Technical report

Real-Time Metro Sensing Hub

Aya A. Allam - Eman A. Mohamed - Malak A. Elattar

Gharbiya STEM High School

Mrs. Nardine Fayek/ G12 capstone leader

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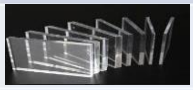
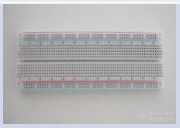
Abstract:

Egypt faces pressing challenges that demand immediate attention, with urban congestion standing out as a critical issue. This problem exacerbates traffic delays, air pollution, and economic inefficiencies, highlighting the urgent need for innovative and sustainable transportation solutions. Addressing this, a smart metro car prototype has been developed, integrating advanced sensors to enhance functionality and safety. The system employs an Infrared (IR) sensor to monitor passenger occupancy, activating a green LED when the number of people exceeds 20, ensuring optimal crowd management. An MQ-135 sensor monitors carbon dioxide (CO_2) levels, triggering a buzzer when concentrations surpass 418 ppm, providing an early warning for air quality concerns. Additionally, a DHT11 sensor measures temperature, activating a red LED when readings fall outside the 10–30°C range to maintain thermal comfort. Sensor outputs are visualized through an Excel dashboard for real-time monitoring and stored on a hard disk for further analysis. Powering the system is two 3.7V lithium-ion batteries, ensuring efficient and portable operation. The setup is housed in an acrylic box with dimensions of 20 cm × 20 cm × 14 cm, simulating a metro car environment. Notably, the system demonstrates the interdependence of variables: CO_2 concentration rises proportionally with passenger numbers, while temperature increases over time with crowd density. This prototype provides a scalable and effective foundation for addressing urban congestion and improving metro system efficiency in Egypt.

Materials and methods:

Materials

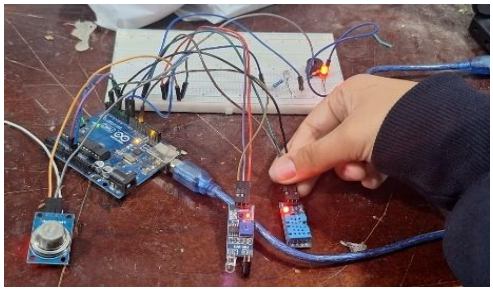
Material	Cost	Used cost	Number	Source of purchase	Usage	Picture
MQ-135	125	125	1	**Electronics shop**	Detection of CO2 level	
DHT11	75	75	1	**Electronics shop**	Detection of temperature	
IR	60	60	1	**Electronics shop**	Detection of number of people	
Acrylic	300	100	1	**shop**	Metro mocking	
3.7V battery	50	50	2	**Electronics shop**	Energy source	
wires	10	10	15	**Electronics shop**	**transfer electrical power**	
Buzzer	05	05	5	**Electronics shop**	**Alter people**	
Arduino uno	500	200	1	**Electronics shop**	**Integration of electrical components**	
Breadboard	30	30	1	**Electronics shop**	**building temporary circuits**	
Total cost	1200 LE	LE 700				

Methods:

Connections

- DHT11 sensor Is Connected to a Red Led to alarm people when temperature isn't between 10-30˚ C.
- The IR motion sensor Is Connected to Green led to alarm people when the number of people inside the metro exceeds 20 person/car.
- MQ135 sensor related to a buzzer if CO_2 concentration exceeds 418 ppm.

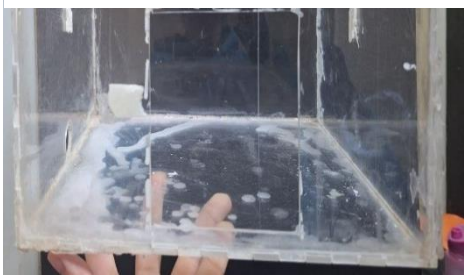
FIGURE 1 THE CONNECTION OF THE SYSTEM



- All the sensors (DHT11, IR motion and MQ135 sensors) and their actuators were connected to Arduino UNO and bread board.
- VCC (Power) was connected to the IR sensor, DHT11, and MQ-135.
- GND (Ground) was connected to the IR sensor, DHT11, MQ-135, LED (via resistor), and buzzer.
- IR Sensor was connected to digital pin 2, DHT11 Sensor was connected to Digital pin 4, LED anode was connected to digital pin 12 via sensor and Buzzer positive anode was connected to digital pin 11 (as shown in fig.1).
- Arduino code: Arduino code

- An excel sheet was created to store data, by data streaming, and visualize them through different graphs: Excel file

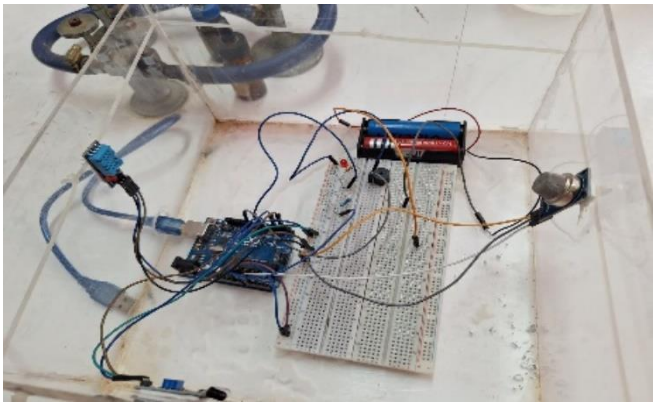
FIGURE 2
ACRYLIC BOX



Prototype construction

- A 0.2 m length and width and 0.14 m height cuboid were constructed from acrylic (as shown in fig 2) to simulate the metro car.
- Sensors were fixed for accurate data detection (as shown in fig.3)
- Hands movement stimulated people pass, CO_2 was produces using vinegar and sodium bicarbonate and temperature were changed using hot water vapor.
- Two chargeable batteries (as shown in fig.4) Is Connected to 5-watt solar panels as source of power.
- The system ran for Certain Time to calculate data.

FIGURE 3
THE WHOLE SYSTEM



First trial (Negative trial):

Number of people wasn't accurate. After searching, it was found that PIR depends on the change in infrared radiation for motion detection so, collected data wasn't the same as the number of people who entered.

Second trial (Positive trial):

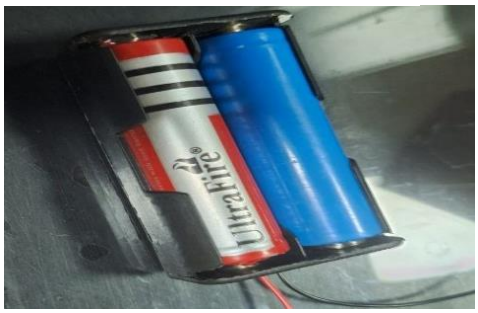
PIR was replaced by IR motion sensor for accurate data detection as IR motion sensor detects motion based on infrared radiation. Number of people stimulated actual number of people who entered.

Third trial (Positive trial):

Temperature and CO_2 concentration were detected using DHT11 and MQ-135 respectively. The graph showed a direct relation between the number of people and both temperature and CO_2 concentration. As the number of people increased, temperature and CO_2 concentration also increased.

FIGURE 4

THE BATTERIES

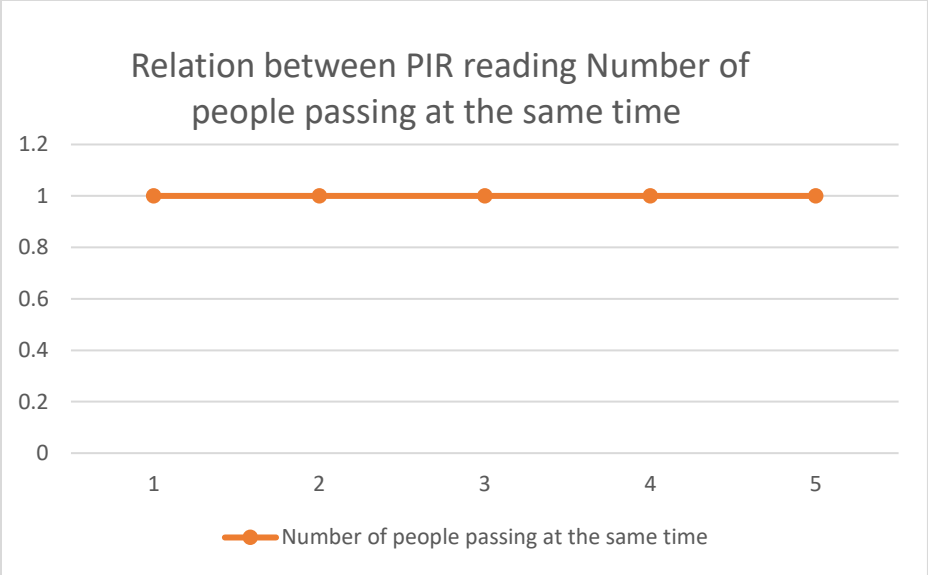


Results:

Addressing the issue of urban congestion through the monitoring system, the outcomes are :

Table1

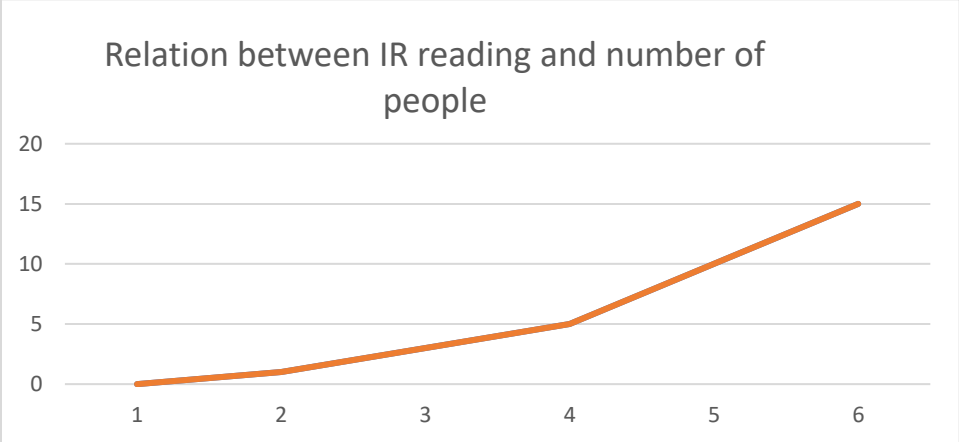
PIR reading	Number of people passing at the same time
1	1
3	1
5	1
10	1
15	1



A negative result: Using PIR sensor instead of IR sensor

IR reading	Number of people passing at the same time
1	1
3	3
5	5
10	10
15	15

Fig 6

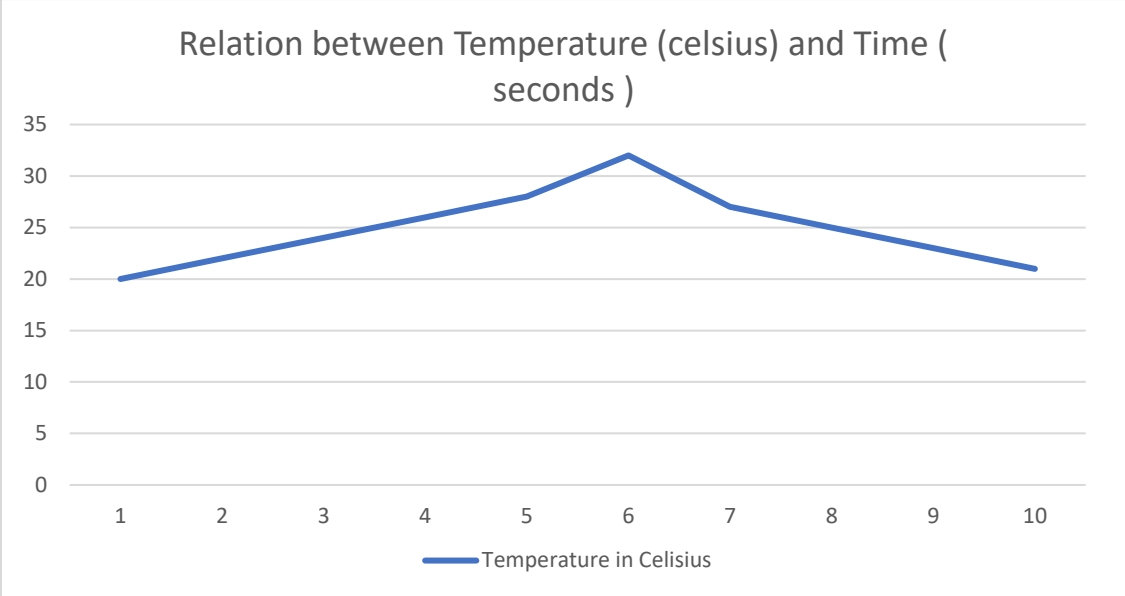


A positive result between the number of actual people and IR reading

Table 3

Temperature in Celsius	Time
20	5
22	10
24	15
26	20
28	25
32	30
27	35
25	40
23	45
21	50

Fig 7

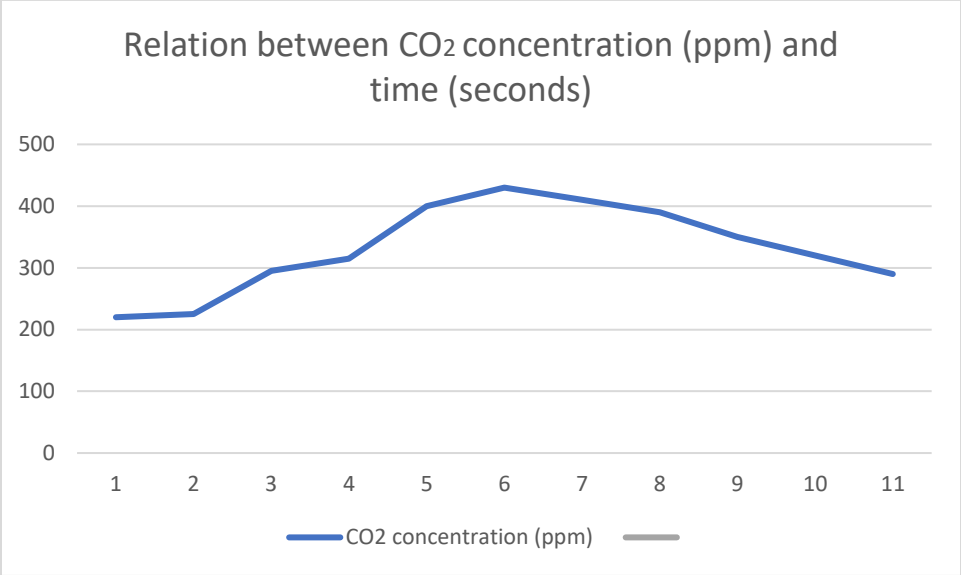


A Positive result: shows the temperature and the number of people

Table 4

CO2 concentration (ppm)	**time (sec)**
220	5
225	10
295	15
315	20
400	25
430	30
410	35
390	40
350	45
320	50
290	55

Fig 8



A Positive result: shows the CO2 concentration and the number of people

Conclusion:

Developing a system for determining people's status inside the metro cars can help to control crowd density in transportations. The chosen system works on determining number of people, detecting temperature and CO_2 concentration inside metro cars. So, it's easy to control crowd by identifying peak times. The used sensors are IR motion sensor, DHT11 temperature sensor and MQ-135 sensor respectively. Usage of IR motion instead of PIR motion sensor increased system efficiency. This system is better than other projects as it provides real time data visualization for both technical and nontechnical users using excel. Excel files can be easily imported and exported to and from other software like Power BI, Tableau, and R for advanced visualization or analysis. Moreover, it's a cost-efficient technique.

Recommendations

It recommends everyone who will work on the project in the future to improve the efficiency of the project by following these recommendations:

1- Use NIDR CO_2 sensor or SCD30 CO_2 sensor instead of MQ-135 Sensor for higher precision and stability for long-term use.

2- Use 3D LiDAR sensor to provide more reliable and accurate crowd counting.

3- Use industrial-grade enclosures for sensors to ensure durability in harsh environmental conditions, such as temperature fluctuations and humidity.

4- Use wireless communication protocols like Zigbee for scalable and efficient data transfer, Zigbee chosen especially due to its low power needs and mesh capabilities.

5- Utilize energy-harvesting techniques like vibration or thermal energy from the Metro to power sensors and Deploy sleep modes in sensors when not actively transmitting data to reduce energy consumption.

6- Use platforms like Grafana instead of Excel Sheet for enhanced data analysis and visualization.

Literature cited

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