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Digitalization at the Point-of-Sale in Grocery Retail - State of the Art of Smart Shelf Technology and Application Scenarios

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Abstract

Digitalization has been shaping economy and society, one of the areas most affected being the retail sector. Especially in the context of smart shelf technologies a variety of companies and solutions – mainly for grocery and drugstore retail – has evolved. However, there is no overview of which technologies are used and for which specific application scenarios they can be applied. In the course of expert-interviews with solution providers, we have analysed the status-quo of different smart shelf solutions, their respective application scenarios, the technologies behind them, the associated benefits and costs as well as planned further developments. Our results show that existing solutions cover a variety of application scenarios, ranging from out-of-shelf detection and checking planogram compliance to optimizing inventory or logistical processes. Our analysis identified two main technology groups: image recognition systems and sensor-based systems. Solution providers stated that generating a positive ROI takes between one and one and a half years. All providers are working on further developments, many are moving in the direction of sensor fusion. The results of our study help retailers to compare existing solutions and enables them to examine various deployment scenarios.

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Keywords: smart shelf; digitalization; retail technology, Point of sale; grocery retail.

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1. Introduction

Digitalization has been shaping and influencing the business world for years. Some sectors are more successful than others in taking advantage of digitalization through new strategies. One of the sectors that has by far not yet used its full potential in this respect is stationary retail. Many digitalization potentials are widely known but hardly implemented in practice [1]. Depending on the product category, possible applications in stationary retail at the point of sale are shopping apps, RFID-based inventory management, digital loyalty programs, geofencing, smartphone-based in-shop navigation, digital product location maps, intelligent dressing rooms, smart mirror, digital signage, digital customer touchpoints, smart shopping trolley and zero-touch checkout to name just a few [1-3]. The Internet of Things (IoT) is one of the key digital transformation technologies. While there is still no single, universal definition of IoT, it is generally agreed that IoT is driving innovation and new opportunities by embedding every object and things with technology that equips them with sensing, identifying, networking and processing capabilities to interact and cooperate each other [4, 5]. One of the most promising next-generation retail technologies with IoT application are smart or intelligent shelves [6]. Smart shelves bring many advantages (e.g. real-time inventory analysis, quick price changes, theft and shrinkage reduction, collection of actionable customer insights) for customers as well as for the company making it an essential tool [3]. Smart shelves are electronically connected shelves that automatically keep track of inventory in a retail store. The shelves are equipped with weight sensors, proximity sensors, 3D cameras, microphones, RFID tags, NFC, electronic printed tags, LED sensors, optical sensors, IOT sensors, etc., to monitor the shelf stock [7]. The different technologies for an efficient management of on-shelf availability and inventory, planogram maintenance and customer behavior analysis are well described in the literature [8-16]. Nevertheless, there is no paper providing an overview of the various technologies available. Information can only be found on the providers' websites, but only very superficially and not in detail. Therefore, this paper concentrates on the technological functionalities of intelligent shelves and is intended to answer the questions for which articles and assortments in grocery retail they are suitable and which further developments are planned from technology providers.

The remainder of this paper is structured as follows: Section 2 gives an overview of our research design. Subsequently the three steps of our research approach are described. In section 3, the results of expert interviews are presented. Finally, implications, conclusion and outlook are presented in section 4.

2. Research Methodology

As the aim of the study is to analyse and describe the state of the art of smart shelf technology and its application scenarios especially in the grocery retail context, expert interviews were selected as an appropriate method for data collection. Expert interviews are either open or semi-structured, qualitative interviews with selected experts, i.e. interview partners holding specific expert knowledge relevant in a given context [17]. The main reason for selecting expert interviews as the focal research method of this paper is the fact that they are especially useful when the goal is to collect insights in a given context that are mainly represented in the form of implicit knowledge [18]. In the course of planning expert interviews, three main elements have to be considered: i) procedure of expert identification and selection, ii) data collection procedure and iii) data analysis procedure. Subsequently, these elements are explained in detail.

2.1. Expert Identification and Selection

In the context of expert identification and selection, two approaches can be applied: random selection and information oriented selection [19]. In accordance to our study and the rather narrow focus area of smart shelves, an information oriented sampling approach is selected. By applying a keyword-based literature and information research in selected databases for research publications and on the Internet as well as in forums, blog posts, studies, etc. smart shelve technology providers were looked for in a first step. A limitation of this approach may be that the list of providers is certainly not complete as it only includes companies that were elicited during this research step. The obtained information about the identified smart shelf technology providers were used as basis for contacting them per email, contact forms or via social media such as LinkedIn. Out of 27 identified smart shelf providers, the following 15 smart shelf technology providers participated in the expert interviews (see Table 1):

Table 1. List of experts

Expert No.	Position/Role	Country	Years in company
1	Co-Founder and Chief Scientist	USA	1 year
2	CEO	USA	5 years
3	Product Line Manager	Germany	4 years
4	Product Development Manager	Lithuania	1 year
5	Sales Manager	Germany	14 years
6	Marketing Specialist	Italy	6 years
7	Founder and Owner	Germany	21 years
8	CEO	Germany	5 years
9	COO	USA	11 years
10	Sales and Strategy Director	India	4 years
11	CEO	Germany	17 years
12	CEO	Austria	7 years
13	Head of Business Development Retail Innovation Division	Israel	3 years
14	CEO	Turkey	6 years
15	CEO	Israel	5 years

2.2. Data Collection

For data collection, a four-step approach was applied following [20]: (i) short introductionary questionnaire, (ii) semi-structured interview guideline, (iii) audio recording of interview and (iv) transcription of interview. At the start of each interview, an introductionary questionnaire was presented in order to get information on the specific background of the participant and his or her company as well as to finally ensure the actual expert status of the interview partner. Subsequently, an interview guideline was used to collect expert knowledge. The semi-structured questionnaire consisted of four thematic blocks and comprised 17 specific questions. The main blocks provided the roadmap throughout the interview, the questions allowed for a detailed navigation route within the blocks and were not necessarily asked in sequential order but as suitable to the argumentation lines and the flow of the interview [21]. The four thematic blocks were as follows: First, the topic of "technology" focused on the presentation of the technology itself, the components used, their functionalities, the retrofitability and the prerequisites for use. Second "scenarios in food retailing" emphasized on possible applications and recommendations with regard to product range, adaptations for new products and restrictions in possible uses. The third block "costs, benefits and profitability" analysed costs (investment, running costs) and benefits (savings, changes in sales, etc.) of the systems for the retailers. Finally, the fourth block "further developments" laid a focus on planned developments of the systems for the next few years.

Due to COVID-19 and the global dispersion of experts, the interviews were contacted and recorded via MS Teams. Each of the 15 interviews lasted around one hour, results were subsequently transcribed for analysis. This combination of notes taken by the interviewer alongside the interview guideline and the audio transcriptions ensure a detailed and complete result collection in the course of the interviews [22].

2.3. Data Analysis

Finally, for data analysis, the transcribed interviews were analysed using the programs MAXQDA (for coding the interviews) and MS EXCEL (for creating the tables and graphs). MAXQDA is a software for computer-assisted qualitative data and text analysis, which enabled us to assign codes in advance for the various subareas, as well as questions from the interview guide [23]. The codes were used to evalute the transcribed interviews. MS Excel was used to create tables and graphs (frequencies of responses).

3. Results of Expert Interviews

In this section, we discuss the results of the primary research approach in detail and draw a picture of the functionalities and application scenarios for smart shelf technologies in stationary grocery retail.

3.1. Technology and Basic Functionalities

This topic focused on the presentation of the technology itself, the components used, their functionalities, the retrofitability and the prerequisites for use.

3.1.1. Technological Details of the Solution

In the first part of the interviews, the providers were asked to describe their technology in detail. As some of the providers combine technologies (e.g., camera technology in combination with weight sensors), multiple answers were possible. The most commonly used technology is image recognition followed by weight sensors and infrared sensors. Details of the responses are shown in Fig. 1. A surveyed company is based purely on data analysis and therefore does not require hardware at the POS. The majority of the companies surveyed generally use self-learning algorithms for out-of-shelf detection. The algorithms not only help with image recognition and data analysis, but also with demand planning.

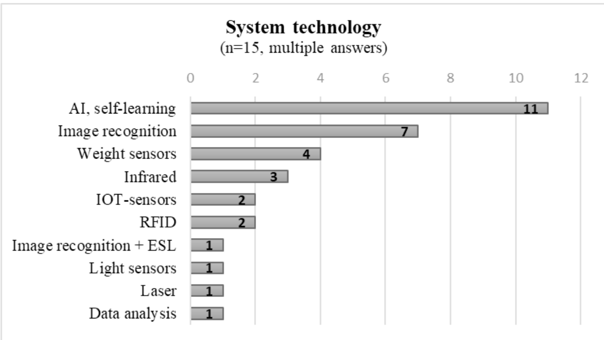

Fig. 1. Technologies used by the companies surveyed

Each technology consists of different components, whereby a rough distinction between IT components and hardware on/in the shelf (sensors, cameras, etc.) can be made. Regarding the IT, it should be noted that all but one company work with a cloud solution, with six companies either requiring a local PC or offering the local PC in addition to the cloud solution (edge computing). Half of the companies also use a gateway computer to transfer the collected data from the cameras or sensors to the cloud. Two companies work with or offer their own server, one of them exclusively offers the service via its own server. Looking at the components that are needed on the shop floor, cameras are the most common. This applies to those eight companies that work with image recognition. However, there are various options: fixed cameras at shelf level or on the aisle/ceiling, but also smartphones or tablets with cameras. Depending on the technology used, various components such as weight cells, pushers/hooks, RFID antennas, sensor rails, price rails or light sensors are required. These components can all be retrofitted to existing shelves.

With regard to the market readiness of the smart shelf technologies, it should be noted that eight of the 15 technologies are already on the market, while seven were still in the proof-of-concept phase at the time of the survey. Some technology providers originally developed the technology or sensors for other purposes (e.g., for logistics or for scales in hospitals) and can therefore draw on many years of experience. The established technologies are now being applied to new fields of application in the context of smart shelves.

3.1.2. Basic Functionalities and Application Scenarios

Following the introduction to the basic description of the technology, the next question was related to the functionalities offered by the systems. The focus of the study was on out-of-shelf detection. Accordingly, all systems offer this functionality (see Fig. 2). As soon as the system detects that a product is no longer available on the shelf, a message is generated for the employees in the stores. In the case of sensor-based systems, the shelf stock is monitored continuously, while in the case of image recognition systems, the stock is only monitored at those times when an image is analysed. Notifications provide the staff with information about which product needs to be replenished on which shelf. This information can also be combined with the store's stock data, because the product can only be replenished if there is still stock available in the store.

The second most frequent response in terms of functionality was Planogram compliance checking, which 14 systems offer. However, here is a significant difference between image recognition systems and sensor-based systems: Image recognition is used to detect actual products on the shelf. This enables an exact match with a given planogram. Sensor-based solutions usually have to make use of certain logics (which are anchored in the algorithms accordingly).

An analysis of customer behavior is possible with nine systems. Sensor-based solutions record every pick and every return. This makes it possible, for example, to evaluate how long a customer looks at a product before returning it to the shelf or whether he buys it. If required, the solutions can be combined with cameras to evaluate customer behavior and receive additional information such as age and gender. However, care must be taken here to ensure compliance with all data protection laws (GDPR).

The detection of a restock level is possible with eight providers. Here, messages are already sent to employees in the stores when a defined restock level of a product is reached. In this way, the product can be replenished before an out-of-shelf situation even occurs. Sensor-based systems also make it possible to detect atypical removal quantities and can thus provide indications of theft. Seven of the providers surveyed enable this feature.

Other functions relate to the evaluation of data, which makes it possible to optimize shelf stock or store stock and, above all, to avoid overstocking. In the case of particularly important items that have to be kept in stock, many retailers draw up stocks to avoid out-of-shelf situations. The use of smart shelves increases inventory and forecasting accuracy, resulting in lower inventory levels. The analysis of acquired data in the head quarter or in stores was also mentioned several times. In many cases, information can be obtained at different levels, e.g. for a region, a store, down to individual SKUs.

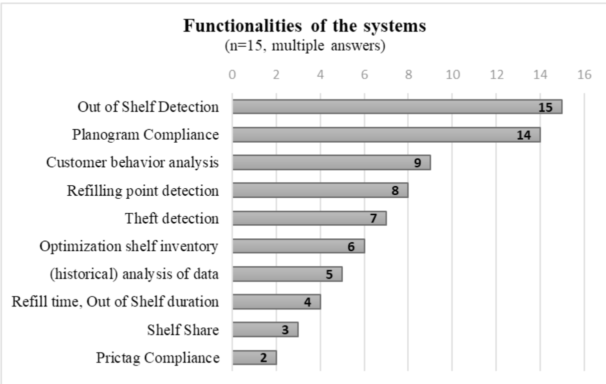

Fig. 2. Functionalities of intelligent shelves

3.2. Scenarios in grocery retail

The second block of topics in the interview guide dealt with scenarios in grocery retail. One question related to limitations of the systems with regard to store design elements. The answers clearly show that the technologies/systems of the various suppliers cannot be used for all shelf types or product assortments (see Table 2). Only four suppliers stated that they can cover all areas in the store and that there are no restrictions with regard to shop fitting elements.

Table 2. Limitations of the systems

Category.	Frequency of mention	Comment
Fruit/vegetables	9	Difficult to identify because (1) there is often no fixed packaging (products are loose) and (2) the products do not have a uniform weight (by nature, but also due to weight loss over time)
Bake-Off	8	Difficult to identify because (1) of the loose products and (2) of the temperature, which could be a problem for some sensors
Frozen products	6	Difficult to identify because (1) humidity and (2) in visual recognition because glass is reflective or fogged up and products are stacked on top of each other
Cooling Area	1	

Further limitations concern the recognition of products. These relate to the type of products, but above all the product characteristics, such as size and weight. When using pushers, the goods must also be capable of being pushed. With weight detection, problems can arise if products have exactly the same weight. Systems that use image recognition can have difficulty recognizing products that are particularly small, as well as products that look very similar. Poor lighting conditions also have a negative effect on the recognition of products. Fruit, vegetables and fresh bakery products are generally rated as very difficult.

The use of intelligent shelves is associated with (high) costs, so the question arises as to whether these systems should be used in the whole store or only in selected assortments. Four of the interviewed providers stated that the system should be used in the entire store, whereby two mentioned certain restrictions: one supplier of a sensor-based solution said that a use only makes sense up to a store size of about 100m² (or 1,000 SKU's), otherwise the system could become too inaccurate and too expensive. One image recognition provider argued that whole-store deployment only makes sense if the images are taken using smartphones rather than fixed cameras. Accordingly, these two and eleven other suppliers stated that the systems would be better used for selected assortments. The recommendation for which articles or assortments the systems should be used clearly goes in the direction of fast-moving goods. Due to the high sales volume, out-of-shelf situations occur much more frequently than with other articles. Alcoholic beverages were named in second place. All other assortments and articles were mentioned a maximum of two times.

3.3. Profitability, costs and benefits

The question of what costs customers incur was in most cases only answered in general terms, as investment costs for example depend on the quantity purchased. In image recognition, costs are incurred that are charged per image. This results in differences in costs, dependent on the number of images per day/week/month. All providers stated that a monthly fee is charged for the services (software, cloud services, etc.), depending on various factors, such as functions used or number of analysed images. Fourteen providers indicated that there are investment costs, and one provider offers only a rental model (i.e., the hardware is also rented). Two companies offer both models: either the hardware is purchased by the retailer or it is rented. A key criteria for retailers when using smart shelves - in addition to the costs - is the benefit that can be generated. The answers to the question on KPI's is shown in Table 3:

Table 3. KPI's

KPI	Frequency of mention	Comment
Increase in Sales	11	Through a better availability of goods
Reduction of out-of-shelf	10	In terms of frequency and duration
Reduction of personnel expenditure	10	Visual shelf control can be omitted
Reduction in theft	5	Sending alerts in the event of atypical removals and a corresponding response from store personnel. This KPI was mentioned by providers of sensor-based solutions, as in these cases the removals are determined in real time.
Improvement of planogram compliance	3	

The question of what ROI customers can achieve was not answered by nine suppliers, as it is very difficult to make an exact statement. The ROI depends on various factors, including what the situation was like before the system was deployed. Accordingly, there are differences between stores and also between assortments (and their respective profitability). Some improvements are also difficult to evaluate, e.g. a time saving in shelf control. For those technology providers whose development is in the POC, there is also often too little data yet. However, six technology providers gave indicative values, four of which cited an ROI of less than one year. One provider that rents rather than sells the hardware said that the ROI is immediate because no investment needs to be made. The monthly (rental) costs have to be covered by additional sales and by reducing personnel expenses.

3.4. Further developments

The last block in the interview guide related to the planned further and new developments of the systems. Eight of the 15 providers surveyed stated that they were planning improvements or developments in the area of data analytics and predictive analytics. Accordingly, the data should become even more accurate and also enable predictions (e.g., better sales forecasts). Five companies are planning to expand their systems to include additional sensors or to combine existing sensors with camera technology (e.g., for better verification of planogram compliance). Similarly, five companies are working to improve accuracy. Extending the system to additional shelf types or products/assortment is also on the agenda of five suppliers. Other developments include the (automatic) checking of best-before dates to reduce food waste and the improvement of processes on the sales floor based on the data obtained. Autonomous stores are currently a present development. Three of the companies surveyed already offer solutions for frictionless shopping. The technologies used for this are (1) cameras & weight sensors, (2) weight sensors & LiDAR technology and (3) cameras, weight sensors and RFID. However, all three solutions are only suitable for smaller retail stores or container-sized stores, and the focus is on packaged items but includes all product categories.

4. Implications, Conclusion and Outlook

In recent years, image recognition systems have gained importance in both research and practice. However, there have also been many developments in the field of sensor technology. Both systems have specific advantages and disadvantages. It is unclear which system is more suitable as an intelligent shelf, as every provider highlights its own advantages. The advantages of image recognition are seen in the lower investment costs, while the main advantage of sensor-based methods is the accurate inventory data on the shelf. A decision, on which system to use therefore depends on various factors, such as which functionalities are to be used and which products are to be monitored. It is also clear that almost all systems have limitations in some way with regard to shop fitting or certain products. Furthermore, it is unclear to what extent the total costs (investment and running costs) actually differ between the various systems and it was found that it is also difficult to quantify the overall benefits of the systems. In terms of future development, the providers of smart shelves are in favor of combining both systems in order to exploit the advantages and generate as many use cases as possible for retailers. In addition, there are only a few retailers that use smart shelves so far. Accordingly, there is little information available on the actual benefits achieved. Furthermore, the success of the use of a smart shelf depends on many factors. These include above all the situation prior to implementation, i.e. how often and for how long did out-of-shelf situations occur. Also, factors such as the selected product range or staff training and awareness of the use of smart shelves influence success. Regardless of the investment costs and running costs, the providers promise savings and sales increases that should enable a positive ROI within 1 to 1.5 years. It should be noted, however, that these figures vary from assortment to assortment. Accordingly, most suppliers recommend using the systems only in selected product ranges. The complete equipment of larger stores does not appear to make sense (high costs), nor is it possible at all for most providers. All suppliers are also working in some way on further developments to make the systems more cost-effective and accurate, but also to reduce currently existing limitations.

To our knowledge, this is the first study to survey different smart shelve technologies and application scenarios. The underlying research approach captures the status-quo of smart shelves, the technologies behind them, benefits and costs as well as use cases from the perspective of the technology providers. The study thus helps retailers to compare sensor-based technologies and image recognition and also enables them to examine various deployment scenarios in the context of their own company.

One limitation lies in the size of the sample. Since new developments are taking place all the time and new providers are constantly entering the market, the study only provides a snapshot of the status quo in terms of deployment options, functionalities and limitations. Many companies are already working on the further development of their own technologies. Therefore, it would be interesting to repeat the study in a few years in order to survey the progress as well as improvements of the technologies. There is also a need for research to shed more light on the user side. On the one hand, this involves retailers, their acceptance, barriers, needs and future plans. But also about the end customers and their views on smart shelf technologies, above all also about concerns regarding data protection.

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