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Machine learning and Image Processing Techniques used for Development of Fasteners Sorting System

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Abstract: Sorting tasks are essential in industrial processes. They are usually done manually, requiring manpower, which is prone to human error, inefficiency, and time-consuming. This paper presents a system considering the mentioned drawbacks and provides a cost-effective solution. The main objective is to develop a Machine Learning (ML) model and mechanically implement the algorithm to sort fasteners such as bolts, nuts, screws, and washers using image processing technique. The hardware structure consists of a bowl feeder which feeds the fasteners to the conveyor periodically. Fasteners get aligned on the conveyor and it starts to proceed as the stepper motor rotates. The Pi camera module captures the image at the intermediate position of the conveyor. The captured image is processed and compared with the dataset in the Machine Learning (ML) model. Machine Learning (ML) predicts the type of fasteners. Based on the predicted result, the tilting mechanism which is connected at the output end using a servo motor tilts to the desired position. Fasteners reach the destination via a tilting mechanism.

Keywords: *sorting, fasteners, Machine learning, Pi Camera, CAD, Image Processing*

1. Introduction

A fastener is a hardware device that mechanically joins or affixes two or more objects together .They are widely used in industries. Most commonly used fasteners are bolt, nut, screw, rivet, nail ,washer etc., sorting is process of arranging items systematically based on physical criterion such as shape, size, color etc., In small scale industries and recycling plant sorting makes imbalance in their working hours were they have to spend their working hours for sorting purpose or they have to employ a human personnel which includes labour cost and might lead to human error and severe time consumption. This paper has a solution to above mentioned problem. we have developed fully automated system. Hardware structure consists of bowl feeder, conveyor and tilting mechanism which is designed using CAD software. The designed structure is built using 3D printer. PCB is designed using Easy EDA software to minimize the circuit connection. Fasteners from the bowl feeder are fed to the conveyor sequentially. The conveyor proceeds as stepper motor starts rotating. Pi camera captures the image of the fasteners at the intermediate position of the conveyor. It communicates with raspberry pi using MIPI serial interface protocol. Captured image is processed in the controller. At the output end of the conveyor tilting mechanism consisting of servo motor is linked. Servo motor rotates based on the predicted output. In real time the captured images are compared with dataset created in Machine Learning (ML) model. Machine learning (ML) is an branch of artificial intelligence. It is a field of study that gives system ability to study without being explicitly programmed. It predicts and classify objects based on the patterns. Data are given to the model initially to train the model then it is put to test after several iteration model is ready to predict.

2. Literature Survey

Previously Sorting has been done using Programming logic control (PLC)[1] conveyor has been used to transfer the component from one end to the other. The signal from the proximity sensor is given to PLC which classifies the object based on distance between the boxes. A paper[2] focuses on moving nuts and bolts which is sensed by proximity sensor and image acquired by web camera is processed through Matlab by developing a image processing algorithm using stationary wave light transformed to normalize cropping images. Another study [3] which has Raspberry pi as the main controller, main objective is to examine its utility and effectively uses mechanical system to sort large number of objects the scanned images is then further processed using open cv and color of the object. With help of processed information in open cv, motor drive is instructed to control

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the servo motors which helps to sort the required object. A study [4] focused to develop a system to recognize difference in nuts-and-bolts separation. This paper use digital image processing and artificial intelligence. The results from feature extraction is given to artificial intelligence to detect the object and applied for required application. Another study[5] includes design mechanism and the flow of the system. In this paper they basically use Raspberry pi and its camera module as the main component .The system consists of color detection algorithm, shape detection algorithm and size detection algorithm. In color and shape detection RGB value is used as the main data for further analysis. For size detection the preprocessing step is done as for previous detection.

The paper [6] focuses on developing simulation to detect and classify the currency coins by machine vision technique using NI 1742 smart camera .To enhance the processing speed system is powered by 533 MHz power PC processer which simplifies machine vision by analyzing images directly. It is evident from previous study that Raspberry Pi and its camera module is efficient and most widely used in image processing.

3. Methodology

*A. **Design***

In the initial stage, the calculation was done to design the bowl feeder and conveyor using standard formulae where the torque of motor, speed of the motor, belt tension, pulley diameter, and loads are considered. With the help of the results obtained from calculations bowl feeder and conveyor are designed in CAD software. The block diagrams are then developed into schematic design using Computer Aided Drawing (CAD) software shown in Figure 1. A schematic design consists of component symbols and net connections between the symbols. The nets will become traces.

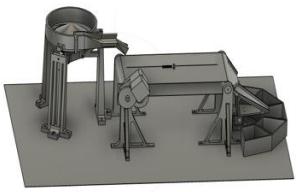

Fig 1. CAD Model for Proposed System

*B .**Development***

The design was further developed using 3D printer. The PCB is fabricated using the following steps:

- Printing -. The picture of the board is produced on a film or directly on the board by a laser during this first step.
- Inner layer etching - Etching is the removal of superfluous copper from a circuit board using a ferric chloride solution.
- Hole drilling – Vias and mounting holes are drilled through the PCB for component placement.
- Etching - The unwanted copper is removed via etching. To resist the layer covering the copper, these layers are removed.
- Plating - Within vias, it produces conductive barriers. Copper, a highly conductive substance, pours into the drilled holes and creates the walls.
- Finishing - At the end of the procedure, the board is protected from the environment, particularly the copper portions, which are prone to oxidation.
- Further, the dataset is created, and ML model was developed.

C. Assembly

The mechanical structure is assembled in the manner where, at the first stage the bowl feeder is mounted then the conveyor is aligned with center axis of bowl feeder, finally the tilting mechanism is mounted in identical axis represented in figure 2 The camera is mounted at the middle of the conveyor is such a way that the camera focuses the fasteners. Then the sensor is mounted at the end of bowl feeder to detect the presence of fasteners. The circuit connections for the motors from PCB is developd.

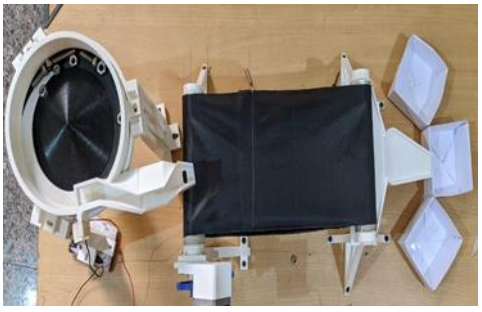

Fig 2. Assemble of Proposed System

Testing

The ML code is compiled and tested with different dataset where 72 percent of accuracy is obtained, further the model is retrained to improve the model to get 81 percent accuracy. The hardware components such as motors, sensors were tested and tuned accordingly. The fasteners were fed to bowl feeder and washer gets sorted. The IR sensor confirm that the fastener is placed on the conveyer periodically. The conveyor torque to rotate the belt is 2.66 Kg-cm. But the stepper motor provides operation torque of 1.5 Kg-cm.

D. Solution

In order to the model, the model is retrained and changing the tuning parameter to improve the model to get 81 percent accuracy. Then to improve torque gears are used. To get the 2.66 kg-cm torque the compound gear mechanism is used with the following number of teeth Gear-1(driver) consists of 15, idler compound gear-2 consists of 50 and 25 teeth, and gear- 3(driven) consists of 50 teeth. With the help of gear mechanism, the required torque is achieved.

4. Hardware and Software

A. Hardware components

Raspberry Pi- is used as main controller to process Image captured by Pi camera and Arduino UNO- PCB is mounted on it to control motors and IR sensors, Bowl Feeder-It is used to feed the fasteners to the conveyor sequentially and Conveyor- It provides path for fasteners from bowl feeder to tilting mechanism. Tilting mechanism- It consists of servo motor which rotates based on output obtained from controller.

B. Software components

Python-ML model is developed using scikit and Google Collaboratory which is used to compile and run ML codes. For development design for PCD an EasyEDA is used Arduino IDE is used to code Arduino using embedded C Solid Edge is used to design bowl feeder, conveyor, and tilting mechanism.

5. Working Operation

A. System flow Block diagram

Fasteners are fed into the bowl feeder; it starts rotating as the Gear Motor rotates. The Gear motor receives the power supply of 12V DC from the motor drive unit L239D.The Gear motor has the capacity to rotate 30rpm with 1Nm torque. The washer gets sorted in bowl feeder as it passes through the gap(5mm).The conveyor is placed in such a way that output of bowl feeder is center axis to it. Fasteners from the bowl feeder are fed to the conveyor periodically which is controlled by IR sensor. The conveyor proceeds as stepper motor starts rotating. The stepper motor receives the power Supply of 12V DC from motor drive unit. Gear ratio of stepper motor are discussed in methodology.

Pi camera captures the image of the fasteners at the Intermediate position of the conveyor. Captured images are transmit to Raspberry pi. It communicates with raspberry pi using MIPI serial interface protocol. Captured image is further processed in the controller. At the output end of the conveyor tilting mechanism is placed which consist of servo motor. Servo motor rotates based on the predicted output. In real time the captured images are compared with dataset created in Machine Learning (ML) model. Machine learning (ML) is an branch of artificial intelligence. It is a field of study that deals with system ability to study without being explicitly programmed. It predicts and classify objects based on the patterns.

B. Circuit working flow.

The Power supply of 230V AC is direct given to the SMPS(Switched Mode Power Supply).SMPS Converts the 230V Ac supply to 12V DC. This 12v DC is given to the motor drive unit of Stepper motor and Gear motor through which they operate. The Buck converter receives 12V Dc from the SMPS and converts to 5V Dc. The output of the Buck converter is given to servo motor, sensors, and Raspberry pi. Figure 3 shows the schematic circuit flow of the system.

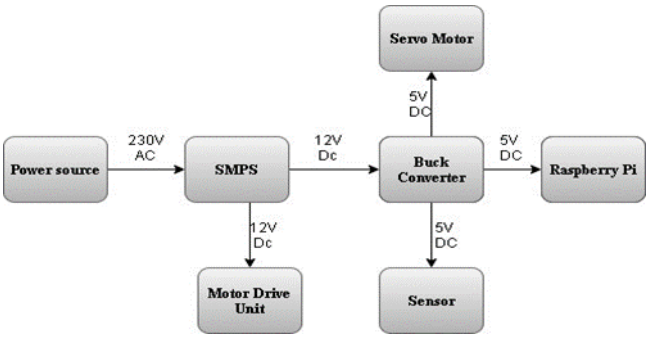

Fig 3: Schematic circuit flow

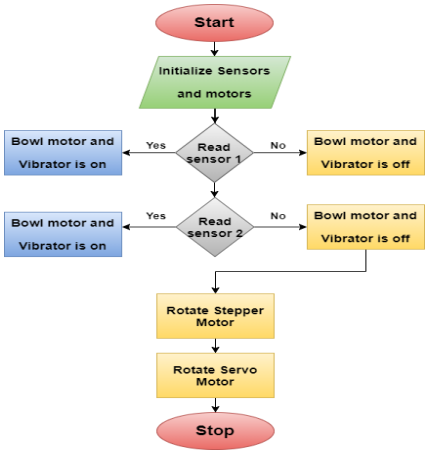

Fig 4: Arduino Code flow chart

Figure 4 represents the algorithm developed using Arduino IDE for the mechanical action of the system. IR sensor1 is connected to digital pin 8 and IR sensor 2 is connected to digital pin 9 of the Arduino uno board when IR sensor 1 detects a part the vibrator and the gear motor starts rotating when IR sensor 2 to detects a part the vibrator and gear motor stops rotating until the part is sorted by the servo motor after IR sensor 2 is high the conveyor starts rotating and the camera captures the image and processes it which gives feedback signal to Servo Motor which rotates at some angle according to the output predicted by the ML model. Figure 5 represent the algorithm developed using machine learning model to train the various images and help to sort the feeder with good accuracy.

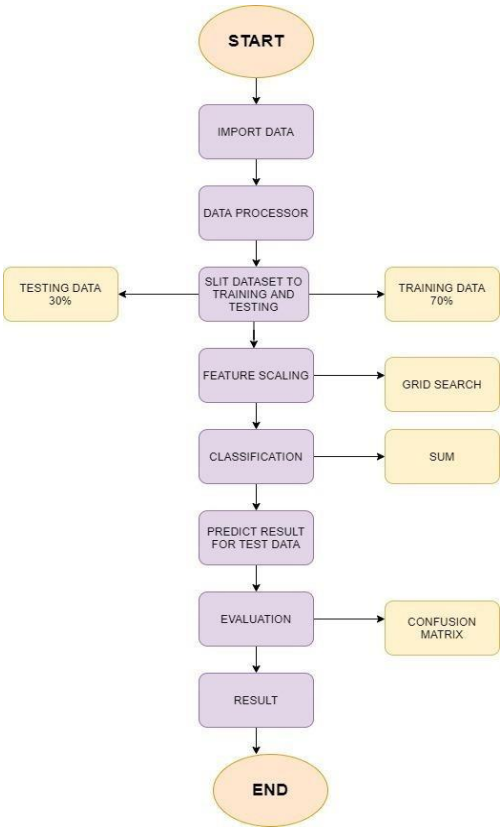

Fig 5: ML code flow chart

6. Result and Discussion

We created a dataset by capturing real time images using Raspberry pi camera. Data (images) from website was also collected. 70% of the data was divided into training data and 30% was divided into testing data. The features are standardized using a Standard Scaler object from the sklearn library. An SVM classifier was created with the following parameters, C=1, gamma=0.1, 0.001 and kernel=RBF. The model gives accuracy of 81%. Figure 6 represents the various stages of the output from initial stage to the final stage. Figure 7 represents the final stage predicted output based upon Machine learning model.

Fig 6: Stages of output

Fig 7: Predicted output

7. Conclusion and Future Scope

In this paper we addressed the Problems of material sorting and its cost-effective solution .One of the main objective of our system is to reduce the time consumption and to reduce the cost.

Usage of the system minimizes human intervention and manual work in industries. The sorting machine sorts the Fasteners based on their shape successfully .The Pi camera module serves as an eye for the system captures image in real time. Machine learning (ML) model predicts the type while fasteners continue its motion on the conveyor from bowl feeder to distribution boxes via tilting mechanism.

Fasteners can be further classified based on their sizes. To increase in the number of fasteners that needs to be sorted Detection of damaged fasteners can be done.

Counting circuit which enables the system to count number of fasteners sorted in each category. Increase in rate of fasteners sorted per minute by choosing much more powerful microcontroller. Design of robotic arm to dump the fasteners on to the bowl feeder.

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