White Paper

Intel IoT
Intel® Architecture Processors

Scaling Fully Autonomous Stores

Autonomous shopping powered by Shekel Brainweigh, Intel® & Hitachi Vantara

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Executive Summary

There's no joy in queueing up at a grocery store for longer than it takes to pick the items you've come to buy. It's why personalization, convenience and experience have driven customers to move towards a new form of completely autonomous stores. These stores, in their many formats, are proving to be the most convenient way to shop, offering a frictionless shopping experience.

When talking about autonomous stores, there are different degrees of autonomy. But they all contribute towards higher-than-average spending, increased loyalty, and better ROI for retailers. It's why retailers are embracing technology to adapt to the changing behaviors and shifting expectations of shoppers. There is explosive growth in this segment, with a higher focus on providing cost effective solutions that are scalable. Autonomous stores can be deployed as independent entities or as part of larger format stores. This supports the accelerated digitization and safety needs arising from the pandemic, enabling operational continuity.

This paper discusses the different technologies being used for autonomous stores and how they combine with edge computing to harness high volume sensor/device data. This data enables the creation of cost-effective autonomous stores that address both customer pain points and retailer margins. The paper also discusses the infusion of technology into traditional stores, enabling both an autonomous experience and a traditional checkout experience.

The rise of autonomous stores

Autonomous stores have been gaining in popularity. In fact, automated checkout/ frictionless payments made it into Forrester's annual "The Top Retail Technology Investments In 2020[1]" research as prioritized by retailers. It's hardly a surprise. Personalization, convenience, and experience have long been at the top of customer priorities. So, retailers are using these same vectors to differentiate and entice customers back to their stores.

The allure for autonomous stores is for both customers and retailers. They are especially suited for selling mid-week essentials or lunch deals. This is because autonomous stores provide a convenient and quick experience that doesn't involve customers spending more time in a queue than choosing the product. In fact, they can drastically reduce the time spent scanning and paying for groceries. Similarly, retailers can potentially reduce staff costs and enjoy a larger footfall by addressing this significant customer need.

Usefully, autonomous stores can often be established as part of a larger store, where forward thinking retailers cater to customers that are in a hurry and prioritize certain popular products. These entities can also exist as part of a hotel, hospital, or airport, where they can offer convenience and guest access 24X7.

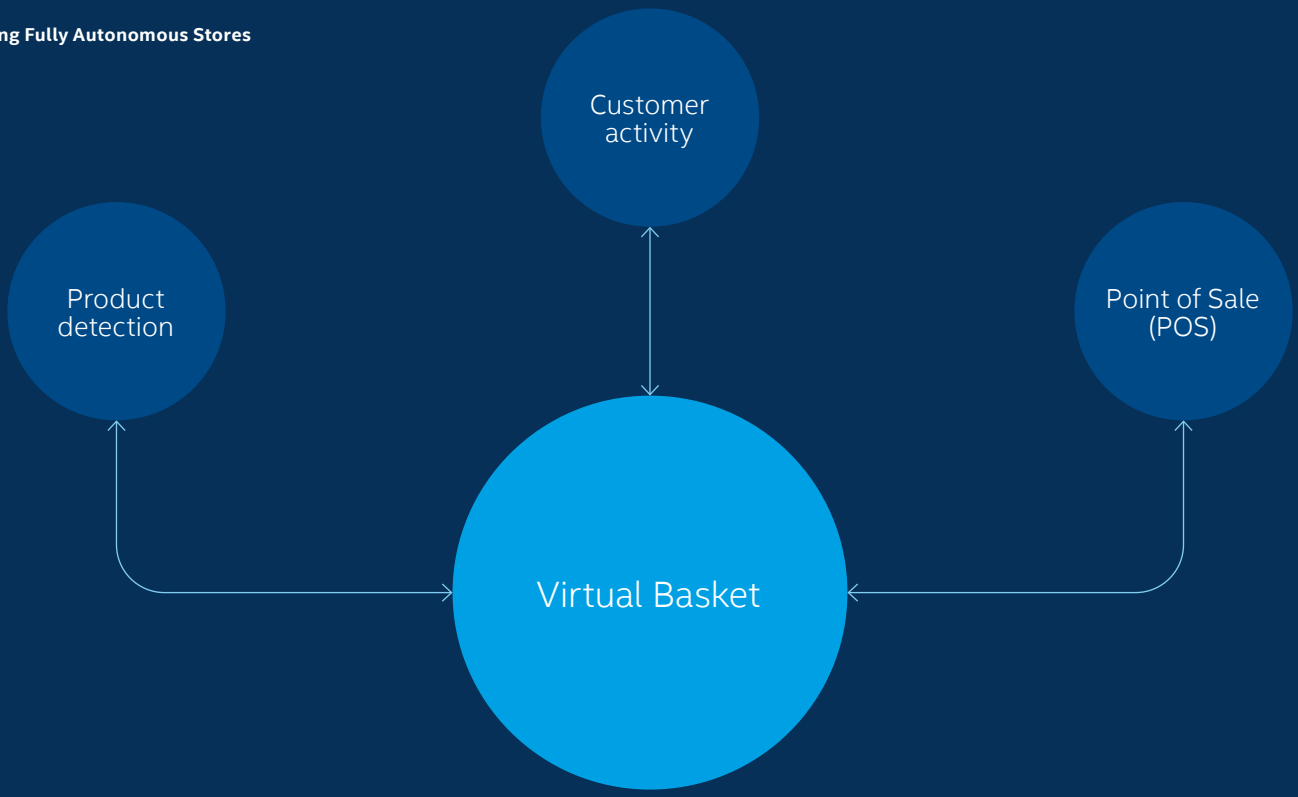


Figure 1: Building the virtual basket

Autonomous stores saw a rapid rise in China early in 2016 and Amazon made the concept popular in the western markets with its Amazon Go stores. We have approximately four years of data on successes and failures of these stores. The size of the store, the types of products on offer and the number of customers at any one time are key considerations. There are also many ways to deploy these solutions with the technologies we have available today. The challenge is to deploy them cost effectively and at scale.

In this paper, we will only be considering autonomous stores that don't require intervention by store staff during the customer journey. Specifically we will be referring to "The Capsule", an autonomous store that has been conceptualized, built and demonstrated by Shekel Brainweigh in collaboration with Intel Corporation and Hitachi Vantara.

Building intelligence into the store

Key to an autonomous store is the intelligence that needs to: (1) accurately identify products, (2) track the customer throughout the shopper journey and (3) integrate to the point of sale (POS). Technologies need to come together to offer the speed and experience shoppers expect.

Let's look at these three aspects individually and then how they work in combination.

Product identification/detection

There are several methods of identifying products. The most popular method, and one we experience regularly at grocery stores, is the keying in of product codes or scanning barcodes. More recently, we have started seeing artificial intelligence employed to identify products in autonomous stores. In the next subsection, we will elaborate on the technology employed as part of The Capsule.

Customer activity

The customer's actions are monitored throughout the entire shopping journey. Each autonomous store has entry and exit barriers to control the number of people in the store and to associate an identity to each customer. The customer journey starts with the barriers opening when an initial customer credential is accepted. Depending on the deployment, this could be the retailer's mobile application or any other acceptable identity required to enter the store.

The actions monitored help to build a virtual basket that is based on the products that have been picked up and those that the customer has returned to the shelf.

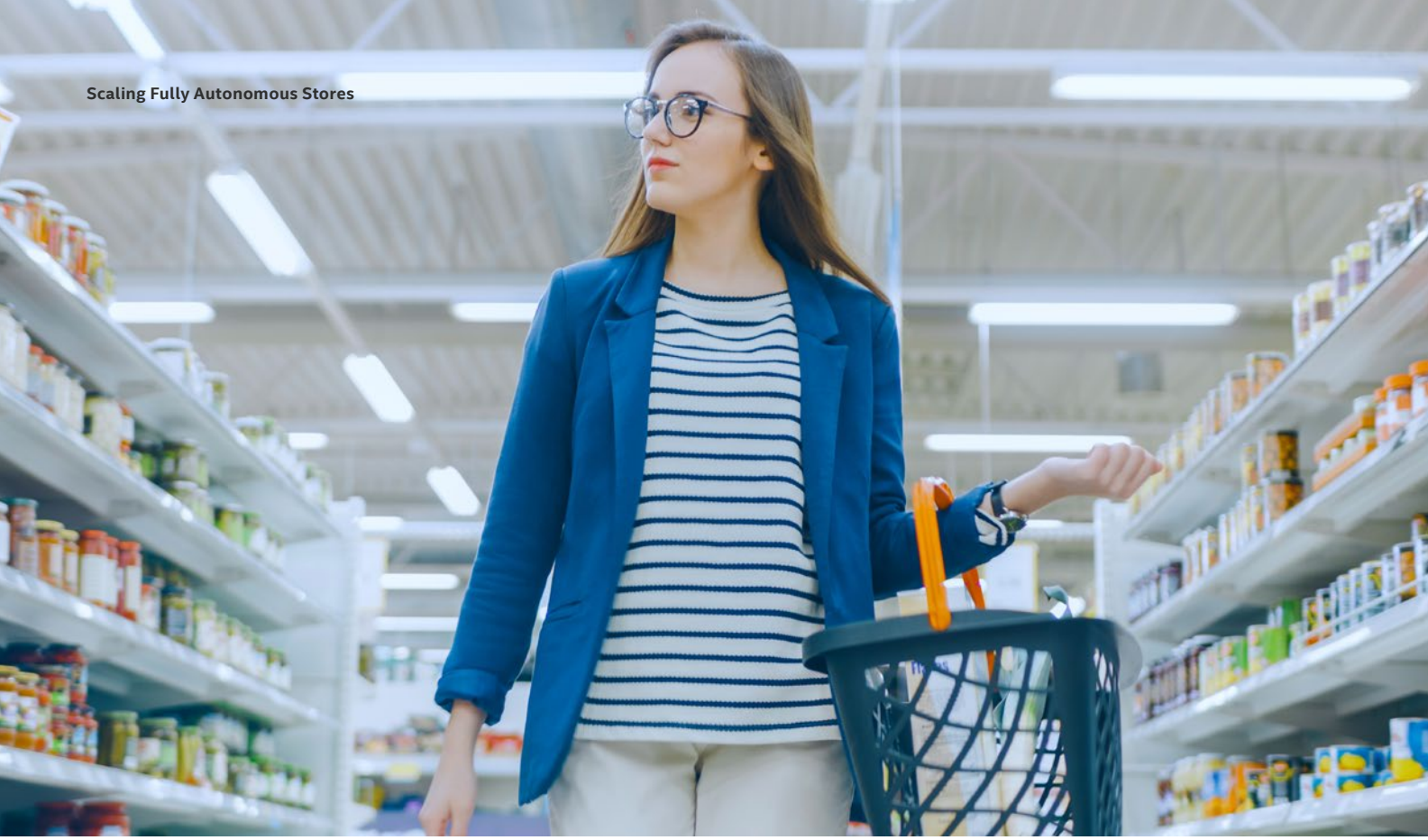
Point of Sale

Central to any retail store is the point of sale. This applies equally to autonomous stores that must be able to dynamically change pricing, push new promotions (reflected in the shelf edge or signage), and ensure SKUs are updated regularly. These POS features are essential in building the virtual basket and ultimately completing the payment.

In more advanced deployments, integration with a CRM system can include customer identity mapped to a payment mechanism that allows automatic payment.

Product Aware technology

Shekel Brainweigh's Product Aware shelves have been built with over 40 years of precision weighing expertise. They bring together artificial intelligence and load sensors to



precisely determine the product(s) being picked up. Many years of product data have enabled Shekel to create a signature for each product using adaptive statistical models to determine products with an accuracy of 1g per 100kg. This is well above industry norms.[2] In fact, the placement of products on the shelf is accurate to within 1 cm^2 and this helps with precisely determining products that conform with the store planogram without shelf separators. This makes it possible to display cans of drink of similar weight and distinguish between them.

It's an always learning system and, according to tests conducted by Shekel Brainweigh, it provides over 98% accuracy in product recognition after 15 product scans. This increases to 99.5% accuracy after 100 scans of the product. The load sensors are ultra-thin and non-visible to the naked eye and therefore the shelf looks identical to a standard shelf. The shelves are also fitted with shelf displays to accurately show pricing and to run promotions.

Continuous location tracking

Hitachi's 3D Lidar Sensor is used to monitor the location of the customer throughout the shopping journey. The technology enables multiple shopper journeys to be mapped simultaneously without the use of any personally identifiable information. The sensors calculate the size, shape

Figure 2: How Product Aware technology works

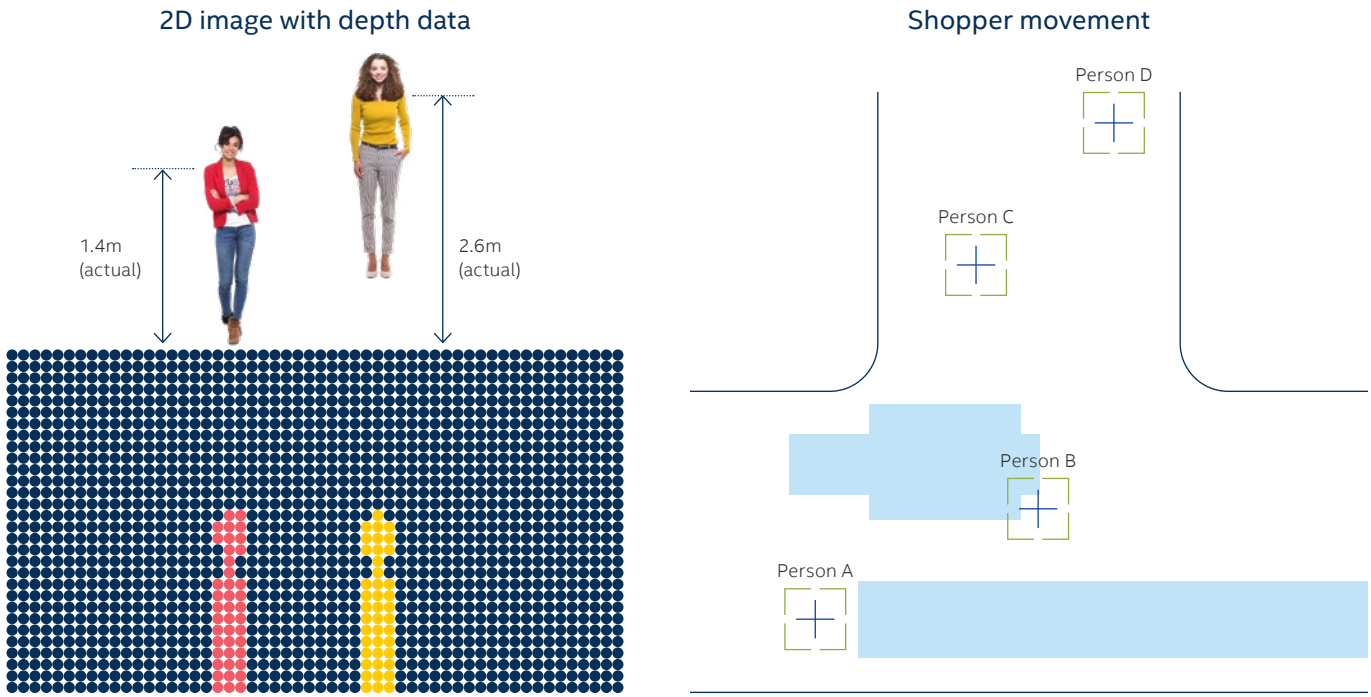


Figure 3: 3D Lidar motion sensors capture shopper movement

and position of shoppers. The technology can also detect individual hand movements that show the customer picking up products and replacing items.

This provides valuable information about the shopper journey, including: most time spent at specific isles or areas of the store; products that were viewed and replaced; the navigation path chosen; average number of shoppers at any one time; and many more analytical details. Insights are provided without using any personally identifiable information, thereby protecting the privacy of customers. And by analyzing the data coming from the sensors, in combination with the information from the shelves, store managers can access key data about the full customer journey. This enables them to optimize a store layout and to place promotional items in the most effective locations.

The 3D Lidar sensors work across a larger view of space and therefore require fewer sensors to monitor the movement of shoppers. Each 3D Lidar sensor covers up to 20 sqm and multiple sensors can be stitched together to cover a larger area or even a complete store.

The importance of edge compute

The successful operation of an autonomous store is made possible by the seamless integration of all the data generated

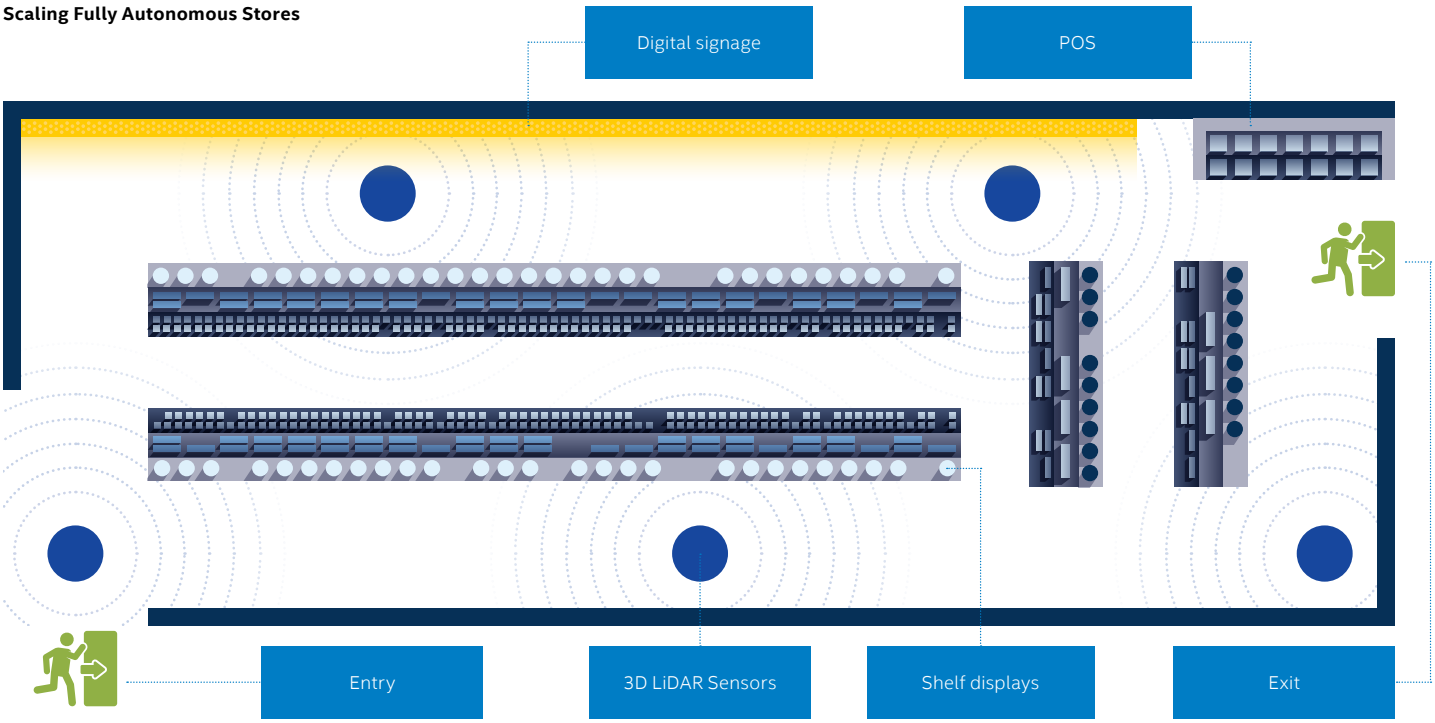


Figure 4: Multiple sensors and devices combine to produce store data

by the multiple sensors and devices. Every aspect of the store needs to be connected to support the customer journey.

Each of the sensors and devices generates large amounts of data, and the data from these multiple systems needs to be combined to make certain decisions. For example, the shopper journey is analyzed along with the products picked. This data is combined with the 3D Lidar data and shelf aware data to accurately build the virtual shopping basket.

Therefore, in addition to acting on the data generated by each of the sensors and devices in real time, these multiple workloads need to be combined in real time too. Powerful edge compute solutions need to be employed to enable the creation of these combined insights and to provide these highly engaged shopper experiences.

As the shopping journey is short, compute at the edge helps determine when products have been put back on the wrong shelf, so that staff can be alerted to rectify the issue immediately. Operationally, this is important when keeping track of inventory in the store. Similarly, a price change on products must not only be reflected on the POS, but also across all promotions, shelf labels and signage.

The following are the key components/workloads brought together by the edge server:

1. **Product Aware shelves**
2. **3D Lidar sensors**
3. **Access control hardware (e.g. card readers, door opening sensors, etc)**
4. **Displays and digital signage**
5. **Security cameras**
6. **Point of Sale devices**

The Capsule concept

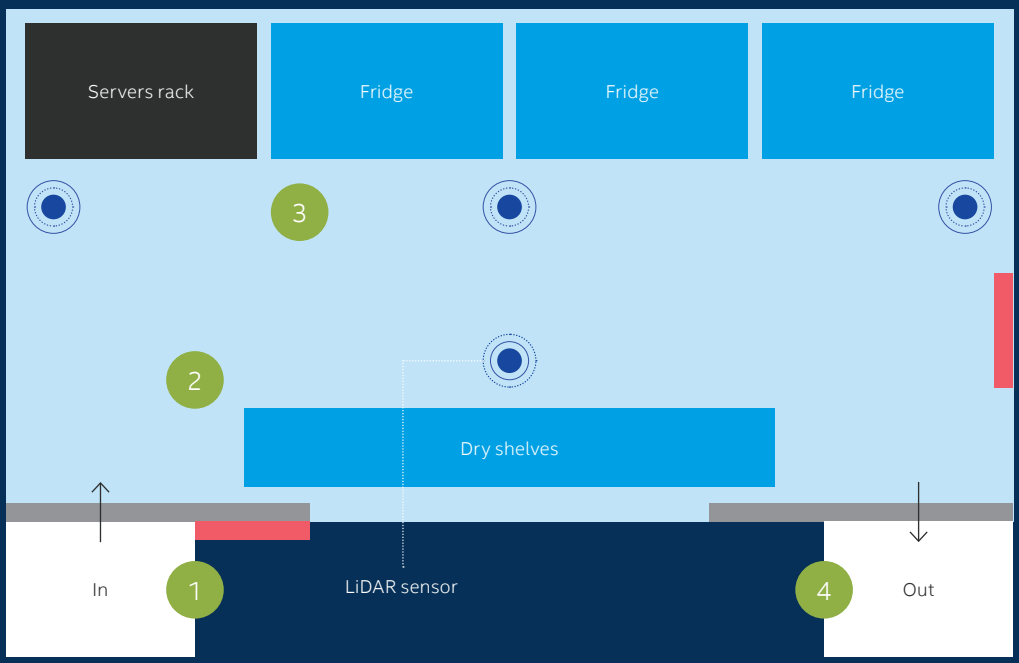
The Capsule was implemented to bring a versatile, easy to integrate and cost-effective autonomous solution to market. The Capsule comes in multiple form factors. The small form factor comes in between 25–50 sqm with support for 300-800 products. The larger format will support up to a maximum of 1,500 products (SKUs).

The solution also allows for easy integration of third-party software solutions. Depending on where the solution is to be deployed and within what constraints, the Capsule could be configured to work with just the Product Aware shelves and a companion mobile application.

In its most basic format, and if only a single user is allowed into the store at a time, the 3D Lidar capabilities aren't required for the solution to work. But, if we want to support up to 1,500 SKUs and 15 concurrent shoppers, this would require all the components of the solution, giving complete flexibility to the retailer.

Customer experience

The Capsule seeks to address two of the biggest customer pain points – product availability 24 hours a day and the removal of lengthy queues at the checkout. Greater product availability, for example, can be achieved through the fully connected store by capturing and providing up-to-date information about the speed at which the various products are being sold. This enables stock to be replenished at an appropriate rate.



How it works:

1 A shopper goes to the terminal at the front of the store and inserts any valid payment/ID card

2 The door opens and the shopper enters the store

3 The shopper takes items of his/her choice

4 The shopper simply walks out of the store, is automatically debited and emailed a receipt

Figure 5: The shopper journey in The Capsule

Figure 5 (above) shows a very straightforward customer journey. However, the implementation considers where multiple products are being picked up by the shopper simultaneously. It also provides solutions for practical exceptions, such as products not being replaced in their original locations.

Building the virtual basket

Crucially, the Capsule solution supports more than one shopper entering the store. The 3D Lidar technology will track the shoppers during their journey through the store and add products taken from the shelves to their shopping baskets. The data coming from Shekel shelves will be used to identify products and the Lidars provide unique IDs to separate the customers from each other.

Key to the accuracy of product identification is the location and the weight of products. However, if the shopper decides to remove an item from their basket and put it in a location that is different to its original location, the system can alert staff that there is a product out of place.

There are also considerations for accurately identifying multiple products that are being picked at the same time by the shopper. It must be noted that the accuracy in this scenario will not be as high as it would be for picking up a single product at a time. But it will be accurate enough to populate the virtual basket.

Incorrect billing

Generally, the customer is encouraged to view the checkout screen, which gets auto populated before completing their payment. The shopper has an option to indicate incorrect product recognition and the system offers the top three probable SKUs to make the right selection. This automatically updates the virtual basket and rectifies any possible incorrect billing. However, on the odd occasion that the customer has been incorrectly billed (and they notice this after they've left the store), they have the option of calling the customer support number printed on the bill to rectify the issue.

Retailer profitability

Brick and motor retailers experience losses due to out-of-stock items, overstock and inventory shrinkage. The Capsule solution addresses all of these aspects. Retailers can take advantage of the insights generated by the platform and increase operational efficiencies.

Operational excellence

The Product Aware technology provides accurate inventory data and ensures planogram compliance. Key to the insights obtained from the system, is the ability to predict over-stock and avoid out-of-stock situations. Due to the friction-free nature of the shopping experience provided, staff labor costs are reduced and this can contribute to store profitability.

Solution Constraints

The Capsule is focused on the converging vending and convenience food retail markets. Vending operators are seeking to enlarge their SKU offering to their customers, going beyond the average vending machine capacity. Grocery retailers are looking to reach younger urban shoppers and offer them on-the-go and close to home points of sale.

These two trends meet and converge around a 300-1,000 SKU selection of fresh food, personal hygiene, and daily

necessities. The Capsule is not intending to replace large supermarkets/hypermarkets.

The Intel collaboration

The technology components discussed in this paper have been powered by the latest Intel® Architecture Processors. The edge compute is powered by Intel® Xeon® servers and drives all the compute requirements of the Product Aware shelf technology, 3D Lidar motion sensors and the aggregation of all sensor workloads across the store. The Intel Xeon processors have enabled multiple workloads to be run on virtualized containers, bringing together data across all sensors and devices to enable a frictionless experience. The Intel Xeon processors also meet the necessary security and scalability requirements, while lowering costs by enabling multiple workloads to be executed at the store edge.

The digital signage displays are equipped with Intel compute based on the Open Pluggable Specification (OPS) or the Intel® Smart Display Module (Intel® SDM) where there are more constrained and sleek displays to be mounted. The Point of Sale (POS) is reliably supported by various Intel Architecture Processors based on Intel Atom® or Intel® Core™ depending on the solution chosen by the end retailer. Both signage and POS take advantage of remote manageability capabilities that are offered with Intel vPro® technology.

Hybrid store journeys

While the urban community enjoys the convenience of fully autonomous stores, retailers with their existing estate of stores can also infuse compute technology to provide an autonomous experience. Such an experience can be added into stores by having part of the store reconfigured or having the technology co-exist across the entire store.

Reconfiguring part of the store will be relevant for larger format stores that offer convenience for their busy shoppers with carefully selected high velocity SKUs in a designated area with special access. Complexity arises when medium-sized, everyday grocery stores (with about 1,500 SKUs) have a hybrid infrastructure. This infrastructure will support traditional shopper engagement as well as the autonomous experience across the entire store.

The Capsule technology has been successfully adapted to consider additional SKUs that come from the deli counter and the variety of beverages from a coffee machine. Most importantly, it can distinguish between shoppers on autonomous journeys and those who are taking the traditional staff-assisted checkout route. New instrumentation has been added to directly enable the integration with coffee machines that determines every button press made by the shopper. Provision has also been added to enable the shoppers to move from their autonomous journey to a traditional journey. This is in case there are products that require electronic tags to be removed, have specific restrictions, or require the intervention of traditional checkout staff.

Conclusion

Autonomous stores are increasing in popularity with shoppers who are in a hurry, who don't like to queue and who need 24X7 access. It is a growing market and retailers who are adapting this as part of a larger store configuration or as an independent, self-contained store, are addressing a real need for shoppers. Meanwhile, the connected nature of the store generates plenty of data to address three key pain points of the retailer – i.e. increasing labor costs, controlling shrinkage and avoiding out-of-stock and over-stock.

The technology stack has been built in a modular fashion with clear APIs to provide the flexibility needed and to bring newer format stores to the market with the right partners. Existing retail stores can also take advantage of the various deployment capabilities of The Capsule's technology to successfully enable hybrid shopper journeys across different store formats.

Learn More

You may find the following resources useful:

- Intel Retail
- Intel vPro® Technology
- OPS
- Intel® SDM
- Hitachi Smart Spaces Retail Solution Profile
- Hitachi Best Practices Guide for Reopening

[1] https://go.forrester.com/blogs/distinguish-hot-from-hype-in-retail-tech-investments-for-2020/
[2] https://www.nist.gov/system/files/documents/2017/04/28/H44-03-all.pdf