**Journal of Industrial Automation and Electrical Engineering**
Vol. 01, No. 01, June, pp. 209~214



# Determining the kinematics of trolley movement using 4 mechanical wheels

**Denis Tito[1], Mukhlidi Muskhir[1,2], Riki Mukhaiyar[1,2], Habibullah[1,2], Afdal Luthfi[1]**
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia
[2]Instrumentation, Control and Automation Research Group (ICARG), Universitas Negeri Padang, Padang, Indonesia

**Article Info**

***Article history:***

Received March 20, 2024
Revised April 18, 2024
Accepted May 25, 2024

***Keywords:***

Trolley
Kinematics
Microcontroller
H-bridge
Joystick

**ABSTRACT**

4.0 Industrial Revolution brings significant changes across various aspects of life, including the retail sector. The adoption of automation technology in supermarkets can enhance efficiency and consumer convenience. One of the challenges is the use of conventional shopping carts, which require pushing and pulling, often creating difficulties for customers with physical limitations. To address this issue, this study proposes the development of an automated robotic cart using mechanical wheels. Mecanum wheels enable dynamic movement in all directions without the need to change the wheel orientation, making them a more flexible solution compared to traditional differential wheels. The robotic cart is equipped with four 120 mm mecanum wheels and uses DC motors controlled by Pulse Width Modulation (PWM) through an H-bridge circuit and microcontroller. This technology implementation is expected to facilitate smoother cart movement and improve the shopping experience. The study presents the design and kinematic movement of the robot, demonstrating the advantages of using mecanum wheels in enhancing the mobility and flexibility of automated shopping carts.

***Corresponding Author:***

Denis Tito
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: denistito2003@gmail.com

## 1. INTRODUCTION

The Industrial Revolution 4.0 is rapidly changing the way we live and work through automation technology [1]-[3]. Machines can now replace humans, control work processes, and increase efficiency and company profits [4]-[6]. However, the application of this automation technology is still minimal in shopping centers [7]-[8]. Supermarkets usually provide shopping trolleys, but manual trolleys often make it difficult for some consumers, especially those with limited hand mobility [9]-[13]. The use of manual trolleys increases consumer hand activity, making them less free to do other activities [14]-[18]. Therefore, a solution is needed in the form of an automatic trolley that can follow consumers consistently to make the shopping experience easier [19]-[21].

This automatic trolley is designed as a holonomic robot equipped with Mecanum wheels, allowing free movement in all directions without the need to turn [22]-[24]. Mecanum wheels are considered more dynamic and efficient than ordinary differential wheels which have limited movement [25]-[27]. In addition, in the movement of the trolley, kinematics is used to determine the position and orientation or direction of the robot [28]-[31]. Kinematics is a field of mechanics that studies the motion of an object without considering the reason why the object moves [32]-[35]. This study uses a DC motor as a driver, which can withstand heavy loads and speeds that are regulated through Pulse Width Modulation (PWM) with an H-bridge circuit controlled by a microcontroller [36]-[39]. To facilitate data collection, this trolley can be controlled using a PS2 joystick, which is a game controller from Sony Playstation. The type of joystick used is a wireless PS2 Joystick which consists of a receiver and transmitter [40]. With this design, the automatic trolley is expected to increase shopping efficiency and comfort, provide an effective solution for consumers with limited mobility, and overcome the problem of less dynamic movement in manual trolleys.

## 2. METHOD

Tool design is an important step in determining the components that will be used in the final project. This aims to ensure that the tool created can operate as desired. This research method includes designing and manufacturing hardware and software. In hardware design, the Autodesk Inventor application is used, while in software design, the Proteus application is used to create diagrams and the Arduino IDE to create tool programming sketches. The creation of this final project begins with the creation of hardware in the form of a trolley modified using mechanical wheels, followed by the design of the tool control system and movement testing. The components used in this final project can be seen in Figure 1.

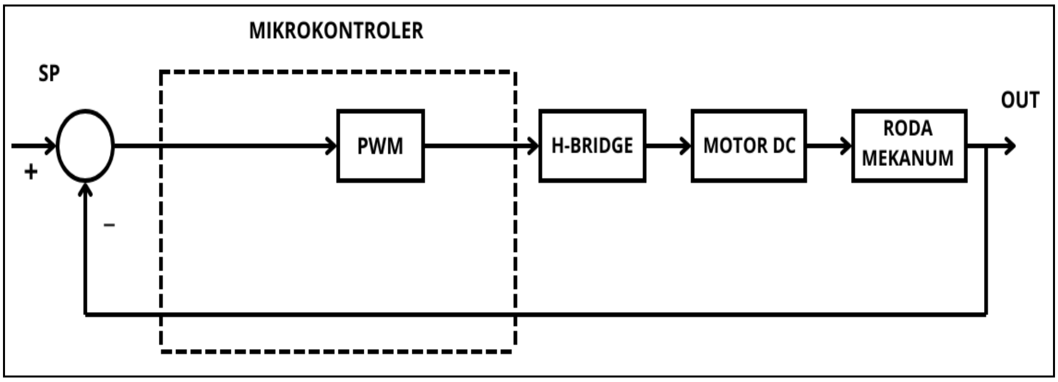



Figure 1. Diagram block of trolley using 4 mechanism wheels

Based on the block diagram above, the design of each block diagram has the following functions: Set point is a value that is set as a reference for the controlled variable. In this final project, the set point value is the desired RPM value and is initialized on the Arduino, a microcontroller that functions to process data or signals that come in as input, an H-bridge circuit that is used to regulate the speed and direction of rotation of the DC motor, a DC motor functions as a driver with a fairly high torque, a mechanical wheel is a type of wheel that is used as a tool to help move the tool.

The working principle of the designed tool is that the process carried out by the microcontroller is an important part of data processing in the tool control system. The data issued by the microcontroller is control data that is sent to the H-bridge module as a component used to regulate the direction and speed of the DC motor as a driver on the trolley. The DC motor used is a DC motor that works at a voltage of 24 VDC, the DC motor can be controlled using the PWM (Pulse Width Modulation) control method, with this method the speed and torque of the DC motor can be adjusted according to needs. The movement of this trolley is assisted by the configuration of four mechanical wheels that allow the trolley to move more efficiently. To facilitate data collection, this trolley can be controlled using a PS2 joystick which is a game controller from the game manufacturer Sony Playstation. The wireless PS2 stick consists of a receiver module and a transmitter module.

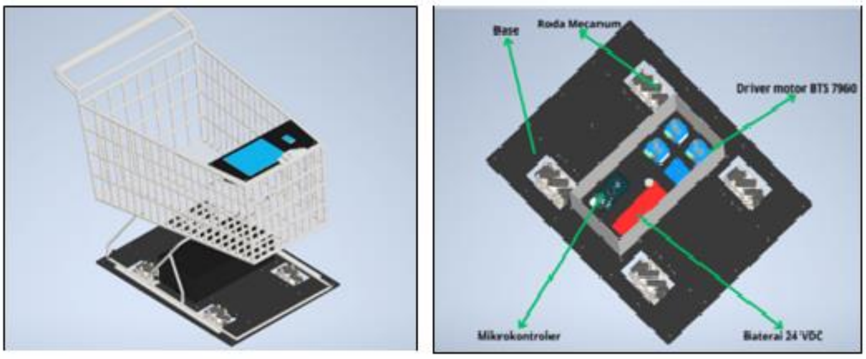



Figure 2. Design of trolley using 4 mechanism wheels

Figure 2 is a mechanical design of the tool making which is used as a reference in the research so that it can reduce errors when making the tool. The mechanical design of the tool on the frame is dominated by iron material with overall dimensions of 850 x 550 mm, while the base uses acrylic material with dimensions of 650 x 500 mm. The system circuit in Figure 3 is a design of the components that will be used in the Trolley using 4 mechanical wheels.

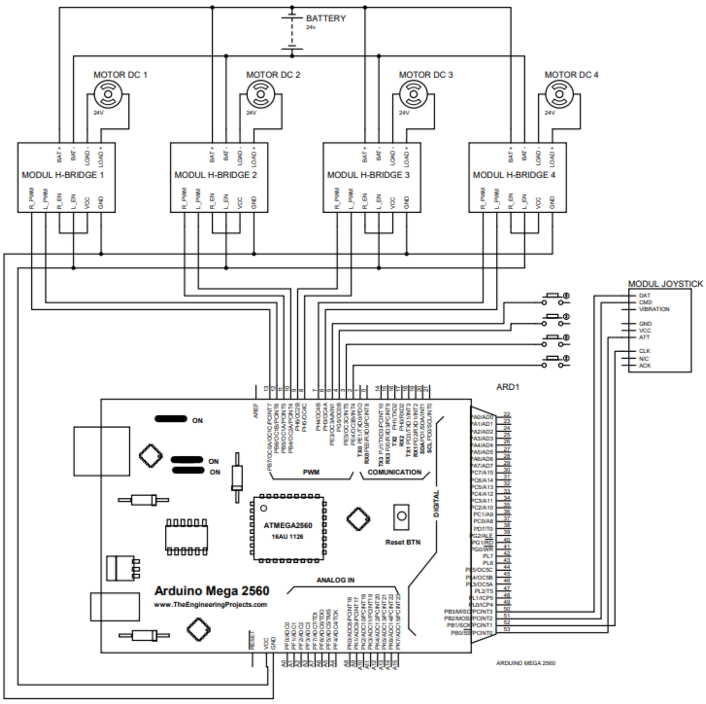



Figure 3. Trolley Hardware circuit using 4 mechanism wheels

## 3. RESULTS AND DISCUSSION

Testing of this tool is carried out after the mechanical design of the trolley is continued by assembling all the components that will be used, namely the microcontroller, H-bridge module, PS2 joystick receiver, DC motor, and several other electrical components. All components used are components that have been tested before being connected to other components, this aims to prevent errors in the testing process. Testing is carried out on a track that is divided into two distances, namely four meters and eight meters, this track is used to visually see the movement of the trolley to be tested. In this test, two comparisons are made, namely the movement of the trolley using kinematics and the movement of the trolley without using kinematics. Figure 4 shows the initial position of the trolley in the test.

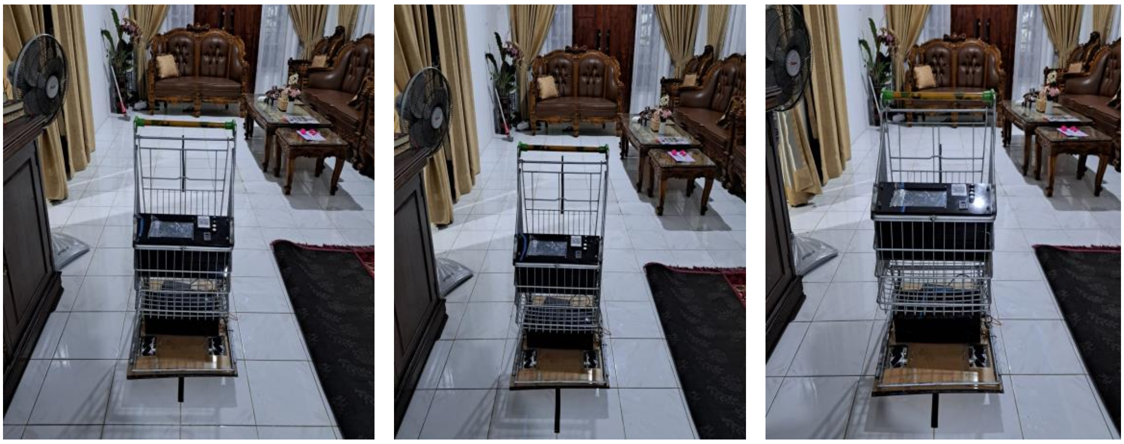
Figure 4. Initial position of trolley during testing

The trolley is positioned at the starting point of the track, the DC motor is given a 24V voltage sourced from a 24VDC battery connected through an H-bridge module and other control components are given voltage from a power bank connected through a microcontroller. The control system on the trolley uses a PS 2 joystick by connecting the receiver to the microcontroller. Testing is done by controlling the trolley to move forward using the PS2 joystick following the track line that has been made with three trials. In a movement with a distance of four meters, the trolley's movement comes out quite far from the track line as seen in Figure 5. In the first trial, the trolley came out 18 cm from the track line, in the second trial, the trolley came out 13 cm from the track line, and in the third trial, the trolley came out 10 cm from the track line.

Test 1 Test 2 Test 3

Figure 5. Test without kinematics on the 4 meter track

The experiment using kinematics showed that the accuracy of the trolley's movement was quite good, as can be seen in Figure 6. In the first and third experiments, the trolley moved according to the track, in the second experiment the trolley moved 1 cm out from the track line.



Test 1 Test 2 Test 3

Figure 6. Trolley test using kinematics on the 4 meter track

Testing with a distance of 8 meters the movement of the trolley out is very far when not using kinematics. The first trial the trolley moved out as far as 44 cm from the track line, the second trial the trolley came out as far as 19 cm from the track line, and in the third trial the trolley came out as far as 31 cm from the track line. In the movement using kinematics the movement of the trolley is much more efficient than without kinematics. In the first trial the trolley managed to move straight according to the track, the second trial the trolley came out as far as 2 cm from the track line, and in the third trial the trolley came out as far as 1 cm from the track line. Tables 1 and 2 describe the test data for trolleys using 4 mechanical wheels.

Table 1. Testing movement trolley at four meters distance

| Movement | Robot Center Distance From Black Line (cm) | | |
|---|---|---|---|
| | Experiment 1 | Experiment 2 | Experiment 3 |
| Without Kinematics | 18 cm | 13 cm | 10 cm |
| Using Kinematics | - | 1 cm | - |

Table 2. Testing movement trolley at a distance of eight meters

| Movement | Robot center distance from black line (cm) | | |
|---|---|---|---|
| | Experiment 1 | Experiment 2 | Experiment 3 |
| Without Kinematics | 44 cm | 19 cm | 31 cm |
| Using Kinematics | - | 2 cm | 1 cm |

After testing with two distances, namely four meters and eight meters, it was seen that the movement of the trolley using kinematics had a more precise movement compared to the movement of the trolley without kinematics. The purpose of testing with these two distances was to determine the movement of the trolley at short distances and long distances.

## 4. CONCLUSION

From the results of testing and analysis in the study on Determining Trolley Movement Kinematics Using 4 Mecanum Wheels, it can be concluded that the application of kinematics to the trolley using four Mecanum wheels was successful, as evidenced by the system's ability to operate according to the planned program. In addition, the application of the PS2 Joystick controller was also successful with good command responsiveness. Testing shows that the trolley with four Mecanum wheels has successfully moved according to the created track, although at a long distance, the trolley moves out of the track about 1-2 cm.

## REFERENCES


[1] H. Zulfikar, D. Rizki Saputra, A. Maulana, Y. Ananda Cahyono, and S. Sahara, “Peningkatan Efisiensi Operasional Pergudangan Melalui Teknologi Canggih,” *J. Ilm. Wahana Pendidik.*, vol. 2023, no. 16, pp. 393–402, 2023, [Online]. Available: https://doi.org/10.5281/zenodo.8242563

[2] A. Tahar, P. B. Setiadi, S. Rahayu, M. M. Stie, and M. Surabaya, “Strategi Pengembangan Sumber Daya Manusia dalam Menghadapi Era Revolusi Industri 4.0 Menuju Era Society 5.0,” *J. Pendidik. Tambusai*, vol. 6, no. 2, pp. 12380–12381, 2022.

[3] I. Studi, K. Di, and P. Industri, “Musytari : 3025-9495,” vol. 6, no. 2, pp. 1–5, 2024.

[4] R. A. Ritonga, “Kegunaan Pembelajaran Robotik Untuk Menghadapi Revolusi 4.0 Dan Society 5.0 Rani,” vol. 4, no. 1, pp. 88–100, 2023.

[5] R. Agustina, S. Nur’aini, L. Nazla, S. Hanapiah, and L. Marlina, “Era Digital: Tantangan Dan Peluang Dalam Dunia Kerja,” *J. Econ. Bus.*, vol. 1, no. 1, pp. 1–8, 2023, doi: 10.61994/econis.v1i1.138.

[6] H. Mantik, “Revolusi industri 4.0: Internet of things, implementasi pada berbagai sektor berbasis teknologi informasi (bagian 1),” *J. Sist. Inf.*, vol. 9, no. 2, pp. 41–48, 2022.

[7] M. Lovita and R. Mukhaiyar, “Rancang Bangun Troli Otomatis Berbasis Computer Vision,” *JTEIN J. Tek. Elektro Indones.*, vol. 3, no. 2, pp. 399–406, 2022.

[8] E. Nursin, G. L. Septiana, C. S. R. Sahidi, and H. A. Aimang, “Penerapan Administrasi Pemerintahan Desa Berbasis Digitalisasi 4.0,” *MONSU’ANI TANO J. Pengabdi. Masy.*, vol. 6, no. 1, p. 47, 2023, doi: 10.32529/tano.v6i1.2296.

[9] S. N. Trisno, A. Ubaidillah, and K. A. Wibisono, “Smart Trolly Design Based on Marker Detection,” *Multitek Indones.*, vol. 15, no. 1, pp. 43–53, 2021, doi: 10.24269/mtkind.v15i1.2429.

[10] N. Popi Wulandari, E. Kurniawan, and R. Intan Vidyastari, “Smart Trolley for Surya Janti Supermarkets Slahung District Based on ATMega 328p,” *JEEE-U (Journal Electr. Electron. Eng.*, vol. 6, no. 2, pp. 133–142, 2022, doi: 10.21070/jeeeu.v6i2.1642.

[11] C. A. Nussy and R. Hartono, “Automatic Trolley Robot Customer Follower Based on Image Processing,” *Telekontran J. Ilm. Telekomun. Kendali dan Elektron. Terap.*, vol. 6, no. 2, pp. 68–79, 2018, doi: 10.34010/telekontran.v6i2.3801.

[12] M. I. Ali, K. Ghozali, and A. S. Indrawanti, “Otomatisasi Sistem Keranjang Belanja pada Supermarket (Marketplace) Guna Meningkatkan Aspek Efisiensi Alur Perbelanjaan Menggunakan Sensor UHF RFID,” *J. Tek. ITS*, vol. 12, no. 1, 2023, doi: 10.12962/j23373539.v12i1.104286.

[13] A. D. Pratiwi, T. S. Pambudi, and ..., “Perancangan Trolley Belanja Mandiri Untuk Kebutuhan Belanja Mingguan Di Pasar Modern (Studi Kasus: Pasar Modern Batununggal Indah).,” *... Art ...*, vol. 7, no. 2, pp. 5673–5682, 2020.

[14] R. Puspitasari and N. A. Watulingas, “Redesain Troli Pusat Perbelanjaan dengan Sistem Sterilisasi dan Pengendali Otomatis,” *Pros. Serenade*, vol. 2, p. 2023, 2023.

[15] I. Febri, T. Setya, and F. Sadika, “Perancangan Troli Mandiri Untuk Pengunjung di Pasar Modern ( Studi Kasus : Pasar Modern Batununggal Indah ),” *e-Proceeding Art Des.*, vol. 7, no. 2, pp. 5642–5654, 2020.

[16] A. Nur, F. Mappasaile, T. Z. Muttaqien, and Y. Pujiraharjo, “Perancangan Troli Belanja Dengan Sekat Barang Belanjaan ( Studi Kasus : Transmart Carrefour Buah Batu Bandung ) Shopping Trolley Design With Groceries Partition ( Case Study : Transmart Carrefour Buah Batu Bandung ),” *e-Proceeding Art Des.*, vol. 7, no. 2, pp. 5634–5641, 2020.

[17] M. Amangesti, D. Puspita, S. Sulaeman, and M. C. Rijal, “Rancang Bangun Troli Pengikut Objek Otomatis,” 2023.

[18] L. A. Yuliani, L. Nurpulaela, and U. Latifa, “Implementasi Node MCU Sebagai Serial Komunikasi dengan Arduino Uno pada

Smart Shopping Trolley," *J. ELTIKOM*, vol. 5, no. 1, pp. 48–55, 2021, doi: 10.31961/eltikom.v5i1.282.
[19] M. A. Suprobo, S. Hariyadi, W. Suryono, and P. P. Surabaya, "Smart Electric Trolley Menggunakan Sistem Pengereman Otomatis Berbasis Wemos D1R1," pp. 1–9, 2021.
[20] T. Wahyuni, W. Rohmanudin, and A. Bastian, "Pengembangan Prototipe Troli Otomatis Menggunakan Arduino Uno R3 Berbasis Android," *J-Ensitec*, vol. 7, no. 02, pp. 535–539, 2021, doi: 10.31949/jensitec.v7i02.1432.
[21] W. D. Nugrahardi, T. Gunawan, and G. I. Hapsari, "Perancangan dan Implementasi Aplikasi Android Pada Troli Pengikut Otomatis," *eProceedings Appl. Sci.*, vol. 5, no. 2, pp. 1308–1325, 2019.
[22] R. Pizá, R. Carbonell, V. Casanova, Á. Cuenca, and J. J. Salt Llobregat, "Nonuniform Dual-Rate Extended Kalman-Filter-Based Sensor Fusion for Path-Following Control of a Holonomic Mobile Robot with Four Mecanum Wheels," *Appl. Sci.*, vol. 12, no. 7, 2022, doi: 10.3390/app12073560.
[23] B. B. Murti, T. Sarwono, E. Apriaskar, and F. Fahmizal, "Desain Robot Holonomic berbasis Roda Mecanum dengan Arm Manipulator," *J. Rekayasa Elektr.*, vol. 16, no. 3, pp. 216–225, 2020, doi: 10.17529/jre.v16i3.17365.
[24] A. Djafar, G. Gunawan, O. Adam, R. Al Wafi, and U. Ali, "Rancang Bangun Robot Penyemprot Disinfektan pada Gedung," *J. Serambi Eng.*, vol. 8, no. 2, pp. 5999–6008, 2023, doi: 10.32672/jse.v8i2.5998.
[25] Y. S. A. Gumilang, K. Krisdianto, H. Haitsam, A. R. Fahreza, and A. Alfayid, "Design of Bluetooth Wireless Transporter Mecanum Wheeled Robot with Android Smartphone Controller for Moving Item," *ELKHA J. Tek. Elektro*, vol. 15, no. 1, pp. 61–66, 2023.
[26] R. Ramadhan, I. Siradjuddin, and D. Dewatama, "Sistem Navigasi Wall Following Robot Omnidirectional Dengan 4 Penggerak Mekanum Menggunakan PID Berbasis myRIO," *J. Elektron. dan Otomasi Ind.*, vol. 9, no. 2, p. 76, 2022, doi: 10.33795/elk.v9i2.263.
[27] A. Azizul, S. Amri, N. Budiyanto, and M. Zamhuri, "Desain Dan Implementasi Komunikasi Control Robot Soccer Beroda Menggunakan User Datagram Protocol (Udp)," *Semin. Nas. Ind. dan Teknol.*, pp. 423–470, 2021.
[28] N. P. D. A. Martini, B. Sumantri, and B. S. B. Dewantara, "Simultaneous Localization and Mapping pada Smart Automated Guided Vehicle menggunakan Iterative Closest Point berbasis K-Means Clustering," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 10, no. 4, p. 742, 2022, doi: 10.26760/elkomika.v10i4.742.
[29] A. A. Fikri and L. Anifah, "Mapping And Localization System Pada Mobile Robot Menggunakan Metode SLAM Berbasis LiDAR," *J. Inf. Eng. Educ. Technol.*, vol. 5, no. 1, pp. 27–33, 2021, doi: 10.26740/jieet.v5n1.p27-33.
[30] L. A. Hisyam Muhammad Fuad AL Azka,Muhamad Syariffuddien Zuhrie, I Gusti Putu Asto Buditjahjanto, "Rancang Bangun Sistem Positioning Mobile Robot Omnidirectional Wheel Menggunakan STM32 Berbasis Fuzzy Logic Controller," *J. Tek. Elektro*, vol. 10, pp. 547–555, 2021.
[31] I. Siradjuddin, S. Wibowo, and A. A. Rofiq, "Pemodelan dan simulasi kinematika robot swerve 4 roda," *J. Eltek*, vol. 20, no. 1, p. 42, 2022, doi: 10.33795/eltek.v20i1.301.
[32] F. Puspitasari, Wahyu Dwi Febrinita, "Persepsi Mahasiswa Tentang Pemahaman Konsep Kinematika Gerak Ditinjau dari Kemampuan Berpikir Kritis," *UPEJ Unnes Phys. Educ. J.*, vol. 9, no. 2, pp. 197–208, 2020.
[33] K. Pawestri Primastuti, N. Putri Anugrah, R. Zakiyah MunawarohPenulis, W. Kurniawati, and U. PGRI Yogyakarta, "Analisis Gerak Lurus Berubah Beraturan Pada Konsep Kinematika," *J. Pengabdi. Masy. Indones.*, vol. 1, no. 2, pp. 23–27, 2023, [Online]. Available: https://doi.org/10.62017/jpmi
[34] I. A. Rizki, N. F. Citra, H. V. Saphira, W. Setyarsih, and N. P. Putri, "Eksperimen Dan Respon Mahasiswa Terhadap Praktikum Fisika Non-Laboratorium Menggunakan Aplikasi Tracker Video Analysis Untuk Percobaan Kinematika Gerak," *J. Teach. Learn. Phys.*, vol. 6, no. 2, pp. 77–89, 2021, doi: 10.15575/jotalp.v6i2.12640.
[35] A. Muzakki, I. N. Ramadhanti, I. N. Alifiyan, and T. S. Ayu, "Kajian Model Pembelajaran Fisika SMA pada Topik Kinematika Gerak Lurus," *Mitra Pilar J. Pendidikan, Inovasi, dan Terap. Teknol.*, vol. 1, no. 2, pp. 85–98, 2022, doi: 10.58797/pilar.0102.04.
[36] M. I. Esario and M. Yuhendri, "Kendali Kecepatan Motor DC Menggunakan DC Chopper Satu Kuadran Berbasis Kontroller PI," *JTEV (Jurnal Tek. Elektro dan Vokasional)*, vol. 6, no. 1, p. 296, 2020, doi: 10.24036/jtev.v6i1.108005.
[37] S. A. D. Prasetyowati, B. Arifin, A. Syakhroni, and M. K. Faza, "Monitoring River Sediment by Optimizing Arduino Capabilities Controlled by the PID Algorithm," *WSEAS Trans. Syst.*, vol. 21, pp. 233–240, 2022, doi: 10.37394/23202.2022.21.25.
[38] S. Sukardi, T. Putra, H. Hambali, and M. Yuhendri, "Rancang Bangun Robot Pelontar Bola Tenis Lapangan Berbasis Internet of Thing (IoT)," *JTEIN J. Tek. Elektro Indones.*, vol. 4, no. 1, pp. 19–30, 2023.
[39] F. Rahmadi and M. Yuhendri, "Kendali Kecepatan Motor DC Menggunakan Chopper DC Dua Kuadran Berbasis Kontroller PI," *JTEIN J. Tek. Elektro Indones.*, vol. 1, no. 2, p. 241, 2020, doi: https://doi.org/10.24036/jtein.v1i2.71..
[40] S. Hussain, R. P. George, N. Ahmad and R. Jahan, "Machine Learning Methods of Industrial Automation System in Manufacturing and Control Sector using Joystick with and Robotic Technology," *2022 11th International Conference on System Modeling & Advancement in Research Trends (SMART)*, Moradabad, India, 2022, pp. 1134-1140, doi: 10.1109/SMART55829.2022.10047023.