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Making vending machines smarter with the use of Machine Learning and Artificial Intelligence: Set-up and Architecture

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Abstract. Vending machines conveniently provide snacks, beverages, cigarettes, food, and other items to consumers. Management of the ma chine supplies and cash is a challenging logistic process. At a time when the Internet of Things paradigm becomes omnipresent, industries are cur rently going through "The Fourth Industrial Revolution". These things combined are also being adopted in the vending machines industry, lead ing to the development of smart vending machines. This paper presents our hoyo.ai chip that can be plugged into non-smart vending machines and enable them internet connectivity and other smart features. With this affordable chip, thousands of vending machines' lifespan can be ex tended, enabling smart features such as predictive maintenance and just in-time restocking.
Keywords: Smart Vending Machines, Just-in-time restocking, Machine Learning, Predictive Maintenance.

Introduction

Industries are currently going through "The Fourth Industrial Revolution", a term also known as "Industry 4.0". What it mostly concerns is the integration amongst physical and digital systems of the production contexts [1]. A prime reason for that is the adoption of machine learning (ML) to provide some ad vantages. Those advantages include maintenance cost reduction, , machine fault reduction, spare-part life increases and inventory reduction, operator safety en hancement, increased production, an increase in overall profit, to name a few. All of them also have a tremendous and strong bond with the procedures of maintenance [2, 3]. Moreover, fault detection is one of the critical components of predictive maintenance, and it is necessary for industries to detect faults at a very early stage [4, 5].

More recent technologies can enrich vending machines with smart features, such as the sizeable digital touch display, various types of sensors, cameras, inter net connectivity, more cost-effective embedded computing power, various pay ment systems, and a wide range of identification technology (e.g., NFC, RFID)
[6]. These smart vending machines engage users in a more rich user experience, reduce operating costs, improve the vending operations' efficiency by remote management and insightful analytics based on the collected data. These ma chines offer everything from entertainment to cashless payments through arti ficial intelligence, facial recognition, and transparent displays. Integrated sen sors and cameras provide valuable data about customer demographics, purchase trends, and other information about the location's specifics where the machine is set up. Global shipments of smart vending machines are estimated to reach around 3.6 million units in 2020 with a penetration rate of 20.3% [7]. Likewise, the market changes so that vending machines now offer fresh food, milk, and juices [8].

With over 2 billion transactions a day on vending machines, the variety of data collected can be analyzed to obtain insights [9]. That vast amount of data aggregated requires a different type of analytics that can increase the vending machines' productivity while offering better customer experience and simplify ing the maintenance and service intervals. The benefits also might include churn prediction [10]. It has implications on profits that depend on the commercial food supplier involvement [11]. Machine learning algorithms can be applied for automated fault detection and diagnosis based on the collected data type. How ever, it is very tricky to select appropriate machine learning techniques, type of data, data size, and equipment to apply machine learning (ML) in industrial systems considering the vast volumes of data. Therefore efficient cloud-based solutions for Big Data processing might be employed [12]. Selection of inappro priate predictive maintenance technique, dataset, and data size may cause time loss and infeasible maintenance scheduling [13].

Even though the benefits of new smart vending machines are undoubted, millions of legacy vending machines are in use across the world that does not possess hardware capabilities to be "smart". This paper presents our hoyo.ai chip that can be plugged into non-smart vending machines and enable them internet connectivity and other smart features. With this affordable chip, thou sands of vending machines' lifespan can be extended, enabling smart features such as predictive maintenance and just-in-time restocking. With the proposed chip, the ultimate goal is to minimize the Total Cost of Ownership (TCO) for vending operators while enhancing the consumer purchasing experience, driving up adoption of the "Internet of vending machines" without having actually to retire vending machines which are still functional but without built-in hardware for smart capabilities.

The remainder of this paper is structured as follows. In section 2 we review the recent related works, and then in section 3 we present the architecture of the proposed system and the created prototypes and production-line chips. Finally, section 4 concludes the paper.

Related Work

Machine Learning and robust optimization techniques can significantly improve logistics operations and improve stock quantity and maintenance intervals. Ma chine Learning will be used to forecast item demands for each of the vending machines, taking into account past demands and calendar effects. In like manner, they can embody context-aware personalized recommender systems [14]. The ap plication of ML in smart vending machines has already been explored in works like [15], where authors describe a use-case in coffee vending machines. Authors of [16] describe a benchmark dataset for smart unmanned vending machines that can be used to verify different machine learning approaches. It is a good rep resentation of the challenges commonly encountered in such multi-modal, and multi-source datasets [17], requiring processing of nominal and categorical data that needs to be combined with time series and other data [18, 19].

A conceptual framework for collaborative forecasting in the food supply chain is presented in [20]. Authors of [21] present a reliable decision support system for fresh food supply chain management. Ideas from such approaches applied to the traditional fresh food supply chain can also be applied to smart vending machines.

In [4] the researchers have chosen simple vibration data collected from an exhaust fan. They have fit different unsupervised learning algorithms such as PCA T2statistic, Hierarchical clustering, K-Means, Fuzzy C-Means clustering and model-based clustering to test its accuracy, performance, and robustness. As a result, they have proposed a methodology to benchmark different algorithms and choosing the final model.

In [5] a novel multiple classifier Predictive Maintenance (PdM) system for integral type faults is presented. The multiple Machine Learning (ML) classifiers work in parallel to exploit the knowledge of the tool/logistic variables at each process iteration to enhance decision making. In their work, the proposed tool guarantees improved maintenance management decisions in terms of minimizing operating cost and can be applied to any maintenance problems characterized by integral type faults provided Run-to-Failure (R2F) historical data can be collected or is available.

Technologies involved in[16] solution of unmanned vending machines include Cloud (1) Management System, (2) Computer Vision and Deep Learning, (3) QR code, Mobile Payment, RFID, and (4) Sensor, Camera, Electronic tag, Antenna. In this paper, the two benchmarks of datasets the examined deep learning models can achieve approximately 99.67% performance on accuracy according to their experiment.

System Architecture

The method is data-driven and uses extensive amounts of data, either streamed, on-board data, or even historical and aggregated data from off-board databases. The methods rely on a telematics hub that communicates with a flespi IoT plat form https://flespi.com/. A knowledge base is created so that it can be used
to predict upcoming failures on other vehicles that show the same deviation. A classifier is trained to learn patterns in the usage data that precede specific repairs and can be used to predict vehicle maintenance. Set-up of SDK script to get sensory data from the vending machine that are additionally attached and Multi-Drop Bus / Internal Communication Protocol (MDB/ICP) that commu nicates with all peripheral devices of the vending machine.

The adoption of the proposed chip relies on a methodology consisting of four phases:

1. **Set up the ecosystem**
   – Setting up additional hardware on existing vending machines – IoT integration
2. **Data collection approach: Gather Empirical data to carry out an experiment – Collecting data about usage behavior**
   – Collecting data with system state
   – Data standardization
3. **Modeling**
   – Feature extraction and data fusion
   – Traditional Machine Learning models
   – Deep learning models
   – Optimization
4. **Deployment**
   – Integrating ML/AI into the UI
   – Cost/benefit analysis
   – Market-basket analysis
   – Iterative improvements of ML models

The foundation for the ecosystem that facilitates the aforementioned method ology is shown in Fig. 1.

The initial prototype developed and field-tested is shown in Fig. 2. The pro totype is an Arduino Uno device connected with A6 GSM/GPRS module. After experimenting with different modules and configurations, the prototype is min imized only with the needed components. SIM900A model of the GSM/GPRS module was selected, with ATMEGA328p placed on the PCB designed to fit this modification. A connector with screws for RS232 communication is used instead of DB9.

The miniaturized version of the prototype is shown in Fig. 3. The following step was to finalize the PCB design so it is ready for serial pro duction. It includes improvements of the module's rigidity and robustness that it is ready for environmental factors, vibrations, and other operating conditions. The result is shown in Fig. 4.

The prerelease version for hoyo.ai is shown in Fig. 5.

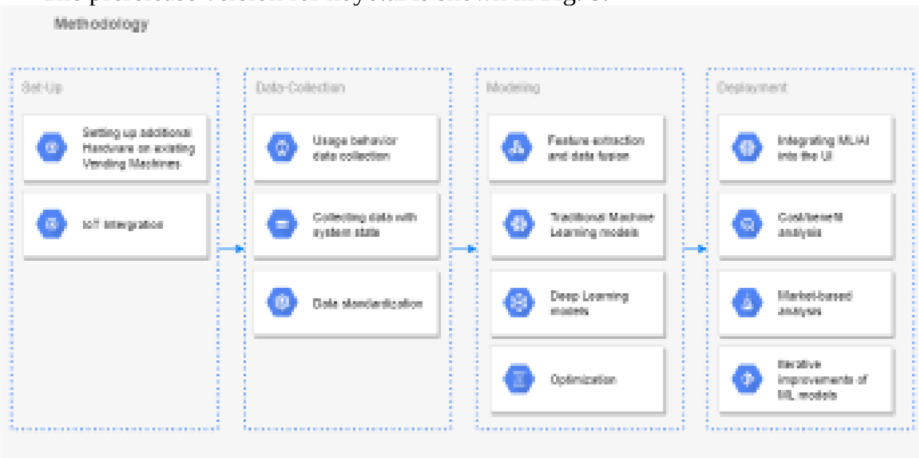

Fig. 1: Methodology of hoyo.ai


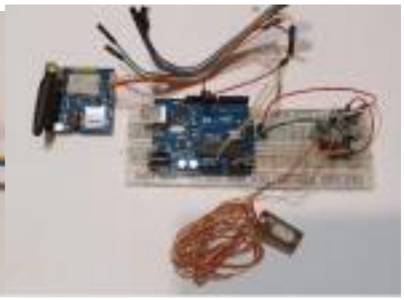

Fig. 2: Initial prototype developed and field tested Fig. 3: Miniaturized version of the prototype

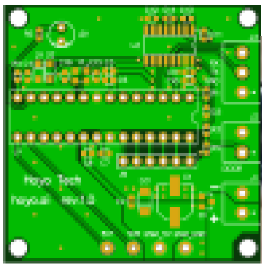


Fig. 4: New PCB design for serial production Fig. 5: Pre-release version for hoyo.ai

4 Conclusion

As cities worldwide go into lockdown and shopping centers, retail outlets are closed; as a result, vending operators need to quickly shift to different strategies like cost-saving initiatives if they hope to ensure their survival on the long run. With the help of big data and artificial intelligence, they might be able to achieve precisely that, meaning that they at least might be able to avoid the Covid-19 induced economic fallout that looms for the rest of the business world.

By performing analytics and predictions, which are forwarded to a robust op timization model, whose outputs will be the cash transport, and these transports guarantee that demand is fulfilled up to the desired confidence level, preventing vending machines' downtime due to unplanned maintenance and out-of-stock situations while also satisfying additional constraints arising in this particular domain. As a result of such operations, we expect productivity improvements of vending machines from 20 to 40%. Machine Learning and Robust Optimiza tion techniques can significantly improve logistics operations and improve stock quantity and maintenance intervals regarding vending devices. Machine Learn ing will be used to forecast item demands for each of the vending machines, taking into account past demands and calendar effects.

In future work, it is planned to prepare the initial dataset and enrich it with more diversity, like more product categories, integrate RFID/NFC cashless payments, IoT portal that interacts with end customers.

Most importantly, the proposed hoyo.ai chip extends the life of existing vend ing machines by providing an affordable upgrade that connects them to the inter net so that vendors and clients can benefit from the IoT advances. The proposed system relies on state-of-the-art automated feature engineering methods for se lecting robust features from various sensors, which are used to generate reliable classification and prediction models. By utilizing state-of-the-art classification and deep learning models, it provides unparalleled performance and benefits.

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