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# A Design and Development of Baggage Sorting Robotic System at the Airport

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**Abstract**: The automation has a vital role in making the execution faster with better efficiency. In airport luggage sorting system the automation can be very helpful in sorting and identifying the luggage economically at faster rate. The authors have tried to implement a novel technique not only in terms of applying the robotic system for sorting but also a new sorting technique implemented with robot. The techniques like radio frequency identification (RFID) detection-based sorting with robots have been a challenge to implement. Therefore, the proposed technique called as Voltage ID (VID) mapped based sorting can be easy to implent. The wide range of voltage IDs can be generated with respect to varying baggage weight on different cities conveyors at the airport. This developed system can be applied for 20 different cities without the use of additional board. The authors have tried to make the system flexible so that it can be implemented not only in airport industry but also in the bus industry and related industries where luggage handling is involved.

Keywords: Robot; Sorting; Automation; Airport; RFID.

## 1. Introduction

People not only want to fly but want to take benefits of aviation industry, which are very lucrative nowadays. Since people want to take benefits of the demand of air travel has increased many folds, therefore as the need is the mother of innovation the concept of conventional baggage handling is losing its importance in this present era, where the air travel is in huge numbers. With this a research problem arises of using of automatic system in luggage handling. The use of automation and robotic systems has gained wide significance in fields of medical surveillance as well as in manufacturing including many other industries.

Robotics is a breakthrough tool in airport industry. Still its usage it's not wide that's why every aviation firm is looking towards use of fully automated system or the robot. The main objective in this concept here is to do build a system which can do sorting of luggage's according to flight destination. The purpose of sorting can be fulfilled by integrating the robot arm with a microcontroller on a single printed circuit board (PCB) board. By increasing the robotic arm and the size of microcontroller we can do the number of cities up to maximum of 20 without any hardware circuit.

Until now either the transport robots were used or the conveyor belt robotic system by ABB robotics is used. We have tried to minimise the automation till sorting but it can be applied anywhere in airport arena. The idea is to do sorting and put the luggage at the desired location upon the weight to voltage ID (VID) generated at the liquid crystal display (LCD) screen. The air travel has eased our life by using many conveyors, automated guided vehicles (AGV's), fleet management, etc. The information taken by the World Bank figures out the consolidated jam in the following figure both international and domestic. The source for organisation for civil aviation, ICAO1).

The facts clearly identify how much is the worldwide increase in this regard with along percentage increase or decrease. There are few irregularities but it can be compensated easily. A comparative increase of passengers over the years is been shown in Fig.1. The graph shown has No. of passengers on Y-axis and years on X-axis. As the above graph shows significant increase in air travelling, in coming years' demand can be forecasted.

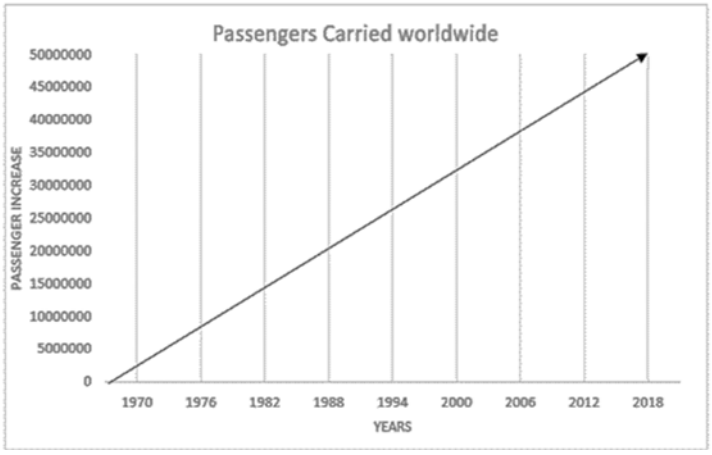


**Fig.1:** Passenger carried Worldwide over the Years (Source: Data from the World Bank, 2017) [2)]

The data is continuously analysed by International air transport association (IATA). Previously in 1990's at the airport of Denver a comprehensive system of automation was implemented where the AGV's were used but it proved to be a complete failure and conventional luggage handling system proved to be stand apart3-4). So, the question arises why we need such a system? Many aviation industries submitted their report in SITA (an aviation industry) that manual labour is injured while loading and unloading tonnes of baggage's, also the hassle-free movement is restricted as per the reports, therefore it needed a more efficient and flexible system along with removing the complexity of the system. But before that the authors have been through comprehensive literature review gone till date.

Therefore, by above information it's clear that the baggage handling system needs to be updated. It's very challenging to change the entire baggage handling system since it's not easy to cope up with the increasing demand.

## 2. Literature Review

This section briefly describes about the different sorting and baggage handling systems and a combined literature review is shown in tabular form. The analysis can be done after going through all the systems. The baggage / parcels carrying system is an automatic system which can reduce the use of manpower for baggage parcels handling and easily adapt to an airport or any baggage / parcels handling organizations process[5)]. The conventional luggage carrying system begins as the traveler checks in his/her luggage item(s) at the airport. The check in data of the passenger is scanned using a mobile phone or the computer. Another checking-in choice is own-service check-in-kiosk at the airports[6)]. In areas especially where we need repeated transportations, AGV's payoff. Repeated designs or the order of arrangement can be found in industry-based warehouse domain. An example of delivery areas can be found in the arena of warehousing with crossed based centre of docking[7)]. AGV's can be a good fit for distribution centres eliminating the need for large spaces aligned to internet commercial operations every now and then use AGV systems for amenities and making less use of the labour intensity[8)]. Vanderlande- one of the leading matters carrying systems and supply chain automated companies has come up with a novel system called FLEET[9)]. This system of AGV's bypasses the necessity for fixed-based conveying and sortation systems in a luggage carrying arena at the airport[10)]. Automated movement and sliding of robots in the airport area is a prime target of the IMULE project[11)]. Another research as in Table 1 review no. 2 uses conveyor and FLEET for handling and the technique applied such as bar code and RFID[12)]. Another autonomous robotic system is the unsupervised sorting which uses a new decision- making module such as convolution neural networks (CNN) and standard clustering algorithms [13)]. SITA's LEO robot is an image processing detection based robotic handled systems where image processing system captures size, weight, type etc.[14)]. Another one can be plaintext detection-based sorting as in review no. 3 is an efficient automatic luggage handling system according to the set of information for identification[15)].

The problem of automatic sorting has a long history in industry, with the first tomatoes sorting system dating back to the 70's[16)]. Since then, it has received a lot of attention, with important focus on combining computer vision and robotics manipulator to solve the pick-and-place task. Although it was among the first robotics tasks, designing a pick-and-place application is challenging and requires solving multiple subtasks. If the objects to be sorted are cluttered, the system first needs to segment the scene and identify the different objects. Then, the systems must use various sensors (2D or 3D cameras, color sensors, bar code readers) to gather data about the different objects[17)]. These data are used to find a grasping strategy for the object and to decide where to place the object. Naturally, all along this process, smart motion planning and control is also required. Several implementations have

considered the problem of recognizing each object as a member of a known database, and sorting it according to an associated predefined rule.

In RFID markers are used to recognize and sort objects. An implementation of a surgical tools sorting application using barcode reading and template matching to find and sort objects from a cluttered scene is proposed in. Finally, the application presented in[18] sorts real-world objects (usb, glue-stick,) with a serial manipulator using template matching. Supervised classification. Many robotics supervised classification applications sort objects based on simple rules (thresholding) applied to simple features. For example, [19] all use color features extracted from either images or color sensors[20] extend these approaches by adding shape features.

During the previous couple of years, the demand and therefore the application of business robots have seen a forceful uplift. within the producing operations the artificial intelligence technology has reduced the assembly price, material wastage and accelerate the productivity by reducing the cycle time and giving higher quality. they're getting used for varied activities like painting, assembly, welding, choose and place and area unit getting used in an exceedingly very wide selection of applications. The essential reasons for such a high demand of those industrial robot's area unit their accuracy and their work capability[21]. Robots have a good vary of applications within the producing sectors thanks to its flexibility and programmability. The sensing range of RFID enabled robotic system can also be improved in order to avoid any misread[22]. There are dozens of advantages which will be extracted with the assistance of associate degree industrial robots. they will provide results with high preciseness and stripped-down errors[21]. Strategic planning can also be involved in order to improve the safety aspect of the robotic system[23].

Waste is a massive urban problem, considering its complex impacts, which include aesthetics, health, economic, and environmental losses that lead to natural disasters[24]. Waste sorting and composting activities are also part of the waste management 3R (reduce, reuse, recycle) principle. These activities involve sorting waste between inorganic and organic matter and then composting the organic fraction in a facility. The inorganic waste is recovered and reused to obtain the remaining economic value of the waste. In the Jatibarang landfill and ITWSs, inorganic waste is taken by scavengers and sold back to the stalls. This can help reduce the amount of waste in landfills[24]. Various inventory optimization techniques can also be implemented to make the sorting process fast[25].

## 3. Design of the Robotic System

This section presents authors approach in detail. The proposed design of the system is shown in Fig.2. Based on the mentioned conceptual modelling the further robotic system is developed. The idea was to develop a sorting system based on the sorting technique such as vision or RFID detection-based sorting with robot (mean sorting done by RFID tag reading and detection with robot i.e., details of the owner of the baggage will be detected by the robotic system).

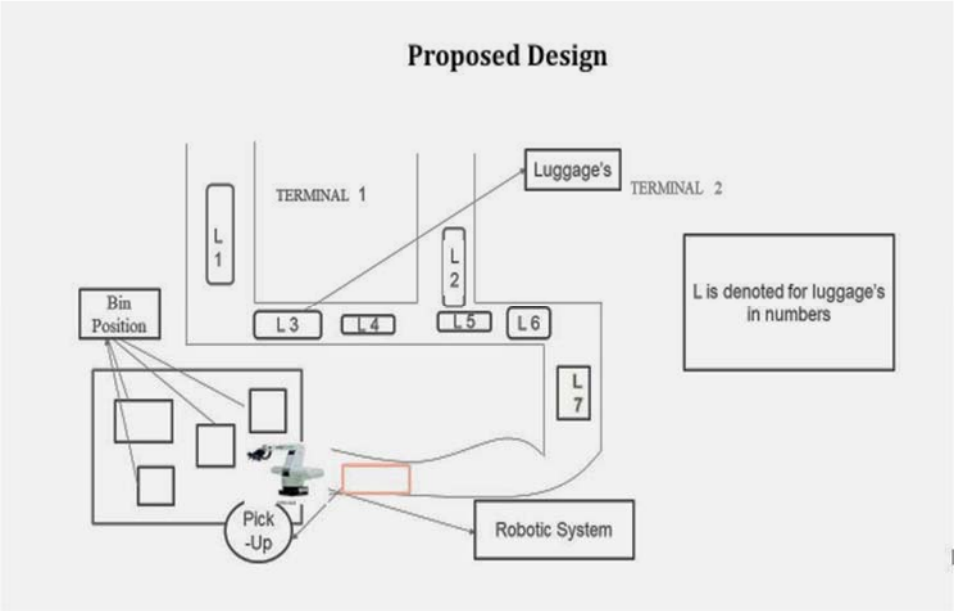


**Fig.2:** Schematic diagram of Proposed Design

After a strong comprehensive literature review (Review no.2 & 8) further experiments were conducted by the authors, robotic arm was programmed, and experimental setup was developed which is being discussed in following sub-sections. The technique is very clear to do sorting of the baggage according to a specific sorting technique and specific robotic system. The bin number is restricted to three since the robotic arm is chosen for only demo purpose. The PCB board or the microcontroller is set according to the robotic arm. Therefore, beforehand a simulation block diagram for the servo motor programming is drawn in ProfiCAD as shown in figure 5. The controller description along with motor used and the working is discussed in following subsections where an idea to develop an autonomous sorting system on a single ADC channel is implemented. The ADC channels can generate ids up to the sensitivity of the voltage. The criteria for the system is changing of weight into the voltage through the ADC channel. The control of robotic arm is integrated with servo motors.

### 3.1 Experimental Setup of Board and Robotic Arm Assembly

In this section the authors have discussed about the experimental board, microcontroller used, the robotic arm assembly used, the microcontroller type and the final setup circuit. The integration of hardware board with robotic arm has been shown and simulated in 3D software. Before that simulation of the circuit is done and robotic arm set up is programmed in Embedded C as shown in figure 5. The four servo motors are programmed according to pulse width modulation (PWM) duty cycle set. The angle rotation can also be programmed and saved in microcontroller. PWM: 7.0 means at 0-degree position, PWM: 3.0 means +90- degree position, PWM: 12.0 means -90 -degree position, PWM: 5.0 means +45-degree position. It is common for all servo motors. Now, the required PWM at a time will be given to the corresponding servo and next and so on till the whole process is completed. The weight to voltage ID generated on LCD screen will depend on the pod values provided (0-5 Volts). The simulated model will place the baggage to the conveyor according to the voltage ID data generated, as shown for pick position 0 volt, placing at Chennai conveyor 2-3 volt (2000-3000 mV), placing at Mumbai conveyor (1000-2000 mV), placing at Delhi conveyor (0-1000 mV). Arm control can be 180 degrees' maximum as base or the right arm control the servos and are set accordingly. The baggage's are picked by the robot at -90-degree position.

### 3.2 Main parameters for Designing Robotic Arm Assembly

The main parameters for the design are just used for trial, evaluation and demonstration purposes. The selection of microcontroller and acrylic sheet robotic arm is selected. The idea is to just give the concept and technology for the system so that sorting is performed by the robot without any hindrance. Certain assumptions were also made beforehand for the analysis of the presented model. They are:

1. The robotic arm will be used for automated sorting.
2. The robot will be installed at the dispatch location.
3. The technique for sorting can be RFID, bar code or some new technique.
4. An industrial robot already installed in any lab can also be used for programming and implementation.
5. The sorting of baggage to be done according to cities.

To check the feasibility of the robotic system, the criterion set by the authors was simple to develop a robotic system which can be used for sorting of the baggage at the airport and to track the performance of the system.

### 3.3 Hardware Board and Set-Up

The final selection of hardware circuit development board is decided, simulated and implemented using MPLAB IDE. MPLAB IDE is a very powerful windows-based graphical user interface (GUI) software tools developed and offered by MICROCHIP for designing, simulating and writing, debugging and programming codes into the chip hardware and also provides an easy to implement software solutions for such critical tasks. The proposed system consisting of an 8-bit microcontroller PIC18F4550 having 11 numbers of inbuilt 10-bit ADC channels for analog feedback measurement, up to 4 channels of 10-bit PWM outputs, which can be used in both PWM and EPWM (enhanced PWM) modes to control the 4-DOF motion of dc servo motors of Robotic Arm as per the instructions provided in the software. Additional I/O pins configuration can be done either inside or output by MPLAB software during embedded code generation. All the required power supply, controller unit and relays are implemented into a single compact board for easy replacement and installation at Airport sites during service. A single system can handle sorting of baggage's of up to 3 different cities and is implemented here for trial, design and evaluation purpose, which can be further implemented using big sizes of arms with increasing the number of cities of up to max. 20 using the same board without any addition of hardware circuit. Only writing and adding the new proposed cities.

### 3.4 Robotic Arm and Assembly

It was quite heavy task of selection of robotic arm. Metal base frame with acrylic sheets is used for making robotic arm having 4 degrees of freedom, consisting of 4 nos. of small dc servo motors fitted at 4 different edges of

the arm. The jaw length is approx. 50-60 mm. System has a provision to transfer the working data from machine to system either by wired or wireless method wherever needed, and which is to be implemented in both hardware circuit and software. The servos motors used in the customized robotic arm is SG90. A CAD model for simulation purpose is shown in four different positions in Fig.3.

The drawing is made for the simulation purpose along with the four pick up positions are shown. Further the 3D model of the complete system is shown in Fig.4.

**Fig. 3**: Robotic Arm with Microcontroller.

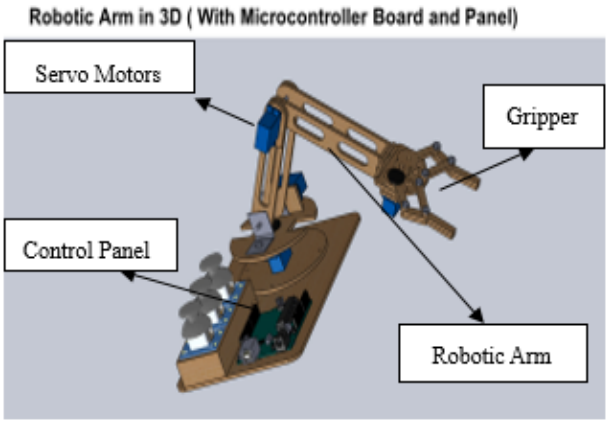


**Fig.4:** Robotic Arm Assembly in 3 D (With Panel and Microcontroller).

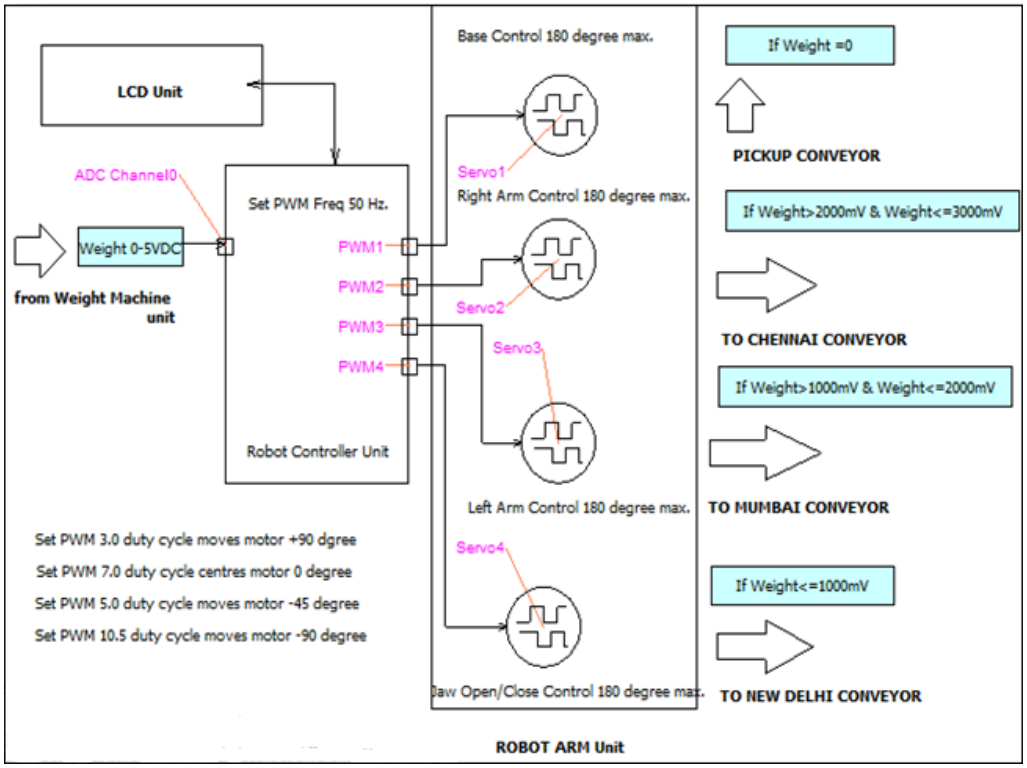


**Fig.5:** Simulation block diagram

## 4. Simulation

The simulation block diagram is shown in Fig.5, first the bags will be weighed in kg, using weight sensor arrangement. Then the corresponding analog signal 0-5 volt will be fed back to the microcontroller ADC unit for further measurement and calculation of visitor's ID and location as per their specific items weight. The same data will be implemented for all city worldwide. And this data will be placed into the server to get the actual identity of the visitor. At the same after the above process a unique code or ID will be displayed on LCD screen mentioning the Location city and country too. 4 nos. of servomotors can be used as in picture and can be programmed to pick up the baggage's and accordingly transfer them automatically or autonomously to the desired conveyor of the city. So, there will be a platform for installing the system where main incoming conveyor first takes the baggage and places them into the weighing machine so that to get ID and location. On the other side of the weighing machine robotic arm system will be placed at the centre and the provisional conveyors can be installed in numbers as required. Once programmed as per number of cities and name it will work autonomously.

## 5. Results and Discussion

After testing the robot on positions at voltage values from 0- 5-volt ADC, a testing is done for different voltage ID's. As shown in figure.6 by allocating the Mumbai location at a definite voltage value picks the porotype and places it to the Mumbai location as per the ID generated on the LCD screen. A comparative analysis of the same at different voltage ID's is depicted in Table 1. From results a comparative analogy can be seen that for the Chennai, the conveyor is also the same as to other locations like Delhi and Mumbai. Some tests have shown the same values as the simulation values.

The repeatability of robot of doing the task is also checked. The prototype was taken as circular item which can be picked and placed accordingly. Since the model is just for demonstration purpose therefore this much flexibility may be accepted. One of the objectives was to track the performance of the system. It is found from the results that, the simulation results were the same as the experimental results as shown in Table-1. The demonstrative system programming and the circuit model-based programming were compared and validated by taking different readings. The different readings show changes if the pod value changes (0- 5 volts). The allocation of the cities is such programmed that the accuracy and performance is 100%. Therefore, the reliability of the system has no doubt. Once it is installed at the airport the same may be checked in live situation.

Table 1. The Comparative Results

| Weight – Voltage ID | Location | Simulation Values | Experimental Values (1-1000 mV) | Performance in % |
|---|---|---|---|---|
| 850 mV | Mumbai | 1-2 V | 850 mV | 100% |
| 75 mV | Delhi | 0-1 V | 75 mV | 100% |
| 1331 mV | Chennai | 2-3 V | 1331 mV | 100% |
| 1250 mV | Mumbai | 1-2 V | 1250 mV | 100% |
| 250 mV | Delhi | 0-1 V | 250 mV | 100% |
| 1275 mV | Chennai | 2-3 V | 1275 mV | 100% |

## 6. Conclusion and Future Scope

The authors have tried to make this robotic system not only specific to airport but also to other luggage carrying transportation vehicles such as buses, railways etc. The robots may be useful and economical for sorting the luggage at different locations in the airport with better efficiency. The authors have tried to simplify the setup. It is established from the results that the system can be implemented at the airport without the use of any sensor and with least human interference. With suggested technology a single robotic arm with a single hardware board can be implemented for 1000 IDS and up-to 20 maximum cities. The authors have given a demonstrative system and can be asset for the airport industry and opens research area for the future researchers in this field.

### Nomenclature

| | |
|---|---|
| *ADC* | Analog Digital Converter |
| *LCD* | Liquid Crystal Display |
| *ID* | Identification |
| *CAD* | Computer Aided Design |
| *GUI* | Graphical User Interface |
| *PWM* | Pulse Width Modulation |
| *PCB* | Printed Circuit Board |
| *RFID* | Radio Frequency Identification |
| *AGV* | Automated Guided Vehicle. |

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