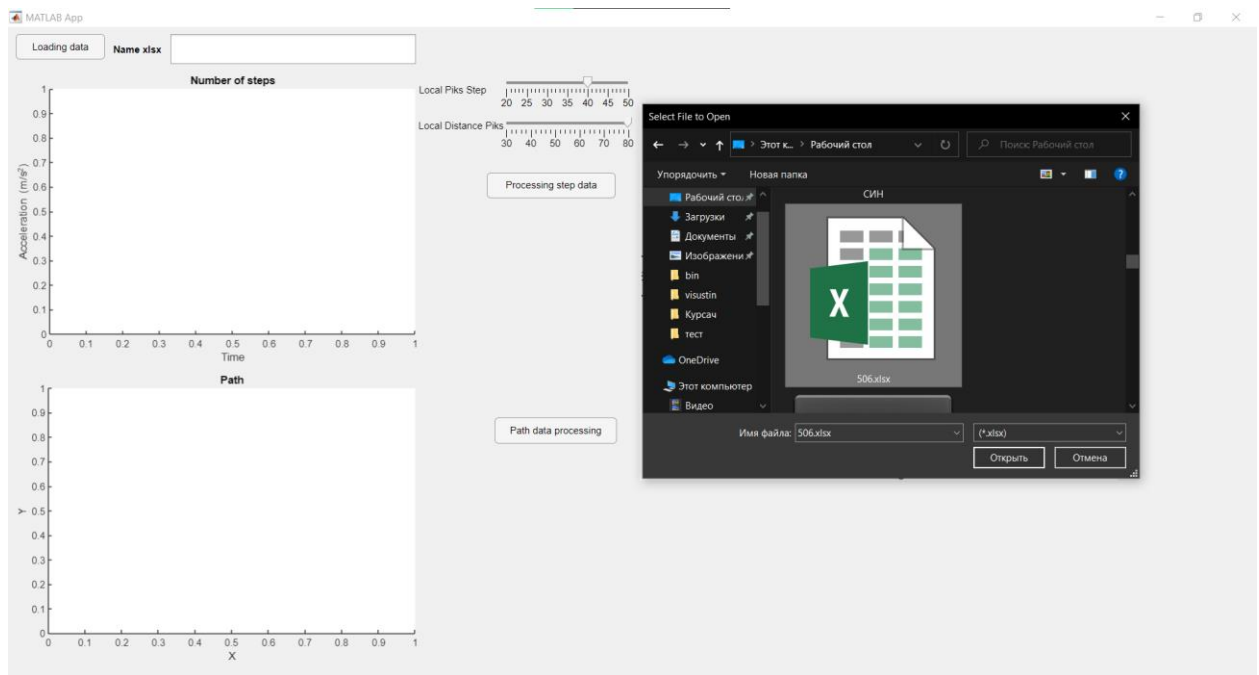


Fig. 3.19. Data loading window

Fig. 3.20 depicts 3 (a), 4–9 algorithmic points that process the accelerometer data received, calculate the acceleration vector module, filter low peak oscillations acceleration, identify all peaks that might exist, identify groups of peaks and false peaks, identify the primary peaks in groups, and separate peaks steps. and graph output of data.

The block diagram of the part of the program that is responsible for the "Processing step data" button is shown in two figures. Fig. 3.22 (a, b).

Odds settings $A_{Local\ Peaks\ Step}$ and $A_{Local\ Distance\ Peaks}$ occur in manual mode, for this need to move the sliders on the slider.

If the user's ultimate goal is to determine only the number of steps, they can stop at this point by clicking the "Processing step data" button, which starts the processing of steps independently of calculating the path.

In Figure 3.21 3 (b), 10–13 algorithmic steps are depicted, including processing magnetometer data received, determining direction and route, layering the route on a world map, and contrasting the GPS pedestrian path and the pedestrian path.

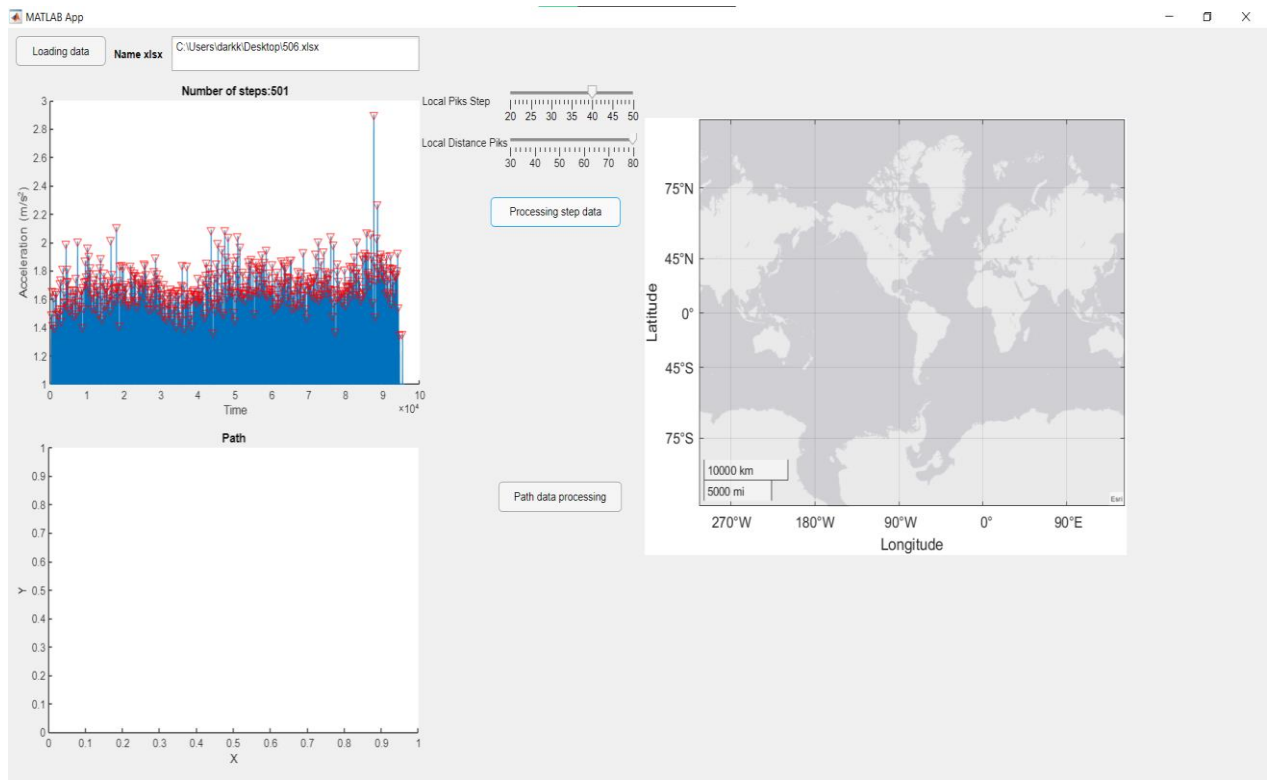


Fig. 3.20. Step data processing window

Following the completion of these calculations, the user has the option to process the route and mileage data by clicking the "Path data processing" button, which opens a new window for choosing coordinates.

Fig. 3.22 displays the block diagram of the program section in charge of the "Path data processing" button (c).

The user can only see his or her path in relation to the starting point of his or her walk while looking at the world's direction in relation to the coordinate axes, where the positive X-axis points east and the positive Y-axis points west. The user can specify the initial approximate coordinates relative to which the inertial traversed path will be built if GPS data is available. The ability to navigate in structures like buildings or even caves without communication is made possible by using this application, which also enables the user to determine his position in situations where communication with the satellite is unavailable or blocked.

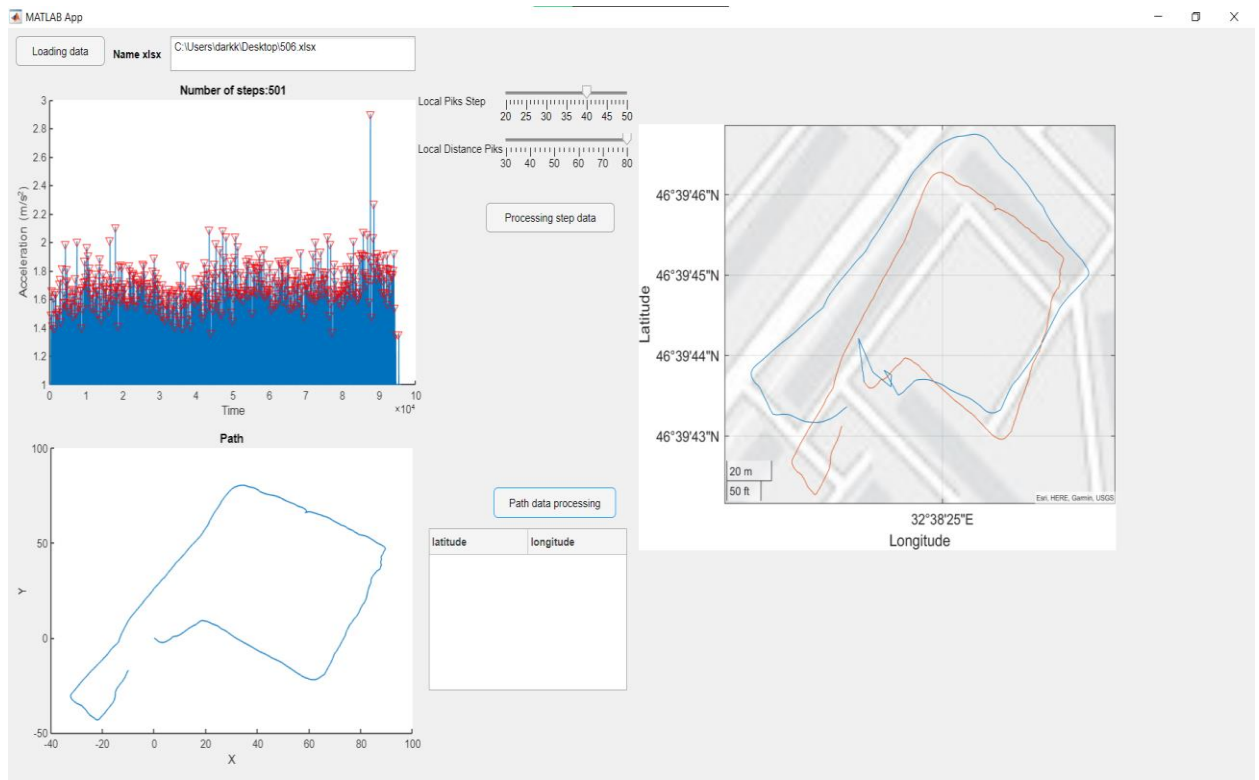


Fig. 3.21. Route processing window

Table 2 displays the expenses related to data processing. The program's workload is minimal, the time it takes to calculate the global route depends on the data type it uses, and the length of the data array itself barely affects performance.

Table 3.2 Elapsed data processing time

No	Number of steps	Amount of data	Elapsed time	Calculating a global route	Expansion file
1	0	4895	2.552359	+	.xlsx
2	13	5146	2.769038	+	.xlsx
3	80	5948	0.408425	-	.xlsx
4	130	9682	0.408125	-	.xlsx
5	150	12462	0.409768	-	.xlsx
6	198	35123	2.803006	+	.xlsx
7	208	38710	2.534432	+	.xlsx
8	506	95921	2.714745	+	.xlsx
9	1053	72803	0.483744	-	.xlsx
10	100	5885	3.456651	+	.csv
11	200	12607	3.055105	+	.csv
12	300	22222	3.980366	+	.csv
13	400	28081	3.046078	+	.csv

A block diagram of the program that was created using algorithms 1 through 13 is shown in Fig. 3.22 (a, b, and c), along with its cycles, branches, and filtering. It is simpler to comprehend how the program operates thanks to the diagram.

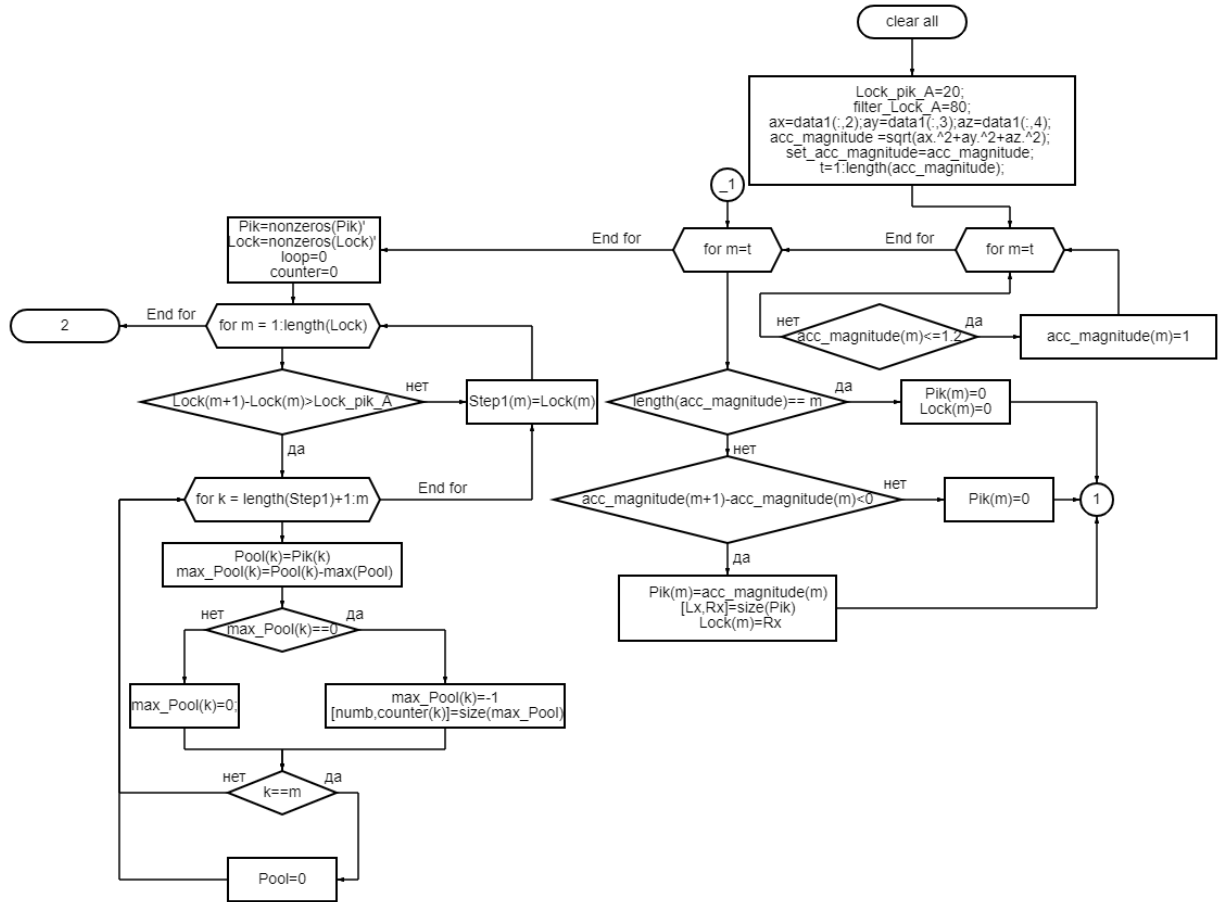


Fig. 3.22. Block diagram of the program (a)

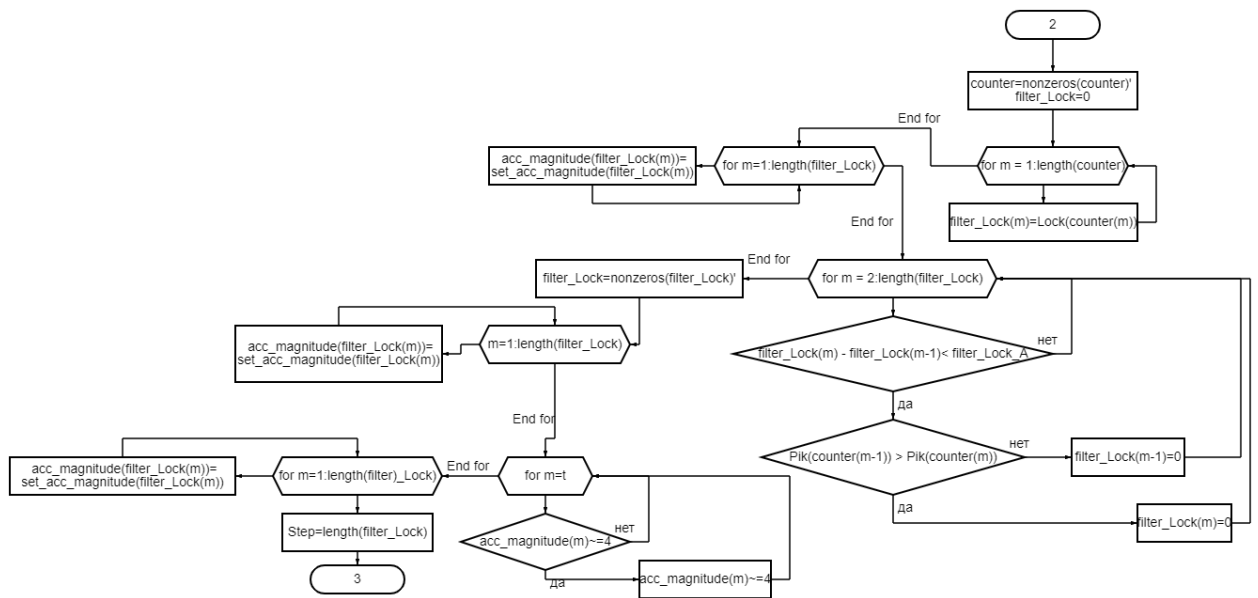


Fig. 3.22. Block diagram of the program (b)

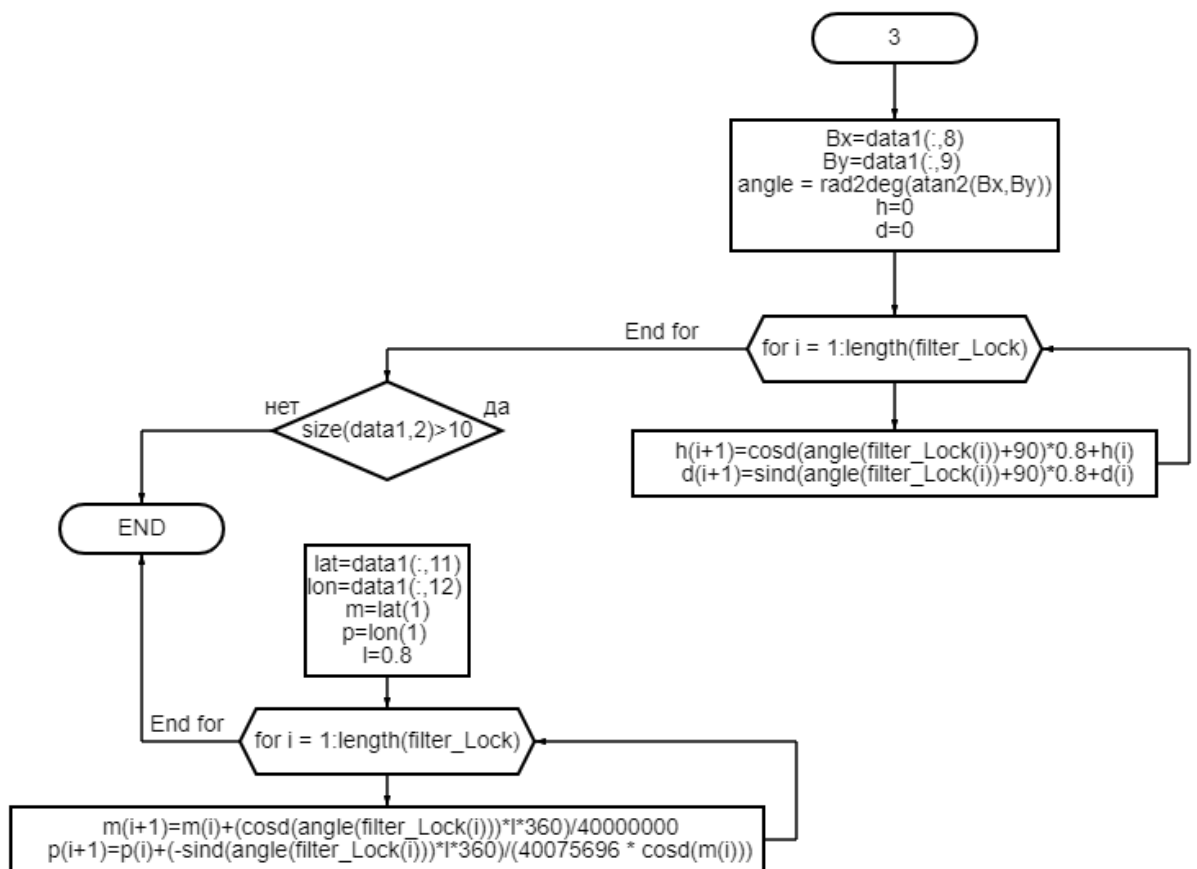


Fig. 3.22. Block diagram of the program (c)

3.5. Conclusions

At the time of writing the diploma, a program was developed with its own structure, as well as a GUI that helps in inertial navigation.

During the development of the software product, such a development environment and tools were used:

1. MATLAB
2. Microsoft Excel
3. Physics Toolbox Sensor Suite

Technologies:

- Object-oriented programming language MATLAB.

Method:

- Finding the peaks
- Calculation of the course based on the magnetometer

These tools were chosen because they have a strong working relationship that makes it simple to combine them into a single system.

Since MATLAB is cross-platform and was chosen as the target platform, software created using it can be used with most operating systems.

Due to its efficiency and accuracy in counting steps, which is crucial for the subsequent construction of the route, the algorithm for finding steps was used during the work. Even if the phone is used arbitrarily while walking, the algorithm successfully counts steps.

Along with a magnetometer-based course calculation algorithm, which enhances the system's speed, accuracy in determining the user's direction, and ability to hold the device in any comfortable position for the user.



CHAPTER 4. DEVELOPMENT TOOLS

4.1. Programs used in development

The developer created the program code of the Program that complies with the criteria at the time of creating the project using the following collection of approaches, methods, techniques, as well as a set of tools (compilers, application / system libraries, etc.).

4.1.1. Application package MATLAB

MATLAB is a collection of practical programs [11] for handling complex computing issues. The program runs on the majority of current operating systems, including Linux, macOS, and Windows, and is used by over a million engineers and scientists.

Programming in languages MATLAB is a high-level interpreted programming language with object-oriented features, a built-in development environment, matrix-based data structures, and interfaces to programs written in other programming languages.

There are two sorts of programs created in MATLAB: functions and scripts. In addition to their own workspace for storing variables and intermediate computation results, functions also have input and output arguments. Scripts function together in one place. Scripts and functions are both stored as text files and dynamically converted to machine code.

The MATLAB language's main selling point is how many matrices it can work with.

MATLAB offers practical tools for creating algorithms, including sophisticated ones that make use of object-oriented programming ideas. It includes a debugger and a profiler in addition to all the necessary IDE tools.

ACIC DEPARTMENT			NAU 22 0492 000 EN		
Performed	Lazarevskiy O.A.		N.	Page	Pages
Supervisor	Vasylenko M.P.			43	120
Consultant			225 151		
S. controller	Filyashkin M.K.		INDIVIDUAL MOBILE NAVIGATION SYSTEM OF WAY COUNTING		
Dep. head	Sineglazov V.M.				

It is possible to develop unique toolkits for MATLAB that increase its functionality. To solve a particular class of problems, toolkits are collections of MATLAB functions and objects.

There are numerous functions for creating graphs included in the MATLAB package Fig. 4.1, such as those for three-dimensional, visual data analysis and making animated videos. The integrated development environment enables the creation of graphical user interfaces with a variety of controls, including input fields, buttons, and others.

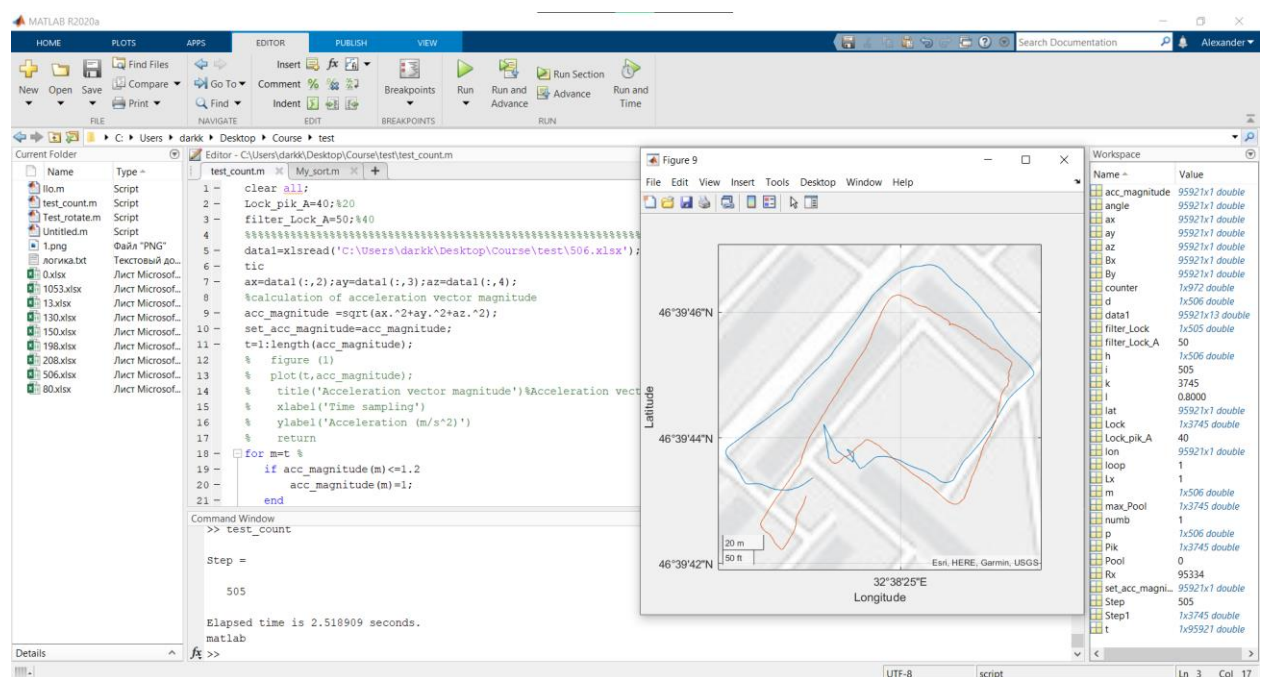


Fig. 4.1. MATLAB window

With the help of the MATLAB Compiler module, MATLAB programs—console and graphical user interface—can be converted into standalone executable applications.

4.1.2. Integrated software for creating applications App Designer

Without being a skilled software developer, one may design professional apps with the App Designer. Layout a graphical user interface (GUI) design using visual components, and easily program its functionality using the built-in editor.

To create a precise layout, drag visual components into the design canvas and apply the alignment tips. The app builder creates object-oriented code that defines the app's layout and design automatically, as shown in Figure 4.2.

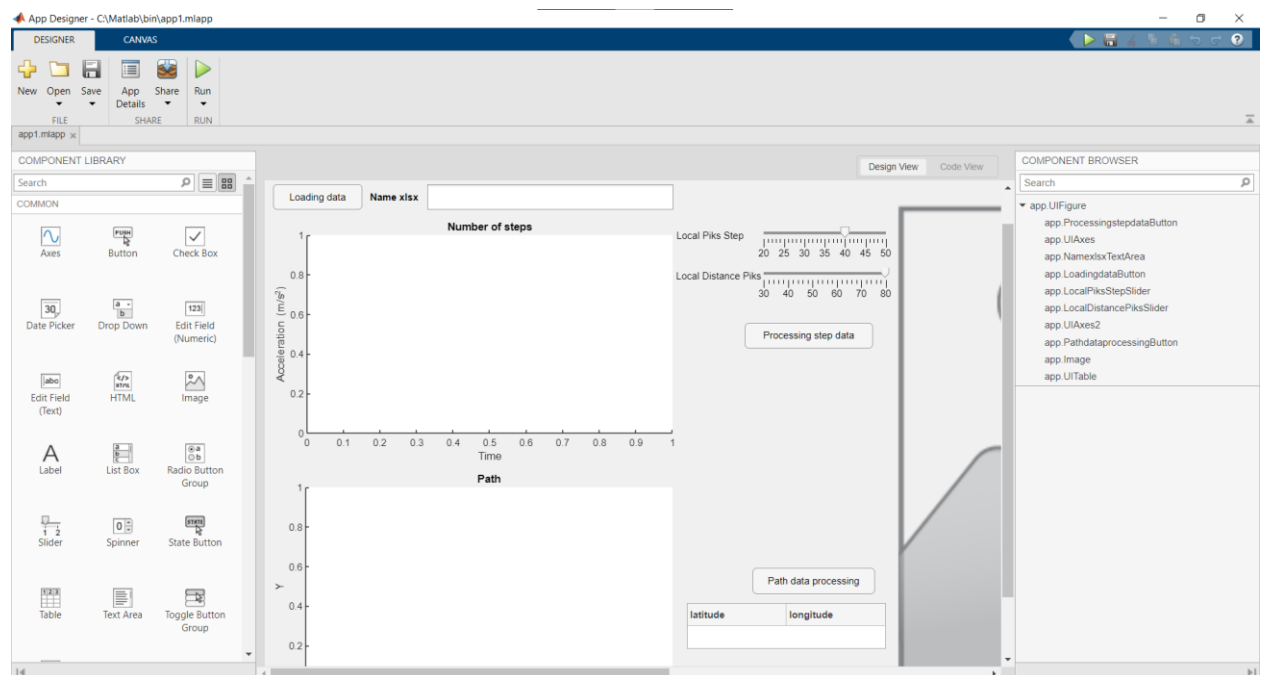


Fig. 4.2. App Designer

To specify the behavior of the program, use the integrated MATLAB editor. Using a code analyzer, the app designer may automatically check for coding issues. Able to develop and alter apps depending on warnings and error messages found in code.

Use MATLAB Compiler to build standalone apps that you may freely distribute to others. MATLAB Web App Server allows users to share programs packaged as interactive web apps. End users don't need to install any software to execute web apps straight from the browser.

4.1.3. Application for removing data from the phone Physics Toolbox Sensor Suite (version 2021.04.19)

Physics Toolbox – This program is helpful [12] for engineers, scientists, and other professionals in the field. It gathers, records, and exports data to a shareable.csv (comma separated value) file using the mobile device's sensors.

The information can be shown quantitatively, as in Fig. 4.3's graph with dependencies, or in the form of an elapsed time graph. Data can be exported by users for use in a spreadsheet or special software for graphing.



Fig. 4.3. Physics Toolbox

The user can choose one or more sensors to record data from simultaneously in multi recording mode. Before exporting or saving to the device, files can be easily renamed, making it simple to organize storage and access to data.

Additional features allow you to record data in relation to the current or past time, choose between the comma or semicolon as a separator in the.csv file, alter the line width of the graph, alter the frequency of data collection from the sensor, and regulate the screen's illumination for the duration of the measurement.

The following sensors were used: a linear accelerometer (x, y, z) for acceleration; a gyroscope (x, y, z) for radial velocity; a magnetometer (x, y, z) for magnetic field intensity; a compass (x, y, z) for magnetic field direction and tilt angle; and GPS (latitude, longitude, altitude, speed, direction, and the number of user-accessible satellites).

4.1.4. Program used for database tables Microsoft Excel

For use with Microsoft Windows, Windows NT, Mac OS, Android, iOS, and Windows Phone, Microsoft Excel is a spreadsheet program [15].

With the exception of Excel 2008 for Mac OS X, it offers the ability to perform economic and statistical calculations, as well as graphical tools and the macro programming language VBA. Microsoft Office includes Microsoft Excel.

4.1.5. Extending used database tables .csv and .xlsx

.csv (Comma-Separated Values) – It is a text format for tabular data representation [13]. A text line with one or more fields, separated by commas, makes up a table line. Fig. 4.4. The CSV format still needs some standardization. It seems sense to use commas to separate fields, but doing so might be problematic if the source table's data already contains commas or newlines. The issue of commas and line breaks can be resolved by enclosing the data in quote marks, although the original data may already include them. Additionally, the name "CSV" can apply to related formats that use a tab (TSV) character or semicolon as its delimiter. Many CSV-compatible programs let you choose the separator character and quote mark.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W				
1	Timestamp	accelX(g)	accelY(g)	accelZ(g)	accelUserX(g)	accelUserY(g)	accelUserZ(g)	gyroX(rad/s)	gyroY(rad/s)	gyroZ(rad/s)	Roll(rads)	Pitch(rads)	Yaw(rads)	Lat(Be)	Long(Be)	Speed(m/s)	TrueHeading(Be)	Altitude(m)	HorizontalAccuracy(m)	VerticalAccuracy(m)	calM						
2	29-Apr-2021 12:18:51.164	-0.0023	-0.1529	-0.9781	0.0004	0.0015	-0.0141	0.0223	0.0155	-0.0465	-0.0012	0.1537	1.1252	50.476060	30.450814	0.0075	213.7969	169.041513	6.0009	7.7136	9.3694	-28.7055	-45.4245	214.3621	0.0652	0.0403	0.5316
3	29-Apr-2021 12:18:51.229	0.0097	-0.1423	-0.9993	0.0133	0.0124	-0.0141	0.0223	0.0155	-0.0465	-0.0012	0.1537	1.1252	50.476060	30.450814	0.0075	213.7969	169.041513	6.0009	7.7136	9.4654	-28.6602	-45.3756	214.3621	0.0653	0.0404	0.5316
4	29-Apr-2021 12:18:51.234	0.0130	-0.1745	-0.9686	0.0132	-0.0164	0.0179	0.0546	0.0034	-0.0394	-0.0013	0.1574	1.1217	50.476060	30.450814	0.0075	213.7969	169.041513	6.0009	7.7136	9.4989	-28.6776	-45.2939	214.3621	0.0669	0.0413	0.5302
5	29-Apr-2021 12:18:51.243	0.0160	-0.1810	-0.9637	0.0170	-0.0227	0.0229	0.0322	0.0006	-0.0183	-0.0014	0.1579	1.1214	50.476060	30.450814	0.0075	213.7969	169.041513	6.0009	7.7136	9.4989	-28.6776	-45.2939	214.3621	0.0672	0.0414	0.5302
6	29-Apr-2021 12:18:51.250	0.0151	-0.1835	-0.9587	0.0168	-0.0258	0.0282	0.0322	0.0006	-0.0183	-0.0014	0.1582	1.1213	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2705	-28.7197	-45.1335	214.4630	0.0673	0.0414	0.5300
7	29-Apr-2021 12:18:51.260	0.0127	-0.1808	-0.9572	0.0148	-0.0236	0.0300	0.0082	0.0148	0.0020	-0.0014	0.1584	1.1214	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2705	-28.7197	-45.1335	214.4630	0.0673	0.0415	0.5300
8	29-Apr-2021 12:18:51.270	0.0092	-0.1780	-0.9551	0.0112	-0.0208	0.0319	0.0062	0.0114	0.0115	-0.0013	0.1585	1.1215	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2585	-28.7269	-45.2666	214.4630	0.0674	0.0415	0.5301
9	29-Apr-2021 12:18:51.281	0.0065	-0.1731	-0.9530	0.0083	-0.0160	0.0341	0.0052	0.0156	0.0183	-0.0013	0.1586	1.1218	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2585	-28.7269	-45.2666	214.4630	0.0674	0.0416	0.5302
10	29-Apr-2021 12:18:51.292	0.0027	-0.1713	-0.9537	0.0049	-0.0138	0.0341	0.0040	0.0248	0.0242	-0.0012	0.1586	1.1221	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2446	-28.8519	-45.4693	214.4630	0.0674	0.0417	0.5304
11	29-Apr-2021 12:18:51.301	0.0003	-0.1655	-0.9579	0.0010	-0.0091	0.0308	-0.0138	0.0307	0.0276	-0.0010	0.1585	1.1224	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2446	-28.8519	-45.4693	214.4630	0.0673	0.0417	0.5305
12	29-Apr-2021 12:18:51.311	0.0025	-0.1612	-0.9645	0.0031	-0.0039	0.0241	-0.0281	0.0255	0.0241	-0.0009	0.1583	1.1226	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3103	-28.8036	-45.3432	214.4630	0.0672	0.0416	0.5306
13	29-Apr-2021 12:18:51.321	0.0012	-0.1617	-0.9670	0.0027	-0.0041	0.0206	-0.0364	0.0075	0.0193	-0.0010	0.1580	1.1228	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3103	-28.8036	-45.3432	214.4630	0.0671	0.0416	0.5307
14	29-Apr-2021 12:18:51.331	-0.0021	-0.1624	-0.9694	-0.0003	0.0050	0.0185	-0.0381	-0.0027	0.0146	-0.0011	0.1577	1.1230	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2554	-28.7402	-45.4465	214.4630	0.0670	0.0415	0.5308
15	29-Apr-2021 12:18:51.342	-0.0020	-0.1600	-0.9686	-0.0011	-0.0043	0.0183	-0.0400	-0.0056	0.0044	-0.0013	0.1574	1.1230	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2554	-28.7402	-45.4465	214.4630	0.0668	0.0413	0.5308
16	29-Apr-2021 12:18:51.351	-0.0010	-0.1610	-0.9650	-0.0000	-0.0038	0.0220	-0.0395	-0.0020	-0.0053	-0.0014	0.1571	1.1230	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2155	-28.5571	-45.2624	214.4630	0.0667	0.0412	0.5308
17	29-Apr-2021 12:18:51.361	0.0026	-0.1652	-0.9622	0.0032	-0.0077	0.0253	-0.0410	0.0031	-0.0120	-0.0014	0.1568	1.1229	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2155	-28.5571	-45.2624	214.4630	0.0667	0.0411	0.5307
18	29-Apr-2021 12:18:51.371	0.0060	-0.1734	-0.9615	0.0066	-0.0165	0.0257	-0.0424	0.0006	-0.0097	-0.0015	0.1564	1.1229	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3150	-28.7268	-45.3058	214.4630	0.0665	0.0410	0.5307
19	29-Apr-2021 12:18:51.381	0.0094	-0.1765	-0.9567	0.0102	-0.0202	0.0302	-0.0464	0.0010	-0.0035	-0.0016	0.1560	1.1229	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3150	-28.7268	-45.3058	214.4630	0.0664	0.0408	0.5307
20	29-Apr-2021 12:18:51.392	0.0004	-0.1818	-0.9525	0.0105	-0.0264	0.0343	-0.0505	0.0081	0.0076	-0.0015	0.1556	1.1231	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3150	-28.7268	-45.3058	214.4630	0.0664	0.0407	0.5308
21	29-Apr-2021 12:18:51.401	0.0117	-0.1818	-0.9483	0.0133	-0.0268	0.0395	-0.0564	0.0230	0.0199	-0.0014	0.1551	1.1234	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.2310	-28.8421	-45.3012	214.4630	0.0660	0.0407	0.5310
22	29-Apr-2021 12:18:51.411	0.0089	-0.1912	-0.9488	0.0104	-0.0350	0.0390	-0.0587	0.0223	0.0438	-0.0014	0.1546	1.1239	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3742	-28.4847	-45.3326	214.4630	0.0657	0.0406	0.5312
23	29-Apr-2021 12:18:51.421	0.0127	-0.1960	-0.9480	0.0133	-0.0424	0.0402	-0.0608	0.0200	0.0631	-0.0014	0.1540	1.1246	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3663	-28.5420	-45.2851	214.4630	0.0655	0.0404	0.5315
24	29-Apr-2021 12:18:51.431	0.0093	-0.1952	-0.9501	0.0120	-0.0430	0.0388	-0.0783	0.0252	0.0853	-0.0014	0.1533	1.1256	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.3663	-28.5420	-45.2851	214.4630	0.0651	0.0403	0.5319
25	29-Apr-2021 12:18:51.442	0.0038	-0.1922	-0.9520	0.0056	-0.0413	0.0364	-0.0919	0.0145	0.1050	-0.0015	0.1524	1.1267	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.1714	-28.5221	-45.3910	214.4630	0.0648	0.0400	0.5324
26	29-Apr-2021 12:18:51.451	0.0080	-0.1882	-0.9542	0.0091	-0.0379	0.0349	-0.1079	0.0106	0.1137	-0.0017	0.1514	1.1279	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.1714	-28.5221	-45.3910	214.4630	0.0644	0.0397	0.5329
27	29-Apr-2021 12:18:51.461	0.0038	-0.1880	-0.9554	0.0073	-0.0380	0.0335	-0.1213	0.0052	0.1173	-0.0020	0.1502	1.1291	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.0918	-28.3085	-45.3119	214.4630	0.0639	0.0393	0.5335
28	29-Apr-2021 12:18:51.471	-0.0046	-0.1907	-0.9556	-0.0009	-0.0415	0.0333	-0.1313	-0.0032	0.1270	-0.0023	0.1489	1.1304	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.0918	-28.3085	-45.3119	214.4630	0.0635	0.0389	0.5340
29	29-Apr-2021 12:18:51.481	-0.0085	-0.1925	-0.9532	-0.0054	-0.0458	0.0349	-0.1477	-0.0103	0.1334	-0.0027	0.1475	1.1319	50.476060	30.450814	0.0016	213.8883	169.118515	6.0009	7.2935	9.1780	-28.3591	-45.7206	214.4630	0.0629	0.0384	0.5347

Fig. 4.4. Database tables .csv

Almost all spreadsheet programs and database management systems, including LibreOffice Calc, Gnumeric, Emacs, Microsoft Excel, Numbers, CSVed, KSpread, and Google Docs, support the CSV file format. Many engineering software programs, including ANSYS and LabVIEW, support CSV import and export.

The.xlsx file format family [14] is used to store electronic documents created using office suites, particularly Microsoft Office. A zip archive containing XML text, images, and other data makes up the format. DOC, XLS, etc., which were previously saved in binary forms, to version 4.4.5. The format was first developed as a rival to the standardized OpenDocument before that and as a substitute for the old binary document format used by Microsoft Office products up to and including Office 2003. Ecma International designated the Office Open XML format as a free and open format in 2006. Applications developed for Microsoft Office 2007 and later use it by default.

time	gFx	gFy	gFz	wx	wy	wz	Bx	By	Bz	Latitude	Longitude	Speed (m/s)
3,818	0,0202	0,1829	0,9541	-0,082	-0,0564	-0,0277	-17,9375	-21,0625	-35,5625	46,66213	32,63982	0
3,821	0,0145	0,184	0,9649	-0,082	-0,0564	-0,0277	-17,9375	-21,0625	-35,5625	46,66213	32,63982	0
3,823	0,0145	0,184	0,9649	-0,0703	-0,0724	-0,017	-17,9375	-21,0625	-35,5625	46,66213	32,63982	0
3,827	0,0145	0,184	0,9649	-0,0703	-0,0724	-0,017	-18,3125	-20,9375	-35,5	46,66213	32,63982	0
3,828	0,0183	0,186	0,9636	-0,0703	-0,0724	-0,017	-18,3125	-20,9375	-35,5	46,66213	32,63982	0
3,828	0,0183	0,186	0,9636	-0,049	-0,0852	0,0053	-18,3125	-20,9375	-35,5	46,66213	32,63982	0
3,829	0,0183	0,186	0,9636	-0,049	-0,0852	0,0053	-18,3125	-20,9375	-35,5	46,66213	32,63982	0
3,829	0,0183	0,186	0,9636	-0,049	-0,0852	0,0053	-18,4375	-20,875	-35,625	46,66213	32,63982	0
3,83	0,0259	0,1839	0,9608	-0,049	-0,0852	0,0053	-18,4375	-20,875	-35,625	46,66213	32,63982	0
3,831	0,0259	0,1839	0,9608	-0,0341	-0,0862	0,0266	-18,4375	-20,875	-35,625	46,66213	32,63982	0
3,831	0,0259	0,1839	0,9608	-0,0341	-0,0862	0,0266	-18,6875	-20,6875	-35,5625	46,66213	32,63982	0
3,832	0,0455	0,186	0,9486	-0,0341	-0,0862	0,0266	-18,6875	-20,6875	-35,5625	46,66213	32,63982	0
3,833	0,0455	0,186	0,9486	-0,0319	-0,0969	0,0287	-18,6875	-20,6875	-35,5625	46,66213	32,63982	0
3,833	0,0455	0,186	0,9486	-0,0319	-0,0969	0,0287	-18,6875	-20,6875	-35,5625	46,66213	32,63982	0
3,834	0,0455	0,186	0,9486	-0,0319	-0,0969	0,0287	-19	-20,75	-35,625	46,66213	32,63982	0
3,835	0,0613	0,1894	0,9406	-0,0319	-0,0969	0,0287	-19	-20,75	-35,625	46,66213	32,63982	0
3,835	0,0613	0,1894	0,9406	-0,0405	-0,1011	0,0128	-19	-20,75	-35,625	46,66213	32,63982	0
3,836	0,0613	0,1894	0,9406	-0,0405	-0,1011	0,0128	-19,0625	-20,625	-35,6875	46,66213	32,63982	0
3,837	0,0694	0,1896	0,9333	-0,0405	-0,1011	0,0128	-19,0625	-20,625	-35,6875	46,66213	32,63982	0
3,837	0,0694	0,1896	0,9333	-0,0596	-0,1043	-0,016	-19,0625	-20,625	-35,6875	46,66213	32,63982	0
3,838	0,0694	0,1896	0,9333	-0,0596	-0,1043	-0,016	-19,0625	-20,625	-35,6875	46,66213	32,63982	0
3,838	0,0694	0,1896	0,9333	-0,0596	-0,1043	-0,016	-19,125	-20,75	-35,6875	46,66213	32,63982	0
3,839	0,0765	0,1883	0,9394	-0,0596	-0,1043	-0,016	-19,125	-20,75	-35,6875	46,66213	32,63982	0
3,84	0,0765	0,1883	0,9394	-0,0894	-0,1043	-0,0564	-19,125	-20,75	-35,6875	46,66213	32,63982	0
3,84	0,0765	0,1883	0,9394	-0,0894	-0,1043	-0,0564	-19,25	-20,9375	-35,375	46,66213	32,63982	0
3,841	0,0706	0,1884	0,953	-0,0894	-0,1043	-0,0564	-19,25	-20,9375	-35,375	46,66213	32,63982	0
3,842	0,0706	0,1884	0,953	-0,1139	-0,0841	-0,099	-19,25	-20,9375	-35,375	46,66213	32,63982	0

Fig. 4.5. Database tables .xlsx

4.2. The system used in the development

The implemented application for calculating an inertial route was created using the integrated MATLAB App Designer on Windows 10 Pro (Version 10.0.19042 Build 19042), with the following system specifications: CPU Intel (R) Core (TM) i3-7130U 2.70GHz, Memory 12.0 GB 2133MHz, and GPU Intel (R) HD Graphics 620.

A configured system and an additional library must be present on the computer for the system to function.

4.2.1. Installation and system requirements

The user requires the least amount of hardware power to operate the developed software system (Table 4.1).

Table 4.1 Minimum hardware power

Device	Characteristic
CPU	Pentium III, Pentium IV, Pentium M or AMD Athlon, Athlon XP
GPU	ATI Radeon HD 3450 (256 Mb), MSI NVIDIA GeForce GT 330 768MB
Memory	256MB
OC	Windows XP/2000/NT/Vista

Supported hardware architectures:

- win-x86
- win/linux/amd64

And the presence of a library:

- mdmcrtr9_8.dll

4.2.2. Scenarios for user interaction with the system

The system's users are local pedestrians in that area. The MATLAB App Designer is used to implement the user interface.

The user is first presented with the window of the executable program (Fig. 4.6), from which he can download and manipulate the data.

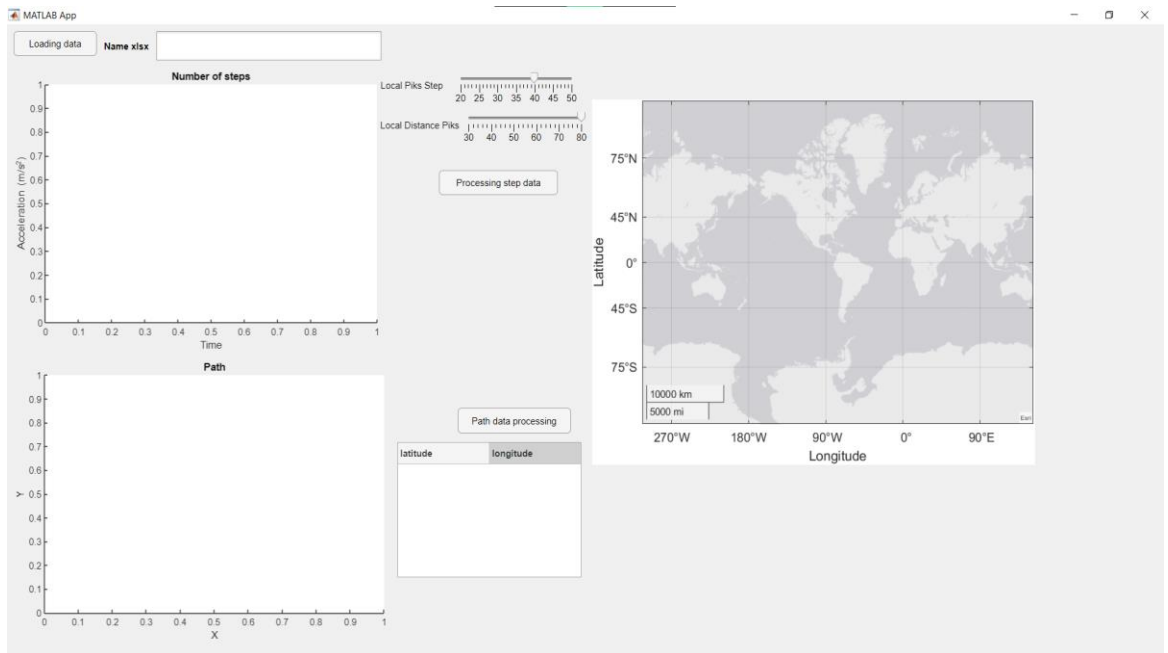


Fig. 4.6. Executable program window

The application is loaded with user data in the screenshot below, Fig. 4.7.

Users must click the "Loading data" button, choose the file in the pop-up window, and then click "Open" to begin downloading data.

The program will display an error in the "Name.xlsx" window and prompt the user to enter correct data if there is no data or data that is in the wrong format.

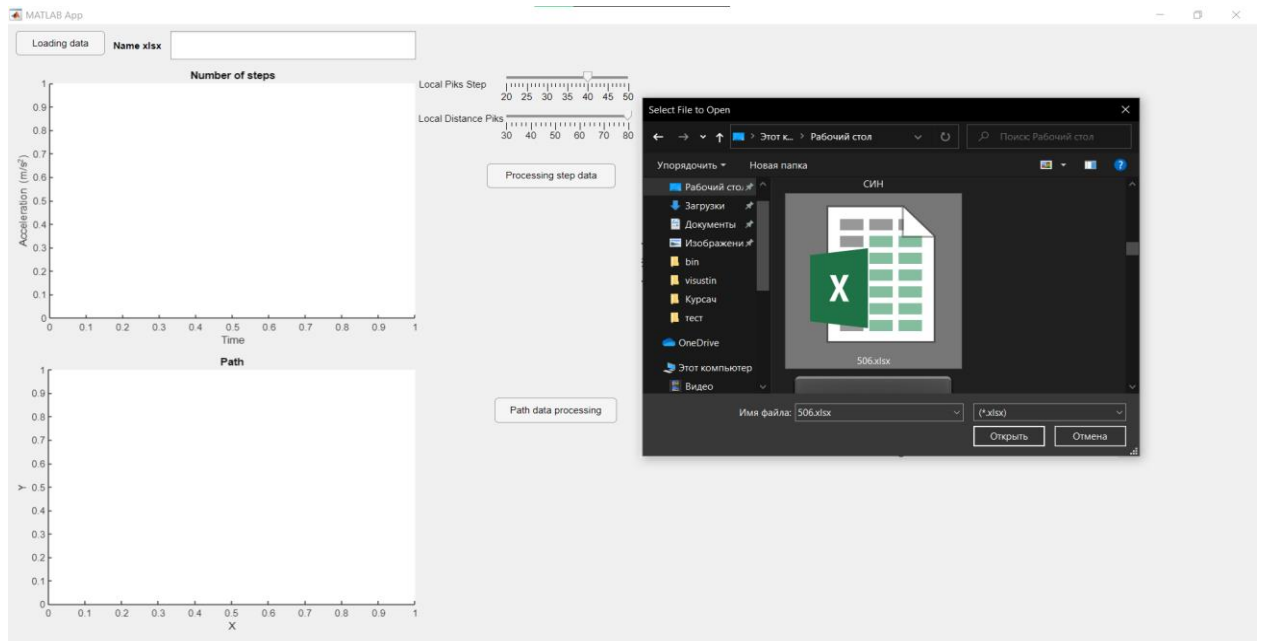


Fig. 4.7. Data loading window

The program will process the data after the user clicks the "Processing step data" button in the next slide's Fig. 4.8, which displays an example of data processing.

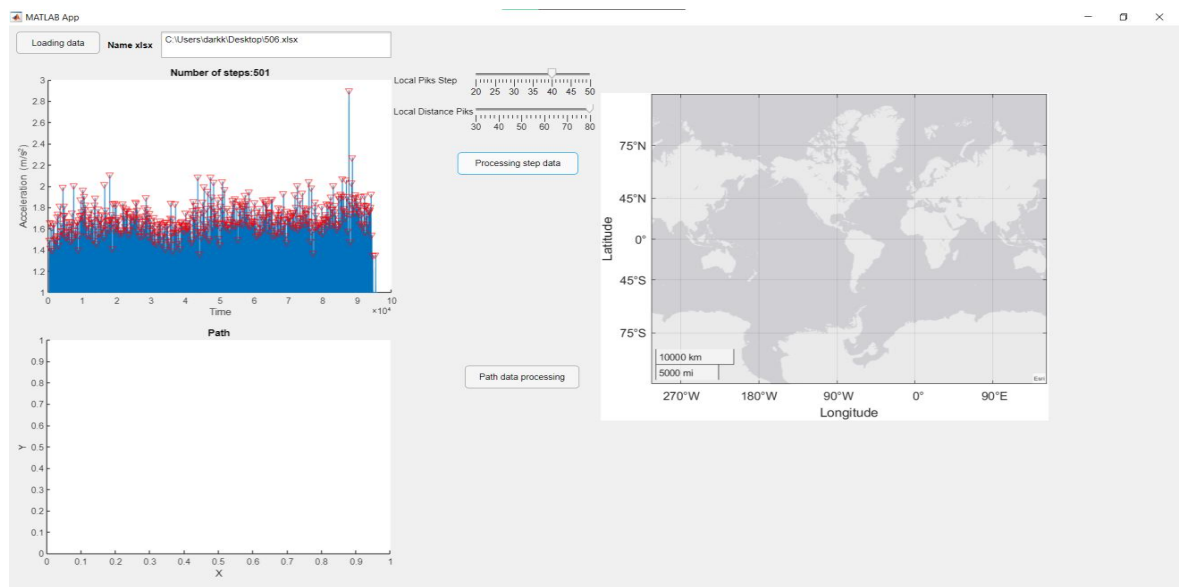


Fig. 4.8. Window for processing these steps

The results of step counting and the user's journey are shown on the last slide, Fig. 4.9. The last button in the middle of the "Path data processing" page does this by processing the user's data and giving him information about the path he has taken as well as the number of steps.

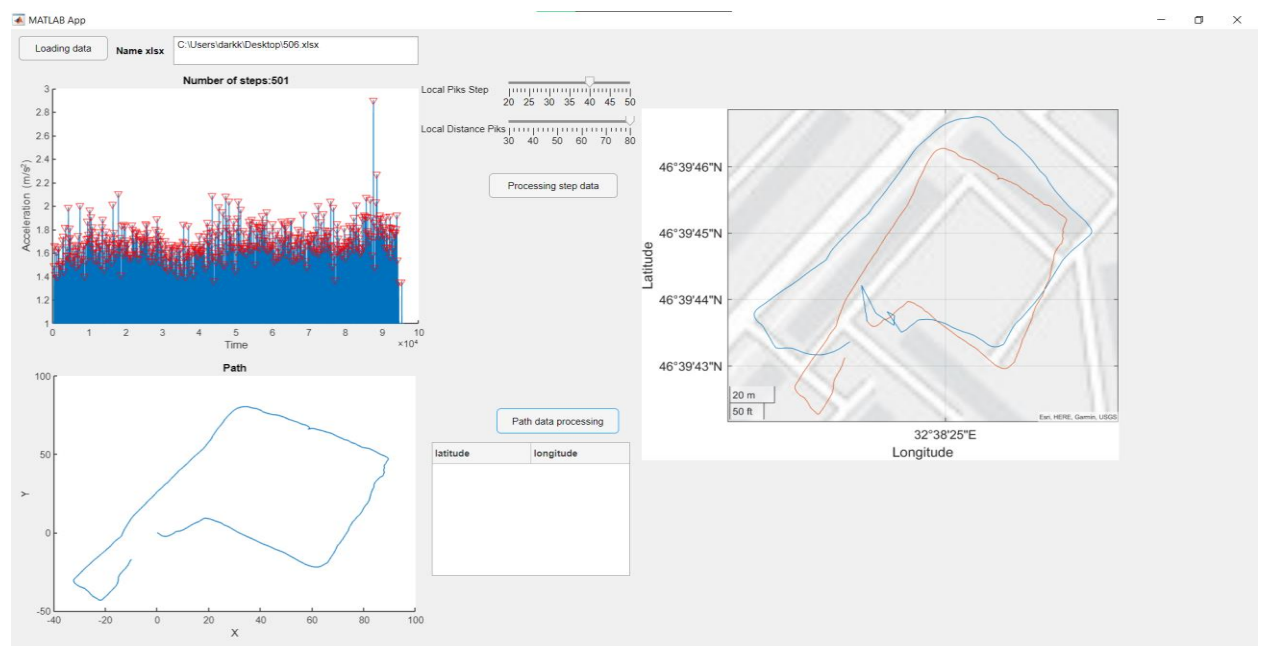


Fig. 4.9. Route processing window

CHAPTER 5. ENVIRONMENTAL PROTECTION

5.1. Actual issues of soil contamination with heavy metals

Pollutants are substances of anthropogenic origin that enter the environment in quantities exceeding the natural level of entry. Soil pollution is a type of anthropogenic pollution. Degradation, in which the content of chemical substances in soils subject to anthropogenic influence exceeds the natural regional background level.

Exceeding the content of certain chemicals in the human environment (compared to natural levels) due to their arrival from anthropogenic sources constitutes an environmental hazard.

Human use of chemicals in economic activities and their involvement in the cycle of anthropogenic transformations in the environment is constantly growing.

The characteristic of the intensity of extraction and use of chemical elements is technophily - the ratio of annual production. High technophilicity is characteristic of the elements that are most actively used by humans, especially for those whose natural level in the lithosphere is low. High levels of technophilicity are characteristic of the following metals: Bi, Hg, Sb, Pb, Cu, Se, Ag, As, Mo, Sn, Cr, Zn.

The need for various types of production is great. With a low content of these elements in rocks (10⁻²-10⁻⁶%), their extraction is significant. This leads to the extraction of colossal quantities of ores containing these elements from the depths of the earth, and to the following their global dispersion in the environment.

ACIC DEPARTMENT

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Performed	Supervisor	Consultant	S. controller	Dep. head	INDIVIDUAL MOBILE NAVIGATION SYSTEM OF WAY COUNTING	N.	Page	Pages
Lazarevskiy O.A.	Vasylenko M.P.	Iavniuk A.A.	Filyashkin M.K.	Sineglazov V.M.			82	120
						225 151		

In addition to technophile, other quantitative characteristics of technogenesis are proposed. Yes, the ratio of technophilicity of an element to its biophilicity (biophilicity - the concentration of chemical elements in living matter) called the destructive activity of the elements of technogenesis.

The destructive activity of elements of technogenesis characterizes the degree of danger for living organisms.

Another quantitative characteristic of anthropogenic involvement of chemical elements in their global cycles on the planet is the mobilization factor or technogenic enrichment factor, which is calculated as the ratio of the technogenic flow of a chemical element to its natural flow. The level of the technogenic enrichment factor, as well as the technophilicity of elements, is not only an indicator of their mobilization from the lithosphere into terrestrial natural environments, but also a reflection of the level of emissions of chemical elements with industrial waste into the environment.

Heavy metals (HM) already rank second in terms of danger, behind pesticides and well ahead of such well-known pollutants as carbon dioxide and sulfur. In the future, they may become more dangerous than nuclear power plant waste and solid waste.

Contamination of HM is associated with their wide use in industrial production. In connection with imperfect cleaning systems, HM enter the environment, including the soil, contaminating and poisoning it. HM refer to special pollutants, observations which are mandatory in all environments. Soil is the main medium into which HM enter, including from the atmosphere and water environment. It is a source of secondary pollution of surface air and waters entering the World Ocean from it. From the soil, HM are assimilated by plants, which then get into food. The term "heavy metals", which characterizes a wide group of pollutants, has recently become widely used. In various scientific and applied works, the authors interpret the meaning of this concept in different ways. In this

regard, the number of elements belonging to the group of heavy metals varies within the limits.

In As membership criteria, numerous characteristics are used: atomic mass, density, toxicity, prevalence in natural environment, the degree of involvement in natural and man-made cycles.

In the works devoted to the problems of environmental pollution and ecological monitoring, to date it is difficult metals include more than 40 elements of the periodic table of D.I. Mendeleev with an atomic weight of more than 40 atomic units: V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cd, Sn, Hg, Pb, Bi, etc. According to the classification of N.

Reimers (1990), metals with a density of more than $8 \frac{g}{cm^3}$ should be considered heavy. At the same time, the following conditions play an important role in the category of heavy metals: their high toxicity for living organisms in relatively low concentrations, as well as the ability to bioaccumulate and biomagnify. Almost all metals, that fall under this definition (with the exception of lead, mercury, cadmium and bismuth, the biological role of which is currently unclear), take an active part in biological processes, are part of many enzymes.

The most powerful suppliers of metal-enriched waste are non-ferrous metal smelting enterprises (aluminum, alumina, copper-zinc, lead-smelting, nickel, titanium-magnesium, mercury, etc.), as well as non-ferrous metal processing (radio-technical, electrical-technical, instrument-making, galvanic etc.).

In the dust of metallurgical industries, ore processing plants, the concentration of Pb, Zn, Bi, Sn can be increased compared to the lithosphere by several orders of magnitude (up to 10–12), the concentration of Cd, V, Sb – tens of thousands of times, Cd, Mo, Pb, Sn, Zn, Bi, Ag - hundreds of times. Waste from non-ferrous metallurgy enterprises, paint industry factories, and reinforced concrete structures is enriched with mercury. The concentration of W, Cd, Pb increased in the dust of machine-building factories (Table 5.1)

Table 5.1

The main technogenic sources of heavy metals

Sources of heavy metals	Elements
Non-ferrous metallurgy	Pb, Zn, Cu, Hg, Mn, Sb, W, Co, Cd
Ferrous metallurgy	Ni, Mn, Pb, Cu, Zn, W, Co
Energy	As, Sb, Se
Oil industry	Pb, Cu, Ni, Zn, Mn
Coal burning	Sb, As, Cd, Cr, Mo
Oil burning	As, Pb, Cd

Under the influence of metal-enriched emissions, areas of landscape pollution are formed mainly at the regional and local levels. The influence of energy companies on environmental pollution is not caused by the concentration of metals in waste, but by their huge amount. The mass of waste, for example, in industrial centers,

exceeds their total amount coming from all other sources of pollution. A significant amount of Pb is released into the environment with the exhaust gases of cars, which exceeds its intake with the waste of metallurgical enterprises.

Arable soils are polluted by such elements as Hg, As, Pb, Cu, Sn, Bi, which enter the soil as part of toxic chemicals, biocides, plant growth stimulants, structure formers. Non-conventional fertilizers made from various wastes often contain a wide range of pollutants at high concentrations. From traditional mineral fertilizers, phosphorus fertilizers contain impurities of Mn, Zn, Ni, Cr, Pb, Cu, Cd.

Distribution of metals in the landscape, that entered the atmosphere from man-made sources is determined by the distance from the source of pollution, climatic conditions (wind strength and direction), topography, technological factors (condition of waste, way of entering the environment, height of enterprise pipes).

The dispersion of HM depends on the height of emissions into the atmosphere.

According to calculations, with high chimneys, a significant concentration of emissions is created in the surface layer of the atmosphere at a distance of 10–40 chimney heights. 6 zones are distinguished around such pollution sources (Table 5.2). The area of influence of individual industrial enterprises on the surrounding territory can reach 1000 km^2 .

Table 5.2

Zones of soil pollution around point sources of pollution

№ n/p	Zone	Distance from sources of pollution in km	Exceeding the content of the VM in relation to the background
1	Security zone of the enterprise	0,5–0,75	100
2	Zone I	0,75–1,5	200-50
3	Zone II	2–8	50-10
4	Zone III	4–15	5-2
5	Zone IV	8–20	5-2
6	Background	20–50	1

Zones of soil contamination and their size are closely related to the prevailing wind vectors. Terrain, vegetation, urban structures can change the direction and speed of movement of the surface layer of air. Similarly, zones of soil pollution can be called zones of vegetation cover.

5.2. Environmental regulation of the quality of contaminated soil

The maximum permissible concentration (MPC) of chemical substances in environmental objects serves as a sanitary and hygienic criterion for the quality of the environment. MPC corresponds to the maximum content of a chemical substance in natural objects, which does not cause a negative (direct or indirect) impact on human health (including remote consequences).

The toxic effect of various chemical substances on living organisms is characterized by a general sanitary indicator, such as the LD-50 (lethal dose) indicator, which shows the mass of the substance that entered the body of experimental animals (mice, rats) and caused the death of 50% of them. The dimension of this indicator is mg of the substance/kg of the weight of the experimental animal. Direct contact of a person with the soil is insignificant and occurs indirectly through other components: soil – plant – person; soil – plant – animal – human; soil - air - man; soil - water - man. The determination of MPC in soils is reduced to the experimental determination of the ability of these substances to maintain the concentration of substances that are in contact with soil, water, air, and plants that are acceptable for living organisms.

That is why the MPC of chemical substances for soils is established not only according to the general sanitary indicator, as it is accepted for other natural environments, but also according to three other indicators: translocation, migratory water and migratory air (Table 5.3).

The translocation index is determined by the soil's ability to provide the content of chemicals at an acceptable level in plants (radish, lettuce, peas, beans, cabbage, etc. are used as test crops). Accordingly, migratory water and migratory air are determined by the ability of soils to ensure that the content of these substances in water and air is not higher than the MPC. However, the sanitary and hygienic standards of soil quality are not without shortcomings; the main of them is that the conditions of the model experiment for determining the MPC and natural conditions are very different.

One of the stages of solving the problem of environmental regulation was an approach based on determining the permissible load on the soil, considering its buffer properties, which ensure the ability of the soil to limit the mobility of chemicals coming from outside, the ability to self-clean. Such approaches are being developed in Russia and other countries.

But it is very difficult to develop MPC for each type of soil. Appropriate MPC development of standards for chemical substances for soil-geochemical associations united by a commonality of basic physicochemical properties that determine their resistance to chemical pollution.

Table 5.3

Maximum permissible concentrations of VM in soils ($\frac{mg}{kg}$)

Element	Clark soils	MPC	Indicator of harmfulness			
			general sanitary	translocational	migratory water	migratory air
General content						
Mn	800	1500	1500	3500	1500	
V	100	120	150	170	350	
Pb	10	32	30	35	260	
Hg	0,01	2,1	5,0	2,1	33	2,5
Movable joints						
Cu	20	3	3	3,5	72	
Ni	40	4	4	4	14	
Zn	50	23	37	93	200	
Co	8	5	5	25	1000	
Cr	200	6	6			

At the next stage, APC (approximate permissible concentrations) of these soil elements were developed for a number of chemical elements, which differ in the most important properties (acidity and granulometric composition). They were not developed on the basis of a standardized experimental method, and on the generalization of the available information on the relationship between the level of load on the soil, the condition of the soil and adjacent environments.

The grouping of soils based on their resistance to HM was primarily based on their acid-alkaline conditions, and the spread of the main geochemical associations of soils on the territory of Ukraine was also considered.

Geochemical associations of soils with an acidic and neutral reaction of the environment with a division into 2 groups have the largest distribution area:

1. soils with a very acidic and acidic reaction (pH of the water extract < 5);
2. soils with a slightly acidic and neutral environment (pH 5–7).

It is important to account for the granulometric composition, especially for the soils of the first group, which were divided into two subgroups from the granulometric composition:

1. sandy and loamy soils, which have the least resistance to pollution;
2. loamy and clay soils, relatively more resistant to pollution.

According to this principle, in our country, approximately permissible concentrations (APC) of TM in soils were determined (Table 5.4).

Table 5.4

Approximate permissible concentrations (APC) of heavy metals in soils ($\frac{mg}{kg}$)

Soil groups	Elements, mg/kg					
	Ni	Cu	Zn	As	Cd	Pb
Sandy and sandy loams	20	33	55	2	0,5	32
Acid loamy and clayey	40	66	110	5	1,0	32
Close to neutral, neutral loamy and clayey	80	120	220	10	2,0	130

5.3. Biogeochemical standardization

Biogeochemical standardization is based on a medical-geographical approach. It is based on natural observations in such regions, where nature has created conditions of excess or lack of certain chemical elements in natural environments. These regions are called biogeochemical provinces.

The results of observations in biochemical provinces on the state of living organisms, including the health of people, make it possible to establish their relationship with the content of elements in natural environments.

On a probabilistic basis, the upper and lower limits of the content of elements are determined, within which limits the state of most living organisms (animals, plants, humans) does not deviate from the norm. But, as a rule, 5-20% of people and animals in endemic areas are affected.

The higher the content of chemical elements exceeds the threshold levels, the higher the number of victims. The process of natural selection is intensifying. According to the results of biogeochemical zoning V.V. Kowalski established threshold concentrations of a number of chemical elements in soils.

Harmful effects of excessive amounts of HM in the environment on human health are revealed based on the analysis of the ecotoxicological situation in the biogeochemical provinces and the health of people living here for a long time. The results of the analysis of the patterns of the spread of occupational diseases in the branches of production, chemical elements, causing environmental pollution.

Ecosystem normalization. Currently, approaches to the regulation of the content of chemical elements in soils are becoming more and more widespread, with an ecosystem focus. Ecosystem normalization prevents not only pathological, but also pre-pathological changes. The goal of ecosystem regulation is to preserve nature in such a state that when all living organisms have an equal declaration of existence. This approach will ensure the preservation of man (population, individual) as a component of the ecosystem. Man differs from other organisms in

that he is the final consumer in most trophic chains. The task is to check whether the level of the content of this or that substance under any anthropogenic influence on ecosystems remains within the limits of fluctuations in its content under natural conditions or exceeds these limits. The theory of ecosystem regulation is consistent, but its methods have not been fully developed, as have the concepts of significant and non-significant changes in the ecosystem.

5.4. The concept of soil ecological monitoring

Soil ecological monitoring is a system of regular, unlimited in space and time control of soils, which provides information on their condition for the purpose of assessing the past, present and forecasting changes in the future. Soil monitoring is aimed at detecting anthropogenic soil changes that may ultimately harm human health. The special role of soil monitoring is due to the fact that all changes in the composition and properties of soils are reflected in the performance of their ecological functions by soils, therefore, in the state of the biosphere.

It is of great importance that in the soil, in contrast to the air of the atmosphere and the surface waters of the reservoir, the ecological consequences of anthropogenic influence are usually revealed later, but they are more stable and persist longer. There is a need to assess the long-term consequences of this impact, for example, the possibility of mobilizing pollutants in the soil, as a result, the soil from the "depot" of pollutants can turn into their secondary source.

5.4.1. Types of soil ecological monitoring

The selection of types of soil ecological monitoring is based on the differences in the combination of informative soil indicators that correspond to the tasks of each of them. Based on differences in the mechanisms and scales of soil degradation, two groups of types of monitoring are distinguished: the first group is global monitoring, the second is local and regional.

Global soil monitoring is a component of global biosphere monitoring. It is carried out to assess the impact on the soil condition of the ecological consequences

of long-range atmospheric transport of pollutants in connection with the danger of global pollution of the biosphere and accompanying processes at the global level.

The results of global or biosphere monitoring characterize global changes in the state of living organisms on the planet under the influence of human activity. The purpose of local and regional monitoring is to identify the impact of soil degradation on ecosystems at the local and regional levels and directly on the living conditions of people in the field of nature use.

Local monitoring is also called sanitary and hygienic or impact monitoring. It is aimed at controlling the level of retention in the environment among those pollutants emitted by a specific enterprise. First of all, natural environments that are most sensitive to this pollutant in real conditions are controlled. It is important not only to detect environmental hazards associated with pollutants early, but also to identify patterns of their accumulation. The results of the soil survey are considered when determining the level of their contamination and making a forecast of health hazards and living conditions of people in settlements, when developing measures for soil reclamation, when preventing human diseases, etc. To establish the level and degree of soil contamination, sampling points are at their disposal considering the wind rose (GOST 17.4.3.01.-83 (ST REV 3847-82)), terrain, vegetation and hydrological conditions, i.e. conditions that ensure the spread of pollutants from the source. Near the source of pollution, sampling points are placed more often (at a distance of 50, 100, 200, 300 m), with distance from it, the sampling frequency decreases. The shape of the survey area is an irregular shape drawn from a wind rose. When controlling soil pollution by transport highways, test sites are laid on roadside lanes, samples are taken from narrow lanes 200–500 m wide at a distance of 0-10, 10-50, 50- 100 m from the road surface from a depth of 0-10 cm. Regular and periodic observations are carried out at the test areas. It is advisable to re-determine the mobile forms of controlled elements in several years (1–5). Periodicity is determined by the degree of industrial

development of the territory, distance from large polluting objects, features of the controlled element.

Regional monitoring is aimed at assessing the impact of all types of human activity on the state of the region's environment. It is an observation of the interaction of nature and man in the process of nature use.

Local and regional soil environmental monitoring includes 3 main types:

1. Specific

Specific types of soil monitoring include monitoring of soils prone to pollution and agrochemical monitoring. Specific types of local and regional soil monitoring differ in that they are aimed at detecting degradation primarily of chemical properties of soils, with which the direct action of soils on living organisms is connected. At the same time, significant changes in the physical properties of soils and their morphology may not be observed (with the exception of extreme degrees of their manifestation, for example, in the man-made desert of heavily polluted and degraded soils).

2. Complex

Within the framework of complex monitoring, monitoring of desertification, monitoring of pastures and irrigation and reclamation monitoring are distinguished. Complex types of local and regional soil monitoring are aimed at identifying the ecological consequences of complex soil degradation, which is based on the processes of degradation of the physical properties of soils, which are inevitably accompanied by the degradation of their chemical indicators (desolation, erosion of soils), or begin with the degradation of chemical properties, which entails a change in physical indicators (degradation of irrigated soils), which can be reflected both in the morphological features and the classification position.

3. Universal

Universal types of soil monitoring include: control of the microbiological state of soils, control of soil quality, and remote soil monitoring. Universal types

of local and regional soil monitoring make it possible to obtain an integral assessment of soil degradation, which is based on either the state of soil microocenosis, or production assessment of soil quality, or its "view from above", which characterizes large areas.

Background monitoring is a mandatory type of monitoring. Its purpose is to control the condition of the soils of the territories, which can serve as environmental benchmarks, a kind of "zero reference points" during local and regional monitoring. The objects of observation for background monitoring are soils, studies characteristic of the region, minimally exposed to anthropogenic influence, for example, soil in reserves or natural monuments.

5.4.2. Monitoring of the migration of heavy metals in the soil profile thanks to the PDR system

Using a pedestrian path counting system using a mobile phone for monitoring.

The main purpose of the software (software) is to provide the user with a more detailed understanding of his location in space, in a place, forest, underground communications, warehouses where conventional GPS devices do not work.

A number of such sensors as a magnetometer, accelerometer, and gyroscope are used to read data. It is the magnetometer that helps to find out the direction of the user's movement, and in movements with a constant magnetic circuit, it is possible to build a separate map of magnetic fields.

Also, the magnetometer helps to collect constant data on the presence of a magnetic field in a certain distance that a person passes. When the GPS is turned on, it is possible to enter values from a mobile phone into a common database on the map. For its further analysis, for example, if over a certain period of time,

if the strength of the magnetic profile changes in one part of the area, then this will also reflect the magnetic composition of the earth in this area, because the



magnetometer is affected by the so-called hard iron (see Fig. 5.1) and soft iron (see Fig. 5.2)

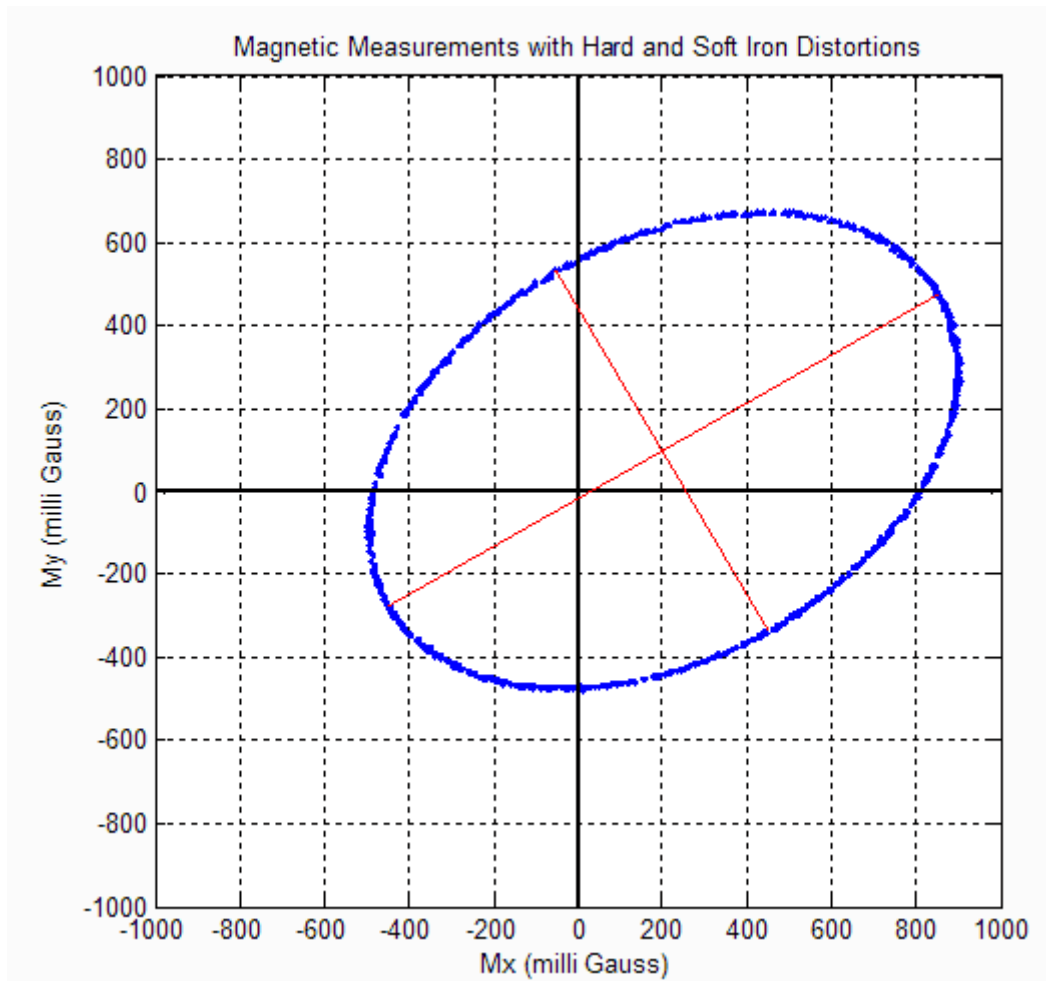


Fig. 5.1 Effect of solid iron on the magnetometer

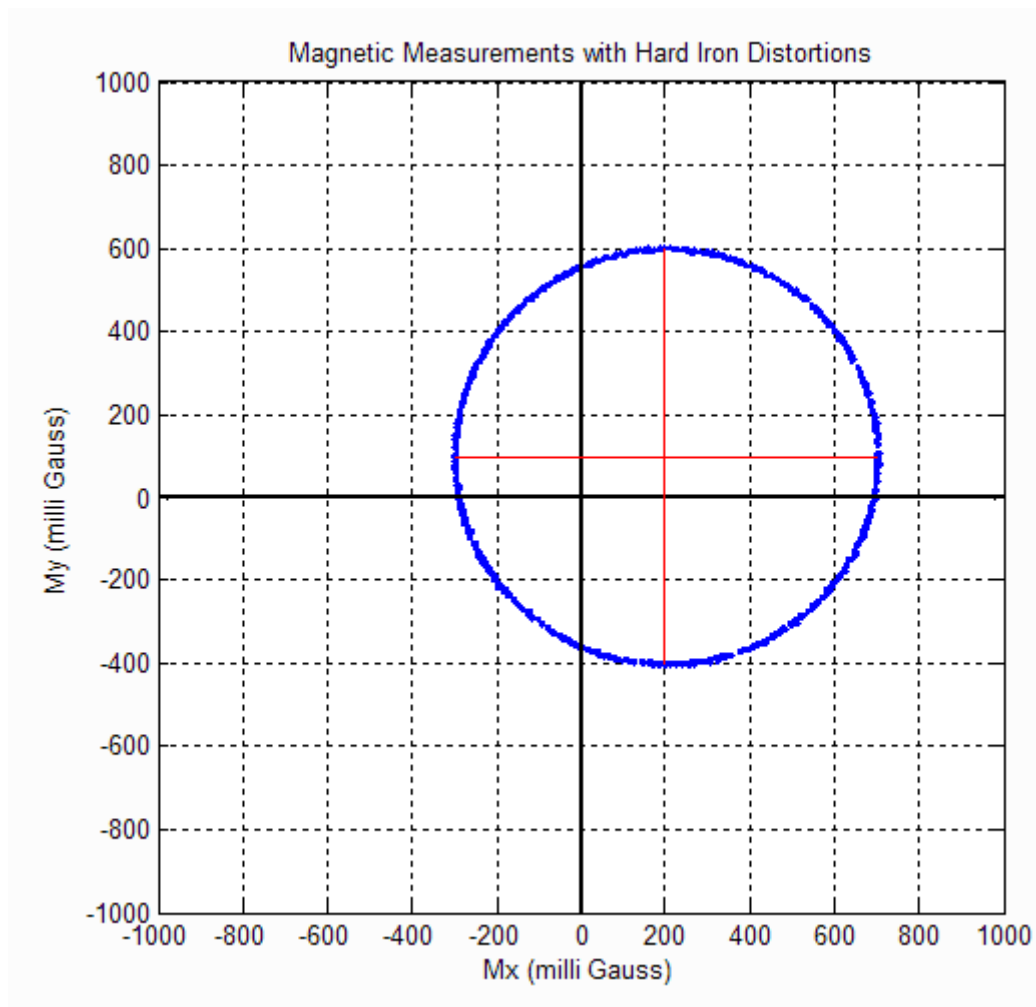


Fig. 5.2 Effect of solid iron on the magnetometer

Accumulation of the main part of pollutants is observed mainly in the humus-accumulative soil horizon, where they are bound by aluminosilicates, non-silicate minerals, and organic substances with the help of various interaction reactions. The composition and number of elements retained in the soil depend on the content and composition of humus, acid basic and redox conditions, sorption capacity, intensity of biological absorption. Some of the heavy metals are firmly held by these components and not only do not participate in migration along the soil profile, but does not pose a danger to living organisms, the negative environmental consequences of soil pollution are associated with mobile metal compounds.

Within the soil profile, the man-made flow of substances encounters a number of soil-geochemical barriers. These include carbonate, gypsum, illuvial horizons (illuvial-iron-humus).

Some of the highly toxic elements can transform into compounds that are difficult for plants to access, other elements that are mobile in this soil-geochemical environment can migrate in the soil layer, posing a potential danger to biota. The mobility of elements largely depends on acid-base and oxidation-reduction conditions in soils. In neutral soils, mobile compounds of Zn, V, As, Se, which can be leached during seasonal soil wetting.

The accumulation of mobile, especially dangerous for organisms, compounds of elements depends on the water and air regimes of the soil: their lowest accumulation is observed in the water-permeable soils of the washing regime, it increases in the soils with the non-washing regime and the maximum in the soils with the leaching regime. With evaporative concentration and an alkaline reaction, Se, As, V can accumulate in the soil in an easily accessible form, and in the conditions of a reducing environment - Hg in the form of methylated compounds.

However, it should be borne in mind that under the conditions of the washing regime, the potential mobility of metals is realized, and they can be carried out of the soil profile, being a source of secondary pollution of groundwater.

In acidic soils with a predominance of oxidizing conditions (podzolic soils, well drained), such heavy metals as Cd and Hg form easily mobile forms. On the contrary, Pb, As, Se form immobile compounds that can accumulate in humus and illuvial horizons and negatively affect the state of soil biota.

If S is present in the composition of pollutants, under reducing conditions a secondary hydrogen sulfide environment is created and many metals form insoluble or slightly soluble sulfides.

In swampy soils, Mo, V, As, Se are present in immobile forms.

A significant part of the elements in acidic wetland soils is present in relatively mobile and dangerous forms for living matter; such compounds are Pb,

Cr, Ni, Co, Cu, Zn, Cd and Hg. Hardly soluble Pb compounds are formed in weakly acidic and neutral soils with good aeration, especially during liming.

In neutral soils, mobile compounds Zn, V, As, Se, and Cd and Hg can be retained in humus and illuvial horizons. As alkalinity increases, the danger of soil contamination with the listed elements increases.



CHAPTER 6. LABOR PROTECTION

6.1. Introduction

Use of a pedestrian path counting system using a mobile phone in production the main purpose of the software (software) is to provide the user with a more detailed understanding of his location in space, in a place, forest, underground communications, warehouses where conventional GPS devices do not work.

A number of such sensors as a magnetometer, accelerometer, and gyroscope are used to read data. It is the magnetometer that helps to find out the direction of the user's movement, and in movements with a constant magnetic circuit, it is possible to build a separate map of magnetic fields.

This helps to monitor the electromagnetic condition of the premises for regulation according to the order of the Ministry of Health "On the approval of the Amendment to the State Sanitary Standards and Rules for the Protection of the Population from the Impact of Electromagnetic Radiation" dated 11/30/2020 No. 2760, according to which the permissible standards of radiation from $10 \mu \frac{W}{cm^2}$ to $100 \mu \frac{W}{cm^2}$.

In case of exposure to an electromagnetic field (EMF), the parameters of which exceed the maximum permissible level, acute and chronic forms of violation of the physiological functions of his body are possible. Such disturbances arise as a result of the action of the electrical component of EMF on the nervous system, as well as on the structure of the cortex of the brain and spinal cord, cardio-vascular system. For the most part, such changes in the activity of the nervous and cardiovascular systems are reversible. As a result of long-term exposure, they accumulate, intensify over time, but, as a rule, decrease and disappear if exposure is stopped and working conditions improve.

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				N.	Page	Pages
Performed	Lazarevskiy O.A.				98	120
Supervisor	Vasylenko M.P.					
Consultant	Kozlitsin O.O.					
S. controller	Filyashkin M.K.					
Dep. head	Sineglazov V.M.					
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Long-term and intense exposure to EMF leads to permanent disorders in the human body and diseases. The combined action of radiations of a wide range can cause radio wave sickness. The severity of its consequences directly depends on the intensity of EMF, physical characteristics of different frequency ranges, duration of exposure, environmental conditions, as well as from the functional state and resistance of the organism to the influence of various factors, its adaptation capabilities. Even at a very low intensity of EMF, which slightly exceeds hygienic standards, the risk of general diseases, diseases of respiratory organs, digestion, etc. increases.

As a result of the effect on the human body of EMF in the range of 30 kHz - 300 MHz, general weakness, increased fatigue, sleep disturbances, headache and heart pain occur. Irritability appears, attention is lost, motor and speech reactions slow down. There are a number of symptoms that indicate a malfunction of certain organs — the stomach, liver, pancreas. Food and sexual reflexes, the activity of the cardiovascular system deteriorate, changes in the indicators of protein and carbohydrate metabolism are recorded, the composition of the blood changes, and changes at the cellular level are recorded. The systematic effect of high and ultra-high frequency EMF on the human body causes an increase in blood pressure, trophic phenomena (hair loss, brittle nails). EMF causes a change in the polarization of the molecules and atoms that make up cells, resulting in dangerous heating. Excessive heat damages both individual organs and the entire human body.

Workers may develop occupational diseases as a result of long-term and intensive exposure to EMF. Most often, those who work in the fields of radio broadcasting, television and communication, the provision of medical services (in particular, in the physiotherapy office), as well as those who perform heat treatment of metals, wood and other materials or heating and welding of dielectrics using EMF.

6.2 Analysis of working conditions at the enterprise

In general, this type of production requires quite different facilities, equipped workplaces in this production room with equipment and facilities, for software development.

6.2.1. Characteristics of the production premises

The list of legal acts regulating this issue in one way or another is quite extensive. Thus, the employer's obligations to provide employees with comfortable and safe conditions for work, as well as the employees' rights to such conditions, are provided for in part 2 of Article 2 and Part 1 of Art. 21 of the Labor Code, as well as Art. 13 of the Law of Ukraine "On Labor Protection».

Buildings and premises where workplaces are located must meet the requirements of the regulatory and technical and operational documentation of the manufacturer of personal computers DSanPiN 3.3.2-007-98 and the Rules. Buildings and premises where workplaces with computers are located, must be no lower than the second degree of fire resistance (The indicator of fire resistance is the fire resistance limit of the structure, which is determined by the time (in minutes) from the start of the fire test under the standard temperature regime to the onset of one of the limit states of the structure: loss of bearing capacity (R); loss of integrity (E) loss of thermal insulation capacity). For all buildings and premises where workplaces are located, the zone class must be determined in accordance with NPAOP 40.1-1.01-97 (Rules for the safe operation of electrical installations). The corresponding marking must be placed on the entrance door of each premises.

Location of premises with workplaces in basements and basement floors is not allowed. The location of premises of categories A and B is unacceptable (Category A. Combustible gases, flammable liquids with a flash point of no more than 28 °C in such a quantity that explosive vapor-gas-air mixtures can be formed, when ignited, the estimated excess pressure of the explosion in the room, which exceeds 5 kPa, develops. Category B. Combustible dust or fibers, flammable liquids with a flash point above 28 °C and flammable liquids in such quantities that explosive dust-air or vapor-air mixtures can be formed, upon ignition of which the

estimated excess pressure of the explosion in the room, exceeding 5 kPa, develops, as well as factories with wet technological processes next to the rooms where workplaces with computers are located, as well as above or below them.

6.2.2. List of harmful and dangerous production factors.

Depending on what type of production will be used in production, the following types of hazards in production can be listed:

- Electricity supply

GOST 12.1.009-76, NPAOP 40.1-1.07-01 "Rules for the operation of electrical protective devices", NPAOP 40.1-1.21-98 "Rules for the safe operation of consumer electrical installations", NPAOP 40.1-1.32-01 "Rules for the construction of electrical installations. Electrical equipment of special installations"

- Road traffic safety at the enterprise

This is how part 2 of Art. 11 of the Law of Ukraine "On Road Traffic" dated June 30, 1993 No. 3353-XI. This norm also applies to ministries, other central executive bodies and associations.

The qualification requirements for employees of road traffic safety services of enterprises of the motor vehicle industry are given in Issue No. 69 "Automotive Transport" of the Handbook of Qualification Characteristics of Employees' Professions, approved by the Order of the Ministry of Transport and Communications of February 14, 2006 No. 136.

- Fire protection

The Law of Ukraine "On Fire Safety" came into effect on January 29, 1994, in accordance with the Resolution of the Verkhovna Rada of Ukraine dated December 17, 1993 No. 3747-XII. It defines the general legal, economic and social foundations of ensuring fire safety on the territory of Ukraine.

6.3. Analysis of harmful and dangerous production factors

6.3.1. Microclimate of the working area

Industrial sanitation involves the creation of the most favorable medical and sanitary conditions at the workplace in order to protect the health of workers.

The microclimate is regulated in the cold season through the heating system (the room is connected to the city-wide heating system), in the summer air conditioning is used.

Despite the fact that the large area of windows in the cold season creates conditions for an additional influx of cold air, and in the warm season - for excessive overheating of the room, the presence of double-glazed windows and air conditioning systems allow you to maintain meteorological conditions within the limits of standards.

A wall-mounted LG G18LHT air conditioner is installed in the room:

Type according to the number of blocks: split system4

Number of internal units: 1;

Mode: cooling/heating/drying;

Remote control: +;

Power consumption: 1.95 kW;

The premises have natural (at least one window) and artificial lighting, which provides round-the-clock lighting. General artificial lighting is used - lamps are placed evenly in the upper area of the room, fluorescent lamps.

The temperature in the room is 20-23 C,

Humidity 40-60%,

The speed of air movement is 0.1 m/s

6.3.2. Ionizing radiation

It is necessary to monitor the electromagnetic condition of the premises for regulation according to the order of the Ministry of Health "On the approval of the Amendment to the State Sanitary Standards and Rules for the Protection of the Population from the Impact of Electromagnetic Radiation" dated 30.11.2020 No. 2760, according to which the permissible standards of radiation have been increased from $10 \frac{\mu W}{cm^2}$ up to $100 \frac{\mu W}{cm^2}$.

In case of exposure to an electromagnetic field (EMF), the parameters of which exceed the maximum permissible level, acute and chronic forms of violation

of the physiological functions of his body are possible. Such disturbances arise as a result of the action of the electrical component of EMF on the nervous system, as well as on the structure of the cortex of the brain and spinal cord, cardio-vascular system. For the most part, such changes in the activity of the nervous and cardiovascular systems are reversible.

6.3.3. Road traffic safety at the enterprise

At enterprises and organizations that have vehicles, the position of road safety specialist is introduced (if more than 50 people operate vehicles) or a road safety service is created (if vehicles are operated by more than 500 people). This is how part 2 of Art. 11 of the Law of Ukraine "On Road Traffic" dated June 30, 1993 No. 3353-XI. This norm also applies to ministries, other central executive bodies and associations.

The qualification requirements for employees of road traffic safety services of enterprises of the motor vehicle industry are given in Issue No. 69 "Automotive Transport" of the Handbook of Qualification Characteristics of Employees' Professions, approved by the Order of the Ministry of Transport and Communications of February 14, 2006 No. 136.

The number of traffic safety service specialists is determined on the basis of 1.4 times increase in the average registered number of drivers employed in passenger transportation.

Persons responsible for road safety at the enterprise must take such measures:

- develop a traffic scheme for vehicles and pedestrians;
- rationally organize and regulate the movement of vehicles;
- familiarize the company's personnel with the scheme of traffic and pedestrian traffic on the territory and in the production premises;
- appoint officials responsible for organizing and ensuring traffic safety.

In order to ensure the safety of personnel at the enterprise, it is necessary to properly organize the movement of vehicles and pedestrians on the territory and in the production premises of the enterprise.

The person responsible for traffic safety, on the basis of the general plan of the enterprise, develops a scheme for the movement of vehicles and pedestrians in accordance with the rules of the road. It is drawn up as an appendix to the Regulation.

- the direction of movement of vehicles on the territory of the enterprise must be right-hand and circular;
- the number of crossings with oncoming traffic and intersecting traffic flows is minimal. At enterprises where there are more than 100 vehicles, there should be no intersection of the main traffic flows;
- intersection of footpaths with traffic flows should be minimal.

On the diagram, it is marked:

- dashed line — permitted directions of vehicle movement, solid line — limits of passageways and parking lots of vehicles;
- footpaths, road signs, safety signs, signal devices;
- fencing of car filling stations, winter heating sites, electric power plants, sewage treatment plants, dangerous traffic areas, etc.

The developed scheme is agreed with the responsible officials of the enterprise, the trade union committee (if there is one) or the person authorized to ensure labor protection. The scheme is approved by the head of the enterprise. It is posted in a prominent place near the entrance to the enterprise's territory, in production premises - before the entrance to them. In addition, the scheme should be in the manager's office, his deputy's office, the control room, and officials responsible for traffic safety and occupational health and safety. Road marking of the territory is done according to the scheme; install road signs, safety signs and signaling devices made in accordance with regulatory documents.

Road traffic safety at the enterprise also depends on the speed of traffic on the territory. The speed of movement of vehicles on the entrances and territory of the enterprise should not exceed 10 km/h, and in production premises - 5 km/h.



It is necessary to enter the parking lot in front with the application of one maneuver in reverse when turning in the passage, while the distance from the moving vehicle to the restrictions of the passage must be at least 1 m.

It is possible to enter and leave the parking lot by road train only in the front lane.

It is necessary to tow a defective vehicle through the territory and in the production premises of the enterprise with a hard clutch. It is forbidden to tow the vehicle to start the engine (after repairs, overnight parking, etc).

6.3.4. Electrical safety

Premises with workplaces of computer users to ensure the electrical safety of the equipment, as well as to protect against electric shock of the PC users themselves, must have sufficient technical means of protection in accordance with GOST 12.1.009-76, NPAOP 40.1-1.07-01 "Rules for the use of electrical protective equipment", NPAOP 40.1-1.21-98 "Rules for the safe operation of electrical installations of consumers", NPAOP 40.1-1.32-01 "Rules for the construction of electrical installations. Electrical equipment of special installations"

Electric current poses a great danger to human life and health. Electric shock most often occurs as a result of: accidental contact with exposed live parts; the appearance of voltage as a result of damage to the insulation on the external metal parts of electrical installations; poor-quality grounding or zeroing, performing work without observing the necessary safety measures.

Technical methods and means of protection against electric shock include: insulation of conductive parts; protective grounding, zeroing; protective shutdown; warning alarm, etc.

6.3.5. Static protection measures

Discharge currents of static electricity can occur when touching any of the equipment located in the security room. Such discharges do not pose a danger to humans, but in addition to unpleasant sensations, they can lead to malfunction or failure of equipment.



To reduce the amount of static electricity generated, the floor covering is made of single-layer polyvinyl chloride antistatic linoleum. Common measures to protect against static electricity include general and local air humidification, for which humidifiers are used. The elimination of static electricity charges is achieved by grounding electrically conductive parts of the equipment. In order to ground non-metallic objects, an electrically conductive coating (conductive enamel) is applied to them beforehand. This kind of grounding is combined with the protective grounding of electrical equipment.

6.3.6. Provision of lighting of the working area

An important place in the complex of measures for labor protection and improvement of working conditions is the creation of an optimal light environment, that is, the rational organization of natural and artificial lighting of premises and workplaces. During the day, natural one-way lighting is used in offices, in the evening and at night or with insufficient lighting standards, artificial general uniform lighting. 72 Rooms for working with displays and video terminals can be attributed to category III visual work (high accuracy). The standard level of illumination for working with displays is 300 lux.

Requirements to reduce uncomfortable blackness and specular reflection in screens are met by using lamps with a combined direct and reflected direction of light, which is carried out with the help of double cross optics. Part of the direct light flux of the lamp goes through the parabolic mirror raster in such a way that that the dazzling effect of direct and reflected light is limited; the reflected part of the radiation of the lamp is directed in a wide stream to the ceiling. Thanks to this light distribution in the upper hemisphere, the brightness of the ceiling in any place, including directly under the lamp, does not exceed $200 \frac{cd}{m^2}$.

Dimensional brightness of lamps in the zone of radiation angles greater than 50° from the vertical is limited to $200 \frac{cd}{m^2}$ (candela per square meter) in both planes. For artificial lighting of the premises of SKB, fluorescent lamps of white (LB) and dark-white (LTB) color with a power of 80 W are used. DBN B.2.5-28:2018

Natural and artificial lighting, DBN B.2.5-28 apply to the design of lighting of territories, new and existing premises subject to reconstruction, buildings and structures for residential, civil, industrial purposes and civil protection, places of work in open spaces, territories of industrial and agricultural enterprises, railway tracks, enterprise areas, outdoor lighting of cities, settlements and rural settlements, streets and roads, green areas (parks, squares, forest parks), rest areas in landscape and recreational areas and resort areas, beaches, pedestrian crossings, building facades, residential areas, playgrounds, garbage 73 sites, parking lots and garages, gas stations, shopping areas, markets, cemeteries.

6.3.7. Measures to ensure favorable (safe) working conditions

The task of labor protection is to ensure safe, harmless and favorable working conditions by solving many complex tasks. Scientific and technological progress is of decisive importance in solving these problems. The use of the achievements of science and technology helps to increase the level of labor safety, culture and organization of production, makes work easier, enhance its attractiveness. Organizational, engineering-technical and medical-preventive measures are taken to ensure working conditions.

Organizational. Organization of briefings on labor protection, control of working conditions, optimization of work and rest regimes.

Engineering and technical. Installation of air conditioning, ventilation devices.

Medical and preventive measures. All professional PC users must undergo mandatory preliminary medical examinations at the time of employment, periodic medical examinations with the mandatory participation of a therapist, a neurologist and an ophthalmologist, as well as a general blood test and ECG.

6.3.8. Use of a counting system to determine the amount of contaminated soil

In Ukraine, the regulation of soil pollution is historically connected with determining the quality of agricultural land soils.

According to this approach, earlier in the USSR, only one standard was established that determined the permissible level of soil contamination by harmful chemical substances, the MPC, or the maximum permissible concentration for the arable layer of the soil, that is, the concentration that does not cause a direct or indirect negative impact on the environment and human health, and also on the self-cleaning ability of the soil.

It is important that in many cases the MPC values are not set for the gross content of soil pollutants, but for metals that can be extracted from the soil with buffer solutions. This is explained by two factors: the regulation of soil quality is based on the principle of preventing pollution of nearby natural environments (primarily, water environment) and analytical determination of the content of chemical substances in the soil is carried out according to the preliminary analysis of the content of pollutants from soil samples.

The lists of MPCs of pollutants in the grants were changed and supplemented repeatedly in the 70s and 90s of the 20th century. The main normative documents of the 90s of the last centuries were the hygienic norms of ГИ 6229-91. Among the modern regulatory documents, we can name DSTU 3866-99 "Soils. Classification of soils according to the degree of secondary salinity".

DSTU ISO 11269-1:2004 "Soil quality. Determination of the effect of pathogens on soil flora. Part 1. Method for determining the inhibitory effect on root growth" (ISO 11269-1:1993, IDT), DSTU ISO 11269-2-2002 "Soil quality. Determination of the actions of pathogens on the soil flora. Effect of chemicals on germination and growth of higher plants" (ISO 11269-2:1995, IDT), DSTU ISO22030:2007 "Soil quality. Biological methods. Chronic toxicity for higher" (ISO 22030:2005, IDT) and others.

For urban soils in the early 90s of the 20th century, for the purpose of ecological zoning of the territory, a methodology was developed for assessing the level of chemical soil pollution based on the total pollution index.

This technique is also used nowadays, both for residential areas of the city and for areas where the construction or reconstruction of industrial facilities is planned.

The main work on establishing soil quality standards in the world is led by FAO and WHO. In 1946, the International Organization for Standardization (ISO) was established. Only in the last 40 years, some attention has been paid to the regulation of pollutants in soils, since soils are a multicomponent system.

Thus, in 1985, the ISO/TC 190 "Soil Quality" Technical Committee was created, the secretariat of which is located in the Netherlands. In the subcommittees of this technical committee, more than 30 working groups, led by specialists from Australia, Austria, Great Britain, Canada, the Netherlands, Sweden, etc., have been created, which develop standards related to specific problems. These working groups cooperate with many international organizations (for example, WHO).

The European Environment Agency (EAA) collects data on soil pollution and the required level of soil purification. Although the distribution of sources of soil pollution by economic sector varies in different countries, industrial activities account for more than 60% of contaminated soils in Europe (the oil sector accounts for 14% of the total).

Among the most common harmful pollutants are heavy metals (35%) and mineral oils (24%). According to EA estimates, over 200 years of industrialization in countries, approximately 250,000 plots of land contain contaminated soils that require further restoration.

The content of pollutants in soils is usually regulated by national standards and legislative acts separately, although there is a tendency to unify regulatory documents.

The three-level system of regulating the content of pollutants is very common and is implemented in many European countries. Thus, the new regulatory indicators of soil pollution in Bulgaria have three levels: precautionary levels, maximum permissible concentration (trigger concentration) and intervention values, the quantitative value of which is established separately for urban, industrial and agricultural soils.

Warning concentration (WC) are values that indicate that the soil is uncontaminated but contains pollutants above background concentrations. This indicates possible adverse changes in the soil that must be avoided. WC values are calculated from data on background concentrations of inorganic substances in the soil.

6.4. Fire protection

The causes of fires and explosions at the enterprise are violations of fire safety rules and regulations, non-compliance with the Law of Ukraine "On Fire Safety".

Hazardous factors of fire and explosion that can lead to injury, poisoning, death or material damage are open fire, sparks, high temperature, toxic combustion products, smoke, low oxygen content, collapse of buildings and structures.

The conducted analysis of fires proves that about 85% of fires in our country are caused by negligence, carelessness and lack of awareness among people in matters of fire safety. So, there is a real opportunity to significantly reduce the total number of fires thanks to a planned and specifically directed complex of fire protection measures.

Fire safety is the state of the object, in which the possibility of the occurrence and development of a fire and the impact of its dangerous factors on people is excluded with a regulated probability, as well as the protection of material values is ensured.

Given that one of the most important components of the general safety of any modern object is its reliable protection against fires, the fire safety management system should occupy an appropriate place in the field of general management.

Unfortunately, there are almost no specific requirements and practical recommendations for the creation, implementation, and ensuring the functioning of fire safety management systems for certain industries and various categories of objects in the current fire safety regulations.

Fire safety of the enterprise is ensured:

- 1 fire prevention system (complex of organizational measures and technical means aimed at preventing the occurrence of fire);

2 fire protection system (a complex of organizational measures and technical means aimed at preventing the action of dangerous fire factors on the working people and limiting material damage from it).

Prevention of the possibility of fire is ensured by the following basic requirements:

1. Buildings must be equipped with fire water mains or have a sufficient number of fire reservoirs (tanks with water).

2. Smoking is allowed only in specially designated places.

3. The operation of both the enterprise as a whole and its individual divisions, plant equipment and tools must be carried out in strict accordance with the established instructions and fire safety rules.

4. Heating and ventilation systems must be constantly maintained in good condition, repaired and serviced in a timely manner.

5. It is necessary to systematically monitor the condition of electrical equipment insulation, monitor its serviceability, the presence of safety and grounding devices.

6. Buildings and structures of the enterprise, regardless of its geographical location, must be equipped with lightning protection.

6.5. Calculation of ventilation systems of the production premises

Natural and mechanical ventilation systems are divided. In the first case, air movement is carried out due to natural physical phenomena, in the second case, air movement is controlled by special mechanical ventilation equipment. With the help of natural ventilation, it is not possible to solve some tasks of ensuring a comfortable microclimate in the premises, therefore, mechanical ventilation is more desirable.

Also, ventilation can be divided into supply and exhaust, and local or general exchange.



The supply ventilation system supplies fresh outside air to the room. However, if the air comes from outside, then the pressure in the room will inevitably increase. Air will leave the room through cracks and other openings, but the capacity of all cracks in the room is limited.

Exhaust ventilation removes used (heated, polluted) air from the room. Mechanical ventilation is exhaust, when a certain amount of air is removed mechanically, and then fresh air is brought in from adjacent rooms. Ductless ventilation - a ventilation scheme without the use of tidal flow. This is how exhaust ventilation is organized in large rooms, hangars based on fans that are installed on the roof and extract air directly from the room under the roof. Fans, both supply and exhaust, can be installed in walls or window openings.

The best simultaneous installation of both supply and exhaust ventilation.

With local ventilation, fresh air is supplied to certain places (local supply ventilation) or removal of used or polluted air (local exhaust ventilation). Local ventilation is mainly used in production.

Vapors of harmful substances are emitted in the premises. The operational process takes place both inside the fume hoods and outside them.

Let's calculate the air consumption through local ventilation according to the formula

$$Q_M = 3600VF \quad (6.1)$$

Where F – the total area of all exhaust openings; V – air velocity in these openings.

If the total area of all exhaust holes $F = 8m^2$, and the air speed is $V = 0.4 \frac{m}{s}$.

According to GOST 12.1.005-88 "System of occupational safety standards. General sanitary and hygienic requirements for the air of the working area" the limit concentration of conversion to carbon is $m_{gr} = 300 \frac{mg}{m^3}$. Then

$$G_{SM} = 300 * 10^{-3} * 11520 * 10^{-3} = 3.46 \frac{kg}{hour} \quad (6.2)$$

The residual number of insoluble vapors is:

$$G_{SR3} = G_{SR} - G_{SM} \quad (6.3)$$

where $G_{SR} = 8 \frac{kg}{hour}$ - hourly indoor discharge.

Then

$$G_{SR3} = 8 - 3.46 = 4.54 \frac{kg}{hour} \quad (6.4)$$

Let's determine the required air consumption of general exchange ventilation:

We believe that no harmful substances enter the room with the supply air, i.e. $em_{pr} = 0$, then

$$Q_{SR} = 4.54 * \frac{1000}{(300 - 0) * 10^{-3}} = 15133 \frac{m^3}{year} \quad (6.5)$$

Therefore, in order to ensure the necessary safe conditions for work in this room, it is necessary that the general exchange ventilation ensures an air flow of at least $Q_{SR} = 15133 \frac{m^3}{year}$

Let's determine the live cross-sectional area of the air damper of the ventilation shaft:

$$F_{pow} = \frac{15133}{6 * 3600} = 0.7 m^2 \quad (6.6)$$

Therefore, the dimensions of the damper of the ventilation shaft are $1000 \times 700 mm^2$.

We will select the fan under the condition that the total pressure in the working area is within 660-820 Pa. Such a fan can be a radial fan VR-80-70. To ensure the required productivity, it must be equipped with an AIR160M8 engine of standard size with a power of 11 kW. The rotation frequency is 730 rpm.

According to GOST 5976-90 "Radial common purpose fans. General technical conditions" execution type - No. 1. This design ensures the compactness of the installation, its reliability, relative silence, as well as economy due to the absence of transmission losses.

Conclusion

In this section, we considered the peculiarities of labor protection when working with computers, electrical safety, industrial sanitation, fire protection and requirements for the parameters of the production environment. The importance of labor protection is manifested primarily in the impact on changes in the growth of labor productivity, the preservation of labor resources through the improvement of working conditions, increasing the total national product. Occupational safety management at the enterprise is a component, a subsystem of the overall enterprise management system, since only a high level of occupational safety can ensure the effective performance of the tasks facing the enterprise and the achievement of the best economic results. Man's work which occurs in conditions of excessive neuro-emotional tension, long-term static loads, limited motor activity leads to neuroses, mental disorders, diseases of the musculoskeletal system, cardiovascular system, etc. Computers, television, communication systems and other means, that use the achievements of radio electronics are generators of a whole series of electromagnetic radiations, the impact of which on the human body has not yet been fully studied. Under such conditions, the role and importance of labor protection as a system of measures and means aimed at preserving health and working capacity is growing.

CONCLUSION

The proposed system allows you to measure the distance of certain user routes, by calculating data from the magnetometer and accelerometer to find the number of steps and the direction of movement, with different behavior patterns. The program is suitable for navigation both in open areas and indoors.

The program has been improved by adding patterns of human behavior when he moves with a smartphone.

The algorithm determines these patterns and separates them into separate routes to improve accuracy. Calibration for this device is only necessary at the first start, as different smartphones have different sensors.

The system can also be used to detect anomalies in the earth's magnetic belt, which will help in studying the partial change of magnetic fields in some areas and improve orientation on the user plane.

The factor of using the system in the enterprise, with shielded walls, was also analyzed for user orientation in large rooms, warehouses, hangars.

In the course of this study, an inertial system built on the MATLAB platform and a mathematical model of a person's step were combined to successfully construct a system that counts a person's steps and also displays the path he or she walked. The system comprises of an application and a MATLAB App Designer-based user interface.

Ordinary pedestrians are the system's users. The data from the accelerometer and magnetometer that the user provides constitutes the input information. The initial data is the outcome of the data calculations made in the application.

Among the main functions of the software are:

- provides data on the number of steps taken;
- provides the ability to find the traversed route in the global coordinate system.

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APPENDIX

Appendix A. Units of measure the data loading tables

Data that was obtained from the MATLAB environment.

time	gFx	gFy	gFz	wx	wy	wz	Bx	By	Bz	Latitude	Longitude	Speedms
Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
time	gFx	gFy	gFz	wx	wy	wz	Bx	By	Bz	Latitude	Longitude	Speed (m/s)
3.8180	0.0202	0.1829	0.9541	-0.0820	-0.0564	-0.0277	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8210	0.0145	0.1840	0.9649	-0.0820	-0.0564	-0.0277	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8230	0.0145	0.1840	0.9649	-0.0703	-0.0724	-0.0170	-17.9375	-21.0625	-35.5625	46.6621	32.6398	0
3.8270	0.0145	0.1840	0.9649	-0.0703	-0.0724	-0.0170	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8280	0.0183	0.1860	0.9636	-0.0703	-0.0724	-0.0170	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8280	0.0183	0.1860	0.9636	-0.0490	-0.0852	0.0053	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0
3.8290	0.0183	0.1860	0.9636	-0.0490	-0.0852	0.0053	-18.3125	-20.9375	-35.5000	46.6621	32.6398	0

Fig. A.1. Loading data

Where column time - time in seconds [s];

gFx, gFy, gFz - is the acceleration of an object in three-dimensional space along 3 axes x, y, z is measured in $[\frac{m}{s^2}]$;

wx, wy, wz - is the angular velocity of an object in three-dimensional space along 3 axes x, y, z, measured in $[\frac{rad}{s}]$;

Bx, By, Bz - this is the magnetic field of an object in three-dimensional space along 3 axes x, y, z is measured in $[\mu T]$;

Latitude and Longitude - it is a coordinate system associated with positions on Earth and is measured in [degree °];

Speedms – is the speed of the object in measured in $[\frac{m}{s}]$.