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Comparing the Efficiency of Intelligent Hybrid Operator Assistance Software with Intuitive Set-up (OASIS) for Assembly Production Line

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Abstract. Pick-To-Light Order Picking System is the operational process when an operator begins to pick the parts in a sequential manner by which the quantity of the parts is recorded. The design of an effective hybrid order picking process in an assembly line is assisted by an intelligent sensing system to improve pick efficiency, accuracy and increase productivity. This research compares between intelligent hybrid order picking versus order picking with pick confirmation system at parts assembly line. The results show that by our proposed system with the elimination of certain steps within the picking process, the better efficiency, accuracy, fewer miss-picks will occur in the system and the operator can perform more intelligently with required picking quantities. The development of this system can provide a low-cost solution with an intelligent order picking system for small and medium-sized enterprises (SMEs) and a fast-moving production assembly line in manufacturing.

Keywords: Order picking, Pick-to-light, automation, intelligent system

1. Introduction

Automation technologies and advanced computing technologies have been widely used in manufacturing industries as a key component in the massive environment's changing for industry 4.0. Development in global competition, a manufacturing company in the UK has to employ more automation technology and an advanced computing system for its performative operations. In many industries, the major manufacturing company is investing in capital to use automation systems at a faster rate in their assembly production line and this will most certainly lead to relatively increasing the levels of productivity and improving the quality [1].

However, on the other side of the spectrum where the SME's, meanwhile one-man bands and new start-ups, the lack of financial resources and technical know-how can be prohibitive to introducing some of these automation technologies within the assembly process to ensure high levels of product quality. For SMEs with low volume production or with high volume parts mix during assembly, the justification for capital expenditure can be very difficult in introducing automation systems in their assembly line. As a result, often with this size of the business, products are predominately assembled manually by the individual at multiple stations on small assembly lines. Assuring the correct components are assembled at the right station and at the right time will frequently rely on the operator's knowledge of the product and process. To facilitate operators with manual assembly processes, there are a number of systems on the market that use pick-to-light and sensors to guide the operator through the scheduled sequence of assembly. Even budget entry-level systems can run into several thousands of pounds for each assembly station and require some configuration know-how, putting it out of reach of some smaller SMEs.

Sustainable Advanced Manufacturing (SAM) [2] is offering support to this type of SMEs to develop the process, product, and technology within manufacturing technology development. This research aims to develop an entry-level, low-cost pick-to-light system that enables SMEs to introduce, set-up and maintain with minimal capital investment and little process configuration knowledge a pick-to-light system. System functionality will offer the levels of control witnessed in high volume Original equipment manufacturer (OEM) manufacturing facilities. The development of an intelligence pick-to-light system with a hybrid sensing unit can determine the picking part sequence and quantity to pick-up with operator assistance software with intuitive set-up (OASIS). The most important aspect of this system is to demonstrate the improvement in picking speed and accuracy that might lead to the significant output of productivity and quality. This research was conducted at the assembly line at Advanced Electrical Machine Ltd. [3] as an internationally recognized center of innovative electric machine's research, to design and manufacture electric motors and drive technologies for the transport sector.

Previous work in pick-to-light research such as a study on the picking process time by [4] showed the standard picking process for lightweight cargo and productivity analysis for warehouse picking system for conventional manual picking versus automatic picking system in comparison with the processing time. Pick-by-HMD (Head Mounted Display) was another technique in using for the directive operator in warehouse part picking was studied by [5] for operating automobile manufacturing plant. There are some comparison study was conducted by [6][7][8] related to order picking system but they only focused on the conventional pick-to-light system and some of them using a head-up-display system to assist with their system [9][10] process mainly applied in warehouse system.

In this study, we mainly focus on the production assembly fast-moving process line with parts picking to assembly to the main part. We develop the system with pick-to-light using an intelligent system by the elimination of some unnecessary processes in picking mainly the process of confirmation of the part after picking process. This system will automatically recognize the sequences of part, the quantity of part and confirm the correct part already assembled at the main part. We will conduct the analysis of the two-environment condition to find the best solution for the development of the low-cost pick-to-light system. The pick-to-light systems require operators to press an "*acknowledge*" button after selecting workpieces from a bin at first setting requirements. Once the switch is pressed, the bin's light is switched off and the new light is on. Such lights allow the user to realize what bins have been viewed sequentially. Having ignored the pick confirmation by pressing the push-button switch, the system won't know the parts are taking away from bins and its likely consequence will be the increase of error rates for the pick-to-light system [11].

This will be compared with a second environment condition setting which is the system will add an intelligent sensor system instead of a push-button switch. The elimination of the push-button switching process will speed up the production cycle time at each process and reduce the error rate during the picking process. Therefore, we compare the sensor-based pick-to-light system to pick-to-light with a push-button confirmation system designed to minimize errors. With this industrial implementation, it is anticipated to increase the productivity of the process by reducing the cycle time.

This paper is organized as follows: Section 2 encompasses a literature review of the related researches of the pick-to-light system. Section 3 describes the detail of the system development, and section 4 explains the experimental setup and implementation for comparing efficiency after implementing the proposed method. Section 5 expresses the result and discussion and finally, section 6 will wrap up the conclusion of the proposed developed system.

2. Literature Review

2.1. Pick-To-Light Overview

Pick-to-light is an order-performance software that uses alphanumeric displays and buttons at storage locations to direct manual "*selection*" and recording products for assembly or packaging or re-packing or shipping [12]. The operator scans a barcode in a standard pick-to-light system[4][13][14][8], the operator scans a barcode, which is in a disposable bin of temporary workpiece containers. Typically, alphanumeric displays will illuminate light-emitting diodes (LEDs) to guide the operator to the correct location and indicate the number of items to be picked. The operator takes the items from the bin and confirms the activity, usually by pressing an "*acknowledge*" button. Displays continue to light up in the work zone of the operator, directing them to the next task of picking parts.

With manual or semi-automated assembly stations, a number of components are given to an operator which is very confusing and difficult to understand exactly what the task and sequence of jobs are. Figure 1 is an example of what an operator could be faced with at a typical assembly station. Multiple part bins with similar shape and color lead to the wrong selection of the parts or probably missing the parts. When the wrong part is picked, it will lead to the wrong assembly, quality issues and also time-consuming during the re-work process.

Figure 1. A typical assembly line at a manufacturing company

A pick-to-light system in its most basic form assists the operator by having a "*pick light*" at each part bin which illuminates a component each time that is picked from the bin and added to the assembly. The addition of motion sensors at the part bins provides feedback to the system to indicate the component that has been picked by detecting hand movement. Further enhancements to this are screens at the station which also shows the operator an image of component and the point of assembly and any specific care points to be noted. All these features are added to the overall cost of the system.

2.2. Methodology

2.2.1 Productivity. We will implement our proposed method at station 3 (St3) in the production line shown in Figure 2. Order picking for each bin with n quantity and time, t will be calculated based on the picking process until finishing assembling of the parts to the main part.

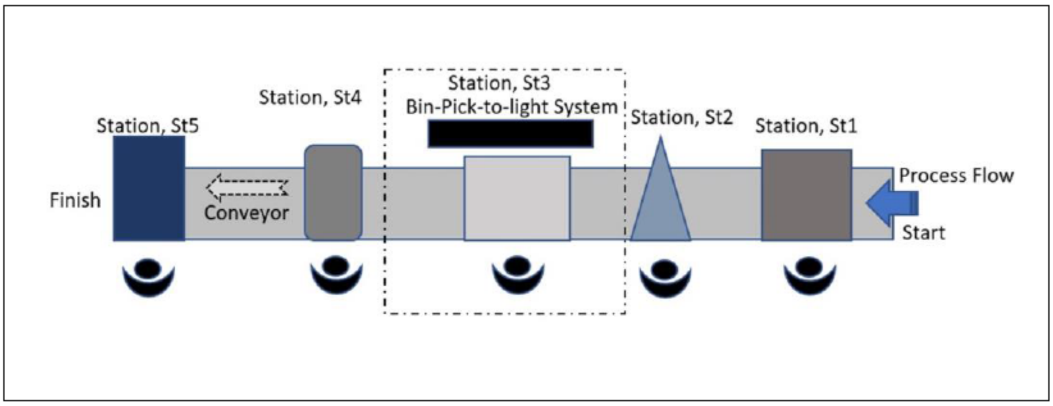

Figure 2. Process flow for the assembly station with the proposed method

We can calculate the total time for this station as below:

$$\sum t = t\,(1) + t\,(2) + \ldots + t\,(n) \qquad (1)$$

Our target is to minimize the total time $\sum t$ for this station and we can express line productivity by the below calculation.

Cycle time (T_c) is the time between start assembly till finishing assembly of each product at that line. This cycle time can be expressed by the following formula:

$$T_c = T_p/Q_n \qquad (2)$$

$$Efficiency = (\sum 〚Task\ Time〛)/(T_c\ x\ n)\ \text{x}100 \qquad (3)$$

$$Productivity = (\sum 〚Production\ output〛)/(\sum 〚Working\ Time〛) \qquad (4)$$

T_p: Production time per day
Q_n: Volume (Quantity) production output per day
Task Time: Total time for each station to complete all task

2.2.2 Error Detection Model. Our proposed system will use a counter verification system either using the "*acknowledged*" button or intelligence sensing system as shown in the *Error Detection Model* flowchart in Figure 3. After each time the operator pushes the "*acknowledgment*" button and subsequently, the system will record the part taken by the operator from each bin. The quantity record will be compared with the actual part balance after finishing each production batch manually by the operator. In this situation, the quantity of the parts used or taken by the operator can be counted. A similar process proposes the sensing system which provides confirmation by sensor automatically instead of pressing the "*acknowledgment*" button. This is a simple error detection model to detect whether excessive parts are taken, or insufficient parts are taken during the process. Different parts or rejected parts are detected by the "*reject part*" button as a counter for this error.

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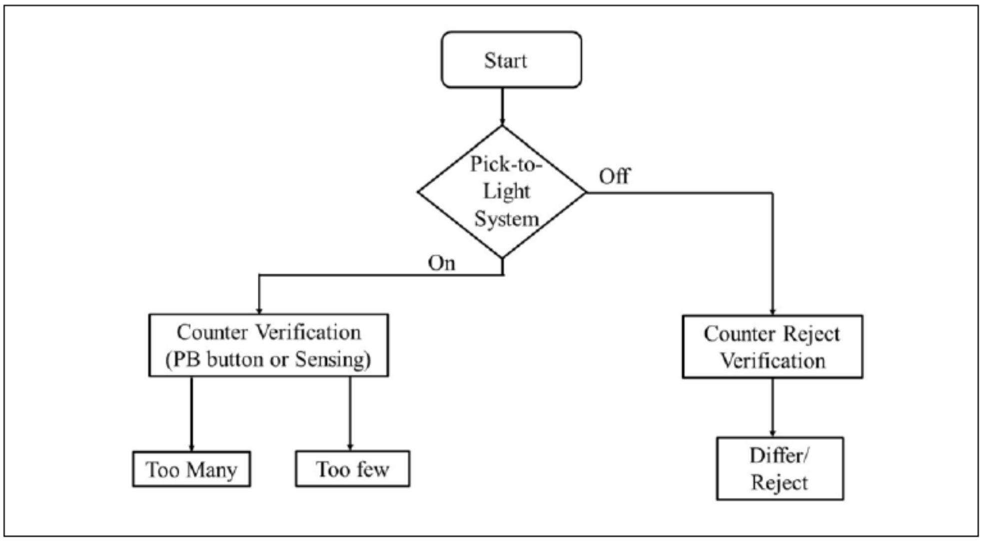

Figure 3. The Error detection model

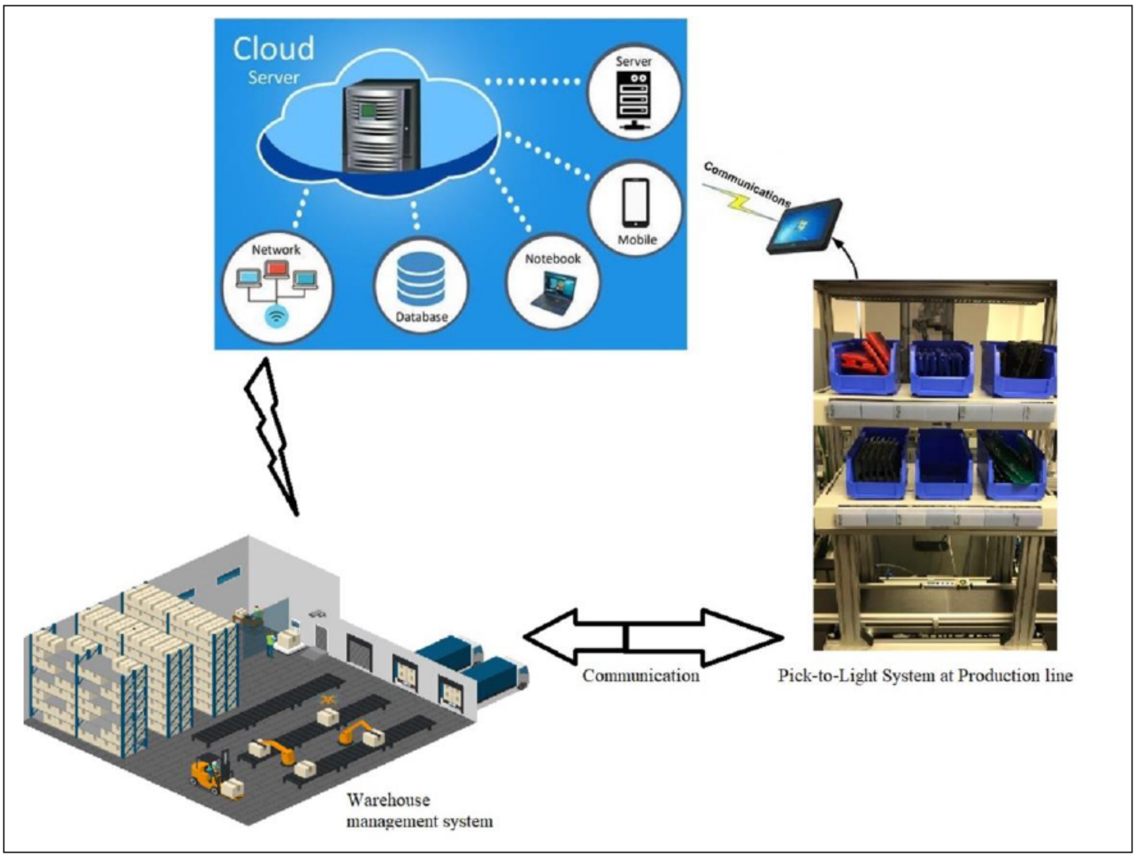

Figure 4. The proposed model

3. System Development

Overall system development is shown in Figure 4. Using the Pick-to-Light system at the production line will guide the operator into the part assembly and monitor the workpiece stock which is linked to the warehouse for stock refill and monitoring stock level at the warehouse. The proposed system will communicate with the cloud server which is connected with the user to monitor the product quantity assemble, quality of product, and status production line in real-time through mobile apps and network connection.

This section is devoted to describe the OASIS GUI for pick-to-light system development in terms of two dedicated tasks. These tasks, namely engineering task and operator task will be comprehensively discussed as follows and can be applied to similar OASIS pick-to-light systems that belong to this class. The design method is implemented using two programming languages, with Livelink interfaces among them: C# and Arduino. The former language is used to design the GUIs, while the latter one is used to program the logical commands between GUIs and lights, buttons or buzzers. The interlink between two languages is provided via serial ports 1 and 2 of the USB ports of the computer. The Arduino microcontroller MKR-1000 that is chosen as a microcontroller platform to implement the pick-to-light system of this research.

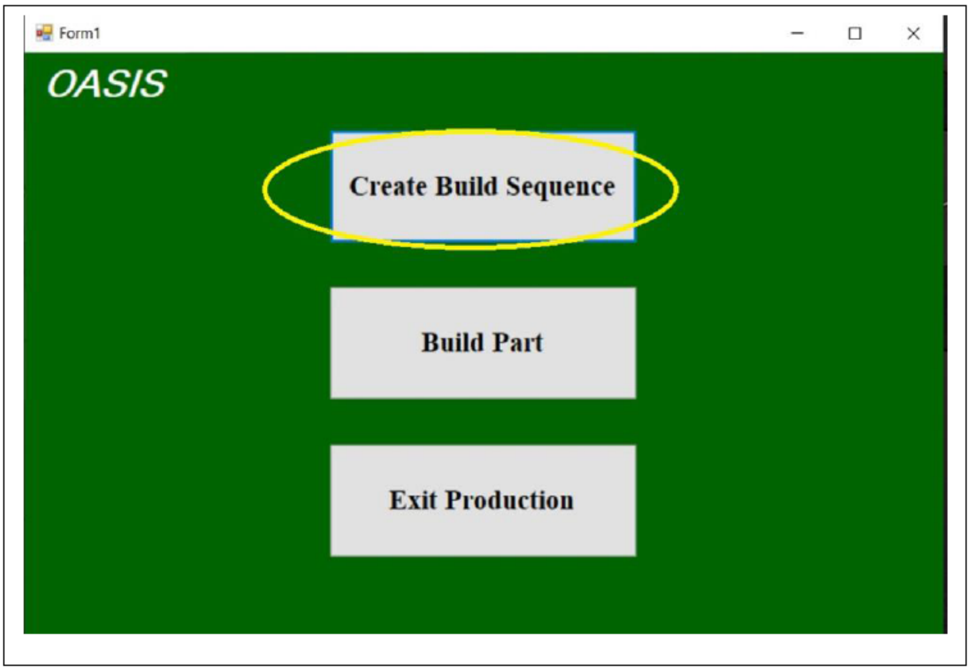

Figure 5. The OASIS main menu GUIs using C# language design

As discussed above, two tasks have to be carried out through the proposed pick-to-light system. One has to be performed by an engineer and another by the operator. For both, the task is initiated from the main OASIS menu, which is shown in Figure 5.

As seen, this menu includes three buttons, namely "*Create Build Sequence*"," *Build Part*" and "*Exit Production*". In this window, the engineer enters the part information such as Part Name, Part Number and their quantity like as shown in Figure 6. Then the data of the parts are saved in the system. At any time, the operator can continue the job and start it by clicking the "*Build Part*" button. After clicking, the "*Build Part*" menu appears again, and the operator can select one part to continue working on it. E.g., Part A is selected as displayed in Figure 8. The part and barcode scanner are prepared, and the part is scanned. Once the main part is scanned, the part number is displayed in the blank space of the "*Barcode Scanning Window*" and simultaneously all lights of the bins belonging to the respective main part are illuminated. These bins contain the subcomponents of the main part and all are equipped by one light which is programmed through Arduino microcontroller. The operator will start assembly of Part A by picking subcomponent from bin 1. After finishing the assembly from bin1, the operator will click the "*Acknowledgment*" button and then the light will be off consequently. After completing the assembly of the main part, all lights will be off, and the main OASIS menu shown in Figure 5 will appear for new tasks. By clicking "*Exit Production*", OASIS will display the print report and exit the operation.

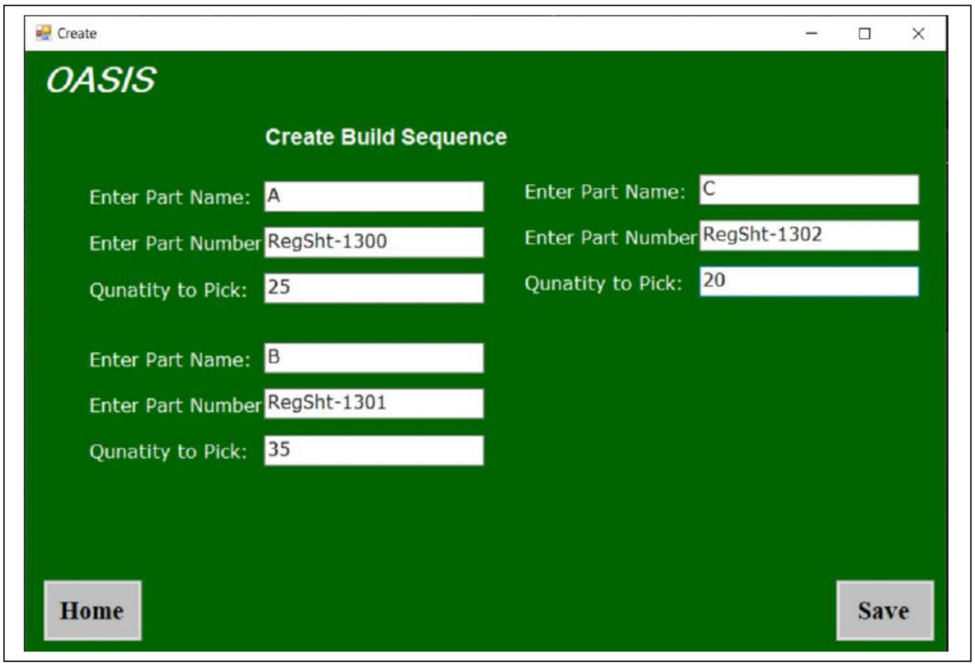

Figure 6. Create Build Sequence menu GUIs

4. Experiment

In previous work, the predominant type of error for the experimental pick-to-light system was arisen from skipping bins in which the operator forgot to pick the parts from them rather than picking excessive or insufficient parts from a required bin. We implemented a pick-to-light method for confirmation of pick-up acknowledgment by a push-button switch. Our LED screens are used by our pick-to-light system to direct the user to the right bin. The proposed system has the same configuration, but the only variation if the pickup verification is automatically recognized by the sensor system.

An LED screen and a push-button switch are connected with each pick bin. If nothings need to be retrieved from the bin, the Light will stay off. Otherwise, in the LED and screen panel, the number of items that have to be selected from that bin will be shown. For our experimental setup setting, using pick-to-light with a push button (PB) button switch and intelligent hybrid system, we suggested the two test conditions as discussed below for scenarios that occur during the picking process.

4.1. Experimental Setup

Figure 7 shows the manual process flowchart for an experimental setup condition or scenario discussed as follows:

A. The good part and normal scenario

- Start Production, the operator will scan Batch Card Barcode and main part barcode and pick light of the bin(s) related to the main part will keep blinking in sequence (one by one) after pressing the button on the tablet.
- The operator will take the part from each bin and press the PB acknowledge button then the next light at the next bin will blink. Pick light will be off after the acknowledge button is pressed.
- After assembling the parts, the operator will press again the PB to acknowledge the part complete and deliver the OK (Good) part to the next station.

B. Reject Part Sequence

- The operator picks the part from the bin and finds it is a rejected part and at this stage, the light is still on until they press the PB to acknowledge button. The operator just presses the reject button to record the parts are out of service at this stage. If the operator picks the part out from the bin and it is faulty, then they will press one of the reject buttons. From this, the system knows what part has just been picked and logs a reject against that part number. The operator will then pick another part, as the light is still on and assembled again to part A, and then press PB to acknowledge. In the end, the light goes off and new light comes on for another parts pickup-up process.

- The operator will continue the assembling process and press PB to acknowledge the job complete and the main part will deliver to the next process as OK or Good part.
- Reject Part for the main part (Part A) show in Figure 8, as an additional experimental setup environment to evaluate the functionality of the system. If we want to reject part A at any stage we could then push and hold the two times reject buttons (Figure 8), this logs the reject in the system and prevents further assembly.
- The operator in the next station will scan the main parts' barcode and will acknowledge the NG (not good) part and not continue the assembly process for this part and pass it to the next station.

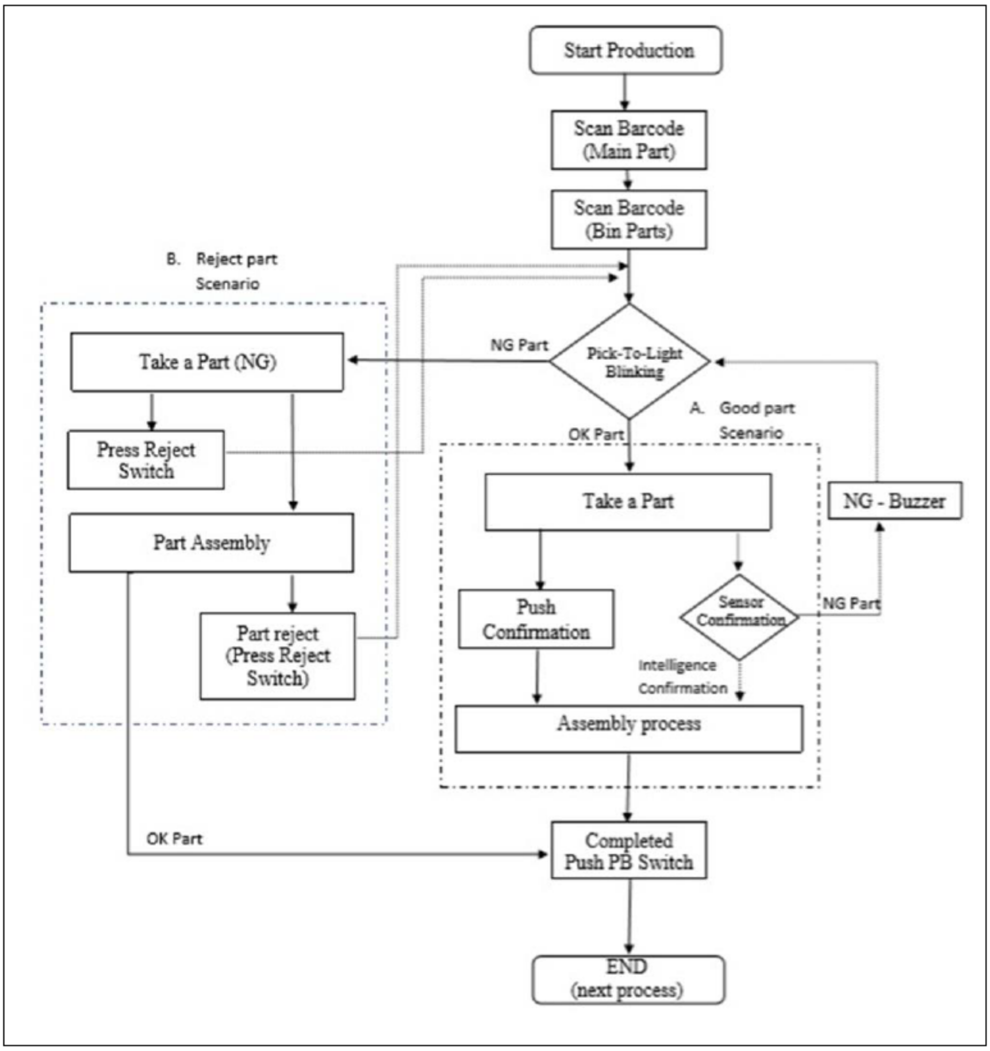

Figure 7. Flowchart of intelligent hybrid pick-to-light and conventional push-button switch system

When the PB push button is pressed by the operator, it updates the device with the number of items picked by the operator. The process compares the number of items picked by the operator by push button switch verification with the number of component balances in the bins to determine the operator's picking error. In this case, the operator must count the remaining parts in the bins manually and notify the system at the end of the cycle or before restocking the new part in the bin. This methodology provides a simple way of error identification for all the above situations. Once the initial part minus remaining parts in the bin is the same with the push-button counter, the error is zero by a particular part/bin.

In a sensor hybrid pick-to-light intelligent system, the operator doesn't need to press the push button switch and instead the sensor will do the detection autonomously. The system will detect the operator hands movement to correct bin to count the part taken away from that bin for each process. If the operator takes the wrong bin, the system will alert the operator by buzzer sound and if the reset button is not pressed, the system will count the part taken by mistake. The system sums the number of items taken and compares the remaining items in the bins at the end to make a simple error detection calculation.

4.2. Implementation
We use a proximity sensor as a hybrid intelligent sensing unit for our proposed method. We are using this pick-to-light module from the Arduino MKR1000 board [15] which incorporates the Zero and Wi-Fi Shield features. Arduino MKR1000 has been developed to provide a realistic and cost-effective solution for developers looking to incorporate Wi-Fi connectivity with little prior networking experience to their designs. It is based on the Atmel ATSAMW25 SoC (System on Chip), which is part of the Atmel Wireless Systems Smart Connect family, designed specifically for IoT projects and systems. We use our previous sensing technique in apply for our proposed system [16][17][18][19][20][21][22][23][24].

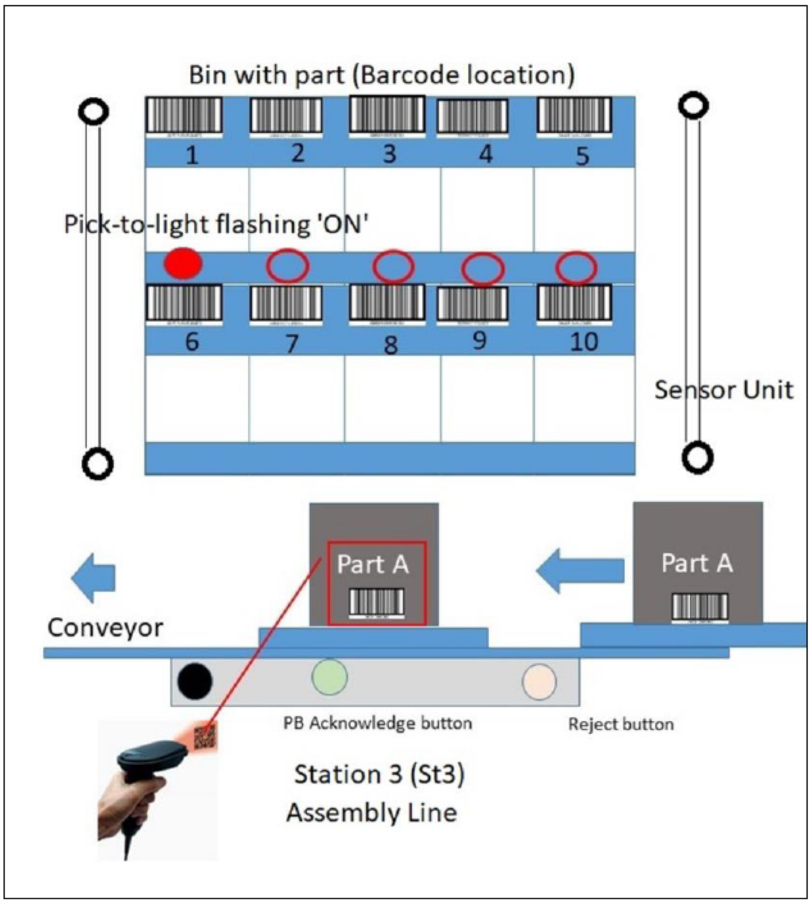

Figure 8. Scan the 1st part A will ON the pick of light by sequence

The system was tested and evaluated by 40 participants using two experimental scenarios for each hybrid intelligent pick-to-light system, the pick-to-light system with push switch acknowledge confirmation and manual condition without any guidance system. The experiment targets, two groups of operators age between 20 until 35 and above 35 among females and males with five participants in each group. Line balancing for an assembly line is very important. After we implemented our proposed method and calculated process time at each station in the respective line, task time $\sum t$ at station St3 was reduced after implementing the new system which is shown in Table 1.

When the operator presses the PB push button switch, it updates the system with the number of items picked by the operator. To calculate the picking error by the operator, the system compares the number of items picked by the operator by push button confirmation switch with the number of part balances in the bins. In this case, the operator should manually count the left part in the bins and tell the system at the end of the process or before refilling new parts in the bin. This method provides a simple error detection mechanism for all the above scenarios. Once the initial part minus remaining parts in the bin is equal with the push-button counter, the error is zero by a particular part/bin.

In a sensor hybrid pick-to-light intelligent system, the operator doesn't need to press the push button switch and instead the sensor will do the detection autonomously. The system will detect the operator hands movement to correct bin to count the part taken away from that bin for each process. If the operator takes the wrong bin, the system will alert the operator by buzzer sound, if the reset button does not press the system will count the part taken by mistake or wrong part. The system sums the number of items taken and compares the remaining items in the bins at the end to make a simple error detection calculation.

We set up each bin at station 3 in an assembly line containing about 50 sets of pieces, and the products are unique and different for each bin. Two columns of bins divided the pick bins identically. There were five boxes in each line which is shown in Figure 8. Each bin is coded with barcode and match with the shelves barcode which has been recorded to the system earlier. The barcode scanner will use for registering each bin and record the part to assemble from the assembly matrix chart recipe. Each picking process time will be calculated. Without using our proposed method, the operating time is also calculated to make a comparison to the effectiveness of the proposed system.

5. Result and Discussion

Line balancing for an assembly line is very important. After we implemented our proposed method and calculated the processing time at each station in the respective line, task time $\sum t$ at station St3 was reduced after implementing our proposed method shown in Table 1.

Table 1: The comparison results after implementation of the pick-to-light system at station 3 (St3) and line balancing process implementation at St1, St2, St3, St4, and St5

$\sum t$ (Second)	St1	St2	St3	St4	St5
Before using the proposed method	152.4	165.0	188.4	169.5	175.2
After using the proposed method (Line Balancing)	98.6	100.4	103.8	88.2	96.0

The average cycle time for station 3 was reduced to 103.8 seconds after using the proposed system as shown in Table 2 below. It can be seen that the cycle time is reduced, and the line balancing is provided for an appropriate time sequence for each operator at the production line. This will result in an increase in productivity at this assembly line.

Table 2: Average time of each assembly task at station 3 (St3) after using the pick-to-light system and after line balancing process

Task No.	Assembly Task	Average Time (Sec)	Cumulative Assembly Time (Sec)
1	Scan workpiece (w/p) and place rear cover to jig	10.70	10.70
2	Take rear pin bush (2 pcs) and insert to w/p	19.02	29.72

3	Take end effector (4 pcs) and insert to w/p	20.15	49.87
4	Take the IC regulator and screw to w/p	17.38	67.25
5	Take Holder and insert to w/p	12.25	79.5
6	Take End Cover and tighten all screw	21.3	100.8
7	Visual check and press "*acknowledge*" button- a process completed	3.0	103.8

This proposed method can increase the efficiency of the line cycle time up to 57.3%. In addition, the error rate in the proposed system is also reduced in terms of wrong part assembly, missing part during assembly, excessive or insufficient parts picking from the bin. By reduction of the error rate, the rework time can also be reduced in the process.

6. Conclusion

The aim of this project is to create an easy-to-build and easy-to-use pick-to-light system that will be installed at Advanced Electric Machine (AEM) assembly line, that can be utilized to improve their assembly line production process (productivity) and improve the quality issues. The results show the more efficient and accurate picking process introduced in the proposed system by the elimination of the unnecessary steps in the process. Furthermore, the operator can move more intelligently with required picking quantities and lower workload. The development of this system can provide a low-cost solution with an intelligent order picking system for SMEs and a fast-moving production assembly line in manufacturing. In future work, several adaptations, tests, and experiments at various assembly processes will be conducted for potential development in the future.

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