Comprehensive autonomous checkout system/ Smart store solution

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Abstract: *An autonomous checkout/smart store solution refers to a system that enables customers to purchase items without the need for a cashier. This is achieved through a combination of technologies such as computer vision, machine learning, sensors, and mobile apps. The customer scans the items they wish to purchase using a mobile device, and the system automatically calculates the total cost and facilitates payment. The goal of such a solution is to improve the shopping experience for customers, reduce wait times, and increase efficiency for retailers. This type of solution can benefit retailers by reducing operational costs, improving the customer experience, and providing valuable insights into customer behaviour and preferences. It can also benefit customers by providing a convenient and efficient shopping experience, reducing wait times, and allowing them to track their purchases and manage their accounts.*

Key Words: *Smart store, autonomous checkout, Just walk out technology, Amazon Go.*

1. INTRODUCTION:

Comprehensive autonomous checkout system is a rapidly emerging trend in the retail industry that aims to streamline and enhance the shopping experience for customers. The technology that we are dealing about is known as Walk Out technology. Walk out technology, also known as "just walk out" technology, is a revolutionary concept in the retail industry that allows customers to enter a store, pick up the items they want, and leave the store without having to wait in line to check out. The technology uses a combination of cameras, sensors, and algorithms to automatically track which items the customer has taken from the shelves and charge them accordingly.

This technology was first introduced by Amazon with their Amazon Go stores and has since been adopted by other retailers such as Walmart and Kroger. The benefits of this technology include reducing the need for cashiers and improving the customer experience by reducing wait times. However, there are also concerns around privacy and data security that need to be addressed. Walk out technology is an exciting development in the retail industry, and it will be interesting to see how it continues to evolve and impact the shopping experience in the future. Walk out technology is made possible by a combination of advanced technologies. In Amazon Go stores, for example, the technology uses computer vision, deep learning algorithms, and sensor fusion to track the customer's movements throughout the store. The cameras and sensors are strategically placed to detect when an item is picked up or put back on the shelf. The technology also keeps track of the customer's identity through the Amazon Go app, which the customer uses to enter the store.

As the customer leaves the store, the technology calculates the total cost of the items picked up and charges the customer's account accordingly. This eliminates the need for cashiers, reduces checkout time, and allows customers to shop at their own pace.

2. LITERATURE SURVEY:

There have been several academic and industry studies on autonomous checkout and smart store solutions. These studies focus on the technology, feasibility, challenges etc. of implementing a smart store:

2.1 "Frictionless Retail: Reimagining the In-Store Experience" by Accenture: This report provides an overview of the benefits of autonomous checkout systems, as well as case studies of retailers who have implemented such systems. The report highlights the role of technology in creating a frictionless retail experience. From self-checkout machines to RFID tags and smart shelves, technology can help retailers streamline the shopping experience and reduce wait times.

However, the report cautions that retailers need to balance the use of technology with human interaction to ensure a personalized experience for customers.[1]

2.2 "Real-Time Object Detection for Autonomous Checkout Systems" by Venkatesh Kannan and Keng Teck Ma: This paper describes a computer vision-based autonomous checkout system that uses real-time object detection to identify and track items.

The report highlights the different types of object detection algorithms used in autonomous checkout systems, including region-based convolutional neural networks (R-CNNs), You Only Look Once (YOLO), and Single Shot MultiBox Detector (SSD). The authors provide an in-depth analysis of each algorithm and their respective strengths and weaknesses. The report also examines the challenges faced by autonomous checkout systems that use real-time object detection. These challenges include the need for high-quality cameras, the variability of object shapes and sizes, and the difficulty in detecting multiple objects simultaneously. The authors suggest that the use of multiple cameras and the integration of other sensors, such as Lidar or radar, could help overcome these challenges.[2]

2.3 "Smart stores: A review and research agenda" by Ann-Kathrin Klose and Jan H. Schumann: This paper provides a comprehensive review of the literature on smart store solutions, with a focus on the benefits, challenges, and future research directions.

The report outlines a research agenda for future studies on smart stores. The authors emphasize the need for research that examines the effectiveness of different technologies and their impact on custo3mer behaviour and store operations. They suggest that future studies should also explore the role of smart stores in the broader retail ecosystem and the implications for supply chain management.[3]

2.4 "Deep Learning for Retail Analytics: A Survey" by Congrui Huang, Zeyu Wang, and Fei Wang: This paper provides a survey of deep learning techniques that can be applied to retail analytics, including autonomous checkout and smart store solutions. These studies highlight the potential benefits of autonomous checkout and smart store solutions, as well as the technical and operational challenges that must be addressed for successful implementation.

The report provides an in-depth analysis of the different types of deep learning algorithms used in retail analytics, such as convolutional neural networks (CNNs), recurrent neural networks (RNNs), and generative adversarial networks (GANs). The authors explain how each algorithm works and its specific applications in retail analytics.[4]

3. METHODOLOGY:[13]

The method used in comprehensive Autonomous Checkout or smart store uses a methodology named "Just Walk Out technology". In order to successfully achieve this JUST WALK OUT TECHNOLOGY, Smart stores have to achieve the following with extremely high accuracy:
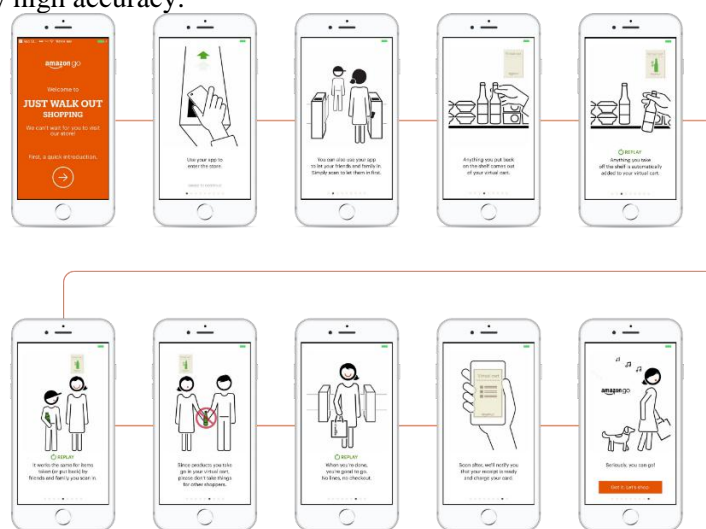

Figure 01: Amazon GO instructions for customers[7]

Register a customer — so the store can link their shopping account.
Track the customer's location — so the system can correlate the customer data, and the actions taken place.
Detect an item that was picked up — so the system can add items to the virtual shopping cart of the customer who was at the location.

Detect an item if it was put back onto the shelf — so the system can remove items from the customer's virtual shopping cart.
Detect when the customer leaves the store — so the customer's online transaction can be completed.

3.1. Register a customer
The experience's most commonplace aspect is this. Consumers must download an app, such as the Amazon app, to their phone. They must scan the QR code on their app at the store door to get to the gate, which resembles a standard metro entrance.

3.2. Track the customer's location
There are a large number of RGB cameras set on the ceiling for tracking specific consumers. Despite the fact that no facial recognition technology is employed by these cameras.

Instead, these cameras identify the overall characteristics of each consumer and follow people using motion detection. A consumer entering Camera B and departing Camera A are recognised by the camera as being the same person. Separate depth-sensing cameras are used to increase tracking accuracy.

3.3. Detect an item that was picked up and put back onto the shelf
This is the most distinctive quality of smart retailers, and it is reflected in the layout of the stores. A weight sensor on each shelf measures the precise weight of each item. The sensor can identify exactly which shelf an item is from when it is picked up. The sensor also recognises when the same-weight object is repositioned.
        The location of each customer and the activities that have taken place on each shelf are related by the central processing unit. Each shelf has distinct guides separating each row as a result of the system design, and they are larger than those in typical grocery stores. Because things must be well arranged and space is essential for proper consumer detection, the store always appears clean and well-organized.

3.4. Detect when the customer leaves the store
Unlike when they enter, customers do not need to scan the QR code to leave. When they exit the store, in-store tracking notices it. After leaving the store, the consumer will be automatically billed through their chosen shopping application. Their entire shopping list, including with the prices of each item, will be included in this application.
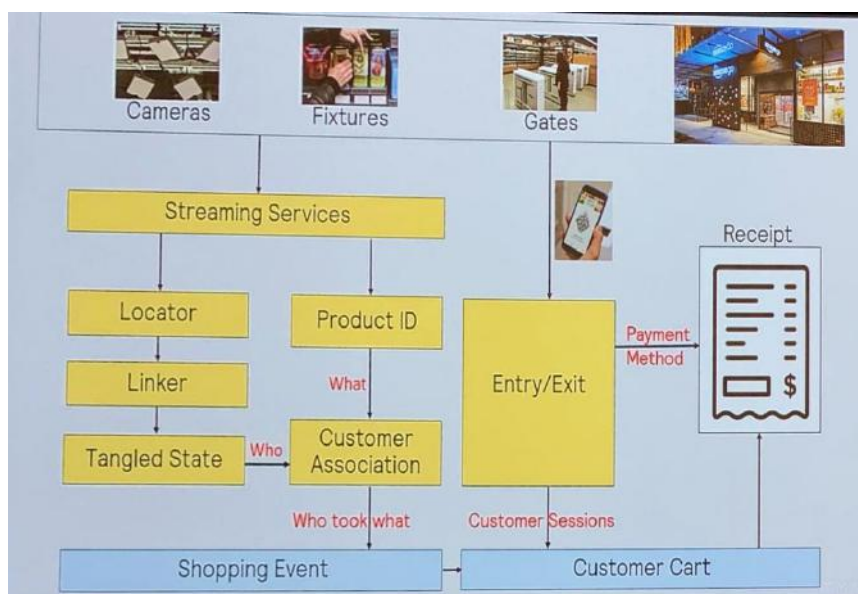

Figure 02: Technologies and devices used

4. WORKING:
        Simply scan in, take what you want and "Go". Each person entering the business to make a purchase would be tagged. As they enter the retail establishment, customers tag their smartphone with the store, which carries the Smart store app.

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When a customer enters the store, when they choose any items from the shelf, and when they leave the store with those items, photos are recorded at each of those moments. Customer information is tracked, including biometrics, facial recognition, and information on the user's height, weight, and other physical characteristics. The store's surveillance system can then use this information to recognise the consumer and follow them as they move about the space. When a customer approaches a shelf, cameras capture images of the person, the things they selected, and whether those items were maintained in the customer's hand or returned to the shelf. As products are removed from or put back on shelves, sensors installed at the shelves automatically notice this and keep track of the items in a virtual cart. Every user with a Smart store account has a virtual shopping cart that is maintained.

Queues and checkout are completely eliminated by this cutting-edge purchasing system. Customers will be charged on their smart store application account as they leave the store, and an automatic receipt will be created.
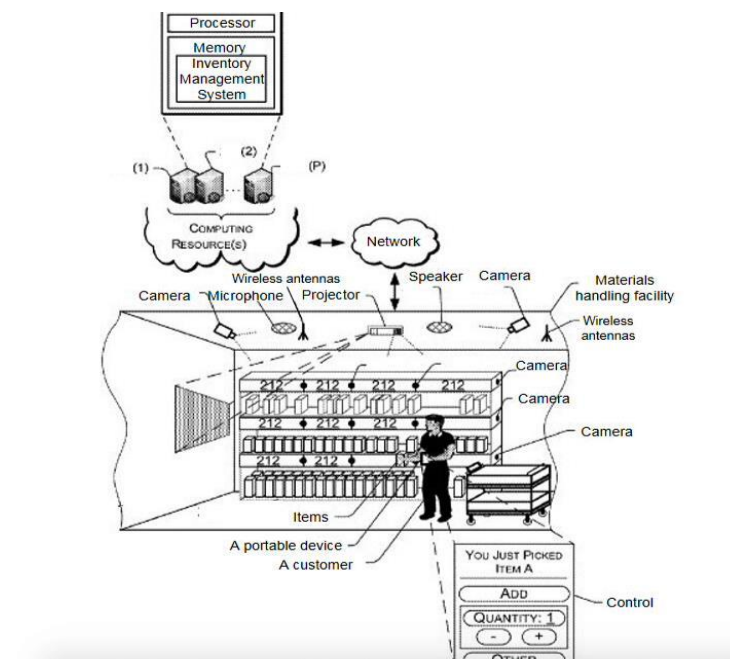

Figure 03: Components of a smart store[8]

5. TECHNOLOGIES USED:
Just walk out technology use a combination of
- Big Data – 20 years of customer buying patterns on Amazon.com
- Analytics – both predictive and prescriptive analytics
- Deep Learning – self learning algorithms trained for retail using troves of data
- Internet of Things – sensors, camera, RFID tags, etc.

	Person	Shelf	Entrance/Exit
Hardware	Smart Device (Smart Phone)	Cameras, pressure sensors, infrared sensors, scales, volume displacement sensors, light curtains, etc.	2D barcode
Software	Smart store app	Warehouse Management System (WMS)	Customize system

Table 01 : Combination of hardwares and softwares[5]

It is an amalgamation of technologies such as:
- Artificial Intelligence
- Machine Learning
- Image Recognition
- An array of "Fusion sensors"
- Decades of data on how humans shop

The Auto-Checkout shopping experience on Amazon Go is created using the same technologies as autonomous vehicles: deep learning algorithms (DLA), computer vision (CV) and sensor fusion.

6. TECHNICAL OPERATIONS:[6]
6.1 : Data Acquisition
The system will be able to determine what things have been taken from the aisles or shelves with the aid of sensor fusion from sensing elements or sensor data collected by several sensors on the aisles: Some sensors whose data smart system will "fuse" are the

- Pressure detector/sensor
- Weight measurement
- Unique Identifier through RFID tags
- Distance and Dimension measurement to monitor which products are picked up and when, as well as if they are placed back on the shelf.
- Based on the array of cameras for image/video data, this will assist Amazon in reducing the quantity of the item in its inventory.
- Where are the sensors expected to be placed?
  - In the aisles and/or on the shelves to see what is being picked up and where the merchandise is being moved.
  - Cameras would be placed all around - aisle, rack, store walls, etc.

6.2: Analysis of acquired data using AI
- Deep Learning (DL) algorithms, which consume a significant amount of data and train "self-learning" algorithms to determine
  - The product has gone into the cart?
  - Customer has put the product back on another shelf after picking up?
  - how long a customer holds/observes the product before making the purchase decision
  - what products are being sold -> what is the best place to position the product to ensure customer finds it easily and product is sold quickly
  - Product/SKU optimization -> keep only the in-demand products and discard products/SKUs (Stock Keeping Units) that customers do not like.
- Analytics: Sensor data + users past purchase history could be used to evaluate whether the product just picked up is chips packet or a pack of candy.
- Confidence scores and hypothesis testing is evaluated along.

6.3: Finally, the result of automated analysis by intelligent machines is presented
- In the form of adding the items to the virtual cart of customer as soon as the customer passes the transition area.
- The final bill is generated

7. SENSORS AND ALGORITHMS:
7.1 Cameras: Cameras are a key component of walk out technology as they are used to track the movement of customers and the items they pick up and put back on the shelves. In walk out stores, cameras are typically installed throughout the store to capture video footage of customers as they move around and shop. Computer vision algorithms are then used to analyze the video footage and identify when a customer picks up or puts back an item. These algorithms can detect the movement of specific items, such as a can of soda or a bag of chips, and track their movement throughout the store.

Cameras can also be used to identify individual customers and track their movement throughout the store. This can help retailers to personalize the shopping experience for each customer, such as by sending personalized offers or recommendations based on the items they have picked up. Also, Cameras can also be used to monitor the store for security purposes, such as detecting theft or identifying suspicious behaviour. In this way, cameras can serve a dual purpose of both enhancing the shopping experience for customers and improving the security of the store.

7.2 Weight Sensors: Weight sensors are another type of sensor commonly used in walk out technology. They are typically built into shelves or shopping carts to detect when an item is picked up or put back. When an item is picked up from the shelf, the weight sensor can detect the change in weight and signal the system that the item has been taken.

Similarly, when the item is put back on the shelf, the weight sensor can detect the change in weight and signal the system that the item has been returned.

Weight sensors are useful because they can provide a more accurate and reliable way to track the movement of items compared to visual tracking alone. For example, if a customer picks up an item and then puts it back on a different shelf or in a different location, visual tracking alone may not be able to accurately track the item's movement. However, weight sensors can detect the change in weight regardless of where the item is placed, providing a more accurate picture of the item's movement throughout the store. In addition, weight sensors can be used to detect when multiple items are picked up at once, or when a customer accidentally drops an item. This can help to reduce errors and ensure that customers are only charged for the items they intended to purchase.

7.3 RFID tags: RFID (Radio Frequency Identification) is a technology that uses radio waves to transmit data wirelessly between a tag or label attached to an item and a reader. RFID tags can be attached to individual items, such as products on a store shelf, and can be used to track the movement of those items throughout the store. In walk out technology, RFID tags can be used to track the movement of items and provide an additional layer of data to supplement the visual tracking provided by cameras or the weight sensing provided by weight sensors. RFID readers can be installed at various points throughout the store, such as on shelves, shopping carts, or at the entrance/exit, to detect when an RFID tag passes by.

When a customer picks up an item with an RFID tag, the tag is detected by the RFID reader, which sends a signal to the walk out system to register the item as being taken. Similarly, when the customer puts the item back on the shelf, the RFID reader detects the tag and signals the system that the item has been returned. RFID can provide several advantages over other tracking technologies. For example, RFID can be read through materials such as cardboard or plastic, meaning that items don't need to be directly visible to the cameras for the system to accurately track their movement. In addition, RFID can detect multiple items at once, making it faster and more efficient to track the movement of items. [9]

7.4 Machine learning algorithms: Machine learning algorithms are a key component of walk out technology, as they enable the system to analyse and interpret the data collected from various sensors and cameras to accurately track the movement of items and customers. One way machine learning algorithms are used in walk out technology is to identify and track individual customers as they move throughout the store. This can be done using computer vision algorithms that analyse video footage from cameras to identify and track unique features of a customer's appearance, such as their face or clothing. By tracking individual customers, the system can accurately associate items that are picked up with the correct customer account, ensuring that customers are charged for the items they intend to purchase.

Another way machine learning algorithms are used in walk out technology is to analyze and interpret data from multiple sensors, such as cameras, weight sensors, and RFID readers, to provide a more accurate and comprehensive picture of the movement of items throughout the store. For example, machine learning algorithms can be used to detect when items are picked up or put back on shelves, as well as to track the movement of items from one location to another. This can help to reduce errors in the system and ensure that customers are only charged for the items they intend to purchase. Machine learning algorithms can also be used to analyse patterns in customer behaviour, such as which items are commonly purchased together or which products are frequently returned. This data can be used to optimize the store layout, product placement, and pricing strategies to improve the customer experience and increase sales.

7.5 Payment processing algorithms: Payment processing algorithms are a crucial component of walk out technology, as they enable the system to accurately process payments for items that customers have picked up and taken out of the store without going through a traditional checkout process. When a customer enters a store using walk out technology, they typically need to sign in to a mobile app or a kiosk to create an account and link it to a payment method, such as a credit card or a mobile payment service. Once the customer has created an account, the system can track their movement throughout the store and automatically add items to their virtual cart as they are picked up.

When the customer leaves the store with their items, the system uses payment processing algorithms to calculate the total cost of the items and charge the customer's linked payment method. These algorithms take into account factors such as item prices, any applicable discounts or promotions, and taxes. Payment processing algorithms can also be used to detect and prevent fraud or errors in the system. For example, the algorithms may flag unusual purchasing patterns or unusual behaviour, such as a customer picking up a large number of high-value items in a short amount of time, which could indicate potentially fraudulent activity.

In addition, payment processing algorithms can be used to provide customers with receipts and transaction records, as well as to provide store managers with data on sales and customer behaviour. This data can be used to optimize store operations and improve the customer experience.

8. DRAWBACKS:

One of the main concerns regarding walk out technology is data privacy and security. Customers who use walk out technology must provide personal information such as their identity and payment information through the retailer's app. This data is then used to track the items that the customer picks up and charges them accordingly. However, this raises concerns about data privacy and security, as customers may be hesitant to share this information.

Another drawback of walk out technology is the potential for errors. While the technology is designed to be accurate and reliable, there is always a risk of errors or malfunctions that could result in incorrect charges. For example, the system may fail to detect when a customer puts an item back on the shelf, or it may incorrectly charge the customer for an item they did not pick up. This could result in customer frustration and dissatisfaction, and may also damage the retailer's reputation. There is also the risk of theft or fraud. While the technology is designed to prevent theft, there is still a risk that customers could find ways to bypass the system or engage in fraudulent behaviour, such as swapping price tags or removing security tags.

To mitigate these risks, retailers who use walk out technology must ensure that their systems are properly calibrated and maintained, and that they have processes in place to detect and prevent errors or fraud. This may include manual checks by employees, regular system updates and maintenance, and ongoing training and education for employees and customers on how to use the technology properly.

9. CONCLUSION:

Just walk out technology is geared up to revolutionize the shopping method by streamlining shoppers flow with innovative technology and by removing the foremost dreaded link of checkout counters in the offline shopping chain. This type of technology explores the evolving relationship between human and machines, examining the ways that robots, artificial intelligence and automation impacting our lives.

Overall, the future of walk out technology is exciting, and it will be interesting to see how this technology develops and expands in the coming years. As the technology continues to evolve, it will be important to weigh its benefits and drawbacks and ensure that it is implemented in a way that benefits both businesses and customers while maintaining ethical and privacy standards.

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