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Data Analysis of the Use of Raspberry Pi 4 Boards and Arduino Uno Boards Using Microprocessor and Program Algorithm Design Models

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Abstract

This research has three main objectives: 1. Examining experimental boards like Arduino Uno and Raspberry Pi 4; 2. Exploring microprocessor theory and algorithms; and 3. Investigating computer architecture associated with microprocessors and programs. The findings are organized into four sections: (1) Microprocessor and Programming Applications, revealing insights into various microprocessor models; (2) Factors for Teaching and Learning Development, highlighting the suitability of Arduino Uno and Raspberry Pi 4 for programming and IoT applications; (3) Factors Affecting Microprocessor Algorithms and Programs, noting observations on core processing speed, clock speed, and technology; and (4) Microprocessor and Program Operation Data Analysis, showing correlations between speed, memory, operating systems, registers, mathematical operations, and bus systems, with an average value of 98.1% indicating efficient hardware and software processing.

Keywords: Data Analytics, Using Raspberry Pi 4 Boards and Arduino Uno Boards, Microprocessor algorithms and program.

INTRODUCTION

Today, technology plays a pivotal role in the ongoing development of hardware and software products, catering to the needs of enthusiasts in these domains. Despite technological advancements, users and developers of the Arduino Uno board encounter various challenges. These include difficulties in connecting the Arduino cable, resulting in messages like 'Windows could not find driver software for your device.' Users are advised to check the manufacturer's website for driver software solutions. Additionally,

issues may arise, such as the Com port not rising in Arduino IDE, errors like 'avrdude: ser_open(): cannot open device '.COM': The system cannot find the file specified,' and 'fatal error: LiquidCrystal_I2C.h: No such file or directory.' Other problems include messages like 'stk500_recv(): programmer is not responding,' upload delays, failure to enter upload mode, and the Arduino board becoming excessively hot and unresponsive. Similar challenges are observed with the Raspberry Pi board, encompassing booting issues, sensor malfunctions, lack of USB-C cable support for board operation, and the unavailability of WIFI functionality. In response to these challenges, the researcher aimed to create a model for microprocessor algorithms and programs. The research objectives include (1) studying the Arduino Uno and Raspberry Pi 4 boards, (2) exploring the theory and algorithms of microprocessors and programs, and (3) understanding the theory and operating procedures of the computer architecture associated with microprocessors and programs. The study involved 75 students from the Faculty of Engineering in Computer Engineering, utilizing a specific test method to gather comprehensive data for accurate analysis. Throughout the investigation, the researcher delved into relevant information from conceptual studies, academic articles, and research papers. The focus was on understanding the utilization of Raspberry Pi 4 and Arduino Uno boards with microprocessor algorithms and programs, leading to the creation of tests for users. Once the microprocessor algorithm and program patterns were successfully tested on users, the designed model was found to offer several benefits. These include increased user awareness of microprocessor algorithms and programming patterns, knowledge of the internal architecture of the trial boards (Arduino Uno and Raspberry Pi 4), understanding of the theory and algorithms of microprocessors and programs, and familiarity with the theory and procedures of the computer architecture of microprocessors and programs.

Review of the Relevant Literature and Research

Data analysis

Data analysis involves transforming raw data into actionable insights using various tools, technologies, and processes to identify trends and solve problems. It plays a crucial role in defining business processes, improving decision-making, and promoting business growth.

The process of data analysis encompasses obtaining information from storage in various ways, classifying data sets, and analyzing data to discover correlations. The ultimate goal of data analysis is to derive insights or summaries (conclusions) that highlight the importance and benefits of data analysis. These include:1. Assisting in the overall analysis of situations. 2.Facilitating real-time problem-solving. 3.Aiding in targeting customers for marketing purposes. 4.Helping in predicting future trends.

Raspberry Pi 4 board **and Arduino Uno** board

The Raspberry Pi board, commonly known as 'Raspberry Pi,' is a versatile tool for creating industrial automation and control systems. It has the capability to run various platforms, execute different software, demonstrate high performance, and support

operating systems such as Linux, Windows, and IoT. Additionally, it accommodates programming languages like Python, C++, and Java.

The origins of the Raspberry Pi can be traced back to four founders: Eben Upton, Rob Mullins, Jack Lang, and Alan Mycroft, all affiliated with the University of Cambridge, England. In 2006, fueled by concerns about the number and skills of university students, they initiated the development of a small and affordable computer tailored for academic studies. The prototype of the Raspberry Pi board took shape at the Computer Lab of the University of Cambridge.

This led to the recognition of the need for confidentiality in network operations. The combination of the DHT-11 sensor and the Raspberry Pi facilitates the monitoring of messages. The encoding and decoding algorithms, each consisting of 11 characters, produce results with encoding verification that does not exceed 1 microsecond. The device utilized for these tasks is the Raspberry Pi, as illustrated in Figure 1.

Figure 1 Raspberry Pi 4

According Figure 1 illustrates that the Raspberry Pi 4 is a compact single-board computer explicitly engineered for straightforward installation in extremely confined spaces.

After introducing the Raspberry Pi Model A, the Raspberry Pi Foundation subsequently developed a range of models for the Raspberry Pi Single Board Computer (SBC), including: 1.Raspberry Pi Model B (2012) 2.Raspberry Pi Model A (2012) 3.Raspberry Pi Model B+ (2013) 4.Raspberry Pi Model A+ (2014) 5.Raspberry Pi 2 Model B (2015) 6.Raspberry Pi Zero (2015) 7.Raspberry Pi 3 Model B (2016) 8.Raspberry Pi Zero W (2017) 9.Raspberry Pi 3 Model B+ (2018) 10.Raspberry Pi 3 Model A+ (2018) 11.Raspberry Pi 4 Model B (2019) 12.Raspberry Pi 400 (2020) 13.Raspberry Pi Pico (2021) 14.Raspberry Pi Zero 2 W (2021). According to a study by Toan Khac Nguyen, L. Minh Dang, Truong-Dong Do, and Jin Hee Lim (2023), the initial exploration of White Rust Disease Recognition using Deep Neural Networks and Raspberry Pi Module Application in Chrysanthemum revealed that the growth factors of peaches enhance the disease resistance of chrysanthemums. The introduction of the Raspberry Pi 3 module played a crucial role in recognizing white rust and testing the neural

network model. This model operates on the principle of a deep neural network, involving a series of white, nondiseased, and rusty leaves, with (1) data collection and (2) data analysis. A comparison of Raspberry Pi models, including DenseNet-121, ResNet-50, VGG-19, and MobileNet v2, indicated that all Raspberry Pi 3 models achieved an accuracy rate exceeding 94%.

Doaa Sami Khafaga, Sarah M. Alhammad, Amal Magdi, Osama El Komy, Nabil A. Lashin, and Khalid M. Hosny (2023) conducted a study titled 'Securing Transmitted Colour Images Using Zero Watermarking and Advanced Encryption Standard on Raspberry Pi.' Consequently, it is crucial to verify the integrity of the data, including watermarks, and encryption has been employed to enhance accuracy. The watermark check is performed through a PC since there is no portable format available. Therefore, the development of advertising software becomes necessary to support real-time data analysis. Additionally, the Raspberry Pi algorithm has been utilized to improve durability, security, and ensure the original data remains unmodified, showcasing its effectiveness. The application can analyze a 256*256-sized image in no more than 2 seconds.

The Arduino board functions as a microcontroller with the capability to read input from a light detector, detect button presses, send messages to Twitter, and manage various outputs like activating motors, turning on LEDs, or transmitting data to internet systems. Users exert control over the board's actions by sending a set of commands to the microcontroller. This necessitates the use of the Arduino language, which incorporates additional commands in C++ format. The Arduino IDE software serves as the primary processing tool. Apirak Panpanasakul's research on developing an on-off control system for electricity and air conditioning via smartphones reveals the Arduino microcontroller board's role in managing electrical appliances and air conditioners. This involves applying knowledge in creating and designing microcontroller board circuit systems and implementing Blynk applications for monitoring and controlling Arduino microcontrollers through smartphones. Administrators can effortlessly browse, enable, and view daily reports via the Blynk application, as illustrated in Figure 2.

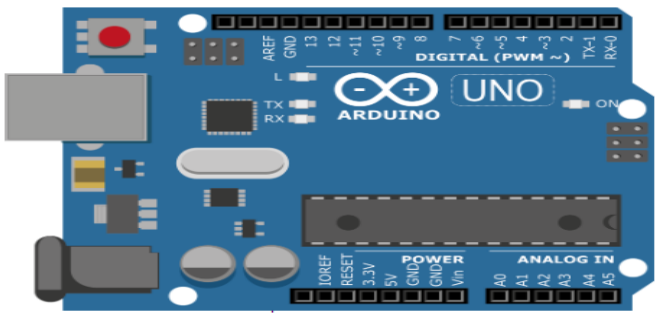


Figure 2 Arduino UNO

In Figure 2 illustrates the Arduino UNO as an open-source microcontroller board. It is intentionally designed to be user-friendly and easily understandable, a quality demonstrated by the example on the board, as depicted in the same figure.

Over the years, Arduino has played a central role in numerous projects, ranging from daily tasks to complex scientific instruments. The global Maker's Online Community serves as a hub where students, hobbyists, artists, programmers, and professionals come together to contribute to this open platform. Their collective involvement has enriched the community with accessible knowledge beneficial to both newcomers and experts. When it comes to developers creating simple 8-bit boards for IoT applications, wearables, 3D printers, and embedded environments, the following products are commonly used: Arduino Uno Rev 3, Arduino Nano, Arduino MEGA, NodeMCU (ESP8266), ESPino 32, Node 32 Lite, Arduino Leonardo, Arduino Mega 2017, Arduino Micro, Arduino Esplora, Arduino BT, Arduino Pro Mini, Arduino Lilypad, Arduino Zero, Arduino Ethernet, Arduino Diecimila. In line with the research conducted by Chokchai Jaecritic (2020) on the application of Arduino for cost-effective experiments to enhance students' understanding of pressure and buoyancy forces, it was discovered that the digital manometer developed with Arduino exhibited a 2.21 percent discrepancy. This suggests that students, through their scientific exploration, actively built their knowledge. The study further revealed that students demonstrated a statistically significant understanding of scientific concepts at a significance level of .05. Additionally, students showed an average academic progress of 0.71. The learners crafted explanations based on the evidence they found, evaluated these explanations by relating them to scientific knowledge, and effectively communicated and reasoned, resulting in a deeper acquisition of knowledge.

Varinee Veerasit and Anucha Chaichan (2020) asserted that the development of microcontroller boards plays a crucial role in supporting learning within the field of electronic engineering. This advancement enables students to grasp programming concepts essential for controlling microcontroller boards, fostering a deeper understanding of the subject. Furthermore, it contributes to the improvement of teaching and learning materials, aligning them with contemporary standards. The satisfaction level with microcontroller boards was notably high, with a rating of 4.28, as reported in the study.

Jirawin Deecharoenpong (2019), who researched the development of a prototype dust detection and warning system using Internet of Things (IoT) technology, explained that the system was crafted with Arduino. Its primary function is to detect dust and issue warnings through cloud network storage, utilizing the Block Box Testing method.

Microprocessor and program algorithms

A microprocessor is an electronic device characterized by an integrated circuit or chip. Arithmetic units, registers, data buses, control buses, address buses, and central processing units are responsible for processing input instructions in the program. It can be categorized based on the following characteristics: 1. Dedicated or Embedded Controller: This type of microprocessor is exclusively used in electronic devices such as washing machines, telephones, calculators, etc. 2. Bit-slice Processor: These microprocessors have been developed to implement functions not available in microcontrollers, including multi-stage functionality and sequential functionality. 3.General-purpose Processor: For instance, the 4040-chip evolved into a Pentium

model, like the 8086 with a 16-bit data bus and a 20-bit address bus. Additionally, the 8088 features an 8-bit data bus and a 20-bit address bus. It is noteworthy that the ALU, local registers, and instruction sets maintain the same 16-bit word size as the 8086 (Juthawut Chantharamalee, 2014).

Research Methodology

The research model is an exploratory study employing descriptive research methodology and questionnaires as data collection tools. The researcher concentrated on factors influencing the study of microprocessor algorithms and programs. The exploratory research encompassed the following steps: 1. Determining the population and sample. 2.Studying interpreters. 3.Creating tools for data collection. 4.Collecting data.5. Analyzing data. 6.Employing data analysis tools. 7.Utilizing statistics in the data analysis process.

Population and sample determination

The research population comprised 30 students in the second and third years, drawn from both public and private sectors in Bangkok province. A simple sampling method (Simple Random Sampling) was employed to randomly select students studying between the second and third years.

The studied variables involve independent factors associated with the specific areas where students are pursuing their studies. Furthermore, dependent variables encompass fundamental factors that significantly impact the quality of learning, specifically focusing on the study of microprocessor algorithms and programs.

Research Tools

The research utilized a questionnaire, organized into five Section for comprehensive data collection:

In Section 1: Personal data responses to questionnaires.

In Section 2: Questions related to Microprocessor and Programmatic Inputs, utilizing both the Raspberry Pi 4 Board and Arduino Uno Board.

In Section 3: Questions addressing teaching and learning development factors, incorporating the Arduino Uno board and Raspberry Pi 4 board.

In Section 4: Questions exploring issues impacting microprocessor workflows and programs.

In Section 5: Microprocessor and Program Operation Data Analysis.

Information Collection of Information

The researcher submitted the questionnaire to enlist the cooperation of the Information Technology and Computer Engineering course instructor. The objective was to secure permission for data collection by seeking the collaboration of 2nd-3rd year students from Rajamangala University of Technology Tawan-ok (Uthenthawai Campus), Rattana Bundit University, Kasem Bundit University, and other universities under the supervision of both public and private sectors in Bangkok. The distribution and

collection of questionnaires took place between November 1st and November 30th, 2022.

Data Analysis

The analysis of information pertaining to fundamental factors influencing learning, the study of microprocessor algorithms, and programs aimed at enhancing quality follows a structured approach:

1.Verify the completeness of all completed questionnaires by returning them, ensuring that all questions are adequately addressed. A total of 30 issues needs to be reviewed.

2.Examine fundamental data about the participants, focusing on the specific area

where each student is pursuing their studies.

3.Analyze data related to fundamental factors influencing learning, microprocessor algorithms, and programs to enhance quality. Calculate averages and categorize them by group, presenting the results in a table for the lecture.

4.Perform a comparative analysis by determining the average based on group classification and providing an overview. Present the findings in a table accompanying the lecture, categorized by gender.

5.Analyze open-ended questionnaire responses for research recommendations, group them into relevant categories, and then propose a descriptive data analysis.

Data Analysis Tools

The Statistical Package for the Social Sciences (SPSS) is a program designed to analyze statistical data in various forms. To conduct this research, we chose SPSS Version 26 because it is readily available and can perform the desired data analysis.

Statistics used in data analysis

The analyze the data by utilizing statistical values and employing the follow in

methods: Percentage and Average.

In Section 1 Personal data responses to questionnaires.

The questionnaire provides personal data that helps elucidate the fundamental demographic characteristics of the sample in this investigation. The data reveals a distribution of 72.00% males and 28.00% females, as outlined in the following table.

Table 4.1 shows the frequency and percentage of samples classified by sex.

Tester gender					
		Frequency	**Percentage**	**Valid Percentage**	**Cumulative Percentage**
Sex	1.00	50	72.0	72.0	72.0
	2.00	25	28.0	28.0	28.0
	Total	75	100.0	100.0	

According to Table 4.1, the male sample size surpasses that of females, with 75 subjects divided into 50 males, constituting 72.00%, and 25 females, making up 28.00%.

In Section 2: Questions about Microprocessor and Programmatic Inputs with Raspberry Pi 4 Board and Arduino Uno Board

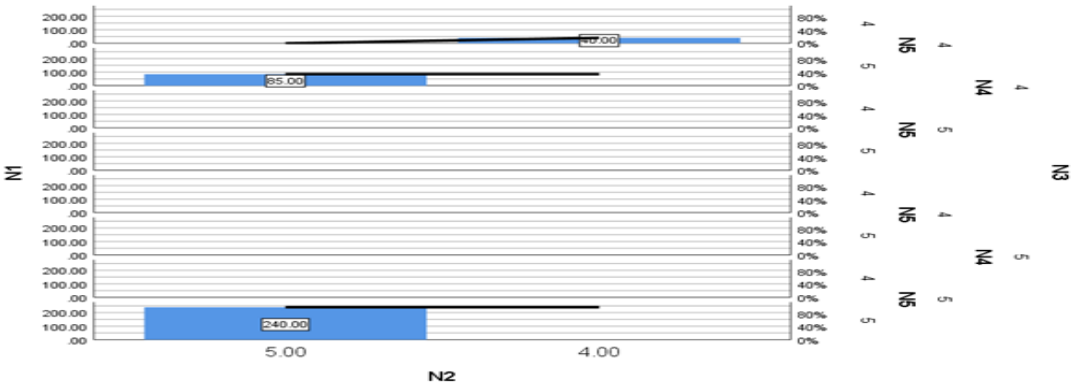


Figure 3 Analysis of factor data related to microprocessors and programs.

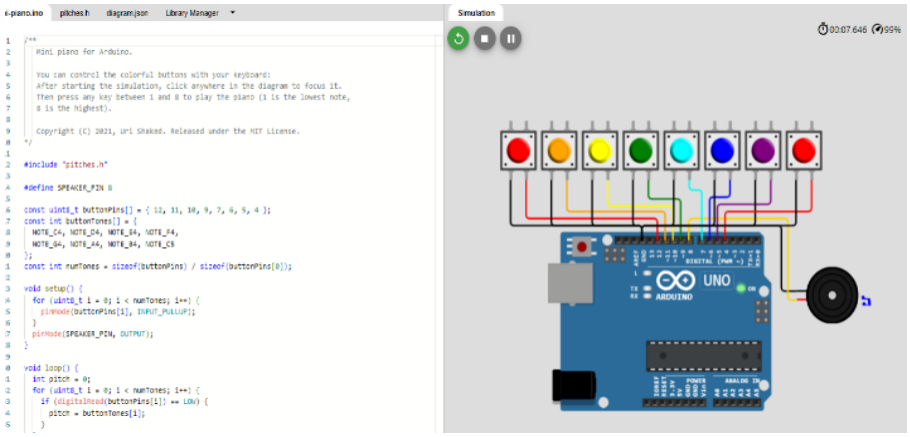
The analysis of factor data related to microprocessors and programs is presented in Figure 3. The results indicate that students predominantly focus on factors 1-2 and 3, with an average of 4.87, suggesting a high level of interest. Following closely are factors 4-5, with an average of 4.64 percent.

Table 4.2 Results of the analysis of the data on microprocessor application factors and programs.

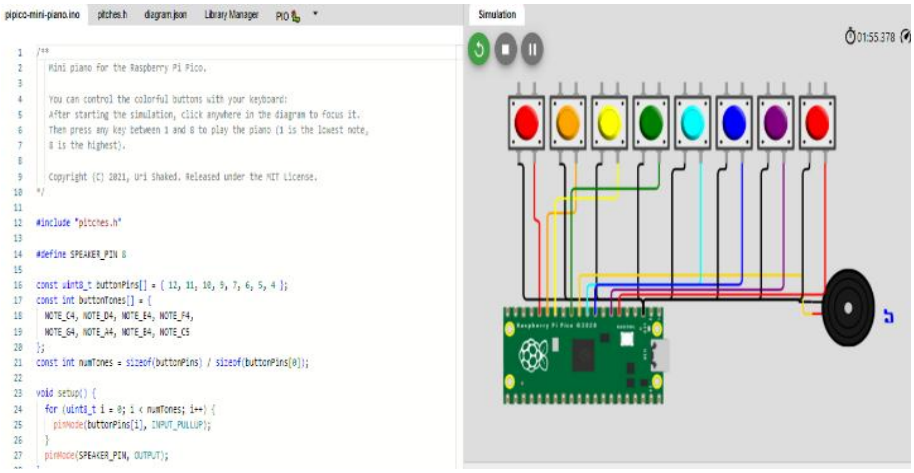
	N	Min	Max	Mean	Std.Deviation	Skewness	
	Statistics	Statistics	Statistics	Statistics	Statistics	Statistics	Std. Error
There should be an internal architecture for the microprocessor and microcontroller.	75	4.00	5.00	4.8667	0.34222	-2.202	0.277
There should be a register structure.	75	4.00	5.00	4.8667	0.34222	-2.202	0.277
There should be a technology bus.	75	4.00	5.00	4.6400	0.48323	-0.595	0.277
There should be a case pipeline.	75	4.00	5.00	4.6400	0.48323	-0.595	0.277
It should include a mathematics and logic processor, as well as control units designed for different models of microprocessors.	75	4.00	5.00	4.8667	0.34222	-2.202	0.277

According to Table 4.2, the presentation of results from the analysis of data on microprocessor application factors and programs is as follows: 1. Internal Architecture of Microprocessors and Microcontrollers: It has an average rating of 4.87. 2.[No specific information provided here - please check and fill in] 3. Average rating of 4.64. 4.Math and Logic Processors: [Details about the average rating or specific information missing] 5. Control Units of Different Microprocessor Models: [Details about the average rating or specific information missing] However, the researcher distilled the data analysis results into five aspects, covering sides 1-2 and 5. This revealed a significant equivalence in the data analysis results. Notably, factors such as implementation, understanding architecture, and programming were identified as crucial for accurately controlling the operation of both the Raspberry Pi 4 board and Arduino Uno board. Additionally, researchers observed significant equality in areas 3-4, suggesting a comprehensive understanding of the bus system's operation and confidence in the components of both the Raspberry Pi 4 board and Arduino Uno board.

In Section 3: Questions about teaching and learning development factors with Arduino Uno board and Raspberry Pi 4 board.



Arduino Uno Board



Raspberry Pi 4 Board

Figure 4: Data Analysis of Teaching and Learning Development Factors with Arduino Uno and Raspberry Pi 4 Board.According to Figure 4, the results of the analysis of data related to teaching and learning development factors with the Arduino Uno board and the Raspberry Pi 4 board are as follows:

For the Arduino Uno board, it was found that it can be applied to programming practice and computer skills, receiving an average rating of 4.98. Additionally, it can be developed into a web server or hardware control device, with an average rating of 4.96. It can also be applied to home electronics or Internet of Things (IoT) with an average rating of 4.95, and to webcam systems with an average rating of 4.94. Moreover, it has the capability to be applied to game creation, with an average rating of 4.81. This versatility is attributed to its ability to comprehend various project models of microcontroller boards. This includes programming control for detectors such as automatic light on/off systems, real-time room temperature monitoring, alarm systems, intensity meters, point counters, detector data collection systems, and database installations such as MariaDB/MySQL, etc. Furthermore, it facilitates the development of sensors and IoT platforms (NETPIE, Anto.io, IoTtweet, Blynk, ThingSpeak, myDevices, CloudMQTT, Thinger.io, ThingsBoard.io), enabling the correct and appropriate creation of various inventions through programming.

As for Raspberry Pi 4 boards, it was found that they can be applied to practice programming and computer skills, receiving an average rating of 4.95. Additionally, they can be developed into web servers or hardware control devices, with an average rating of 4.95. Furthermore, they can be applied to home electronics or Internet of Things (IoTs) with an average rating of 4.95, and to webcam systems with an average rating of 4.84. This adaptability is attributed to the Raspberry Pi 4's understanding of the central processing unit (CPU), RAM memory, Wi-Fi receiver, Bluetooth receiver, and various peripherals such as HDMI, Audio Output, USB, or even LAN, etc. This allows for the further development of programming and the creation of various inventions correctly and appropriately.

In Section 4: Questions about issues affecting microprocessor workflows and programs.

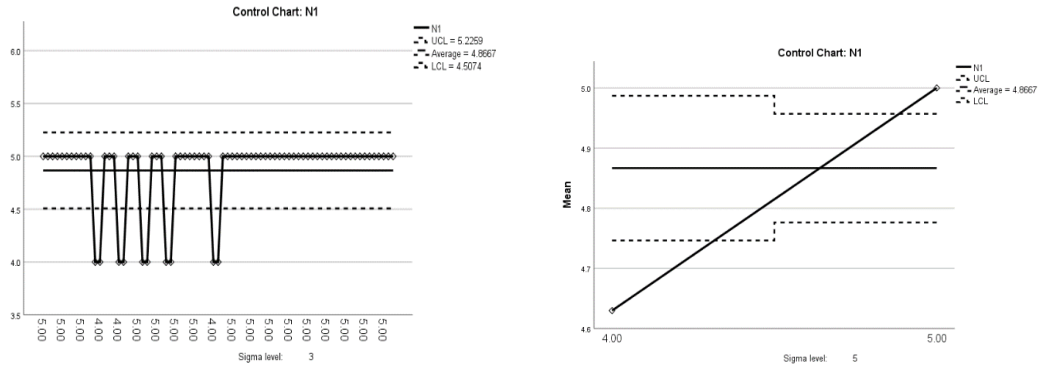


Figure 5 Data analysis of factors affecting the algorithm Microprocessors and Programs.

According to Figure 5, the analysis of data on factors influencing microprocessor workflows and programs reveals an average score of 4.86 for technology and an average score of 4.98 for core processing speed and clock speed. This is crucial because the processing speed of a computer (CPU speed) is the most significant element when comparing computer specifications. The constant evolution of technology can significantly impact the operation of microprocessors and programs.

In Section 5 Microprocessor and Program Performance Data Analysis.

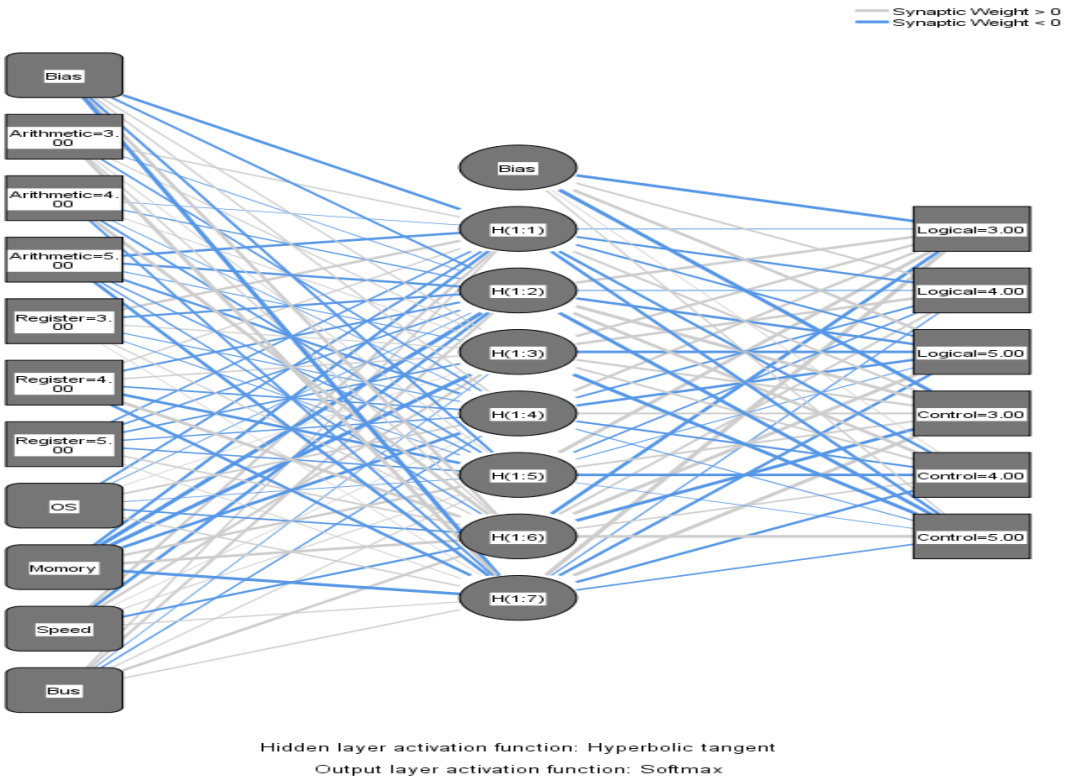


Figure 5: Results of the microprocessor and programs operation data analysis

According to the data presented in Figure 5, the analysis of microprocessors and programs reveals several correlations. Speed is found to be relative to control and logic (1:2, 1:6), memory is relative to control and logic (1:1-1:3, 1:7), the operating system is associated with control and logic (1:1, 1:6), registers correlate with control and logic (1:1-1:7), arithmetic is linked to control and logic (1:2, 1:4), and bus systems are associated with control and logic, with an average value of 98.1 and a mean squared error value of 0.684.

In summary, a significant correlation is observed in the data on microprocessors and programs, encompassing speed, memory, control, logic, registers, arithmetic, and bus. This suggests that the board tester possesses knowledge, understanding, precision in board use, and makes appropriate selections for the operation of microprocessors and programs.

CONCLUSIONS.

The results of the research involving data analysis of the utilization of Raspberry Pi 4 and Arduino Uno boards in developing a design model for microprocessor algorithms and programs, the researcher can draw conclusions aligned with the following objectives: Firstly, the investigation aims to explore the practical applications of the Arduino Uno board and Raspberry Pi 4 board, enabling users to control electrical transmission under various conditions, as demonstrated by the provided samples. These applications include an automatic light on/off system, an automatic light on/off system with a push button, and servo direction control, among others. Secondly, the study delves into the theory and algorithms related to microprocessors and programs. This includes an understanding of the use of programs compatible with Arduino Uno boards and Raspberry Pi 4 boards, such as connecting the system to the internet. Acquiring this knowledge provides users with a deeper understanding of contemporary computer operations. Lastly, the research aims to explore the theory and procedures of the computer architecture of microprocessors and programs. This phase allows users to produce or create Arduino boards, as these MCUs are open source. This openness enables users or other hardware manufacturers to generate or develop hardware or software incorporating elements of the computer architecture.

Hence, the investigator possesses the capability to succinctly encapsulate the outcomes derived from the application of the design model concerning the microprocessor algorithm and user program. The velocity aspect serves as an indicator of optimal hardware and software processing, manifesting noteworthy precision within software algorithms. Furthermore, the hardware components showcase commendable precision and reliability, contributing substantively to the overall efficacy of the system.

Furthermore, the investigator possesses the capacity to furnish a comprehensive summarization of the findings, methodically organizing them into five distinct categories as delineated below:

In Section 1, dedicated to the examination of the personal data of the participants, it was noted that the preponderance of individuals in Section 1 exhibited a male gender distribution (72.00%). Furthermore, second-year students constituted the prevailing demographic, accounting for a substantial majority (98.00%).

In Section 2 encompasses inquiries pertaining to microprocessor and program application factors associated with the Raspberry Pi 4 board and Arduino Uno board, succinctly outlined as follows: (1) Internal architecture of the microprocessor and microcontroller, exhibiting an average rating of 4.87 percent. (2) Register structure and (5) mathematical and logical processing units and control units of diverse microprocessor models, likewise averaging 4.87 percent. Following a rigorous analysis of the acquired data, the researchers discerned that the test group manifested the utmost concurrence with the presented inquiries.

In Section 3 comprises inquiries into the factors influencing teaching and learning development through the utilization of the Arduino Uno board and Raspberry Pi 4 board, succinctly outlined as follows:

(1) Arduino Uno board: Demonstrated to be conducive for programming practice and the acquisition of computer skills, achieving a commendable average rating of 4.98 percent. Its versatility is underscored by its ability to transition into a web server or hardware control device, garnering an average score of 4.96 percent. Moreover, its application extends to home electronics or Internet of Things (IoTs), with a notable average of 4.95 percent.

(2) Raspberry Pi 4 board: Similarly distinguished for its aptness in programming practice and the study of computer skills, attaining a commendable average rating of 4.95 percent. It showcases the potential to metamorphose into a web server or hardware control device, maintaining a consistent average score of 4.95 percent. Furthermore, its relevance extends to home electronics or Internet of Things (IoTs), also averaging 4.95 percent.

Upon scrutinizing the summarized data, it becomes apparent that the test subjects exhibited the highest level of concurrence with the provided statements, systematically organized in descending order of mean values.

In Section 4, dedicated to scrutinizing factors that impact microprocessor workflows and programs, the researcher deduces the following findings: The core processing speed and clock speed demonstrate noteworthy proficiency, attaining an impressive average rating of 4.98. Simultaneously, the evaluation of technology yields a commendable average rating of 4.86.

In Section 5, the primary focus is the meticulous analysis of microprocessor and program operation data. The researcher delivers a succinct summary of the findings: Speed, memory, operating system, register, arithmetic, and bus systems exhibit a notable correlation with control and logic, achieving an average value of 98.1 percent and a mean squared error averaging 0.684 percent. These results suggest that the tester possesses a comprehensive understanding and depth of knowledge, showcasing expertise in the precise utilization of the board. This is evidenced by a demonstration of precision and the ability to make informed decisions regarding board selection, particularly in the realm of microprocessor and program operations.

The researcher can draw conclusions and analyze the data based on the research objectives as follows: 1) Concerning the study of the Arduino Uno and Raspberry Pi 4 test boards, it was observed that instructors and students comprehended the experimental boards, Arduino Uno, and Raspberry Pi 4. They executed the tests accurately and proficiently, fulfilling the exercises of the test kit, resulting in a median rating of 4.77 percent. and 2) In the examination of the theory and algorithms of microprocessors and programs, the tester demonstrated knowledge and expertise in the theory and operation of microprocessors and programs. The median value was 98.1 percent, with a mean squared error averaging 0.684 percent.

Furthermore, the test respondents exhibited knowledge of the structure and composition corresponding to the computer architecture of the microprocessor and program, with median values of 4.99 percent, respectively.

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