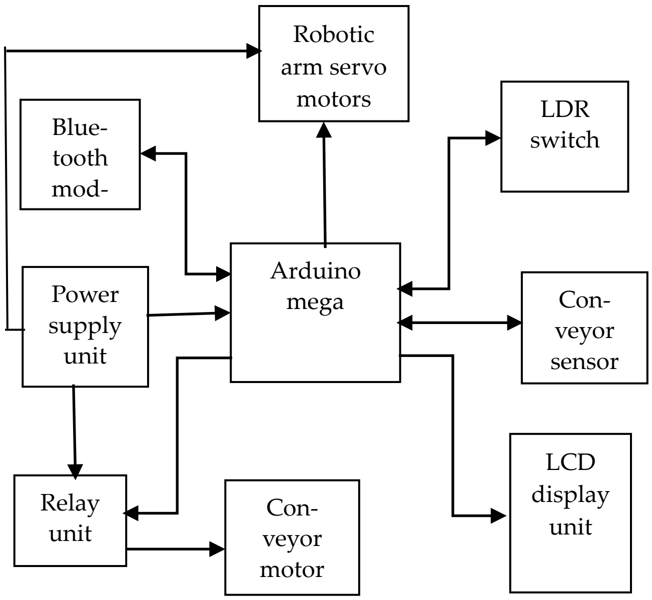

Figure 4: Different units and component within the machine

2.7 Remote Application (Android Base)

This is the second option for communicating with the device. This android application (once installed) allows any android phone become automatic remotes to this device. In addition to the GUI, it has features like selecting automatic mode (continuous operation) and precise mode (discrete operation) which allows the user to input a certain amount of operation to be carried out. This application was developed using the android studio and app inventor online tool.

3 Operation Principle

This machine system is primarily made up of five main parts, The feeder, receiver, conveyor, pick-up arm and the power supply unit. The feeder holds and guides the fruits to be sorted into the conveyor. The conveyor conveys the fruits to the image processing unit (color sensor) located at the end of the conveyor where data is being read from the fruit and fed to the Arduino for further processing and decision [9]. The color sensor works by beaming white light on the fruits, other colors (components of light) except for colors corresponding to that on the surface of the fruits are absorbed, the rest (reflected colors of light) passes through the filters of the color sensor to the photodiodes and the frequency of each color is been read and sent to the Arduino. The Arduino measures the PWM of the received frequency in microseconds and makes a decision based on the parameters set by the programmer. Based on the decision of the Arduino on the data received, an instruction is sent to the pick-up arm that performs a set of controlled mechanical movements by picking and placing the fruit in the appropriate receiver tray.

3.1 Algorithm for the machine system

Algorithm

1. Initialize LCD and display welcome message and wait for any button to go low
2. Scan for any Bluetooth connection
3. If Bluetooth connection is established, wait for transmission of a character from established connection and goto no 7.
4. Else scan for any key to go low, hence commence manual operation.
5. LCD display menu.
6. Select which fruit to sort using push buttons
7. If fruit is selected, activate conveyor driver motors. Else wait
8. If LDR resistance is <500 Ω, stop conveyor driver motors. Else allow conveyor to run
9. If fruit meets ripe criteria, pick and place in ripe basket, else pick and place in unripe basket
10. If LDR resistance does not go <500Ω in 2 minutes, initiate standby mode. Else continue operation
11. End

3.2 Project Assembly

This device came to actualization from interconnecting various components, modules, and frames together using appropriate tools and equipment. Tools used in the implementation of this work includes; screwdriver, tester, multimeter, hand engraver, plier, cutter, hacksaw, glue, hammer and soldering iron, soldering lead, drilling machine and some programming software (Proteus 8 professional, Arduino IDE, code blocks, android studio, app inventor). Also, materials used include aluminum plates, plexiglass, pen casing, vero board. Plates 1 to 5 show the various parts and the assembled machine.

Plate 1: Fabricated joints and parts of the system

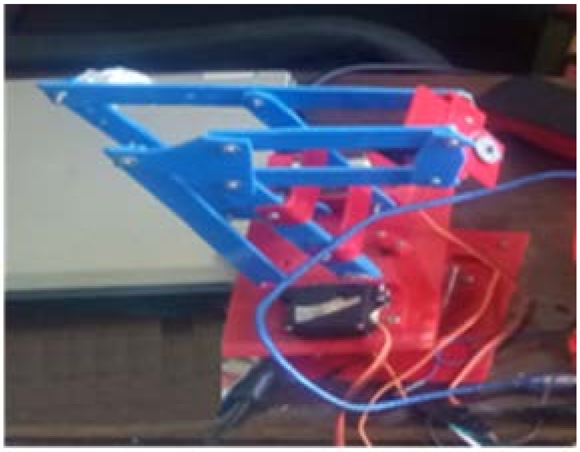

Plate 2: Robotic arm assembly for the system

Plate 3: Robotic arm attached to the main body

Plate 4: Roller Convetor Belt Arrangement

Plate 5: Developed Image of the System coupled to the robotic arm

4 PROTOTYPE TESTING

For testing, different fruit (both defective and sound objects) with moderately circular shape and different colors were used. A threshold value for the fruit colors with respect to their intensity were recorded and input in the Arduino. First, the fruits were loaded on the conveyor belt, which has a conveying capacity of 5 fruits at a time. Arduino sends the signal to microcontroller for capturing object image through 5- megapixel camera at the object reaches the LDR sensor. The object image was successfully analyzed by microcontroller according to the specified threshold value for the respective color lighting condition.

The fruit was them picked-up by the robotic arm, which has a conveying capacity of five fruits at a time and a stall weight of 5kg. The robotic arm also has a lifting capacity of 1kg and a stall weight of 1.5kg. Them after the inspection by the robotic arm, the fruit is placed in the respective bowl pending on defective or ripe.

Finally, it was tested and found to be precise in its pick, drop and reposition routine. However, it is imperative to note that strong electromagnetic field interferes with the operation of the servo motors which are the building blocks of the robotic arm. The machine has successfully sorted wrong color object and discarded it from the conveyor line by a micro servo operated robotic arm. Tables 3 and 4 shows results obtained from test running the device to show its efficiency.

Table 3: Number of fruits before sorting

Fruit Type	Total no of fruit	Total no of ripe	Total no of unripe
Tomato	30	20	10
Orange	30	20	10
Lemon	30	20	10
Mango	30	20	10
Udala	30	20	10
Apple	30	20	10

Table 4: Results obtained from testing the automated fruit-sorting machine.

Fruit Type	No of ripe sorted	No of unripe sorted	Error	Accuracy (%)	Time taken
Toma-	17	13	0.3	85	5
to	18	12	0.2	90	5
Orange	15	15	0.5	75	5
Lemon	14	16	0.6	70	5
Mango	17	13	0.3	85	5
Udala	12	18	0.8	60	5
Apple					

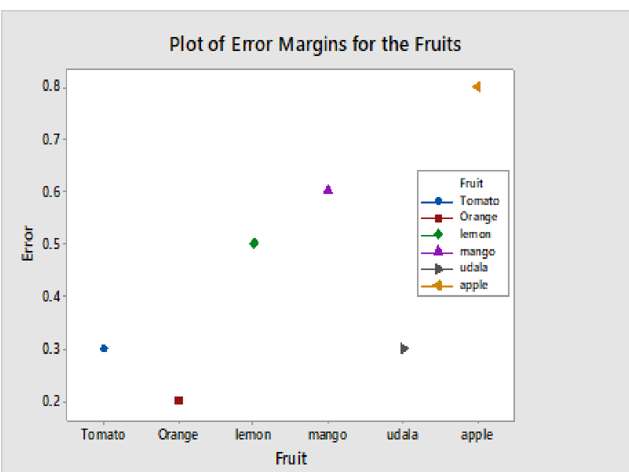

Figure 5: Sample Inspection Respect to Machine Error

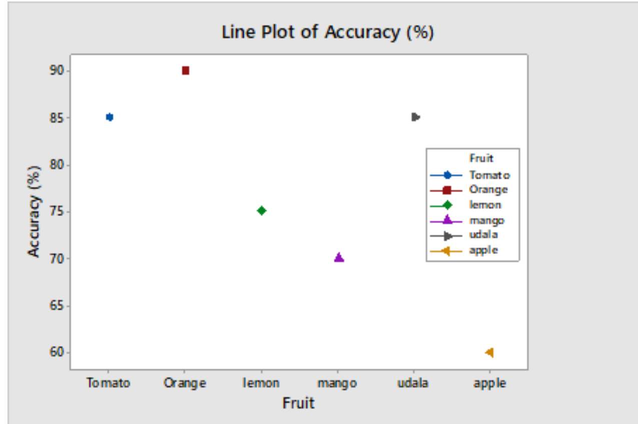

Figure 6: Sample Inspection Respect to Machine Accuracy

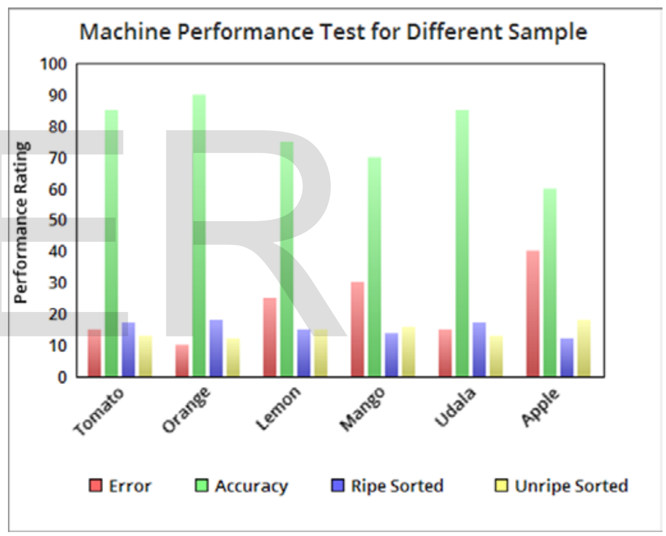

Figure 7: Machine Performance for Different Sample Tests

5 Discussion

The developed machine has successfully worked on color error detection to identify and remove the defective items from the conveyor line and overall reduce the rate of repetitive failure in production system results better dealing with product quality characteristics within control limits.

Six different fruit of different color were used to evaluate the machine performance. First, each sample was tested and run for five minutes with the inspection rate of 10 pieces of fruit per test (see table 3 and table 4).

Although the machine has the ability to inspect more than 10 pieces per minute based on the requirement as the machine is built with high feed rate but was not loaded beyond 10 pieces since it was under test run.

For each test, number of ripe and unripe or defective fruits were recorded and machine performance evaluated by comparing with the number of fruits identified and sorted by the machine. Machine performance determines how much it closes or deviates from the set standard criteria. Thus, a maximum of 90% accuracy was achieved with less than 0.8 error margin. (figure 5, 6 & 7). Though the target accuracy was 100%, the deviation of the machine inspection accuracy may be due to variation of lighting intensity and wind effect at test room [10], [11]. Therefore, there is the need to work on the calibration of the machine to reduce the effect of lighting intensity variation.

5 Conclusion

The objective of this project was to develop an embedded system with quality control and process automation for sorting fruits either ripe, unripe or defective. The developed system has proven to be simple, efficient and user friendly, as all components worked properly in line with the designed specification. The developed system has a machine performance accuracy that is near 100% and an error margin is less than 0.9%. The developed system has a robotic arm with some degree of freedom in order to pick and place the ripe, unripe or defective fruits at the designated bowl for ensuring the smooth processing operation.

The possible outcome of this machine is an automated system based on color error detection technique that will encourage and enhance quality production of products. Similarly, Local industries having tight budgetary constraints can also benefit from this outcome by implementing this automated sorting system. This work will also provide a guidance for adopting automated color error detection based system to sort defective or unripe fruits from good or ripe ones.

Acknowledgment

The authors wish to thank the Department of Physics, IBB University Lapai, Nigeria and Technology Incubation Centre Tunga, Minna Nigeria for their support.

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