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Design and Development of IoT-Based Tracking for Humans using Arduino

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Abstract: Technological advancement and innovation in the field of biometric identification technology and security of lives and properties have enabled the evolution of intelligent monitoring systems. In light of this, this paper intends to present the results of the hardware platform set up for the data collection of human tracking that would ultimately be integrated into the Kalman Filter Algorithm (KFA) to be developed in our further work. To provide a fast tool for creating a VLSI test bench, particularly for sensors, Arduino Mega 2560 was chosen and used as the heart of this hardware platform. As a consequence, its working principle and other applications were explored in this paper. Furthermore, since a two-dimensional Kalman Filter model would be developed, the positions and velocities of the object to be tracked (i.e., humans) were estimated in both x- and y-directions in a tabular form.

Keywords: Arduino Mega, Arduino IDE, Internet of Things, Object tracking, RFID sensors

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1. INTRODUCTION

Detection and tracking of objects are among the most common and demanding tasks the surveillance system performs to distinguish relevant incidents and questionable or malicious activities. An object can be a face, a head, a human, a queue of people, a crowd, and a product on an assembly line. For example, object tracking helps to systematically evaluate the influx of people to public places, such as supermarkets, malls, and travel sites, and then to achieve congestion and demographic analysis to better control crowd traffic. Such intelligent systems would replace the conventional monitoring systems where the number of cameras exceeds the capacity of costly human operators to monitor them.

Undoubtedly, object detection and object tracking have extensively been applied in the fields of computer vision and image processing over so many years to estimate the locations and motion parameters of the targeted object(s) in a video sequence. Their applications include surveillance, traffic pattern analysis, medical image processing, recognition, human-computer interaction, etc. However, this paper presents a different approach to object tracking using Arduino devices and RFID sensors to measure the object's positions and velocities. With the pre-estimated positional location of each RFID sensor in the provided rooms and the knowledge of the time it takes to advance from a room location to another, the velocity can easily be estimated. Ultimately, this makes it possible to measure the position and velocity of human motion.

If only one measurement is involved, e.g., estimating the true/actual value of a room temperature with several temperature measurements taken and using the Kalman Filter method, the one-dimensional Kalman Filter algorithm would have been perfect. However, it becomes more difficult and complicated when more than one measurement is involved, as in this work where humans are to be tracked. In this case, the targeted object's position and velocity must be known in the x-direction and y-direction. In addition, the two-dimensional KFA gives better and more accurate results than the one-dimensional KFA. Hence, the proposed two-dimensional Kalman Filter method is suggested to analyze the datasets obtained for the positions and velocities in our further work.

Arduino is an open-source microcontroller that comprises incredibly simple-to-use hardware and software. Arduino boards can recognize and interpret inputs that are as simple as sensor light, a finger on a button, or a Twitter message, and then transform them to outputs, such as activating a motor, switching on an LED, report a message online. A set of instructions could be sent to the onboard microcontroller by telling the board what to do. Arduino board can be programmed as fast as possible, erased, and reprogrammed at any point in time. Arduino consists of both a physical programmable circuit board (sometimes called a microcontroller) and a piece of software or an Arduino IDE (Integrated Development Environment) running on a computer to write and upload a computer code to a physical board.

According to Abdelali et al. [1], Internet of Things (IoT) technology has enabled the connection of any physical object to the Internet. Tags can identify the object, and its location can be tracked. The collected data can then be processed and analyzed.

In his work, Louis [2] disclosed that the Arduino platform was introduced in 2005 and was developed to provide a cheap and simple way for engineers, scientists, students, and other enthusiasts. He added that the Arduino platform was created to build devices that communicate with their environment using sensors and actuators, making it an IoT scheme. With the aid of Arduino shields, the Arduino device can receive and send information over the Internet. These microcontrollers can be programmed using the C or C++ language in the Arduino IDE. Being the brain of thousands of electronic projects, Arduino was used with RFID sensors to carry out human tracking in this research. According to Kaswan et al. [3], a comparison based on Arduino's prominence over the other two IoT-based programming boards of Raspberry and PIC microcontrollers was made using Google Trends results. Their work revealed that Arduino is the most commonly used microcontroller board, while PIC is the least-used board for five years from 2014 to 2018. Arduino was also listed as the most searched board between 2014 and 2018, while PIC was the least searched board on a global web search basis.

Due to its wide variety of applications in many fields and disciplines, including home automation [4], defence and military warfare [5]-[6], industry supervisory systems [7], traffic signal control [8], laboratory monitoring systems [9], medical treatment and equipment [10]-[11], aerospace and flight control systems [12]-[13], Arduino devices have attracted considerable interests from various researchers and engineers. Consequently, they have also played a significant role in the past few years.

Jyothi and Vardhan [14] identified in their work the flaws of using CCTV or other video surveillance systems to solve security issues, such as irregular pictures, complicated structures, poor stability, and high device costs. They proposed a real-time security surveillance system that would use IoT to deploy a motion detection algorithm in Python. However, the algorithm's reliance on the threshold value was a disadvantage. Only when specific objectives are satisfied will the algorithm perform optimally [14]. In another work, Jung and Agulto [15] proposed designing an IoT-based global platform to monitor and track real-time information relating to COrona VIrus Disease 19 (or COVID-19) as either a suspected infection or confirmed case to curb the spread of the virus.

2. DESIGN IMPLEMENTATION

The design of this device is composed of two modules: the hardware interface module and the software communication module. Figure 1 shows the complete architecture with the interfacing of the hardware platform and software module.

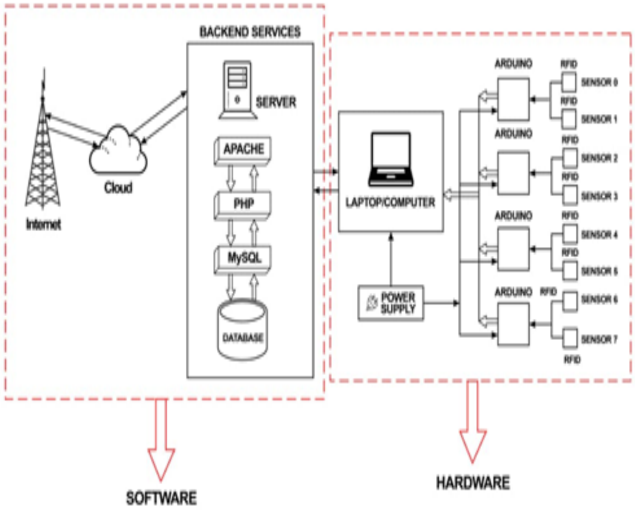

Figure 1. The architecture of the hardware platform and software module

2.1 Hardware Interface Module

Arduino can detect the surroundings by collecting input signals from a wide range of sensors and influencing its surroundings through actuators. The heart of this design is the Arduino Mega 2560 microcontroller. Four Arduino Mega were used with 2 RFID sensors connected to each Arduino (a total of 8 RFID sensors – RFID-RC522). In addition, two RFIDs were connected to an Arduino so that the processing speed will not be excessively slowed down. The components used for the hardware module are Arduino Mega 2560, Arduino Wi-Fi Shield ESP8266, RFID Reader and RFID Card RC522, 5V DC USB hub, 5V DC power supply, and Jump wires: the male-to-male and male-to-female types.

The circuit layout was done in such a way that:

- The VCC pin of RC522 was connected to one of the power pins (i.e., 3.3V) of the Arduino Mega while their GROUND pins were connected.
- Their RESET pins were also connected.
- The MISO, MOSI, and SCK pins of RC522 were connected to the SPI pins 50, 51, and 52 of Arduino Mega.
- Each of their SS or SDA pins (i.e., SS pin of RFID sensor 1 and SS pin of RFID sensor 2) were connected to the PWM pins 9 and 12 of the Arduino Mega.

Figures 2 and 3 show the pinout or configuration of RFID-RC522 and Arduino Mega 2560, respectively, while Figure 4 shows the connection between an Arduino Mega 2560 and two RFID-RC522. Finally, figure 5 shows the complete circuitry involving the four Arduino Mega with each one connected to two RFIDs, making a total of eight RFIDs.

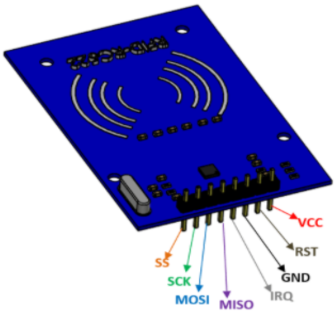

Figure 2. Pin-out or configuration of RFID – RC522

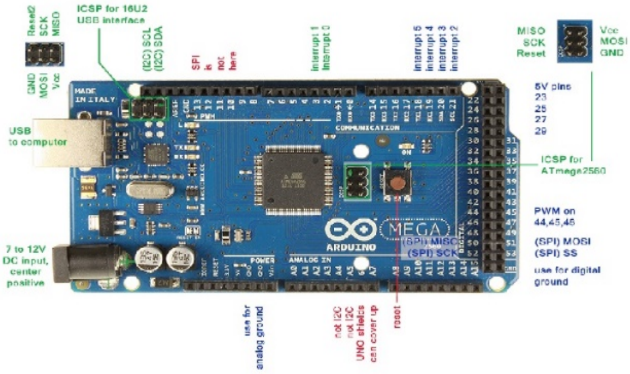

Figure 3. Pin-out or configuration of Arduino Mega 2560

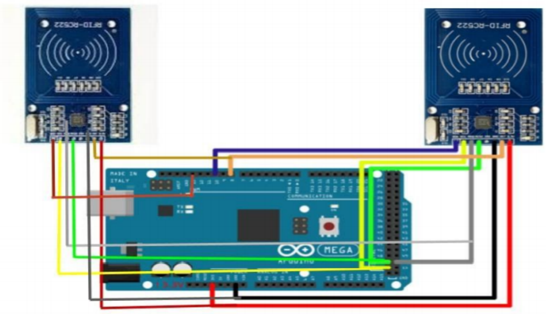
Figure 4. Connection of two RFID-RC522 to Arduino Mega

2.2 Software Communication Module

The program code written for Arduino is known as a sketch. The software used to create Arduino sketches is generally referred to as the Arduino Integrated Development Environment (or Arduino IDE). Figure 6 shows the flowchart of the code that was burnt to the Arduino microcontroller. In addition, it depicts all the various actions performed when the Arduino-based hardware platform is started (i.e., booted).

2.3 Other Design Consideration

The RFID sensors would be placed in different locations (or rooms), and the RFID cards will be used to scan the mounted RFID sensors. The card id (which is attached to a particular individual) and the sensor id (i.e., the room location number) with other information, such as the position, time, and velocity, will be sent to the server or processing unit. If an incorrect RFID card is used to scan the sensor, no access will be granted to such individual. However, if a genuine RFID card is used, access is granted.

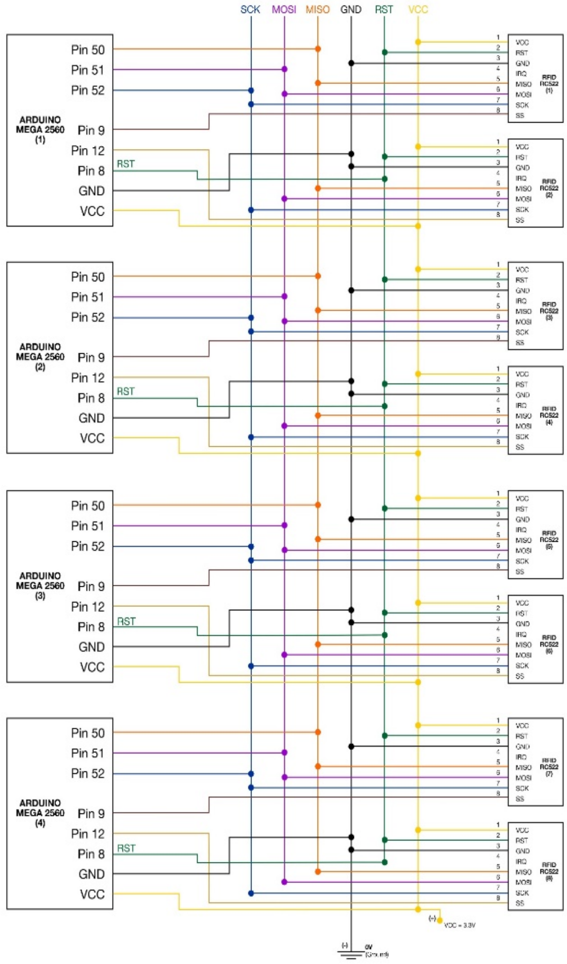

Figure 5. Complete circuitry for the connection of Arduino and RFID sensors

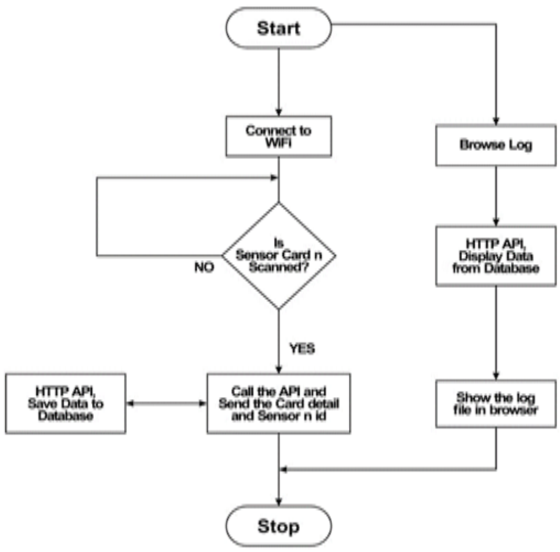

Figure 6. Flowchart of the code written for Arduino microcontroller board

If a person gets into the control area, his activity or movement is continuously tracked, and his location is reported until he leaves the control room. Because human tracking is being performed, it is essential to know the object's position in both the x and y directions and its velocity in both the x and y directions. To obtain the person's position to be tracked, a distance location of Figure 7 was assumed by locating the eight RFID sensors in 8 different places or rooms in a plane by use of a coordinate system, i.e. (x, y). For example, if he moves from room 1 (7, 16) to room 7 (17, 25), he would have moved a distance of (17 – 7 = 10) in the x-direction and (25 -16 = 9) in the y-direction. Therefore, his position becomes (10, 9). His motion or movement is also assumed to be uniform, implying that his velocity in the x- and y-directions are the same.

The data obtained or collected would thereafter be integrated into the Kalman Filter Algorithm to be developed in future work to track and predict his next or following location.

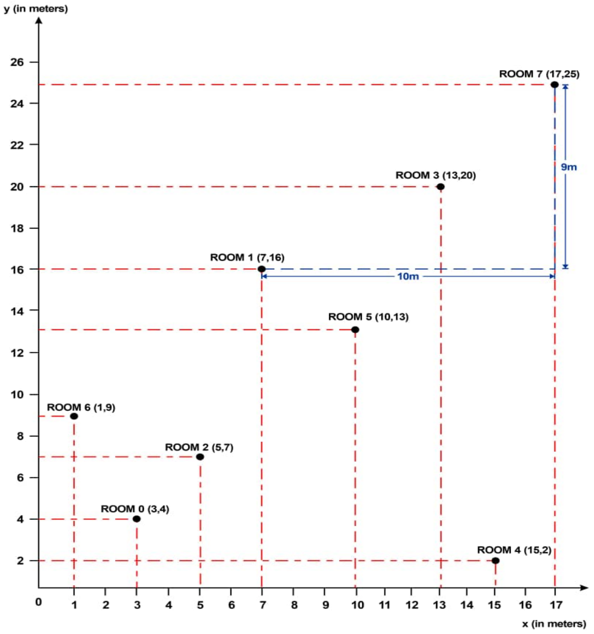

Figure 7. Distance location for the various sensors used (located from room 0 – 7)

3. RESULTS

Some of the results obtained are exported in Excel format, as shown in Tables 1 to 4. It depicts the tracking results of 4 different people A, B, C, and D, with their respective sensor id. Each person is assigned a unique card id to distinguish one person from another.

Observing the tracking record of first-person, named A, with card id 109016622, as an instance, he started from room id 5 with 0m as his position in the x- and y-directions. Then he moved to room id 0 with a positional distance of 7m in the x-direction and 9m in the y-direction with a corresponding velocity of 1.0m/s along with both directions. After that, he moved to room id 7 with a positional distance of 14m in the x-direction and 21m along y-direction with a velocity of 2.3333m/s along x- and y-directions, as shown in Table 1. While he continued to move from one room to another, his positions and velocities are recorded in x- and y-directions.

Similarly, when the tracking record of second-person B, with card id 89171231110, is carefully observed, it was noticed that he began from room id 5 as well with a position of 0m in both the x- and y-directions, just as person A. He then moved to room id 0 with a positional distance of 7m and 9m in the x-direction and y-direction, respectively. His velocities were 0.8421m/s along both x- and y-directions. Compared with A, B took more time to move from room id 5 to room id 0 than A. Thereafter, B advanced to room id 2 with a positional distance of 2m and 3m in the x- and y-directions, respectively, and also with a velocity of 0.3846m/s in both directions. Table 2 depicts B's other positions and velocities as he continued his movement from one room to another.

However, the third person, C, with card id 9121919934, began from room id 3 with a position of 0m in both the x- and y-directions. After that, he advanced to room id 5 with a positional distance of 3m and 7m in the x- and y-directions, respectively. His corresponding velocity was 0.625m/s in both directions, as shown in Table 3. Furthermore, C moved from room id 5 to room id 6 with a positional distance of 9m and 4m in the x- and y-directions. His velocity was 0.722m/s in both directions. All of C's positions and velocities are depicted in Table 3.

Finally, the same discussion could be made up for the fourth person, D, with card id 16718911375. Table 4 depicts D's positions and velocities in the x- and y-directions.

The results obtained show a great deal of agreement with the distance location in Figure 7. Figures 8 and 9 depict the various positions of person A in x- and y-directions, respectively. Their corresponding velocities in x- and y-directions are shown in Figures 10 and 11, respectively. As observed in Tables 1 to 4 and Figures 8 to 11, thirty (30) data samples were taken for each person A to D. Figures 8 – 11 are the graphical representations of Table 1 – 4. The graphical model is the format of the input into the Kalman Filter Algorithm (KFA) that will be developed in our further work, with a lot of modifications to the already existing KFA.

Table 1: Tracking results of first-person, A

	PERSON A (CARD ID: 109016622)				
S/N	POSITION ON X-DIRECTION (in meters)	POSITION ON Y-DIRECTION (in meters)	VELOCITY ON X-DIRECTION (in m/s)	VELOCITY ON Y-DIRECTION (in m/s)	ROOM ID
1	0	0			5
2	7	9	1	1	0
3	14	21	2.3333	2.3333	7
4	12	18	1.4286	1.4286	2
5	10	5	0.8823	0.8824	4
6	8	14	1.5716	1.5713	1
7	6	7	0.7648	0.7647	6
8	12	11	1.1501	1.1499	3
9	4	5	0.4286	0.4285	7
10	7	12	1.0001	1	5
11	3	7	0.5882	0.5882	3
12	6	4	0.7143	0.7143	1
13	6	7	0.9286	0.9285	6
14	14	7	1.1052	1.1054	4
15	10	5	1.3636	1.3638	2
16	2	3	0.3333	0.3333	0
17	4	12	1.0667	1.0667	1
18	2	9	0.7858	0.7857	2
19	8	13	1.4998	1.5001	3
20	2	18	1.6667	1.6667	4
21	5	11	1.2308	1.2308	5
22	9	4	0.7647	0.7647	6
23	16	16	2.4615	2.4615	7
24	2	23	1.9231	1.9231	4
25	12	2	1.0001	0.9997	0
26	2	3	0.3571	0.3571	2
27	2	9	0.5239	0.5238	1
28	3	3	0.2	0.2	5
29	9	4	4.3334	4.3332	6
30	2	5	0.35	0.35	0

Table 2: Tracking results of second-person, B

	PERSON B (CARD ID: 89171241110)				
S/N	POSITION ON X-DIRECTION (in meters)	POSITION ON Y-DIRECTION (in meters)	VELOCITY ON X-DIRECTION (in m/s)	VELOCITY ON Y-DIRECTION (in m/s)	ROOM ID
1	0	0			5
2	7	9	0.8421	0.8421	0
3	2	3	0.3846	0.3846	2
4	10	5	1.2499	1.2501	4
5	14	7	0.75	0.7501	6
6	6	7	0.9286	0.9285	1
7	6	4	0.6667	0.6667	3
8	3	7	0.6667	0.6667	5
9	7	12	1.4616	1.4615	7
10	14	21	2.6923	2.6923	0
11	14	21	1.0938	1.0938	7
12	7	12	0.6334	0.6333	5
13	5	11	1.0667	1.0667	4
14	2	18	0.8333	0.8333	3
15	8	13	1.9089	1.9092	2
16	4	2	0.4286	0.4286	6
17	16	16	2.4615	2.4615	7
18	10	9	1.4616	1.4615	1
19	3	3	0.5	0.5	5
20	3	7	0.625	0.625	3
21	4	5	0.7501	0.7499	7
22	12	18	2	2	2
23	2	3	0.2941	0.2941	0
24	10	16	1.6251	1.625	3
25	12	11	1.5334	1.5332	6
26	6	7	1.0001	0.9999	1
27	8	14	1.5716	1.5713	4
28	2	23	1.7857	1.7857	7
29	4	5	0.6001	0.6	3
30	10	16	1.5295	1.5294	0

Table 3: Tracking results of third-person, C

	PERSON C (CARD ID: 9121919934)				
S/N	POSITION ON X-DIRECTION (in meters)	POSITION ON Y-DIRECTION (in meters)	VELOCITY ON X-DIRECTION (in m/s)	VELOCITY ON Y-DIRECTION (in m/s)	ROOM ID
1	0	0			3
2	3	7	0.625	0.625	5
3	9	4	0.7222	0.7222	6
4	4	2	0.4	0.4	2
5	2	9	0.8462	0.8461	1
6	8	14	1.5716	1.5713	4
7	2	23	1.5625	1.5625	7
8	10	9	1.7273	1.7272	1
9	6	7	0.7648	0.7647	6
10	2	5	0.5385	0.5385	0
11	12	2	0.9334	0.9331	4
12	2	18	0.9091	0.9091	3
13	8	13	1.6152	1.6155	2
14	2	3	0.2941	0.2941	0
15	10	16	1.7334	1.7333	3
16	2	18	1.25	1.25	4
17	14	7	1.4999	1.5002	6
18	6	7	0.8667	0.8666	1
19	2	9	0.8462	0.8461	2
20	5	6	1.1001	1.0999	5
21	7	12	0.9048	0.9047	7
22	12	18	1.7647	1.7647	2
23	10	5	1.1538	1.154	4
24	5	11	1.1429	1.1429	5
25	3	3	0.4	0.4	1
26	10	9	1.2667	1.2666	7
27	14	21	2.6923	2.6923	0
28	2	5	0.5	0.5	6
29	12	11	1.7694	1.7691	3
30	8	13	0.9999	1.0001	2

Table 4: Tracking results of fourth-person, D

	PERSON D (CARD ID: 16718911375)				
S/N	POSITION ON X-DIRECTION (in meters)	POSITION ON Y-DIRECTION (in meters)	VELOCITY ON X-DIRECTION (in m/s)	VELOCITY ON Y-DIRECTION (in m/s)	ROOM ID
1	0	0			2
2	2	9	0.5239	0.5238	1
3	8	14	1.3751	1.3749	4
4	2	23	2.0833	2.0833	7
5	7	12	1.1876	1.1875	5
6	5	6	0.9168	0.9166	2
7	2	3	0.3846	0.3846	0
8	2	5	0.4667	0.4667	6
9	12	11	1.643	1.6427	3
10	8	13	1.3123	1.3126	2
11	2	3	0.3846	0.3846	0
12	4	12	1.1429	1.1429	1
13	3	3	0.2727	0.2727	5
14	3	7	0.625	0.625	3
15	12	11	1.7694	1.7691	6
16	14	7	1.1666	1.1668	4
17	2	23	1.7857	1.7857	7
18	12	18	1.7647	1.7647	2
19	8	13	1.4998	1.5001	3
20	2	18	1.4286	1.4286	4
21	2	23	0.8621	0.8621	7
22	12	18	2.1429	2.1429	2
23	8	13	1.3123	1.3126	3
24	3	7	0.7143	0.7143	5
25	3	3	0.4615	0.4615	1
26	6	4	0.7692	0.7692	3
27	2	18	1.4286	1.4286	4
28	12	2	1.077	1.0766	0
29	2	5	0.3684	0.3684	6
30	6	7	0.6191	0.619	1

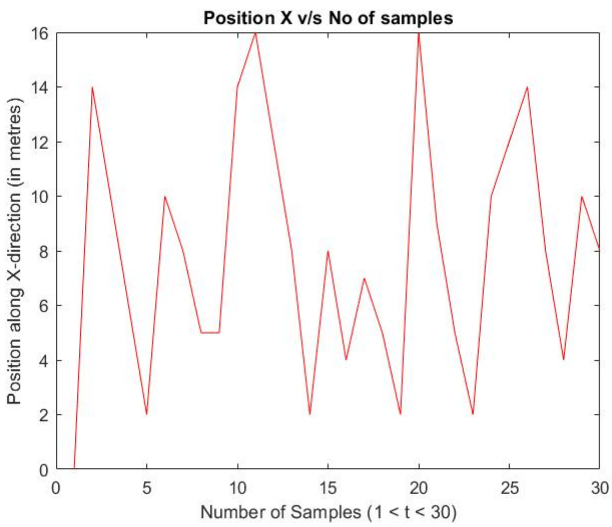

Figure 8. Positions of person A in the x-direction.

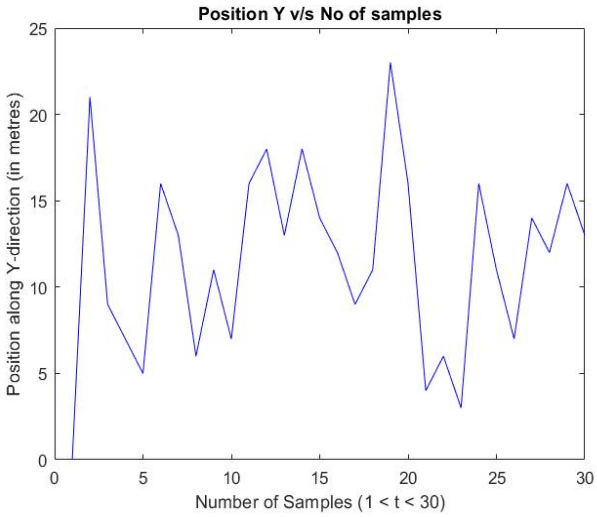

Figure 9. Positions of person A in the y-direction.

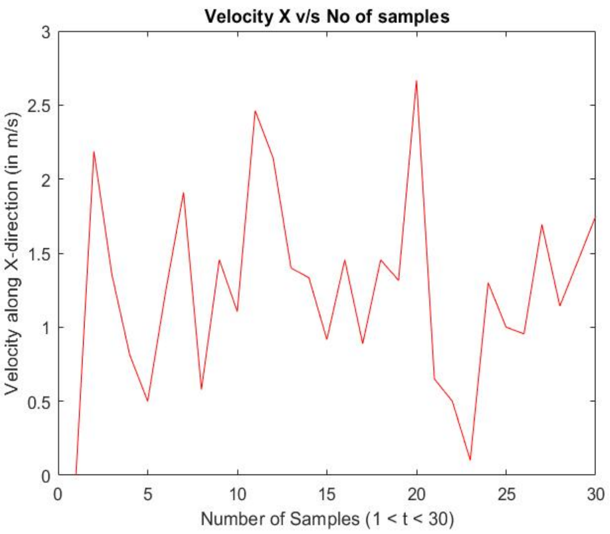

Figure 10. Velocities of person A in the x-direction.

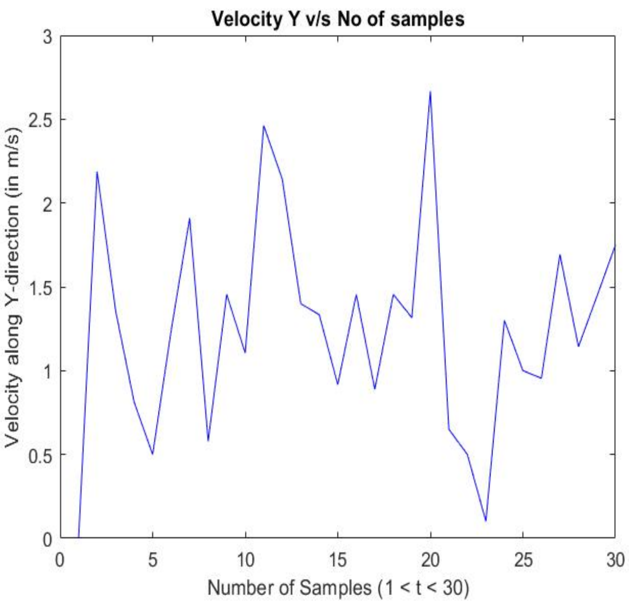

Figure 11. Velocities of person A in the y-direction.

4. CONCLUSION

In this paper, a hardware platform based on Arduino Mega has been designed and developed to collect data. The Arduino and RFID sensors were extensively utilized for data collection of human tracking. It has offered insight into how sensors can be used to track suspicious human movement or motion. This goes a long way in curbing insecurity of lives and properties and also prevent illegal intrusion of unauthorized persons in restricted areas. These collected data would later be incorporated into the modified Kalman Filter Algorithm to be developed later for future work.

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