Journal of Biology and Life Science
ISSN 2157-6076
2025, Vol. 16, No. 1

Measurement of Acceleration Due to Gravity Using Arduino

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Received: October 20, 2024 Accepted: November 30, 2024 Published: December 1, 2024

doi:10.5296/jbls.v16i1.22331 URL: https://doi.org/10.5296/jbls.v16i1.22331

Abstract

The undertaken research paper is an easy experiment based on Arduino was constructed in order to investigate the acceleration of the object while it was falling freely and to estimate the value of "g" (the acceleration that is generated by gravity). The reseach aimed to achieve three objectives through this research: first, to comprehend the manner in which airborne gravity gradiometers synthesise gravity fields using residual terrain modelling and the equivalent source layer method; second, to evaluate the durability of systems based on Arduino in various environments; and third, to contrast the accuracy, efficiency, and user-friendliness of these systems with those that are more conventional. The investigation of the acceleration due to gravity measurement using Arduino was conducted using secondary sources, which include books, websites, academic papers, newspapers, and magazines. These sources are not directly comparable. The evaluation and severity determination of a diverse array of research topics are facilitated by this explanatory research approach to the analysis of the conceptual components. The result of the study implies that in order to obtain distance time curves, readings realted to gravity is made at a variety of intervals throughout the course of application of the traditional kinematic equations made it possible to compute the acceleration that happened during the free fall. There has been found to be a good agreement between “the shape of the distance-time graphs” that were gathered from the secondary setup and the graphs that were expected, and the values of g that were calculated were within the range that was anticipated. It has been further discovered that the magnitude of gravitational acceleration is 9.805 metres per second squared after a series of research study were carried out.

Keywords: arduino, acceleration due to gravity, basic physics experiment

1. Introduction

This undertaken research reveal a major issue of the sort that in the laboratories of elementary and secondary schools, there is a lack of sophisticated technology for data capture, especially in the developing nations. The existing routines are used in the form of manual procedures which permit time consumption and a comparatively low degree of accuracy. In a study conducted by Chen with colleagues, constant laboratories within microprocessors and apparatus for mobile data collection lead to better outcomes in data analysis in addition to precision and accuracy in the process (Zhao, Chen, & Su, 2022). Arduino owes its origins to the students of the school called the Interaction Design Institute based in Ivrea, Italy in the year 2005. Arduino is that special device which plays an interlink between the electronic and mechanical systems. This popular gadget has both digital and analogue input/output connectors, allowing it to be easily connected to sensors, expansion boards, and other circuits. Soon, the ubiquitous and indispensable Arduino UNO circuit board will allow regular people to participate in hands-on discovery. You have two options for powering this block: a USB connection or an external 9-volt battery. One option for programming is to use the Arduino IDE, which includes both the language and software (Liu et al., 2017). In order to find the friction coefficients, the author of this work used an inclination-based laboratory experiment with a wooden block. An example of how the Arduino UNO could improve the automation of physics lab work is shown in this demonstration.

1.1 Background

Gravity is an essential phenomenon in physics that is used to explain force whichcontrols mass-containing objects like planets, stars, galaxies, and even light. Primordial gaseous material in the early cosmos applied gravitational force to cause the creation of stars and galaxies in the Universe. Gravity is infinite but conventional gravity weakens as objects move further away—(Shoaib, 2021). Gravity is necessary for stability and gives weight to the objects on the surface of the earth to allow us to move around. According to Newton law of universal attraction all objects having mass have mass falls towards their center and when dropped from the top, fall towards the ground. In this case, the parameter that specifies the character of acceleration due to gravity increases with a constant rate.

Research conducted to ascertain the value of g, with the most renowned experiment being carried out by Galileo at Pisa, Italy. This experiment yielded a result of g as 9.8 m/s2. With the current accessibility of microprocessors, sensors, and data processing software, it is now possible to create an experimental setup to observe a freely falling body and measure the amount of 'g' using existing technical breakthroughs (Harnsoongnoen, et al., 2024). This research examined the motion of a body in free fall by periodically analysing it using the Arduino UNO and an ultrasonic distance sensor HC-SR04.. Other tools that were used for data analysis include Microsoft Excel, Origin Pro, and DESMOS and graphs were prepared as a result. The distance-time data was used to determine the slope of distance time graphs, and the value measured was used in determining the acceleration of gravity. Unlike traditional sophisticated experiments, this experiment creates an interest in the students to learn about physics experiments, and also educates the students about simple principles of physics like sound waves, gravity, newton’s motion equations, calculus, etc.

2. Literature Review

Importance of Measuring Gravity Accurately

Barriot, & Sichoix, (2021), This research study is primarily concerned with the established theory and various strategies of ground-based gravity taking place on the Earth’s surface. The article focuses on the aspects of monitoring and analysis of the geopotential of the surface of the Earth at present time in terms of the most effective approach. Here, the author covers such topics as hydrology, seismology, volcanology, basic physics, tide, ocean loading and atmospheric gravitation, and their influence. Unearthed from the article is a message that even though gravimeters are seen to be potent tools for monitoring several important signals such as tides, earthquakes, volcanic activities, and despite the fact that they are useful in studying seasonal variation in hydrology; they are only useful in sensing several of these critical signs. Signals are often periodic and differ in both space and time, or from 0 to some maximum value.

Specifically, signals are often periodic and may differ in space and time or vary between maximum of 0 and some value. 1 to 5. 0 μGal (Yang, et al., 2021). The use of gravimeters proves rather expensive at the onset owing to its highly technical design. Nonetheless, the potential of their performance to be impacted has been significantly improved in the last few years due to these developments. Many so-called seismo-expressions at present are linked to such recognized geophysical occurrences. Co-seismic effects, post-glacial rebound, local changes in hydrologic mass balance, and even more, searching for non-tidal variations in sea level are considered. To better understand how data from the Lamont-Doherty Geological Observatory (LDGO) has developed a vast catalog of global marine gravity data, we tested crossover errors (COEs) along ship tracks (Serway, & Jewett, 2018). The participants were 63,000 COEs with MMU having a typical variation of 22. 43 mGal. It normally causes a decrease in COEs as latitude increases, though the unpredictability of the Eotvos adjustment makes it varying. Maritime gravity surveys appear to be noisy due to high errors resulting from inadequate navigation hence implying that regions with large gravity gradients are associated with high COEs. For overall COEs, the reduction over the last two decades indicates improvements in navigational aids and instruments for aircraft navigation. What might have led to the observed bias of 9 mGal in the earth data is the defect was caused by the selection of the reference field. The AMM added to the dataset was used to compute the gravimetric geoid for the northwest Atlantic ocean.

Arduino Board (Specifications and Selection)

The research paper made by Widhalm et al. was published in 2021, where the authors focused on a study on how the chapter’s usual SBCs in conjunction with such standard shields and sensors can be used as the main building block elements of Internet of Things devices with sensing, controlling, and networking functionality. The Arduino family of boards is highly promising in developing self-contained remote measurement and control systems: an open-source hardware and software platform, one of the most stable microcontroller boards to date, with a long lifespan, possessing standard connections and relatively low overall cost. It is still possible to differentiate the techniques of composing code and using Arduino boards between very simple ones and those that are used in the present day. The libraries explored in this research are the Johnny-Five library, Galilio-io Firmata rival library, and the mraa library. The paper also discusses the relevance of NodeJS as a programming environment for the Arduino boards. The paper also discusses the relevance of the NodeJS platform as a programming environment for Arduino boards Arduino boards have been selected from boards like Uno, Due, Galileo on the basis of their physical requirements. The other boards are scattered in the middle region of the pack.

Calculating Acceleration Due to Gravity

Toroš, et al., (2021), Relative acceleration noise mitigation for nanocrystal matter-wave interferometry: Applications to entangling masses via quantum gravity. Physical Review Research, 3(2), 023178. Within the context of the fundamental constants of physics and celestial mechanics, the research article that Cook published in 1965 analyses the function that absolute measurements of gravity play. The reversible pendulum experiment and the free-motion experiment are the two primary approaches that are discussed in this article. It also explores the history of absolute measurements. In the study, the fundamentals of these methodologies, as well as their definitions and the consequences of perturbation, are defined in detail. Leningrad, Teddington, and Sèvres were the locations of three completed determinations in Europe, and Washington, Ottawa, and Princeton were the locations of three completed determinations in North America. Only through the measurement of the gravity variations that exist between the six different sites is it possible to make comparisons between the results. Hence, it appears that the results from North America are more dispersed than those from Europe and varied by more than two metres. It is necessary to conduct additional absolute measurements in order to support or disprove this determination.

2.1 Reasearch Gap

Despite the expanding usage of Arduino for educational and experimental reasons, there are significant research gaps in detecting gravitational acceleration. Precision and accuracy of measurements must be improved, particularly through advanced calibration and noise reduction techniques. The long-term stability and reliability of Arduino-based devices under different environmental conditions are little understood. Integration with high-resolution sensors, real-time data processing algorithms, and IoT-based automation are all issues that have yet to be addressed. Furthermore, full comparison studies with traditional methodologies, cost-benefit assessments, and the influence on educational results are scarce, implying significant prospects for future study and innovation in this subject (Sari, 2019).

2.2 Research Question

I How may calibration approaches increase the precision and accuracy of gravity measurements performed with an Arduino?

II What is the long-term stability and dependability of Arduino-based gravity measurement devices under different climatic conditions?

III How do Arduino-based gravity measurements do against established methods in terms of accuracy, cost, and convenience of use?

2.3 Importance of the Research

Research on detecting acceleration due to gravity with Arduino is critical because it democratises scientific experimentation, making it more accessible and economical to educational institutions and amateurs. It promotes hands-on learning and improves STEM education by demonstrating the actual application of physics ideas. It can also spur innovation in low-cost scientific instrumentation, promoting further advances in sensor technology and data analysis. Understanding and improving these measures has larger ramifications in domains such as engineering, geophysics, and space exploration, all of which require precise gravity measurements. As a result, this research has important educational and technical implications.

2.4 Research Objective

I To understand the "integration of residual terrain modelling and the equivalent source layer method in gravity field synthesis for airborne gravity gradiometer test site determination".

II To determine the long-term stability and reliability of Arduino-based systems under a variety of environmental situations.

III To evaluate the accuracy, affordability, and usability of Arduino-based approaches vs standard gravity measurement systems.

2.5 Scope and Limitations

The scope of Arduino-based gravity acceleration measurement research involves establishing low-cost, accessible methods for educational and experimental purposes, improving precision and accuracy with advanced sensors and calibration approaches, and incorporating real-time data processing. It can be used in classrooms, labs, and fieldwork to promote hands-on STEM teaching and innovation in scientific instrumentation. However, drawbacks include the possibility of reduced accuracy when compared to professional equipment, sensitivity to environmental conditions, and the necessity for technical skills to set up and calibrate the system. Despite these obstacles, Arduino-based solutions provide useful insights and educational benefits.

3. Research Methodology

3.1 Research Method and Design

Researchers utilise study designs to ensure that all data points are accurately recorded. Data collection, analysis, and interpretation are all elements of a study's research design. The study's primary objective is to evaluate logical movements. This study's data was gathered from secondary sources, which are not directly comparable but include books, websites, academic papers, newspapers, and journals. This investigation of the conceptual components, which applies an explanatory research technique, enables the assessment and severity determination of a number of research issues. The researchers extrapolated the data from other credible sources.

3.2 Research Approach

The study uses an illustrative technique to investigate the current objectives and questions, setting the framework for a causal chain. The author used an explanatory and remedial methodology in this investigation. The study's authors supported their claims using qualitative data analysis. Examining the assumptions used when selecting data gathering methods is an important part of this process(Serway & Jewett, 2018). Any research methodology must include the collection and analysis of data related to the study's topic. When tackling a specific research subject, qualitative researchers frequently use a descriptive method.

4. Analysis of Study

4.1 Integration of Residual Terrain Modelling and the Equivalent Source Layer Method in Gravity Field Synthesis for Airborne Gravity Gradiometer Test Site Determination

The second-order derivatives of gravity potential are known as gravity gradients. These gradients are superior to gravity anomalies in terms of their ability to explain the mass distributions and gravity field. Resources are typically explored, subsurface navigation is performed, geological surveys are carried out, and ultra-detailed gravity field determination is performed with their assistance. The field of gravity gradiometry has had substantial expansion over the past few decades, with the Torsion Balance being the first instrument to measure all of the constituents of the gradient tensor. The first gravity gradiometer in the world was developed by Lockheed Martin in the 1970s for the purpose of being utilised for defensive purposes on submarines. The FALCONTM "Airborne Gravity Gradiometer (AGG)" manufactured by BHP Billiton and the "Lockheed Martin Air Full Tensor Gradiometer (FTG)" manufactured "by Bell Geospace" are both examples of several gradiometers that belong to the Lockheed family.

"The Università degli Studi di Firenze", the "Observatoire de Paris, and" the "Office National d'Etudes et de Recherches Aerospatiales (ONERA)" are some of the organisations that have developed alternative technologies. These technologies include the Superconducting Gradiometer, the MEMS gravity gradiometer, the cold-atomic interferometer gravity gradiometer, and the quantum gravity gradiometer. When evaluating the dependability of gravity gradiometers based on a variety of concepts, calibration and accuracy validation are essential operations to carry out.

As the technology behind gravity gradiometry continues to advance, the number of gravity gradiometer test locations in China is growing at an exceptionally rapid rate. An area that has the potential to be used for geodesy and geophysical purposes is the "Wudalianchi Volcano Geopark". approaches for measuring gravity have been developed in order "to gain a better understanding of the gravity field"; nevertheless, the solutions to these approaches are limited by the spatial distribution of terrestrial gravity observations. The purpose of this study is to offer a method for computing regional gravity field signals by merging "the long-wavelength gravity field of GGM", "the high-frequency gravity field signals of RTM", and "residual signals resulting from density anomalies". Due to the absence of actual gradient data, the suggested method is validated by comparing it to gravity data and tested through the use of a numerical simulation.

4.2 long-term Stability and Reliability of Arduino-based Systems under a Variety of Environmental Situations

The use of dependable and precise data may significantly enhance building microbiology, thermal comfort, indoor air quality, and energy usage. However, specific software and technology may sometimes further distort these aspects, leading to unforeseen impacts on

Journal of Biology and Life Science
ISSN 2157-6076
2025, Vol. 16, No. 1

factors like as expenses, adaptability, and data integration. OSBSS, which was established in 2013, seeks to reduce the expenses associated with gathering building science data by using open source sensors. The stated objective is to find a more effective and cost-efficient method of gathering data on crucial building environmental and operational aspects.

The OSBSS platform offers a wide range of open-source sensors and data recorders, all of which are developed on the open-source Arduino platform. Several prototype sensors undergo testing in a controlled environment for a duration of one week, followed by a comparison with their commercially available counterparts. The sensors now under investigation include those that assess air and surface temperatures, relative humidity, light levels, carbon dioxide concentrations, and a versatile voltage data recorder capable of capturing signals from sensors such differential pressure sensors.

Initially, OSBSS data recorders used microSD cards with associated time indications. Considering that the 3.3 V version had an adequate supply voltage and its logic levels fell within the permissible range of 2.7 to 3.6 V, it was determined to be the best option. MicroSD cards are very cost-effective, with a basic 8 GB card priced at less than $5. They provide almost unlimited storage capacity, capable of holding billions of measurements.

The power consumption was reduced by making modifications to the Pro Mini boards. One modification was the segregation of the two integrated LEDs and the elimination of the circuitry associated with the status LED. The objective was to ensure uninterrupted data transmission on the SPI bus. The ATmega328P microprocessor has three distinct hibernation modes to minimise power usage during periods of inactivity.

4.3 Accuracy, Affordability, and Usability of Arduino-based Approaches vs Standard Gravity Measurement Systems

Because of their potential to rapidly analyse soil compaction and bearing capacity through reliable elastic modulus measurements, lightweight deflectometers, also known as LWDs, are an essential component of quality control and assurance testing for earthworks. It is possible to obtain an accurate assessment of the characteristics of the soil by using these sensors, which monitor the interaction between mechanical components and the soil. The commercial LWD signal interpretation kits, on the other hand, are often quite inexpensive. The purpose of this research is to facilitate the development of a low-cost LWD sensor signal interpretation kit with the intention of lowering production costs and making this technology more accessible (Soni et al., n.d.).

This is because LWDs give data that is necessary for ensuring the structural integrity of infrastructure such as roadways and pavements, which makes them a key component in the construction and civil engineering industries. Arduino® boards, such as the Arduino® Uno (ATmega328), are utilised extensively in a variety of domains due to the fact that they are simple to operate, inexpensive, and possess precise measuring capabilities. In geotechnical engineering, they have been utilised for the purpose of calculating and controlling the levels of soil moisture.

The purpose of this inquiry is to investigate the implementation and deployment of a low-cost, moderate-precision, regulated, and routinely calibrated LWD sensor signal interpretation kit that makes use of open-source hardware, particularly Arduino® boards. The purpose of this study is to investigate whether or not it is feasible to enhance the accuracy of measurements by merging Arduino® boards with MEMS-based sensors and precision analog-to-digital converters (ADCs). In addition, the limits of Arduino® boards, particularly with regard to monitoring dynamic behaviour, are discussed. The Young's modulus of soils is measured in the field using this signal interpretation kit in conjunction with a LWD. This is done in order to evaluate the model (Mothy, n.d.).

5. Results

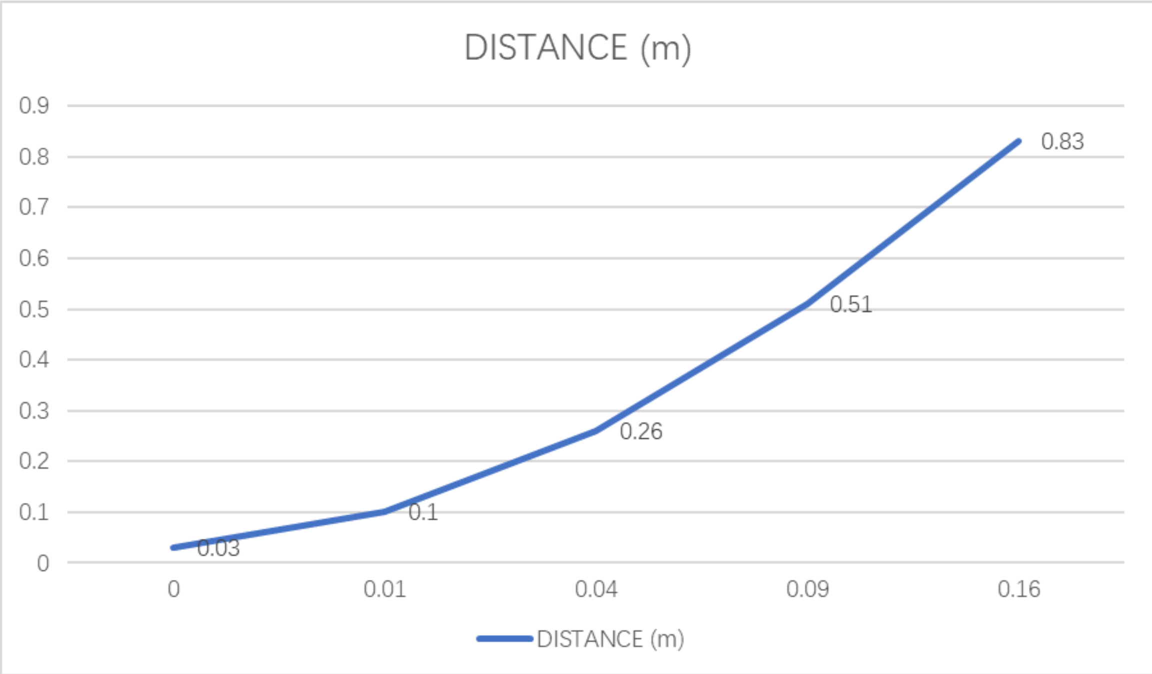
It was possible to identify the behavior of an object prone to the force of gravity through the secondary analysis of the received information. The readings were recorded at one hundred milliseconds and the numerical and the standard values presented in the two tables are as shown below Table 1: Table 2: When distance is graphed against the square of time, a near-linear behavior was established as just described. This enabled us to find the value of the acceleration due to gravity whereby using desmos the value was calculated to be approximately 9. 8m/s sq. As a final check, the peak of the graph yields a slope of half the acceleration; hence confirming the expected gravitational constant.

Table 1. Data of free fall motion experiment (in SI units)

TIME (ms)	**DISTANCE (cm)**
0	3
100	10
200	26
300	51
400	83

Table 1. Data of free fall motion experiment (in SI units)

TIME (ms)	**DISTANCE (cm)**
0	0.03
0.1	0.1
0.2	0.26
0.3	0.51
0.4	0.83



GRAPHS 1. Distance versus time curve for the free fall motion experiment

Table 2. Distance and t^2 data for the free fall motion experiment

t^2	**DISTANCE (m)**
0	0.03
0.01	0.1
0.04	0.26
0.09	0.51
0.16	0.83

In the study the time taken to fall was determined at 100 milliseconds interval where it calculated the distance an object fell under the force of gravity. From the information obtained above, the raw distance data are presented in Table 1 while the filtered results in meters and seconds in table 2. The distance-time graph is shown as an outline of a straight line that rises from the origin to the right, which shows the velocity is increasing. When looking at the distances plotted against the squared times, we can see that the points lie almost perfectly along a linear line as indicated by Table 3. This linearity was used to evaluate also the acceleration due to gravity which, was estimated to be approximately 9. 8 meters per second squared, which coincides with the values predicted by the teory

6. Conclusion

According to Latha et al. (n.d.), an experiment was carried out using an Arduino platform to measure the gravitational acceleration felt by an object in free fall. A breadboard, an HC-SR04 ultrasonic distance sensor, and an Arduino UNO board may be used to quickly gather data for this physics experiment (Matijevic & Cvjetkovic, 2016). The obtained distance-time experimental results are in good accord with the theoretical model. Our aim is to provide teachers with the tools they need to accurately assess the speed of an item in free fall and make accurate acceleration estimations. In addition, we want to make it easier for anyone to use this technology to create experiments..

6.1 Future Scope and Recommendation

Future research on "Measuring Acceleration Due to Gravity Using Arduino" aims to improve sensor integration, develop algorithms, explore IoT capabilities, create educational tools, adapt to environmental conditions, develop open-source frameworks, investigate interdisciplinary applications, conduct comparative studies, develop cost-effective solutions, and encourage community collaboration for improved accuracy and accessibility.

Acknowledgments

Not applicable.

Authors contributions

Not applicable.

Funding

Not applicable.

Competing interests

Not applicable.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Macrothink Institute.

The journal’s policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.

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