

# Color Guided Vehicle – An Intelligent Material Handling Mechatronic System

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**Abstract—** Industries established earlier were using material handling systems which were time consuming, less efficient, demanded more manpower, which ultimately increases the manufacturing lead time. As a result of that, productivity reduces. To overcome these demerits, industries need an efficient system, which can be automatically controlled. Such concept has been demonstrated in this paper. Vehicle has been developed by using concepts of electric drives, ElectroPneumatics, machine vision, microcontroller (Arduino) and Zigbee wireless module. For human machine interface, Matlab GUI toolbox is used (windows 8 touch screen) in this paper. The color guided vehicle (CGV) will convey the object to the desired destination according to its color. Moreover the undesired object will be rejected instantly by pneumatic system. Such a vehicle or a system works as a color detector automated guided vehicle. Therefore here developed CGV can be considered as an intelligent material handling Mechatronic system.

**Keywords—**Machine Vision; Zigbee wireless Module; Arduino Microcontroller; ElectroPneumatics; Mechatronic System

## Abbreviations:

CGVCU:	Color Guided vehicle control Unit
CGV:	Color Guided Vehicle
GUI:	Graphical User Interface
C1 & C2:	Wireless camera 1 and 2
PS1 & PS2:	Proximity Sensor 1 and 2
WM:	Wiper Motor
S1, S2, S3:	Solenoid 1, 2 and 3
DA & SA:	Double acting and single acting cylinder
PSD:	Position step diagram
I/O:	Input output
NC & NO:	Normally Close and Normally Open
RGB:	Red Green Blue
HMI:	Human Machine Interface
tx / TX:	transmission pin / Unit
rx / RX:	Receiver pin / Unit
XCTU:	Software name used for Zigbee
COMPORT:	Communication Port Created by Arduino

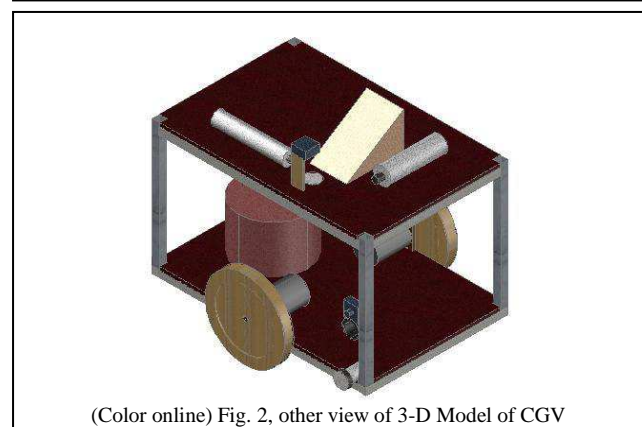
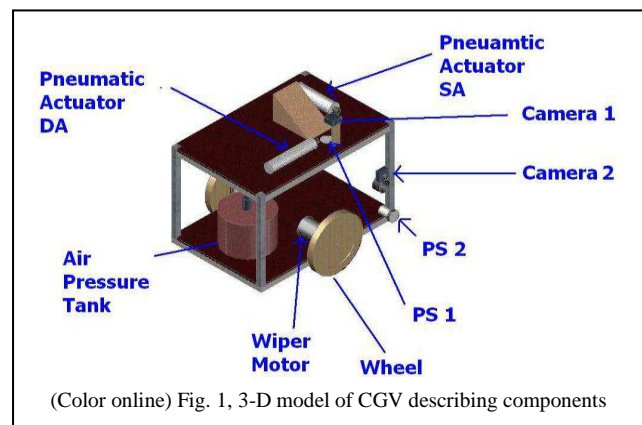
## I. Introduction

In this paper two interrelated block diagrams came into existence which are shown and described in next subtopic. CGVCU is the control unit and CGV is a mobile material handling unit. It can be observed that CGVCU is the transmitter unit and CGV is receiver unit. Combination of CGVCU and

CGV makes a complete wireless Mechatronic (intelligent) material handling system. One can understand that Matlab GUI along with windows 8 touchscreen will constitute HMI. CGVCU includes a microcontroller (Arduino UNO) unit, Zigbee wireless module (as a transmitter), a laptop (windows 8 touch screen model), and Matlab academic software. CGV includes a microcontroller (Arduino UNO), Zigbee wireless module (as a receiver), two wireless camera, two wiper motors, pneumatic unloading system, pressurized air storage tank, small compressor unit, DC power source (+12 volts).

## A. Objective and motivations of CGV

Some industries are trying to get rid of lazy workers. Due to those workers, their production schedule gets failed, which results in poor lead time and productivity. In addition with that workers are not comfortable with fully automated systems. To overcome above mentioned problems, it is desirable to design a user friendly fully automated low cost material handling system.



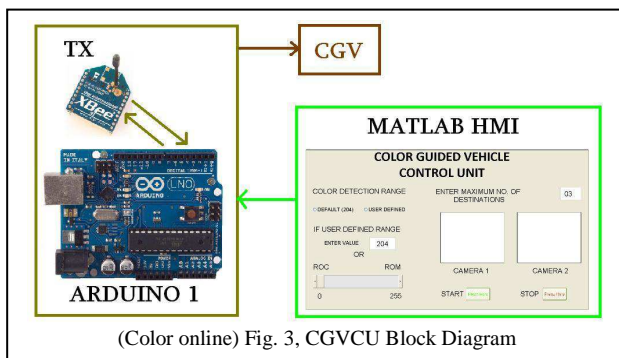
Soliton has developed a color sorting system for pencils. [22] But that system is stationary, so authors have decided to make it movable, so that bulky and costly conveyors can be avoided for material handling.

### B. Working principle of CGV

CGV being an intelligent system, is controlled by a Laptop and a microcontroller. User will put an object on the CGV. PS1 will sense the object and send a signal to CGVCU (with the help of Zigbee). Then C1 will take a picture of that object. That picture will be sent to the laptop of CGVCU. If that object's parameters are desired (i.e. 'Valid Object'), then wiper motor will start rotating and CGV will start moving straight forward. By 'Valid Object' we mean that color of the object is one of the three pre-decided colors – Red, Green and Blue. If on the way there is a destination box then PS2 will sense it and CGV will stop. C2 will take a picture of the destination which is ultimately conveyed to CGVCU. Matlab will compare both the images (from C1 & C2). It means that RGB values of object and destination box are to be matched. If both are getting matched then ElectroPneumatic system will be activated and object will get unloaded. If both the colors are not matched then CGV will start moving again in search of the other 'valid' destination box till it finds out or until maximum number of destination entered earlier by user has been reached in the counter. In a nutshell this vehicle's movement is guided by various colors, so it is called color guided vehicle. (Refer fig. 1 and 2)

### C. Block Diagram Representation of CGVCU

In the fig. 3, Zigbee (TX), Arduino1 and Matlab HMI screen are shown. User will specify input values accordingly using Matlab HMI. Computer will provide signals to Arduino. Zigbee transmits those signals to CGV. TX pin of Zigbee is connected to RX pin of Arduino and vice versa. Laptop (with Matlab HMI) is connected with Arduino via USB to USB cable.



### D. Block Diagram Representation of CGV

Fig. 4 shows three interconnected units. The first unit is a signal receiving and processing unit (unit 1). It contains Arduino UNO and Zigbee Rx. This unit accepts the signal coming from CGVCU. Second unit is input unit (unit 2) which contains two wireless cameras and two proximity sensors. This unit will give inputs to unit 1. Based on signals coming from CGVCU and unit 2, unit 1 generates outputs at its output ports. These output signals will be fed to unit 3, which is an output unit. It contains two wiper motors (connected in parallel) and three solenoids.

### E. Components connection with Arduino

Table 1 shows system's I/O configuration. First column shows names of the components. Second column represents type of mode. Here, I/P can be represents an input mode and O/P can

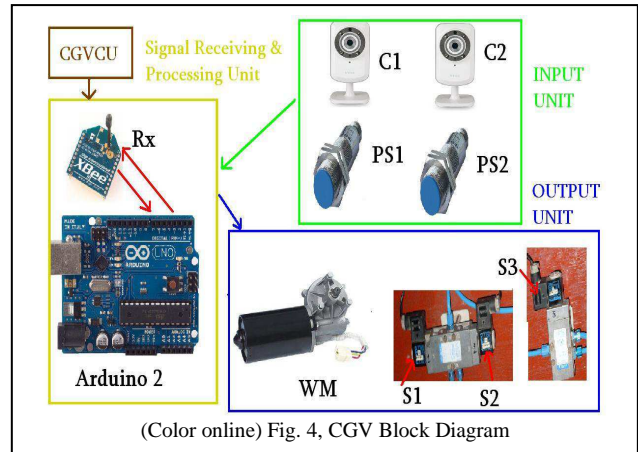


Table I, System I/O Configuration

System Components	Mode	Arduino 1, Pin No.	Arduino 2, Pin No.
Proximity Sensor 1	I/P	NCN	2
Proximity Sensor 2	I/P	NCN	3
Wireless Camera 1	I/P	NCN	NCN
Wireless Camera 2	I/P	NCN	NCN
Zigbee Transmitter side	TX & RX	1,0	NCN
Zigbee Receiver side	TX & RX	NCN	1,0
Wiper Motor	O/P	NCN	10, 11
Solenoid 1,2 & 3	O/P	NCN	6, 7, 8

be interpreted as output mode. Column No. 3 & 4 shows which component is connected to Arduino 1 & 2 at respective pin numbers. For example, consider row1, proximity sensor 1 works as input and connected at Arduino 2 at pin no 2. Here it is not connected with Arduino 1, so NCN (not connected) is mentioned at that place. Mind well, Arduino 1 belongs to CGVCU, means at the transmitter side. Arduino 2 belongs to CGV, means at the receiver side. As far as wireless cameras are concerned they are not connected with any of the Arduino, but they are connected serially with the windows 8 touch screen laptop. However, cameras are situated in the CGV but connected with CGVCU.

### F. Mechanical Design and dimensions

Few points shown below clarifies the basic dimensions and capabilities of the CGV.

- Length of the CGV = 0.75 m (max)
- Width of the CGV = 0.55 m (max)
- Height of the CGV = 0.50 m (max)
- Floor Area = 0.75 X 0.25 m<sup>2</sup> (max)
- Object Size and Weight = 0.10 X 0.10 X 0.25 m<sup>3</sup> approx. and 1.75 Kg approx.
- Weight of the CGV = 25 Kg (Battery Included)
- Maximum Speed = 1.3 m/sec (100 rpm)

As this research is based on Mechatronic concept, so instead of focusing more on body design our major focus is on wireless & machine intelligence. Using AutoCAD 3D modeling, this design is prepared virtually and then as per design it is manufactured and tested.

### G. Advantages of CGV

- Accountability - Once a product is onboard a CGV, it is tracked so "lost" or misplaced product will be minimized.
- Cost control - CGV system's costs are very predictable, while labor costs tend to increase and can change quickly depending on local economic conditions.
- Flexibility - CGV's path can be changed as production and handling needs evolve.
- Fewer restrictions - Free-roaming, CGVs eliminate access issues created by conveyors and require less space than conventional forklifts, allowing operation for narrower aisles.
- Repeatability - CGVs perform repetitive movement tasks predictably and reliably.
- Safety - AGVs always follow their guide path and stop if they encounter an obstruction, improving the safety of surrounding personnel. CGV is designed by keeping this idea in mind.
- Scheduling - Because of their reliability and on-time delivery, CGVs improve scheduling capabilities and the efficiency of operations.
- Scalability - More CGVs can be added to expand capacity and throughput.

### H. Applications of CGV

- Automotive Industry, Beverage Industry, Chemicals Industry (Special care needs to be taken)
- Commercial printing Industry, Food Processing Industry, Manufacturing Industry, Paper Industry
- Pharmaceutical Industry, Plastics Industry, Warehousing and distribution functions of an Industry

### I. Literature Review

Mechatronics is a rapidly developing interdisciplinary field of engineering. It deals with the synergic Integration of mechanical engineering, electrical engineering, electronic engineering, computer technology and control engineering in the development of electromechanical products through a unified design approach. It is the need of the present era where manufacture of final products requires interdisciplinary knowledge. In the present age of Automation, mechanical structure cannot be separated from electronics or electrical connections and control. Hence the scope and potential of Mechatronics is virtually unlimited and incomparable.

According to Material Handling Industry of America, Automated Guided Vehicles are carriers of load which travel along the floor of a facility without an on board operator or driver. Their operation is directed by a combination of software and sensor based guidance systems. Such vehicles are used in the variety of areas to support processing and handling throughout facility. For assembly, kitting, transport, delivery, staging, warehousing, and many more applications this systems are used. Material handling applications help industry to predict or make forecasting, resource planning, production planning, flow and process management, inventory management and control.

Graphical User Interface will provide easy and comfortable view as well as control. There are many techniques available for the GUI. MATLAB being powerful Mathematical software, is a best alternative available to make GUI for the system. Many Projects and papers published on this area. [16][20]. Mobile robotics is a large field and is more than just move. It polishes

the supermarket floor, keeps guard in a factory, mows the golf course, provides tours in a museum, or provides guidance in a supermarket. [4]. Nowadays, new concepts emerges of design and development of Mechatronics systems. As can be seen by [12] path prediction of AGV, [11] design of unmanned aerial vehicle, [17] design of small electrical vehicles are proposed.

To accomplish the defined task, we have taken reference of few fundamental knowledge books such as Digital Image Processing [1] [2] [3], Machine Design [5], Measurements & Instruments [7], Handbook of sensors [8], Handbook of robotics [9], ElectroPneumatics [10]. V. Chauhan, S. Sheth and related authors developed system which can sort parts based on their colors which can solve problems formerly restricted to the manual (visual) inspection and sorting in the year 2011 [15]. S.N. Bhavsar and P.A. Parikh directed the way in which one can control actuation of pneumatics and hydraulic actuators using DTMF wireless Technology in the year of 2013 [13]. Online reference made huge impact on this research. [20][21][22]

## II. Communication Between Arduino And Zigbee

Having gone through the introduction part of this research paper, it is very much clear that, two Arduino and two Zigbee are used for this project. Among them one Zigbee and one Arduino belong to CGVCU (transmitter unit). On the other side the second Zigbee and Arduino belong to CGV (receiver unit). In the next subtopics of this module, introduction to Arduino and Zigbee are shown in brief. Also pairing method is shown to pair two Zigbee with the help of Arduino and XCTU software.

### A. Introduction to Arduino & Zigbee

Arduino is a tool that makes the computers to sense and control the physical world. It is an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects. Taking inputs from a variety of switches or sensors, controlling of variety of lights, motors, and other physical outputs can be achieved. Projects of Arduino can be stand-alone, or they can be communicating with software running on the computer (e.g. Flash, Processing, Max MSP) The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free. In this research work Arduino UNO has been utilized. It has 14 digital I/O and 6 Analog I/O. It works on +5volts DC, 10 bit analog to digital converter and 14kb ROM. Fig. 5 shows the image of an Arduino UNO controller. [21]

ZIGBEE (Xbee) is an established set of specifications for wireless personal area networking (WPAN), i.e., digital radio connections between computers and related devices. This kind of network eliminates use of physical data buses like USB and Ethernet cables. The devices could include telephones, hand-held digital assistants, sensors and controls located within a few meters of each other.

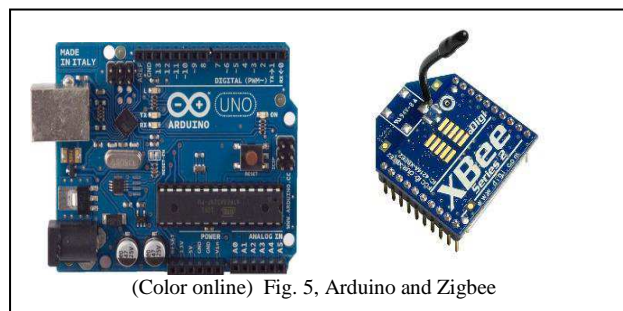




Table II, Zigbee Specifications

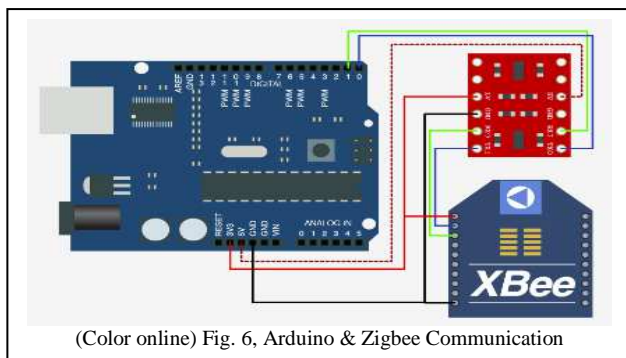
Zigbee Parameters	Specifications
Model	Max Stream
Frequency	2.4 GHz
Range	300 m to 20 km
Serial UART	9.6 Kbps
Power Supply	3.3 to 5 volts
Antenna	Wire Antenna
No. of Channels	16
Addressing	PAN ID

Table III, Arduino Specifications

Arduino Parameters	Specifications
No. of digital I/O	14
No. of analog Inputs	06
PWM pins	03, 05, 06, 09, 10, 11
Clock Frequency	16 MHz
Power Supply	5 to 12 volts
Flash Memory	32 K
Microcontroller	Atmega 328
Board	Arduino UNO

### B. Zigbee Arduino interface

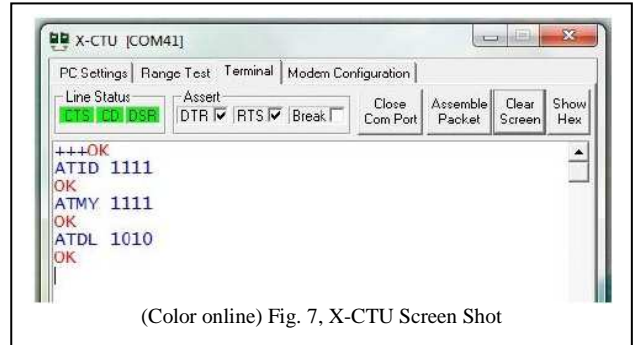
In this subtopic of this module, connection technique is shown (connection between Arduino and Zigbee). We need two Arduino UNO, two Zigbees & Zigbee Explorer. Zigbee explorer is shown in fig. 6. It can be used to configure Zigbee Series 1, 2 or Pro. It has USB-Serial and a voltage regulator onboard. It can be plugged in the breadboard by using standard 0.1" pitch headers. It is compatible with X-CTU software (V2.3). Arduino UNO, Zigbee and Zigbee explorer make one set. Two such sets are required for the whole system. One is for CGVCU and another is for CGV. As far as connection between Arduino and Zigbee is concerned, tx of Zigbee is to be connected to rx of Zigbee and vice-versa. Only one set is shown in fig. 6. The explorer has a USB port, so the complete system has to be connected via USB cable to the Laptop, which belongs to CGVCU. The moment when the set is connected with laptop, laptop will generate a COMPORT (if drivers are successfully installed)



(Color online) Fig. 6, Arduino &amp; Zigbee Communication

### C. Pairing between Zigbee1 and Zigbee2

Two Zigbee have to be paired with each other as communication between CGVCU and CGV is wireless. To pair them some AT commands are to be sent to both the Zigbee. To send the AT commands, XCTU software is used. X-CTU is a Windows-based application provided by Digi. This program was designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface



(Color online) Fig. 7, X-CTU Screen Shot

to them. In XCTU software any COMPORT can be connected. Also any baud rate can be set as well as signal range can be tested. In fig.7, screen shot of XCTU software is shown. Further details can be obtained from table 4 for the function provided by specific commands.

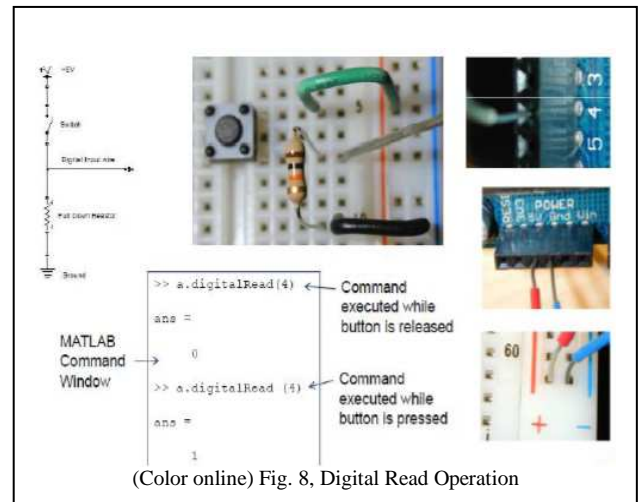
Table IV, Zigbee AT commands

AT command	Function
++++	Make Xbee ready to accept AT
ATMY 1000	My AT command Address is 1000
ATDL 1001	Lower destination address is 1001
ATID 1111	PAN ID is 1111

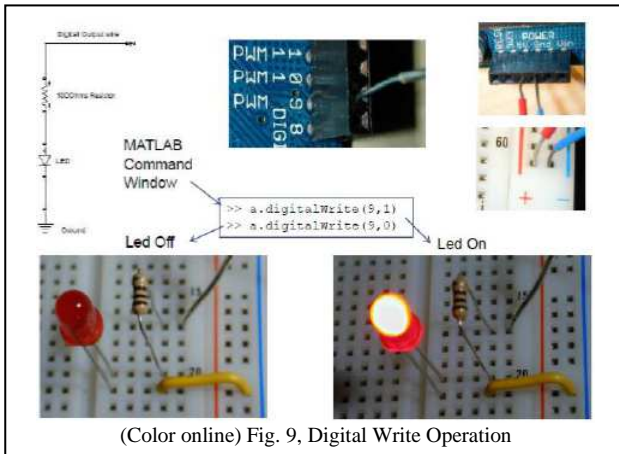
## III. Interfacing Arduino with MATLAB

There must be a serial communication between Arduino and Matlab to make the system controllable. Arduino alone cannot handle wireless web cameras. Also HMI is not possible with Arduino alone, so there must some computer controlled software should be connected with Arduino to support it. After adding Matlab in this system, no need to do coding in Arduino. Programming has to be done only in Matlab. Laptop will use Arduino as a serial port to generate and to accept inputs and outputs. To do so one program has to run in Matlab and simultaneously one program has to feed in the memory of Arduino. These two programs will create an environment between Arduino and Matlab. [21]

Fig. 8 and 9 shows a simple system which includes a pushbutton and a LED. In fig. 8, pushbutton is connected with pin No. 4. In fig.9, LED is connected with pin No. 9. It should be noted that pushbutton is input and LED is output. Connections have been made as per the diagrams. Simple program is shown (incorporated with the figure) to glow the LED (full intensity) when pushbutton is pressed.



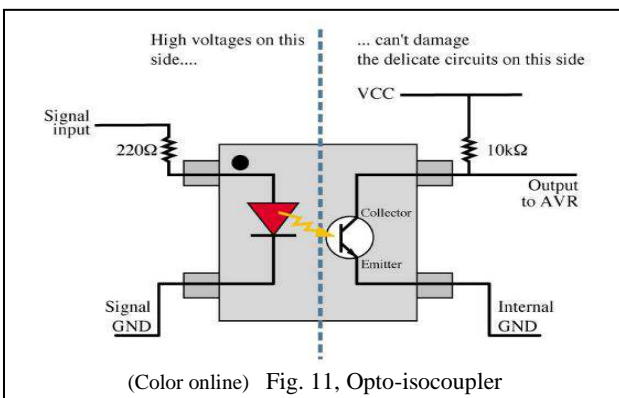
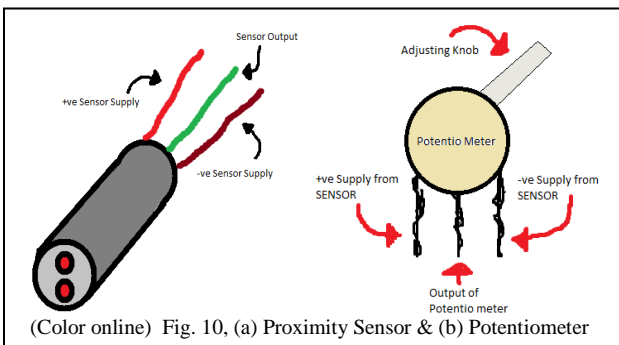
(Color online) Fig. 8, Digital Read Operation



#### IV. Inputs In The System

Here we can see that CGV takes input from the sensors as well as wireless cameras. To detect availability/presence of object we used proximity sensors. We used Normally Open type of sensors which means that it gives output voltage which is same as voltage supplied to it when it senses, in this case we have 12 volts. Normally open sensors do not provide output or provides zero voltage at output it is not sensing. Other types of sensors are the normally closed sensors. In this case, when sensor is not sensing, Output is the Input voltage (i.e. 12 volts). The time when it senses output of it becomes zero results in the open circuit.

Therefore we received 12 V from sensors when it senses. Directly it cannot be given to the Arduino controller. The reason is, Arduino controller operates on 5 volts and a few mA of the current. To make signal compatible with Arduino, we used potentiometer. By rotating knob we can change resistance of the potentiometer (pot) and hence reduce voltage from 12 to 5. As sensor output does not carry high current, no need for current reduction. Now we have given this output (of potentiometer) to the Arduino controller. Here we used 470 k  $\Omega$  Potentiometer.



To prevent delicate circuit (microcontroller, processing ICs, etc.) from accidental high voltage/current damage, we have used opto-isocoupler. Optoisolator is a component that transfers electrical signals between two isolated circuits by using light.

#### V. Machine Vision (Image Processing)

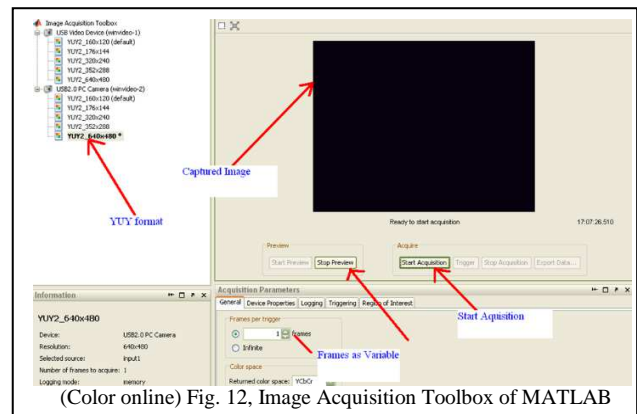
To achieve objective, it is our primary concern to use data acquisition toolbox of Matlab, which regulates the operation of the wireless cameras. These cameras have got critical duty to perform. They will create virtual port in the Laptop and thereby makes wireless connection with it. Each camera has specific device number in Matlab, which is called device id. Device id is unique for any device. To take snapshot automatically when proximity sensor senses the object, one simple program execution is triggered. That program is shown here for sake of clarification and understanding.

```
vid=videoinput('winvideo',2); preview(vid);
set(vid, 'ReturnedColorSpace', 'rgb');
I=getsnapshot(vid); delete(vid); figure, imshow(I);
```

'vid' is the video object created by us which uses 'winvideo' adaptor to process data, '2' is device id. Second command line ensures the preview on the screen by camera. Before capturing image, third command line forces camera to return image in RGB format so that we can process it according to our logic. Next command line obviously, tells camera to take the picture. Now, we don't need the object so it must be deleted which is shown in the next command line. Last line shows us the image of the photograph which is captured by the camera.

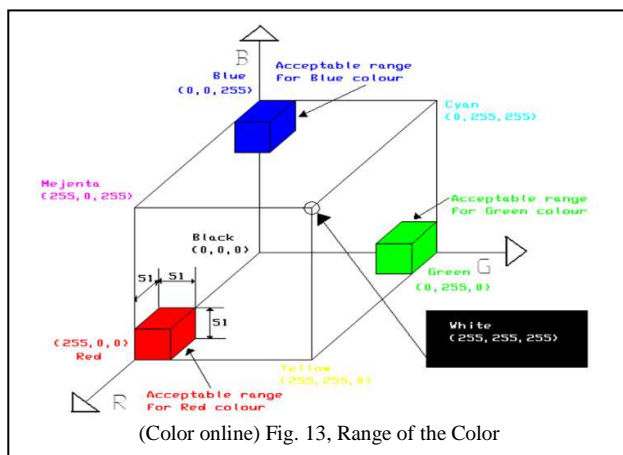
Typical image acquisition toolbox is shown in fig. 12. Again, C1 is for taking photo of object whereas C2 is for the photo of destination. If two colors get matched then only motor should stop (other condition: when maximum no. of destination reached) and deliver object to the bin, otherwise start the motor to find other 'valid' bin (same color as that of object's). Max. Numbers of destination is number up to which CGV will try to find 'valid' bin, after it is reached, CGV will stop and do not move forward (this is provided for the safety and energy saving consideration). To compare color of two images GP method is employed. In this method, whole image is represented by a pixel called generalized pixel (GP) which has 3 attributes of red, green and blue. These attributes of GP is in fact, average values of the all pixels in the picture. In other words, by comparing two GPs of two images we can identify whether both color matches. Here comes concept of the range of the color.

There are many colors, Infect- World is colorful! Human eyes can see/distinguish certain color very easily but beyond that it is next to impossible to differentiate between two different but identical colors (only difference is of minimum intensity of one compared to other). Here, RGB color model is employed for the process. Therefore, we have basic three colors red, green and



blue. User must choose proper range of the colors in order to get desired work done. Also there are 0 to 255 intensities available for each of the color. Permutations and combinations of the total available colors left to the reader if interested!

Let us understand range of color by an example. Suppose range is X (that should be in between 0 to 255 because of the fact that register for color is 8 bit, it gives us freedom of choosing any values from 1 to  $2^8$ . As we considered 0 also which made our span from 0 to  $(2^8)-1$  and that is 0 to 255). A picture is only considered red only if its GP's red attribute has value greater than X and other two attribute's value is less than X. Similarly, it can be said for the other colors. Here by default, CGV takes range as 204, if user wants his/her range then he/she can enter his/her own range or simply adjust slider on the screen of the HMI. Two important possibilities associated with the range selection. These are Risk on customer and Risk on manufacturer. To illustrate that in single line –'sometimes right object gets rejected (Unapproved) is risk on manufacture and sometimes wrong object selected (Approved) is risk on customer'. Default range is 204 which gives quite risk on manufacturer because very compact range for acceptance of color is employed.



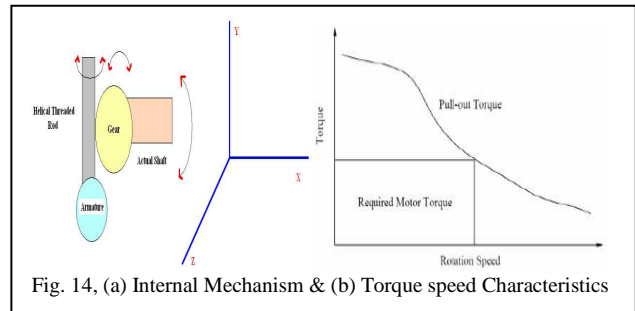
## VI. Outputs In The System (Output Unit)

With the reference of table No. 1, it can be predicted that CGV has four outputs. First is the wiper motor. The rest three are to be given to the solenoid valves. Ultimately digital outputs are to be given to the relay card.

### A. Wiper Motor

CGV unit has two wiper motors connected in parallel. It should be noted that CGV can travel only a straight path, so both the motors working as a single motor (as they are connected in parallel). The wiper motor is nothing but simply a DC motor, but gives very much higher torque than an ordinary DC motor. In fig. 14 (a), we can see a gear box. In which a vertical helical threaded rod is there. Motors original shaft tries to rotate it. Threaded rod rotates about Y axis & motors original shaft rotates about Z axis. Due to this gear attached with helical threaded rod rotates about Z axis. This gear tries to rotate one another shaft, which rotates at less rpm & gives high torque.

Wiper motor Characteristics are as shown in the fig. 14 (b). From external calculations, it has been concluded that at 12 DC input supply and at 60 rpm, motor will absorb almost 2.5 Amp current and will be giving the torque of 5Nm. In this condition motor will be giving its maximum efficiency that is almost 45%. As this research is based on machine intelligence, mechanical calculations are not shown much.



### B. ElectroPneumatics

CGV will unload the object with the help of pneumatic system. Here two cylinders are used to unload the object. Pneumatic System comprises of two air cylinders, out of them one is single acting spring return and the other is double acting cylinder. To control the air flow direction, two solenoid operated direction control valves are used. Out of them one is 3/2 spring return valve and the other is 5/2 valve (both side solenoid). Both the valves have an opening of 1/2 inches. The fig. 15 shows the position step diagram, which has to be achieved.

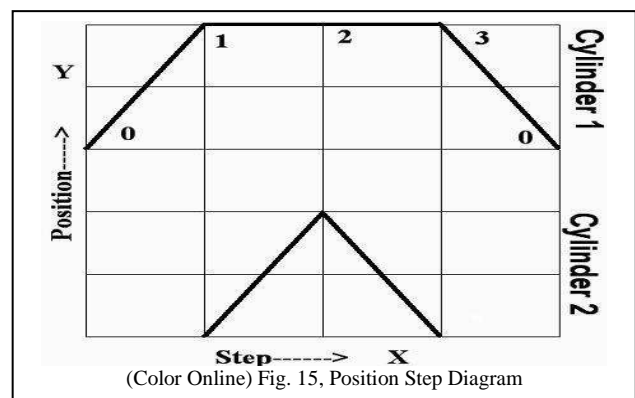


Fig. 16 (a) shows the actual settings of the cylinders on the CGV while fig. 16 (b) shows the pneumatic circuit diagram. Table V shows the specifications of the pneumatic system. When solenoid 1 gets triggered, cylinder 1 will be activated and occupies position 1 shown in respective diagram. At the same time Solenoid 3 of cylinder 2 will get triggered, cylinder 2 will be activated and achieved position 2. The moment it achieves position 3, solenoid 3 gets deactivated and cylinder 2 retracts (position 3 achieved). The second moment solenoid 2 gets activated and solenoid 1 gets deactivated, thereby making cylinder 1 movement in the reverse direction (retract). [14] [19]

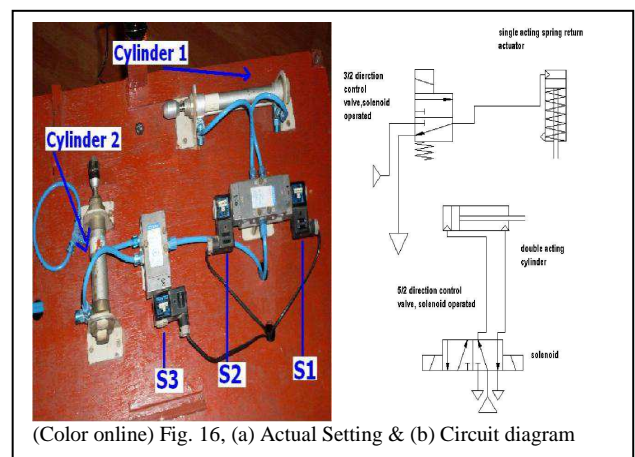


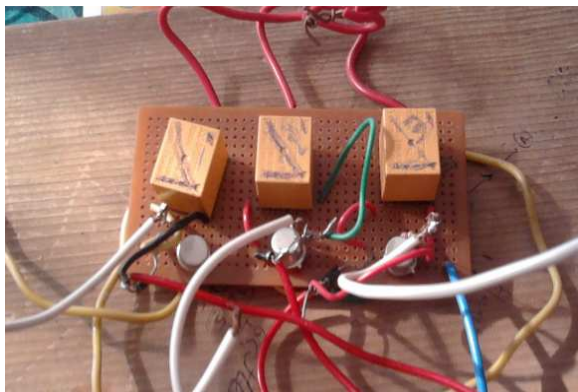
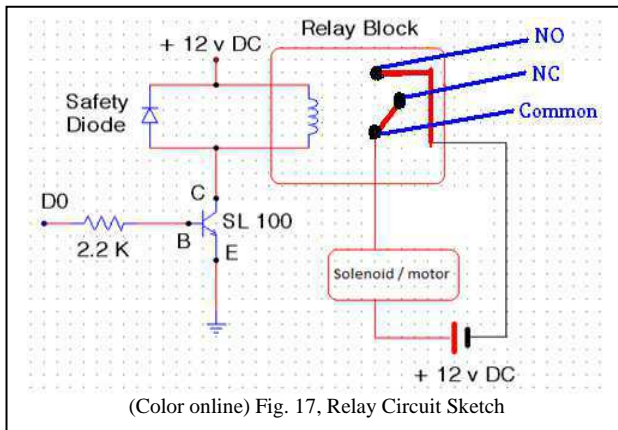


Table V, Pneumatic system Specifications

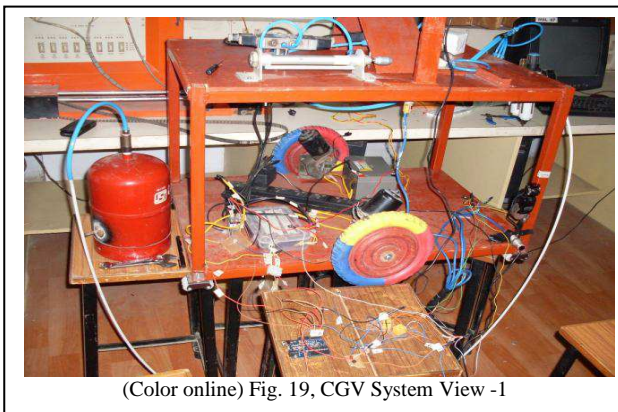
Pneumatic Components	Cylinder 1	Cylinder 2
Working Pressure	0.7 Mpa	0.7 Mpa
Stroke length	0.25 m	0.15 m
Piston Diameter	0.020 m	0.025 m
Piston rod Diameter	0.009 m	0.012 m
Pushing Capacity	11 Kg	12 Kg

### C. Relay Circuit

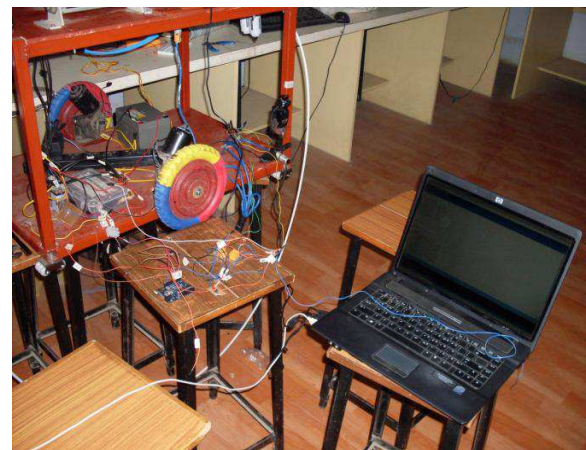
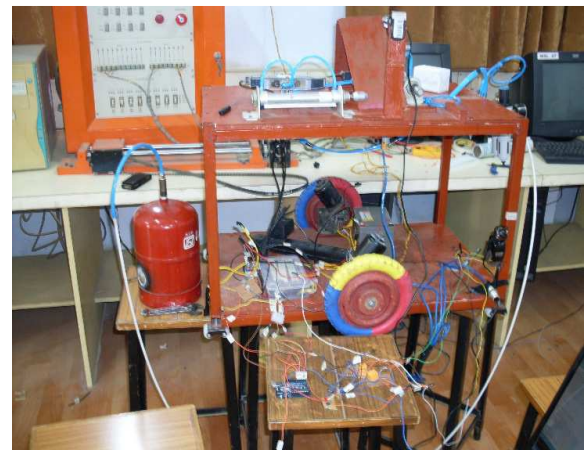
To run the wiper motor, the signal coming from the Arduino has to be given to the relay card. The coil works on +12 volts and the contact capacity is 6 Amp, which is sufficient for the wiper motor circuit. The Fig. 17 shows the driver circuit sketch and fig. 18 shows the actual circuit. When Arduino gives a signal at DO in figure, transistor gets activated, coil gets energized, and relay contact gets closed. Hence, motor rotates.



### VII. Actual System Photographs



Here, Actual photographs shown which were taken during the work. First two (fig. 19 & 20) shows the connections of the CGV and the last one (fig. 21) shows both- CGV and CGVCU.



### VIII. Results And Conclusion

Case 1: Object color is red which is loaded from loading station to CGV. Bin-1 color is also Red. So, our one cycle ends at Bin-1. As per working principle, to start next cycle other object must be loaded to CGV from Bin-1 Station. Taken distances are shown in the respective figure.  $Time1\ cycle = TL + LdV + TU$ , where  $TL$  is time taken for loading of the object,  $Ld$  is distance travelled by CGV,  $V$  is velocity of CGV and  $TU$  is time taken for unloading object. Assuming 2 seconds for loading and 3 seconds for unloading, velocity of CGV as 0.65 meter/second (calculated from  $V = \pi DN/60$ , 25 cm as diameter of wheel, 50 RPM speed). We get the resultant time for one cycle as described in the table VI, for the theoretical approach. [6]

Case 2: Object color is red which is loaded from loading station to CGV. Bin-1 color is green. So, our one cycle will not end at Bin-1. Bin-2 Color is red that is our cycle ends at Bin-2. Equation remains same but distance travelled is increased to 15.5 meters (here we considered dimensions of the bin also which is not negligible here). Also, Time taken for the recognition of 'invalid' Bin-1 must be incorporated in the formula which ultimately increases cycle time. Here, this time is taken as 3 second. From the table VI, values of theoretical

approach can be interpreted easily. Fig. 22 shows the conceptual path for the CGV and its environment. [6]

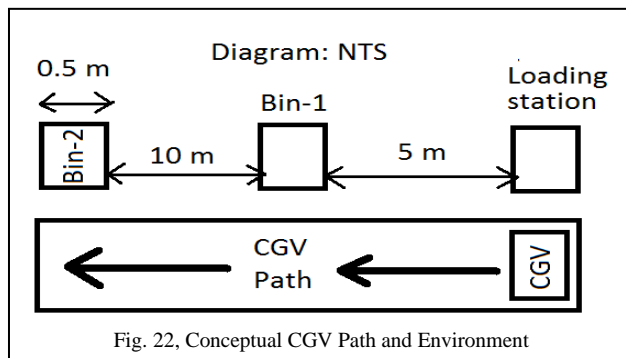


Table VI, Theoretical and Practical Results Obtained

Different Cases	Theoretical Time (seconds)	Practical Time (seconds)
Case 1: Cycle Time	12.69 = 13	18 Approx.
Case 2: Cycle Time	31.84 = 32	46 Approx.

Conclusion: From table, it can be seen that there is significant amount of difference between theoretical and practical values of time. This is because our assumptions are hardly satisfied if we compare it with real time system. Also velocity of CGV is taken uniform and time to achieve that velocity is neglected. However, if we take all these features into account and then obtain results, it will improve significantly.

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