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MONITORING RESTAURANTS IN REAL-TIME EMBEDDED SYSTEMS

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***Abstract*—**Consumers in developed countries are wasting an estimated 222 million tonnes of food products per year, and most of the waste is produced at restaurants. The brazilian health regulatory agency: ANVISA requires that restaurants are monitored by nutritionists. One of their tasks is to control the temperature of food preservation to verify compliance with ANVISA regulations. For restaurants to avoid food waste and work within these regulatory standards, an efficient management is needed to streamline internal processes and to make more accurate decisions. The objective of this work is to create an intelligent software to monitor the quantity and temperature of a self-service restaurant buffet in order to minimize food waste, improve the handling of nutritional information and optimize the restaurant management. The system should be able to check the temperature and the consumption of food presented in buffet vats (also know as gastronorm) and make data available to relevant restaurant divisions like cooking, nutrition and real-time management. The system is created using resources of IoT, Edge/Fog and Parallel/Distributed computing. Node-red, ThingSpeak and Arduino IDE compose the technology framework .

***Keywords*—**smart monitoring systems, Edge/Fog computing, IoT integration, parallel computing, smart network devices

I. INTRODUCTION

The process of producing and displaying food in restaurants that adopt the self-service model has several stages. Initially ingredients are purchased, supplied, then go through food preparation in the kitchen, and finally are exhibited to customers in a buffet. In general, the food preparation process in the kitchen is most critical in the overall production chain, because if not well managed and monitored by a professional nutritionist, it can lead to waste, compromised customer service (lack of food supply in the buffet),

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inconsistencies in stock, an increase in the labor force allocated to the production process and ultimately a decrease in the profit margin. Faced with these challenges, a software solution can reduce the problems mentioned above. Thus, in this context, a smart system that provides management, monitoring of food preparation for restaurant chefs and that allows a nutritionist to work with food temperature information in real time and online, as well as enable managers to monitor indicators of food consumption, can bring significant gains to the restaurant operation. The system proposed in this paper is based on the IoT concept. Its core component evaluates, in real time, variables such as load (amount) and temperature of the food that is currently available for costumers at the buffet. In addition, graphs and dashboards are displayed to restaurant staff for productivity optimization, waste minimization, optimization and improvement of the costumer services in the restaurant. IoT is changing the way we interact with things around us, transforming different areas of knowledge [1]. It is present in most sectors of life such as energy, safety, engineering, health and food. Implementations ranging from a simple system of the automation of LEDs, through to large systems monitoring data from ubiquitous environments or objects, are already reality in different areas of industry and academy. The production and handling of food at professional standards is very important because otherwise health of consumers is being compromised. Thus, it is essential that nutrition professionals are involved in monitoring production and is the way how food is exposed when marketed to customers in a restaurant buffet, for example. In addition, the nutritionist can also contribute to a more efficient food production in commercial restaurants where production volume is significantly larger in comparison to domestic households and there are large amounts of food waste. The brazilian health regulatory agency ANVISA provides technical regulations for good practices for food services. In Resolution RDC No. 216, dated September 15, 2004, establishments working with food are advised to follow item 4.8.15 of [4]. To follow these regulations nutrition professionals have only a very few tools available and there is a shortage of software in the market to automate the process. After being cooked, the prepared foods must be kept under conditions of time and temperature that do not favor microbial multiplication. For warm preservation, the food must be kept at a temperature higher than 60ºC for a

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maximum of 6 hours. For preservation under refrigeration or freezing, the food must be pre-cooled and, when exposed, must not exceed 10ºC. According to the Food and Agriculture Organization of the United Nations, consumers currently waste around 1.3 billion tonnes of food annually where consumers in rich countries waste around 222 million tonnes of food products. In the city of Rio de Janeiro, 43% of food is thrown away each time an individual is fed [6]. Most of the food waste generated in restaurants comes from the production stage. A number of factors and their inefficient management are the main reasons for this waste in restaurants or collective eating establishment. A restaurant is understood to be an establishment or commerce that provides a service of preparation of meals or food to clients. In Brazil there are several types of restaurants with different concepts. The self-service type, became very popular from the 1990s. Fonseca [7] still states that the selfservice restaurant targets a clientele that has time or budget limitations. This type of restaurant also has a menu with a wide variety of offerings where the client follows a "mandatory flow" of a pre-defined route to use the food exposed in the buffet and finally finds a scale or a cashier to weight of the dish. Although this model brings convenience to the customer, it can also bring serious problems to the restaurant. The biggest of them is the waste of food left over from the buffet at the end of the day [6]. In fact waste is much higher in comparison to other types of restaurant where food is prepared on demand only, as for instance in à la carte restaurants. Food waste in the production stage, the lack of software tools to support nutrition professionals, and inefficient resource management are some of the main problems of restaurants in Brazil's self-service model. In this sense, software this is trying to minimize food waste, improving the collection and storage of nutritional information, and assisting restaurant managers in decision making would provide an important tool for food service companies. The set of gastronomic vats with exposed foods is considered a buffet. The vats that are used in commercial restaurant buffets have simple design and do not include any technological components. The work presented in this paper transforms a buffet vat into a smart object capable of identifying the quantity and temperature of food in its interior. Other proposal of this work is an efficient software monitoring in real-time to try to minimize food waste, improve the collection and storage of nutritional information, and assist restaurant managers in decision making.

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This would make a significant contribution to food companies and their collaborators. The system is created using resources of IoT, Edge/Fog and Parallel/Distributed computing. Node-red, ThingSpeak and Arduino IDE compose the technologies framework used. The architecture of the smart system (named SmartBuffet) is divided in 4 distinct parts: physical layer, controller layer, data layer and view layer. Thus, the project work created a platform of intelligent hardware and software for monitoring variables such as weight, time and temperature of the food inside a vat at a restaurant buffet. The system checks in real time the amount of food and its respective temperature as well as combinations between these variables over time. It presents this data in dashboards through video monitors in the relevant parts of the company: cooking, nutrition and management. Using the information shown in the system, chefs can prepare food on demand, avoiding waste in the buffet and so increasing efficiency in production. Nutritionists do not not need to make measurements and annotations of food temperatures (as required by ANVISA RDC No. 216, 2004) manually and also have historical data organized in a database which is always available and online. Restaurant managers are able to improve management as they can consider historical data on food consumption and system-generated indicators in making decisions, Additionally labour costs are reduced as no staff needs to be allocated to verify the status of consumption at the buffet. The paper is organized as follows. In the next section are presented some related work. Section III describe the proposal (SmartBuffet). Sections IV describe preliminary results and conclusions of our work.

II.LITERATURE SURVEY

In [8] is developed a system based on RFID (Radio Frequency Identification) to monitor the state of food conservation. Before being exposed to customers in a supermarket, the food pack is labeled with smart tags containing information about the product, such as, date of manufacture and expiration date. The products are then scanned with a smart tag scanner before storing them. The scanner is configured to retrieve food product information through smart tags. Finally, the time the food is exposed to the user can be monitored, and the manager is even alerted if the recovered information indicates that the life time of the product has expired or is about to expire. The patent [9] describes a wireless food information monitoring system at a food merchandising establishment. It installed battery-operated

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sensors in remote food containers divided into the environments kitchen, storage and buffet. Each unit holds sensors that gather data and temperature variation of food in at least two ways, which can be through internal or auxiliary temperature sensors, smart trays or other external food data sources. Collected data are transmitted, incisively or not, to a server. The system performs the analysis and processing of data using desktop software, a report configuration form It is also possible to choose the type of report, as well as its periodicity in daily, monthly, yearly increments or any other date interval. In [10] is proposed a system for the implementation, evaluation and management of food waste from IoT-based restaurants. The work is based on sensors to improve the management of Restaurant Food Waste (DAR) in the city of Suzhou, China. However, the authors also faced problems with radio frequency identification (RFID) tags, which need to be renewed frequently, thus increasing costs. In addition, dynamic weight sensors presented errors and inaccuracies. An intelligent cooling system combining IoT and tSmart Kitchen consists of a sensing module, a control module and a transmission module in [5]. The sensing module consists of load cells and odor sensors, while the control module consists of Arduino UNO and a power supply unit. The transmission module consisting of an LCD module and a Wi-Fi module. These modules work together to determine the content inside the refrigerator and notify the user about the condition and quantity of the food by means of an SMS or an email message. The solution can be applied in home automation and restaurant kitchen management. However, it has some limitations such as poorly robust graphics, slow response time, and restricted access information. The management system in [11] is capable of detecting gas leaks, water tank overflow and water levels in buckets in a kitchen. The system also allows sending alerts via SMS, if the captured data leaves the previously set threasholds. The work has some critical points, such as the safety of the gas sensors, the dependence on electric power and the imprecision of the load sensors. In addition, the work does not make measurements of the quantity, temperature, humidity of the food itself, which are all factors that contribute to waste volume. In [12] a sensor network system is proposed to refine the supervision and management of food waste through timers. The system was customized for kitchens that suffer from food wastage during cooking on the stove due to the large number of meals prepared

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at the same time and to prevent the Chef from forgetting food on other stoves during the preparation of other meals. It was verified that the same one is not able to identify how many times the Chef cooked a certain meal, what are the foods most consumed by the clients, as well as the measurement of the amount of food that was consumed in a meal during the work, for example. The advent of the Internet of Things [13] and the Industry 4.0 has made monitoring systems more popular in the market. Examples of such systems are the solutions of the company Information Technology NEXXTO [14] and the company AGEON [15] that propose monitoring the temperature of frozen foods in cold rooms. These systems, meanwhile, do not make a more detailed control over other variables that can compromise foods that are handled in restaurants. Both the NEXXTO solution and the AGEON solution are unable to identify critical points due to being particular products, and to exploit them it would be necessary to acquire them through the companies mentioned. Both solutions are not able to capture the temperature of fresh food that is exposed in a buffet nor to check the amount of food stored in it. The work presented in the paper is particularly addressing this aspect.

III. PROPOSED SYSTEM

The container intended for the display of ready-to-eat food in restaurants in Brazil is called a gastronomic vat.

Fig. 1. Buffet vat (left) and buffet (right)

As shown Figure 1, a vat is a rectangular cube-shaped metal part which is used for temporary storage and food handling. The set of gastronomic vats with exposed foods is considered a buffet. The vats that are used in commercial restaurant buffets have simple design without any technological devises attached. The proposal of the presented work is to transform a buffet vat into a smart object capable of identifying the quantity and temperature of food it is holding at any time. Food waste in the production stage, the scarcity of software tools for nutrition professionals, and inefficient management are some of the main problems of restaurants in Brazil's selfservice model. In this sense, a smart software is proposed to try to minimize food waste, improve the collection and storage of nutritional information, and assist restaurant managers in decision

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making would make a significant contribution to food companies and their collaborators. This work create a platform of intelligent hardware and software for monitoring variables such as weight, time and temperature of the food inside a vat at a restaurant buffet. The system will check in real time the amount of food and its respective temperature as well as combinations between these variables over time and will show this data in dashboards through video monitors in some sectors of the company: cooking, nutrition and management. Thus, from the information shown in the system, cooks can, prepare food on demand, avoiding waste in the buffet and increasing efficiency in production. Nutritionists, however, will not need to make measurements and annotations of food temperatures (required by ANVISA RDC No. 216, 2004) manually and will have historical data organized in a database that is always available and online. Restaurant managers will be able to improve management by making decisions based on historical data on food consumption and system-generated indicators, minimizing the manpower allocated to verify the status of consumption of the buffet. The architecture of proposed smart system (SmartBuffet) is divided in 4 distinct parts, see Figure 2: physical layer, controller layer, data layer and view layer represented by the four columns in Figure 3. Initially, for example in the physical layer, was arranged the hardware of the vat, two sensors and two microcontrollers. This case was the initial model of a restaurant. The architecture model is flexible and can grow depending on the demand and with the size of the size of the restaurant, where many, different devices can be connected in the proposed smart devices network. The smart devices network is very heterogeneous. Typically those sensor devices have limited processing power and often, by related works, rely on cloud services for compute-intensive tasks.

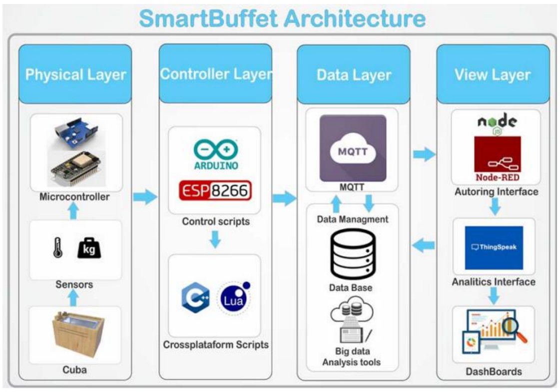

Fig. 2 - SmartBuffet Architecture.

How there this solution may not be practical in all cases as real-time application do not necessarily tolerate the latency of offloading tasks to a cloud server. As some nodes can have multi-core processors that can be customized for certain parallel applications. For example,

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the Raspberry Pi3B+ is an interesting device and much more powerful prototype, with a GPU capable of processing digital images 1080p resolution (FullHD) with greater ease and better performance. It is the latest product in the Raspberry Pi 3 range, with 64-bit quad core processor running at 1.4 GHz, 2.4 GHz wireless LAN and 5 GHz dual band, Bluetooth 4.2/BLE, faster Ethernet and PoE capability through a separate HAT PoE. The dual-band wireless LAN comes with modular compliance certification allowing the card to be designed into end products with significantly reduced wireless LAN compliance testing. The Raspberry Pi 3 Model B+ has the same physical footprint as the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B [21]. We need to consider the trade-off between moving data to a remote processing device-point to increase parallelism and computing things locally to reduce communication and energy costs while keeping performance. Edge/Fog computing proposes bringing computation closer to where data is generated and/or stored by adding computational capabilities to network devices and adding edge gateways/servers, possibly in multiple layers with different latencies and computing performance. The parallel and distributed programing is a non-trivial task, but can be necessary in order to explore the potential of this modern computing platform. Therefore, it is important the design of a parallel model connecting the different computation devices of the proposed smart network. The distributed model solution can tackle problems such as application deployment, resilience and scheduling/offloading of tasks, high latency, limited bandwidth, slow response time and high performance. In initial prototype configuration, the hardware of the vat is composed of recyclable wood and two containers of aluminum that simulate a real vat, as described above, see Figure 4. A load sensor will be positioned just below one of the trays to capture the weight of the food that is in the vat. A temperature sensor will be placed on the top of the vat to capture the food temperature. For the physical layer, the current device is an Arduino microcontroller and a Esp8266 which are responsible for receiving data signals from the load and temperature sensors. The control layer manages the data sent by the physical layer sensors. In this layer controls and scripts are responsible for performing the main functions and routines. They are programmed in the Arduino IDE, a desktop software development environment that is compatible with the C++ and LUA programming languages. The storage,

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manipulation and transport of data resulting from the control layer are used in the data layer. This layeris composed of a database management system (RGBD), the MQTT protocol (Message Queuing Telemetry Transport) and Big Data tools. Because it is simple and lightweight, MQTT is responsible for receiving data from the control layer and for exchange messages in the Publisher-Subscriber model, maintaining a two-way communication with the RGBD. Next, Big Data data analysis tools are used to generate indicators for the next layer. Finally, the view layer is responsible for receiving information from the data layer through Node-red[19] and ThingSpeak[20]. The Node-red is a development tool with visual programming created by IBM and was built on the Node.js. It interfaces between the data layer and the view layer. Its choice was motivated by the fact that it has a very active community and it is known for its high productivity and high performance for the creation of Web applications focused on IoT. ThingSpeak provides an API by IoT. It was chosen because it is open source, has a very active community, uses HTTP protocol and runs a MATLAB based analysis. ThingSpeak acts as an API that communicates with the data layer and then is consumed by Node-red to create the Web pages and an analytic interface. Through the Web interface , the end user of the system is able to view the graphical of the Web through dashboards. To close the proposal, we show the hardware prototypes of the smart vat, as well as explain the functioning of the prototypes of the Web system screens developed. Through some screens we can understand how the data are shown to the end user of the software. The SmartBuffet's vat is a rectangular cube, composed of recycled material and have 2 metal trays overlapping each other (Figure 3). A load sensor (weight) lie between the two metal trays and at its top a temperature sensor is arranged pointing constantly at the food inside the vat. After logging in to the system the user can see the kitchen, nutrition and management screens and check five indicators of each vat. The screens includes information such as the amount of food in the vat in grams, the temperature of the food, how many replenishment have been made, how many minutes are left until the vat empties, and finally the amount of spoons taken from that vat. Through these indicators the kitchen staff have a more accurate can plan ahead before producing a a new shipment of food to the vat, thus avoiding wastage. A screen represents six different vats and the main indicators that are visualized by the nutritionist. The presented data for

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each individual vat show the individual current temperature, a temperature history over time, the average of the minimum and maximum temperatures, the time the food was exposed in that respective vat and, the number of times the vat was replenished. SmartBuffet automatically stores food temperature information (as recommended by ANVISA), so no manual data collection by the nutritionist is required. Thus, the nutrition professionals can remotely supervise the food safety at the restaurant. The restaurant manager can monitor in real time the history of food consumption throughout the year, on a month-by-month base and weekly. It also is possible to monitor daily and weekly consumption per vat allowing to identify which food is being the most consumed over a period of time. This screen show the history and quantity of food in the buffet. Thus, having these indicators, restaurant managers can make more accurate decisions on such which ingredients should be purchased in lesser or greater quantities, thus increasing their bargaining power. It will also be possible to forecast demand through historical data in the database, thus making resource management more efficient.

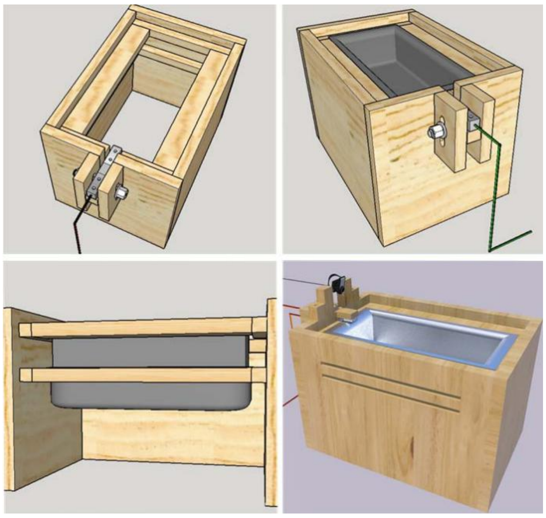

Fig. 3 - SmartBuffet cube 3D prototype

IV.RESULTS

The research is close to its completion and already has some preliminary results. Some of the main points already completed are the development of the SmartBuffet 3D vat and the software manager. Some initial tests were done in the UFRN university restaurant and the IMD/UFRN laboratory. After the development of the 3D prototype, a microcontroller Arduino Uno and 3 sensors were added to create the cube, which monitor the temperature of the food, the ambient temperature, the quantity, weight and volume of food arranged inside the tank, according to Figure 4.

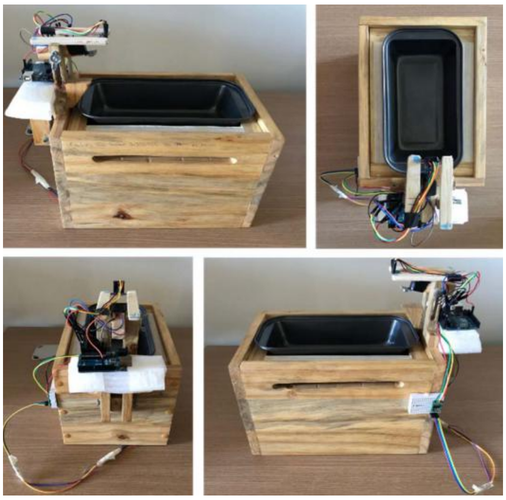

Fig. 4 SmartBuffet Cube, built from 3D cube prototype

On the home/login screen (Figure 5) the admin user was able to access and test the entire system and the permissions. The kitchen screen was used by the cooks of the university restaurant to monitor the consumption and condition of the food. On the nutrition screen, a nutritionist who participated in the research was able to monitor behavior and food compliance variations. Finally, on the management screen the restaurant manager arrived at important conclusions regarding how lunch was made and organized, from decisions that were taken with data and indicators obtained by SmartBuffet. The case study comprised four steps: (1) examining the required functionality of an IoT-enabled system in the specific context of the university; (2) configuration of the system architecture; (3) verify operation of the IoT system components in the facilities; (4) evaluation of the performance of the entire system, based on data obtained. Several positive results were considered, such as: (1) better management to control food waste; (2) better work of the nutritionist and restaurant manage, can made possible by the monitoring capabilities of the IoT system; (3) an overall reduction in activities and better process optimization along students lunch.

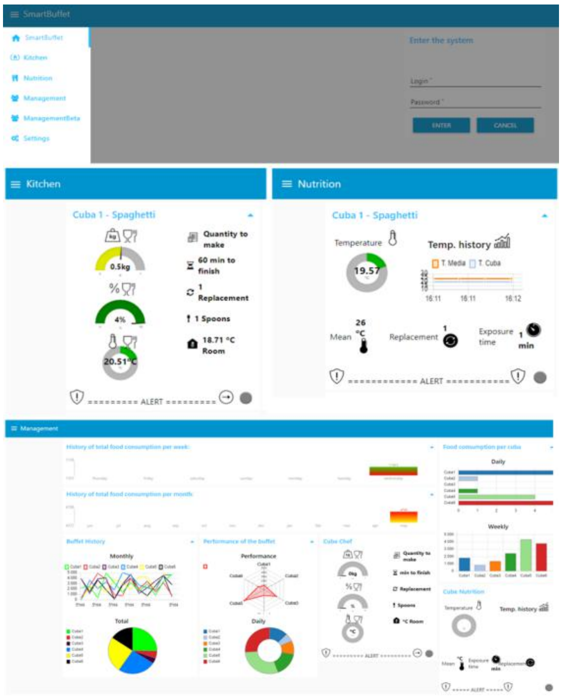

Fig. 5 – SmartBuffet Software Overall, the system had a good impact and helped to minimize the waste of food in some sectors in the university establishment, for example, was detected that inappropriate storage is one of the main reasons for increased food waste. Once foods are purchased and placed in the refrigerator, employees forget the shelf life unless they

are individually examined and monitored. In addition, for foods that are not labeled with an explicit expiration date, it can lead to a quicker deterioration of them, thus generating more expenses. The advent of the Internet of Things and the Industry 4.0 [22] has made monitoring systems more popular in the market [23]. The SmartBuffet monitors food temperature with more effective and detailed control. Our system is also capable of generating various indicators on the existing foods in a restaurant buffet. From these indicators, cooks, nutritionists and restaurant managers can make internal decisions more efficiently. As an example, the system can help in deciding what to buy to avoid idle inventory. This would prevent food waste and improve the food compliance management required by regulatory agencies. Finally, after finishing the tests that prove the efficiency and feasibility of this solution, upon completing research, the author intends to make a patent of his idea, considering that no identical proposals were found in the market throughout the research. According to INPE a patent can be requested for the fact that the author has made improvements in the use or manufacture of objects of practical use, such as utensils and tools. It may be an Invention Patent (PI) or Utility Model Patent (MU) (INPE, 2019).

V.CONCLUSION

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