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Remote Retail Monitoring and Stock Assessment using Robot

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Abstract—

This paper describes a Virtual Reality (VR) based system for data collection and surveying in a retail store using robots. The manpower cost for surveying and monitoring the shelves in retail stores are high, because of which these activities are not repeated frequently causing reduced customer satisfaction and loss of revenue. Further, the accuracy of data collected may be improved by avoiding human related factors. We use a robot platform with on-board cameras to monitor the shelves manually through tele-operation. A remote operator can control the robot from a console which shows a view of the store as well as, capture real images and videos of the store. The robot is designed to facilitate automatic detection of Out-of-Stock (OOS) situations. It would be possible for a single operator to control multiple robots placed at different stores thus optimizing the available resources. As the deployment of the proposed system does not require modifying existing infrastructure of the store, the cost of the entire solution is cheaper with shorter return-on-investment (ROI) period.

Index terms: Robot; Power Supply; ARM7; Wireless Camera

I. INTRODUCTION

Temporary out-of-stock (OOS) situation is considered to be an important problem in the retail industry. It is estimated that the global average out-of-stock rate is about 8% and it costs retailers about 4% losses in sales. The out-of-stock situations may arise because of several reasons. However, it is estimated that about 70-90% of stock outs are caused by defective shelf replenishment practices as opposed to 10-30% resulting from the problems in the supply chain. The former case leads to shelf-OOS while the later leads to store-OOS. We are primarily concerned with the case when the items are available in the warehouse or the backroom inventory of the store but they are out-of-stock on the shelves. This is more frequent with fast moving consumer goods (FMCG) which are depleted faster than their replenishment. Higher frequency of checking can reduce the OOS related problems to a greater extent. Currently, most of these surveys are carried out by humans at pre-defined intervals. Hence, a higher frequency of surveys would lead to higher cost leading to lesser profit margins. Moreover, the data collected through humans is erroneous and unreliable. RFID based technologies have been found to be useful in dealing with OOS situation apart from automating the supply chain management. Some of the companies like NeWave and Shelfx provide smart shelf solutions based on RFID that can detect OOS in real-time apart from facilitating automatic checkout. However, use of RFID based technologies require altering the store environment to accommodate antennae, sensors etc. And thus require more time and money for deployment. Moreover, RFID-based solutions which require item-level tagging is still expensive for low cost grocery items. In this context, we propose to use mobile robots to carry out these surveys and detect shelf-OOS in real-time as well as on demand. However, our focus is on providing a robust solution by keeping a human in the loop. The robots are partially or completely controlled by a remote operator. Our solution is not only cost-effective but also, does not require any modification to the existing infrastructure. Apart from detecting shelf-OOS and misplaced items, a mobile robot can provide several other value added services like providing useful information to customers in the form of promotions or discounts. It may also be used as a platform to facilitate automatic check-out thereby avoiding queues at point of sales (POS) counters. It could also be used for warehouse monitoring and surveillance during night time. Some of the benefits of using robots in retail store have been described later. The claims or novel contributions made in this paper are as follows: (1) The idea of monitoring the shelves using remotely operated robots is a new concept. (2) We rely primarily on on-board sensors for data collection thereby minimizing the changes needed in the environment it has to operate in. The presence of a human operator in the loop provides robustness to the entire solution compared to a robot only solution without any significant increase in the cost.In this paper, we describe the implementation of a Proof-of-Concept carried out in our lab. The usability is demonstrated through various experiments. The use of low cost hardware makes the whole solution affordable and thus, viable as a commercial solution for retail store monitoring. The rest of this paper is organized as follows. An overview of related literature is provided in the next section.

II. RELATED WORKS

This section provides an overview of various related works where robots have been used in the retail environment. Kamei *et. al.* use a network robot system to incorporate recommendation methods used in e-commerce system into a real-world retail shop. While sensors like LRF and cameras are used to analyze pre-purchase behaviour of customers, the physical robots are used to present recommendations and show directions. In another work, Matsuhira *et. al.* develop a robotic transport system to assist people during shopping. The system consists of two robots - one of them follows the person while the other acts as shopping cart carrying purchased items. The on-board robot sensors and environmental cameras are used to facilitate human-robot interaction. Similarly, RoboCart assists visually impaired customers navigate a typical grocery store and carry purchased items. It relies on RFID tags for localization and laser for navigation. There are few related patents as well. Bancroft *et. al.* developed a mobile robot system for interacting with customers and assist them by providing useful informations. The mobile robot was capable of travelling from one location to another and could accept inputs from a customer and give output verbally or in written messages. Ostrowski and Hudnut *et. al.* developed a shopping cart which could detect the items lying on the bottom of the shopping cart. It used a visual sensor identify products using visual features like SIFT. There objective was to speed up the check out process. Konstad *et. al.* developed a similar shopping cart system which could detect object using RFID and weight sensors. The US patent by Razumov describes a novel robotic system for selling goods at a retail facility having a storage area not accessible by customers. The system includes multiple robots and a control system. Based on the order placed by a customer, the control system assigns at least one robot to each customer which picks up multiple items from separate places and brings it to the customer. We are excluding the robotic inventory systems as in. Apart from AndyVision, none of the above robots can be used for carrying out surveys within a retail store. AndyVision can precisely localize itself using external sensors. It can update the planogram in real-time. It can detect empty shelves or misplaced items, recognize labels and products. The computationally intensive tasks are off-loaded to a cloud server. AndyVision project aims to revolutionalize the retail stores by using robots to automate all aspects of retail store management. However, the commercial viability of such a system is still questionable at this point. Our primary focus is to provide a commercially viable solution to the problem of retail stock monitoring. While it is always possible to build a sophisticated robot to do everything on its own, presence of a human operator in the loop can not only make the solution robust against various unseen circumstances, it can reduce the overall cost of the solution significantly and thus, making it acceptable to the market. The details of the proposed scheme are discussed next in this paper.

III. THE IDEA

We propose to use a robot to automate the data collection in a retail store environment. We plan to use onboard cameras to collect images and videos of the shelves which are transmitted to remote server over radio. These images will be processed over cloud to generate several analytics. The use of robots for retail monitoring is expected to provide following benefits: (1) It will be possible to carry out surveys more frequently thereby reducing the cost per survey.(2) It will increase the reliability and authenticity of data being gathered. (3) A robot can provide other value added services which will enrich the shopping experience of customers. The schematic of a retail robotics framework is shown in Figure 1. The robots can be controlled and managed by a remote call centre providing round-the-clock service. The product manufacturers can obtain survey reports from these call centres as and when required. A customer can obtain various product related information from the call centre through telephone calls or from servers using mobile apps. The user can also get the real-time data availability of a product from the nearest store through this system. In this paper, we only discuss the implementation of a part of the solution.

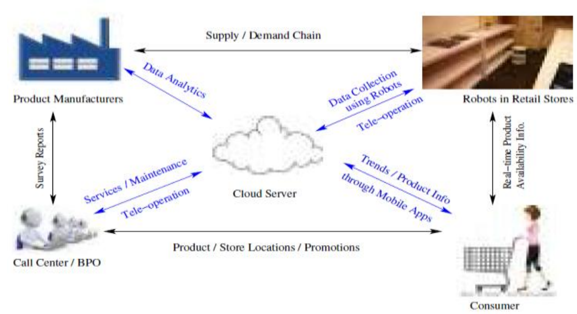

Fig. 1. A cloud-based retail robotics framework. Robots are used for collecting data from retail stores in real-time which can be used for improving the efficiency of the entire retail ecosystem.

As a proof-of-concept, we set up a mock store where a teleoperated robot is used for gathering visual data. The robot can operate in a tele-operation mode as well as goal-based autonomous navigation mode. Through the operator console, the remote operator can obtain live stream of videos and images recorded through on-board camera. The operator can capture images of a shelf whenever required. The operator console has commands for robot navigation.

IV. THE SYSTEM HARDWARE

In order to demonstrate the proof-of-concept, we set up a mock retail store in our lab. The robotic system consists of a having an on-board Kinect camera for navigation and a low-power netbook for running essential algorithms. It uses two USB cameras to capture images and videos of the racks on either side of the robot. The robot with cameras are shown in Figure 2. The robot is controlled through a operator console (described later) running on a remote computer. The remote computer running the operator console communicates with the robot using wireless network. Surveillance cameras available in the store could be used for obtaining the bird's eye view of the store. It could be used for improving the localization of robot as has been done.

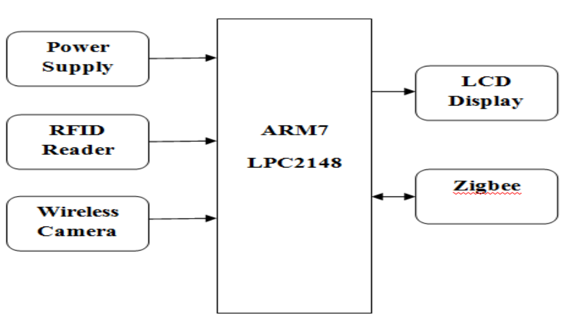

Figure 2: Block diagram of Proposed system

ARM7 LPC2148: The LPC2148 microcontrollers are focused around a 16-bit or 32-bit ARM7TDMI-S CPU with constant imitating and implanted follow help, which consolidate microcontroller with inserted high velocity streak memory extending. Serial interchanges interfaces running from a USB 2.0 Full-speed gadget, various UARTS, SPI, SSP to I2c-transport and on-chip SRAM of 8 kilo Bytes up to 40 Kilo Bytes, make these gadgets extremely appropriate for correspondence entryways and convention converters, delicate modems, voice distinguishment and low end imaging, giving both extensive cradle size and high transforming force.

***RFID Reader*:** RFID based technologies have been found to be useful in dealing with OOS situation apart from automating the supply chain management. However, use of RFID based technologies require altering the store environment to accommodate antennae, sensors etc. And thus require more time and money for deployment. Moreover, RFID-based solutions which require item-level tagging is still expensive for low cost grocery items.

***Wireless camera interface**:* In this section wireless camera is installed in the robot. Then camera can transmit the video continuously to the controller unit through tuner is connected at the controller unit. Controller monitor the video and where ever we need images can be captured by using ulead software.

Power supply: The info to the circuit is connected from the directed power supply. The a.c. info i.e., 230v from the mains supply is venture around the transformer to 12v and is encouraged to a rectifier. The yield acquired from the rectifier is a throbbing d.c voltage. So as to get an unadulterated DC voltage, the yield voltage from the rectifier is nourished to a channel to evacuate any AC parts present much after correction. Presently, this voltage is given to a voltage controller to get an immaculate steady dc voltage.

LCD Display: LCD screen comprises of two lines with 16 characters each. Each one character comprises of 5x7 spot grid. Differentiate on presentation relies on upon the force supply voltage and whether messages are shown in one or two lines LCD is by design cleared, just the once the power supply is turned on. This process after everything else for approximately 15mS. Subsequent to that, the display is ready to function.

ZIGBEE: ZIGBEE Technology is one of such movement in remote innovation. Remote is not another innovation as remote systems administration and remote web are now being used; yet ZIGBEE TECHNOLOGY set another angle in remote engineering.. The ZIGBEE standard uses little low-control gadgets to join together to structure a remote control web ZIGBEE convention is enhanced for long battery life measured in months to years from reasonable, off-the-rack non-rechargeable batteries, and can control lighting, aerating and cooling and warming, smoke and blaze alerts, and other security gadgets.

V. THE SOFTWARE SYSTEM

The Software Architecture: XCTU SOFTWARE this software is used to control the robot by using zigbee modules. Two zigbee modules are used one is transmitter and second one is receiver. This software can control the whole robotic action like move forward, backward, left and right.

VI. EXPERIMENTAL RESULTS

A. The experimental Setup

The experiment is carried out in a mock retail setup. The room has a size of 4.8 m × 3.4 m × 2 m. It has six racks (1.5 m × 0.5 m × 0.9 m) forming three rows. In this case, the robot has one closed-loop path in the retail store. The robot used for the experiment which carries two USB cameras facing the racks on either side of the robot path. The two on-board USB cameras could be used for monitoring both the shelves lying on either side of the robot simultaneously. The views from both the cameras are transmitted to the operator's console and they appear as shown in Figure 8. This scheme makes it easier and faster to monitor shelves in a retail store.

Figure 3:Experimental Setup with power supply

Figure 4:Retail Stock Assesment display on LCD

VI. CONCLUSION

In this paper, we provide an implementation of a robotic system which can be used for carrying out surveys and stock assessment in retail stores with reduced manpower. The entire solution is implemented with a low cost robot. The robot could be teleoperated by a remote operator to monitor and check individual shelves without moving away from his desk. He can also control multiple robots from the same console. The robot can also be operated in autonomous mode taking pictures and videos which could be processed over a cloud to generate statistics. Currently, our focus is on detecting OOS situation or misplaced items on the racks and generate alarms in real-time. The remote operator has a virtual 3D/2D environment where the robot location is updated in real-time to show its current location. The operator also has flexibility of viewing and storing videos as seen by the on-board cameras. This humanin-loop solution provides robustness to the whole solution making it commercially viable for deployment in real-world scenarios.

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