Automated Supermarket Navigation and Guidance System

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***Abstract*—Whenever a person enters a shopping mall trolley is the first thing that any shopper would require to wander around the mall by placing items in it. The shopping arena has scaled up to a huge extent and the malls are getting bigger. As a result, how much does a person have to roam inside the shopping mall to get the desired product? The solution to this has been a brute force approach rather than an intelligent approach until now. Here we have proposed an approach to atomize the entire shopping experience of a user towards finding the shortest path to get all the commodities and without even touching the trolley to maneuver it around the mall. The desired products are entered in the phone through the mobile application and the trolley acting as a guide to move in the shortest possible path to reach the destinations.**

Keywords—Automated trolley, Navigation, QR code, Server, Raspberry Pi, PID controller, CartBot

I. Introduction

The world has seen the evolution of technology to an unprecedented extent in the past era of science and this field is still evolving beyond limits. Per this rapid advancement, the expectation of human beings for making their jobs easier has. Everyone is aware of the impact of robotics on the lifestyle of commoners. The field of robotics has spread its roots into all the domains ranging from domestic applications to rocket science. With regards to all these advancements, one such realm which has also undergone rapid advancements is shopping. This project is pivotal in achieving a much more interactive shopping experience for the consumer. Shopping malls created a sensation when they arrived in the market as people were able to obtain most of their goods if not everything, in one single place. And trolley is the first thing that any shopper would require to wander around the mall by placing his/her item in it and move forward to buy their other required items.

Technology has improved since then to many other aspects and has made the shopper's job easier for manoeuvring around the mall. Even though such advancements in the shopping arena exits, customers are often found in a state of turmoil when it comes to navigating the supermarket for the desired product. This is where this project comes into the picture. This project aims at creating an interactive robot that helps the user navigate to the required product(s) of his/her choice. The idea is to take the user input of all the products he/she requires and navigate to the required location. Such a system is required in modern supermarkets with an ever-growing diversity of commodities and increased size of the supermarket. This architecture can be taken to the next level by choosing your robot to guide one through a vast environment such as a warehouse, college campus, or any big infrastructures.

II. Objective

The objectives of this project can be divided into distinct parts such as the communication establishment, object detection and tracking, actuation, path calculation and navigation and collision prevention. The individual objectives can be explained as follows:

A. *Communication establishment*:
- Establishing two-way communication between the Raspberry pi 4 and the central processing system.
- Communication between android application and the central processing system.

B. *Interface Design:*
Designing a user-friendly android app through which the selection of the desired items as well as the movement of the trolley can be controlled.

C. *Path planning and navigation*:
Calculation of the path to the desired product(s) and redirection towards the billing section(navigation).

D. *Actuation:*
Autonomy in the motion of the robot throughout the supermarket. Intelligent following of customer by collision detection and avoidance mechanisms.

III. Design

A. Block Diagram

The proposed system is to come up with a centralized architecture for the smart trolley actuation as mentioned previously in the objectives. The entire process can be summarized in terms of a single block diagram as shown in figure 3.1. This project can majorly be divided into six main stages.

Stage 1 : Customer enters into the supermarket. If the user is new to the supermarket he/she will be given a unique customer id. If he has already visited the supermarket then he/she can use the already given customer id itself.

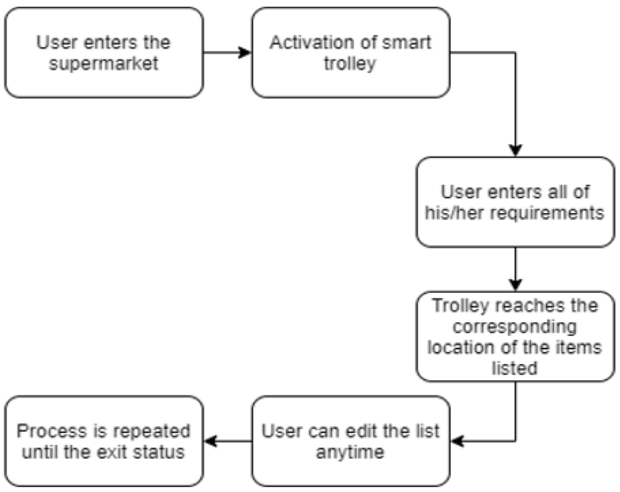

Figure 1. Block diagram

Stage 2 : Activation of the trolley includes assignment of the trolley to the particular user. Basic level of authentication is done so as to confirm whether he/she is a valid user. Costumer id is used for the authentication of the user.

Stage 3 : As soon as the trolley is activated the user is allowed to enter all his needs at once. All the items are stored in a list one after the other. Items are checked with the database simultaneously. If there is no match then a notification is displayed to re-enter the item.

Stage 4 : once the list is ready, the trolley chooses the shortest path to the corresponding to the items. It reaches the item which is nearer rather than the item that has been listed first. According to this the trolley will be smart enough to avoid the collision with other users/trolleys.

Stage 5 : this stage is optional provision provided to the user. User can edit the list of items whenever he/she wants to. There are no restrictions to the number of items that can be listed. Algorithm will be developed in such a way to adapt to the updated list and find the new shortest path accordingly.

Stage 6 : Exit status will stop the movement of the trolley. User can either stop the trolley or can send it to the billing area which will be the final destination. Exit status also has the facility of tracking down the user if in any case he/she has lost the track of the trolley.

B. *Flow Chart*

Detailed procedural approach of the proposed system can be depicted into a flow diagram as shown in figure 2. As soon as the user enters the supermarket, he activates the trolley with the help of the customer ID. This primary level of authentication helps to validate the customer. Once the trolley is activated user is allowed to enter the list of items required. Items are checked with the database for their presence in the supermarket. If not available item is cleared from the list and user is allowed to enter new item. If all the items are matched then trolley is actuated to move to the desired location. Effective shortest path determining algorithm is developed so that least amount of distance is covered during the shopping. Once the trolley is reached to the position of the first item it has to wait for the command

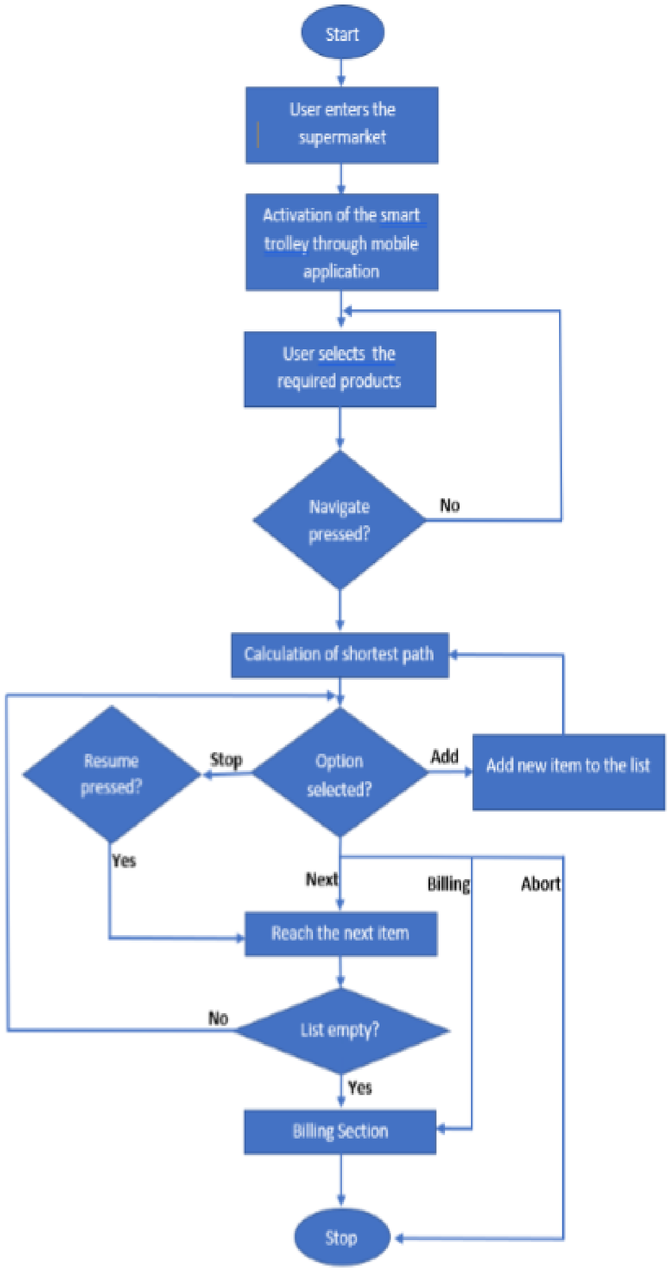

Figure 2. Flow Diagram

from the user for its next action. User will be provided with following options.

1. Next: Trolley moves to the position of the next item.
2. Stop: Trolley stops its movement irrespective of the position.
3. Resume: Trolley movement resumes from the stopped position.
4. Add Item: User can add new item to the list containing the existing items at any moment.

5. Billing: Trolley reaches the billing station automatically.
6. Abort: Shut down the complete system. User has to take the trolley manually.

Apart from these facilities there is also option for the user to make the trolley to return to the position of the user in case of losing the track of the trolley. The entire process is centralized with single processing unit which acts as the server for the different hosts (Trolleys)

IV. IMPLEMENTATION

The project is trying to focus on implementation of the entire working of the proposed system. It is a nice blend of both robotics as well as software application. Detailed integration of the hardware and software along with the procedural execution can be interpreted as follows:

A. *Authentication of the user with their respective trolley:*

In order to link the trolley to its user, authentication needs to be done. As soon as the costumer enters the supermarket, he needs to be authorized to get access to any one of the trolley. Customer is asked to enter the passkey to get the access. Each customer will be provided with the unique key which will then be associated with the trolley of his/her choice dynamically. This architecture makes sure that at any given point of time, there will be unique pairs of trolley and its user.

B. *Taking the input from the user through mobile application:*

User interface will be an Android application, provided to the customers through a QR code. QR scanner will be placed at the entrance of the supermarket. Interface displays every item to the user section wise. User has to just select the products that are required and proceed with the navigation.

C. *Calculation of the shortest path:*

A new customized algorithm has been developed on the basis D* shortest path algorithm. The algorithm calculate path for n! Combinations of the total number of goals and select the shortest among them.

D. *Movement of the trolley:*

After the calculation of the shortest path, an array of coordinates is generated, which is the path that trolley should follow. Gyroscope is used for the proper movement and alignment of the robot. PID controller is used for the alignment of the trolley. Detailed explanation of the PID controller is given below.

PID Controller

The PID controller designed for the straight path motion of the bots has a set of equations which are implemented on the values provided by the gyro sensor. Any PID controller that is designed for a kinematic has three PID constants namely proportional constant (Kp), Integral constant (KI) and a differential constant (KD). These equations are defined in the control system domain as follows

Proportional = 1

Differential = error

In our project, we are not dealing with sum of errors of the values provided by the gyro sensor. Thus the integral part of the PID is neglected and hence our controller is defined as a PD controller. We have fixed these values for the respective constants

- Proportional constant, Kp = 50
- Integral constant, KI = 0
- Differential constant, KD = 1

The PID equations involving these constants that are used for our application are

For left wheel PD

valueL = Kp × proportional + KD × differential

For right wheel PD

valueR = Kp × proportional − KD × differential

IR array is used to maintain the record of the blocks that are covered by the trolley. This data is matched with the path given as the input. Hence the position of the trolley can recognize for further processes.

E. *Flexibility during navigation:*

Several flexible services are provided to the user during the navigation of the trolley. The services are as follows:

1. Next: Move to the next item.
2. Add item: New items can be added to the existing list. This can be added only when the trolley reaches the previous goal. The list will be updated, and new shortest path will be calculated.
3. Stop: User can stop the trolley whenever necessary. This allows the user to pick up the items that he sees during the navigation. Trolley will be in idle state until resume is clicked.
4. Resume: The trolley will resume its motion and automatically and move towards the desired item.
5. Abort: Process can be aborted at any time. If aborted the user must manually take the trolley to the billing station.
6. Billing: User can send the trolley to the billing station at any time during the navigation

V. RESULTS

A. *Hardware results:*

Miniaturized structure of a simple supermarket structure has been created for the demo purpose. Each block of tile represents each cell in the matrix. Figure 3 gives a proper representation of the supermarket. Red block represents the obstacles through which the movement of trolley is restricted. Products are mentioned in green cones. Yellow tile indicates the start and the blue tile represents the billing counter.

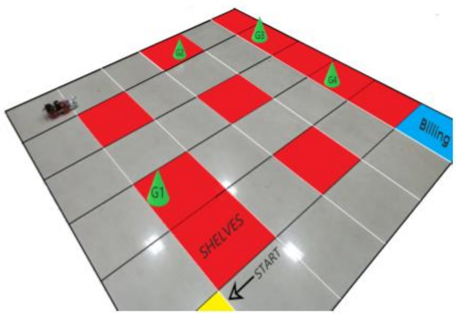

Figure 3. Miniaturized Supermarket Layout

Top view of the assembly is as shown in the figure 4. Lead acid battery Is placed in the middle to balance the weight. It weighs around 700g. Power bank is placed at the back end. Raspberry Pi will be facing front. Type C cable runs from the power bank to the Raspberry Pi input port. Motor driver is placed in between battery and raspberry pi. Wheels are attached to the axis with permanent glue to have high precision in the movement. Gyroscope is placed in between the chassis so that it is not disturbed by any other component.

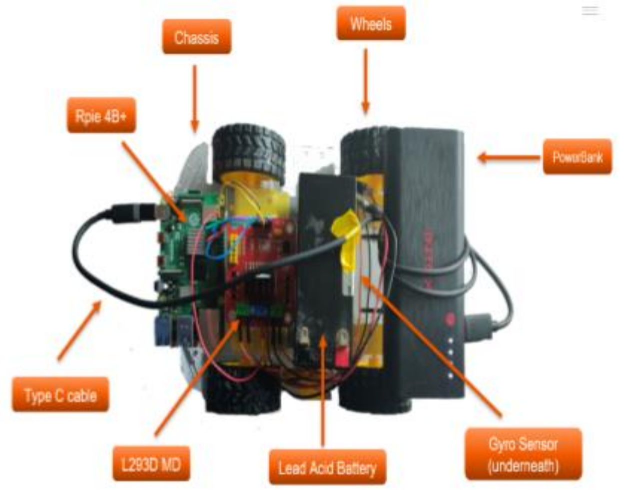

Figure 4. Top View of the Assembly

Figure 5 depicts the front view of the robot. IR Track is used for precision in movement of the robot. IR array is used to detect the track. This track will be imprinted on the floor of the entire supermarket. As we can see there are 8 IR pairs with calibration ports for each one of them.

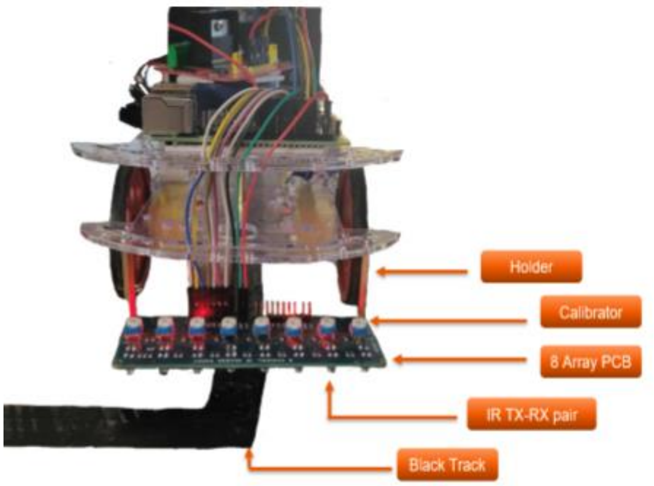

Figure 5. Front View of the Assembly

Lighting affects performance of the IR array. Therefore, we have designed an IR shield as shown in figure 6 which prevents the influence of external lighting. A strip of LED is placed inside the shield. This ensures the constant lighting for the IR array. Proper readings can be taken from this arrangement. The LED strip is driven by a regular 9V battery.

B. Simulation Results :

Simulation is performed on the python platform using turtle graphics. Turtle has three attributes: location, orientation (or direction), and pen. The pen, too, has attributes: colour, width, and on/off state. The turtle moves with commands that are relative to its own position, such as "move forward 10 spaces" and "turn left 90" . The pen carried by the turtle can also be controlled, by enabling it, setting its colour, or setting its width. We have mimicked the action of the trolley in the supermarket with the help of turtle graphics. Circle represents the trolley and the path traced by the trolley is tracked with a line. Impression of the circle is left on the place where the trolley stops (in front of the desired products). Every option that has been provided is depicted in the simulation. There are different scenarios that a user may encounter while using the system. Major scenarios are tested, and simulation results are obtained accordingly.

1. Scenario 1: When user fails to scan the proper QR code. When user scans the QR code present on a particular trolley, it gets authenticated by the server. If he/she uses this on any other Q R code which is not relevant or QR code that has been disabled due to improper functionality of the trolley, then user will be notified with a not authorized pop-up as shown in figure 7.

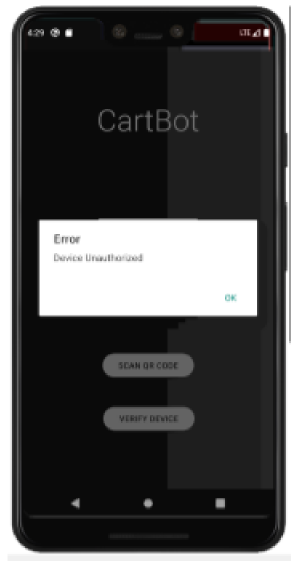

Figure 6. Validating an Un-authorized device

2. Scenario 2: Ideal Working Condition This is the scenario where everything goes right, and user collects all the products required by the user. At the end of the process he/she will be automatically taken to the billing section if no products are left to purchase. Note that he/she can also add items in the middle of the process if required.
3. Scenario 3: Emergency This scenario explains the functionality of the billing option. For example, assume that a user selects 5 products and starts shopping. After collecting 4 out of 5 products, user might want to finish the shopping or in the middle of shopping if any emergency appears for the user, they can press the billing option provided in the application. This will take

the user directly to the billing section from their current position, ignoring the rest of the products.

4. Scenario 4: Aborting the system

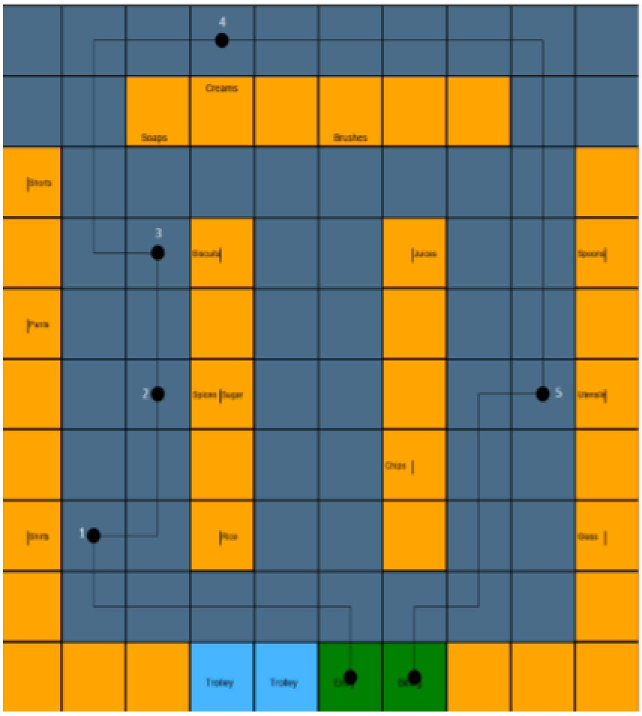

Figure 7. Simulation Output for Scenario 2

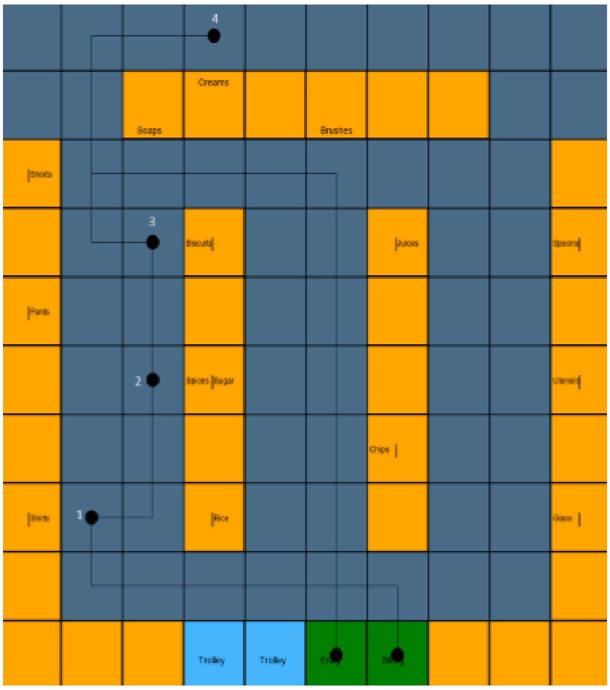

Figure 8. Simulation Output for Scenario 3

Figure 9. Alert screen for Abort

CONCLUSION

After successfully procuring all the products needed and the customer clicks the "Billing" button for the trolley to reach the billing section. This action can be considered as the cessation of the product cycle. Since the inception of this novel idea to the implementation of it into a product, the entire process has been highly involving and educational. Different pillars of this project such as the GUI, Server, and the hardware have evolved and been improvised at every step of the way. The simulation serves as a testimony to all the possible shopping scenarios. The hardware demonstration vindicates how once can shop without any monitoring of the trolley. The application hence provides control and interface to the user in the most efficient way. All these factors put together culminate to demonstrate the optimum working of the project in its ecosystem. The product has been subjected to various scenarios and test cases to check for its robustness and versatility. The algorithm has been improved and made effective to deal with a countable infinite number of goals. The robot which depicts the trolley has been scrutinized to various physical parameters and has been improvised for stellar performance. The entire project has achieved its objectives and fulfilled the mission statement.

FUTURE WORK

The future scopes of this project can be broken down into various compartments involving a broader spectrum and a narrow spectrum of elements included in its development. The plethora of technologies available at our disposal in the 21'stcentury is overwhelming but yet subtly elusive during integration. Factors such as cost, developmental procedures and viability come into the picture when planning on upgrading the product. Coming to the physical and tangible attributes of the hardware compartment of the project. The following domains can be improved in the near future for enhanced performance.

1. Battery
2. Power train

3. Sensors
4. On-Board processor
5. Connectivity

With regards to the software architecture of the project the following amends can be made to increase the efficiency and speed of execution. Also, a refinement of the software inevitably leads to better user experience as well.

1. Refined Algorithm
2. Better UI
3. Cloud support and User database for mobile app
4. Troubleshooting Abilities
5. Updates and bug fixes

REFERENCES

[1] ”A Pilot Study: Development of Home Automation System via Raspberry Pi” by M. Mahadi Abdul Jamil and M. Shukri Ahmad, 2nd International Conference on Biomedical Engineering (ICoBE), 2015.

[2] “A Self Stabilizing Platform” by Vladimir Popelka, Proceedings of the 2014 15th International Carpathian Control Conference (ICCC), 2014.

[3] “Design of Two-Wheel Balance Car Based on STM3” by Guoping You and Wanghui Zeng, 9th International Conference on Information Technology.in Medicine and Education (ITME), 2018.

[4] “A New Approach for Line Following Robot Using Radius of Path Curvature and Differential Drive Kinematics” by Jitendra Singh and Prashant Singh Chouhan, 6th International Conference on Computer Applications In Electrical EngineeringRecent Advances (CERA), 2017.

[5] “Robotics, Vision and Control” by Peter Corke, textbook, 2nd edition, Springer publications.

[6] ”Study of Kalman Filtering Algorithm and Fuzzy PID Controller for the Coriolis Acceleration Tester” by ZHANGJian, GUOLei, WEI Shimin, SONGYuan and ZHANGYin, 35th Chinese Control Conference (CCC), 2016.

[7] “Moving Object Detection and Tracking in Indoor Environment” by Shucai Wang, Liying Su, Kim Wang and Yueqing Yu, Proceedings of 2011 International Conference on Electronic Mechanical Engineering and Information Technology, 2011.

[8] “Tracking of Moving Objects With Regeneration of Object Feature Points” by Igor I. Lychko, Alexander N Alfimtsev and Sergey A, Global Smart Industry Conference (GloSIC), 2018.

[9] “Edge based Moving Object Tracking Algorithm for an Embedded System” by Kai Xiang Yang, Ming Hwa Sheu A, IEEE Asia Pacific Conference on Circuits and Systems (APCCAS), 2016.

[10] ”Dual Model Learning Combined With Multiple Feature Selection for Accurate Visual Tracking” by Jianming Zhang,Xiaokang Jin,Juan Sun,Jin Wang and Keqin Li, IEEE access journal article, 2019.

[11] “Simulation Of A Human Following Robot With Object Avoidance Function” by Nattawat Pinrath and Nobuto Matsuhira, 12th South East Asian Technical University Consortium (SEATUC) 2018.

[12] ”An Adaptive 2D Tracking Approach for Person Following Robot” by Shenlu Jiang, Meng Hang, Ling Li and Toiyong Kuc.

[13] ”Development of the Human Following Robot Control System Using HD Webcam” by Jutarat Jommuangbut and Kiattisak Sritrakulchai, International Symposium on Computer Science and Intelligent Controls (ISCSIC), 2017.

[14] “Review of Geometric Distortion Compensation in Fish-Eye Cameras” by Ciaran Hughes, Martin Glavin, Edward Jones and Patrick Denny, IET Irish Signals and Systems Conference (ISSC), 2008.

[15] “An Approach for Fully Automating Perspective Images Based On Symmetry and Line Intersection” by Robin Tommy and Mohan S, International Conference on Image Information Processing, 2011.