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MyRestaurant: A Smart Restaurant with a Recommendation System

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Abstract: In this paper, we discuss, in an internet of things environment, our solution regarding context management in the area of food services. We propose a system that automates the different services offered in a restaurant and connects the various equipment of this restaurant, in order to simplify and facilitate the work of employees using this system. We also have integrated a content-based recommendation module, that is based on the use of a similarity measure to keep track of the client order history in order to suggest or recommend to him similar dishes for his next orders.

Keywords: Internet of things, Context awareness, Connected restaurant, Recommendation System.

1. Introduction

The Internet of Things (IoT) is a world where a huge number of objects are interconnected and can sense, communicate and share information. The intelligence of these objects primarily means their ability to consider the context in which they operate and interact with other objects in the environment.

In recent years, we have witnessed the emergence of a growing number of embedded sensors including intelligent devices (mobile phones, smart watches or smart goggles). Each device connected to the Internet can provide important information for decision-making. The number of sensors deployed all over the world is growing at a rapid pace. These sensors generate constantly huge amounts of data. The challenge is to understand this data in order to add value and meaning to it.

Applications that use connected objects are gaining in popularity. In this context, we like to contribute to the emergence of new applications in the field of the internet of things. Thus, we found it useful to propose a system based on context management that automates the various services offered in a restaurant and connects the different equipment of this restaurant such as oven, refrigerator, hob, etc. Furthermore, the goal is to simplify and facilitate the work of employees through applications and improve the users experience.

The rest of the paper is organized as follows, section 2 introduces the world of internet of thing, section 3 gives an overview of context fundamentals in an IoT environment, section 4 presents our proposed solution, section 5 provides an overview of some existing systems of connected restaurants. Finally, section 6 draws conclusions about the proposed system and gives some perspectives.

2. Internet of Things

The Internet of Things (IoT) concept has been around since 1991. But, the term *Internet of Thing* was first coined by Kevin Ashton's in 1999 in the context of supply chain management [1], which drew attention to how information is collected and shared via the internet. IoT point out to the idea that our physical environment, "the things", would transmit information to the internet without any help from human, making our physical world become an information system where almost all things are connected and communicates in a smart way. "A world of the Internet of Things (IoT) is a world where billions of objects can sense, communicate and share information, all interconnected over public or private Internet Protocol (IP) networks. These interconnected objects have data regularly collected, analyzed and used to initiate action, providing a wealth of intelligence for planning, management and decision making.

Everyday objects include more than the electronic devices or the products of higher technological development such as vehicles and equipment, it includes also things that we usually think are far from being electronic like food and clothing.

Examples of things include: people, location (of objects), time Information (of objects), condition (of objects). These things of the real world will smoothly merge into the virtual world, enabling anytime, anywhere connectivity. In 2010, the number of everyday physical objects and devices connected to the Internet was around 12.5 billion. Cisco forecasts that this figure is expected to double to 25 billion in 2015 as the number of more smart

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devices per person increases, and to a further 50 billion by 2020" [1].

A. Definition

The main goal of the Internet of Things is to enable things to be connected anytime, anyplace, with anything and anyone ideally using any path/network and any service. Internet of Things is a new revolution of the Internet. Objects make themselves recognizable and they obtain intelligence by making or enabling context related decisions thanks to the fact that they can communicate information about themselves and they can access information that has been aggregated by other things, or they can be components of complex services [2]. The Internet of Things is defined by IERC (European Research Cluster for the Internet of Things) as a "dynamic global network infrastructure with self-configuring capabilities based on standard and inter operable communication protocols where physical and virtual "things" have identities, physical attributes and virtual personalities, use intelligent interfaces and are seamlessly integrated into the information network" [2].

B. Application Area

For the last decade the evolution of market applications continued to increase, which made social trends change drastically such as health and wellness, transport and mobility, security and safety, energy and environment, communication and e-society.

There are a variety and several potential applications of the IoT that invade all aspects of our everyday life. The IoT application includes smart environments in domains such as: Building, City, Lifestyle, Retail, Transportation, Agriculture, Factory, Supply chain, Emergency, Health care, Culture and tourism, Environment and Energy.

3. Context Fundamentals

The diversity of devices used by users to access resources, using several types of networks, creates a growing need for dynamic services adaptation in order to return a response adapted to the specific needs of each user. This cannot be done without considering the context surrounding the service to be offered and the user's profile. In this section we present a brief review about context fundamentals.

A. Definition of Context

Many researchers have attempted to define the context in their own work. The term "context" was introduced the first time by Schilit and Theimer [3], they refer to context as location, identities of nearby people and objects, and changes to those objects. Brouwn et al. [4] define context as location, identities of the people around the user, the time of day, season, temperature, etc. Ryan et al [5] define context as the user's location, environment, identity and time. Dey [6] enumerates context as the user's emotional state, focus of attention, location and orientation, date and time, objects, and people in the user's environment. These previous definitions that define context by listing examples are difficult to apply because it is hard to determine whether a type of information not listed in the definition is context or not. Other definitions have provided synonyms for context. For example, Brown [7] defined context as the elements of the user's environment that the user's computer knows about. Franklin and Flaschbart [8] see it as the situation of the user. Ward et al. [9] view context as the state of the application's surroundings. Definitions that simply use synonyms for context are also difficult to apply in practice.

Dey and Abowd refined the definition given by Schilit et al. and defined context in the following way: "Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" [10]. This definition makes it easier for an application developer to enumerate the context for a given application scenario. If an information can be used to characterize the situation of a participant in an interaction, then that information is context [10].

Sensor data can be used by customized context-aware applications and services, capable to adapt their behavior to their environment. However, sensor data present high complexity, dynamism, accuracy, precision and timeliness. An IoT system should be concerned with interpreting the information into a higher, domain relevant concept, rather than the individual pieces of sensor data. For example, sensors might monitor temperature, humidity, while the information needed by a watering actuator might be that the environment is dry. This higher-level concept is called a situation, which is an abstract state of cases interesting to applications [11].

B. Definition of Context-awareness

The term context-awareness was defined by Dey as follows: "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task" [10]. Context aware system is a core feature of pervasive and ubiquitous computing systems. From last decade, context aware system focuses on Web applications, desktop computing and IoT [12].

C. Context-aware Features

A context-aware application can support three features that were identified by [10]: presentation, execution, and tagging.

Presentation: Context can be used to decide what information and services need to be presented to the user.

Execution: Automatic execution of services based on context is also an important feature in the IoT paradigm.

Tagging or annotation: sensor data collected through multiple sensors needs to be fused together. To accomplish the sensor data fusion task, context needs to be collected and tagged together with the sensor data to be processed and understood later. Context annotation

[1] https://www.imda.gov.sg//media/imda/files/industry%20development/infrastructure/technology/internetofthings.pdf?la=en

plays a significant role in context-aware computing research.

D. Context Types and Categorization Schemes

Ryan et al. [5] suggest context types as location, environment, identity and time. Schilit et al. [13] list the important aspects of context as where you are, who you are with and what resources are nearby. Abowd et al. [10] introduced one of the leading mechanisms of defining context types. They identified location, identity, time, and activity as the primary context types. Also, they defined secondary context as the context that can be found using primary context. For example, given primary context such as a person's identity, many pieces of related information can be acquired such as phone numbers, addresses, email addresses.

Primary context: Any information retrieved without using existing context and without performing any kind of sensor data fusion operations (e.g. GPS sensor readings as location information) [14].

Secondary context: Any information that can be computed using primary context. The secondary context can be computed by using sensor data fusion operations or data retrieval operations such as Web service calls (e.g. identify the distance between two sensors by applying sensor data fusion operations on two raw GPS sensor values). Further, retrieved context such as phone numbers, addresses, email addresses, birthdays, list of friends from a contact information provider based on a personal identity as the primary context can also be identified as secondary context [14].

According to [14] Context categorization should be in two different perspectives (Figure 1): conceptual (allows an understanding of the conceptual relationships between context) and operational (allow the understanding of issues and challenges in data acquisition techniques, as well as quality and cost factors related to context). They consider that both operational and conceptual categorization schemes are important in IoT paradigm.

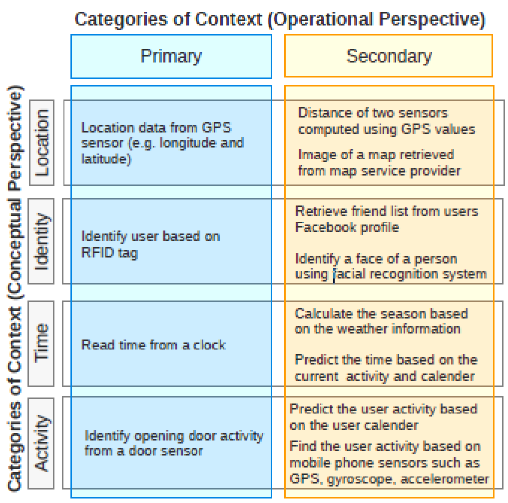

Figure 1. Context categorization [14]

Context information can improve people activities by creating new services that are capable to adapt to the circumstances in which they are used. A context manager is a software component computing high level information from different sources of data. Its main functionalities are context data acquisition, context data processing (fusion, aggregation, interpretation, inference) and context data presentation to context-aware applications. Entities that provide raw data are considered as producers, and context-aware applications are considered as final context data consumers. Context managers can build high-level context information from the enormous amount of data collected from diverse connected objects belonging to one or multiple owners. The context information is delivered at the end to any interested context-aware application [15].

To describe context information, different languages and models can be used. In order to provide application dependent context information through a context framework, a uniform way for representing and sharing context is required.

The data structures used for representing and exchanging context information are: key-value pair, markup scheme, graphical, object oriented, logic based and ontology-based models [16].

As an example of contextual information description language:

The PPDL (pervasive profile description language) is an XML-based language that can be used to describe preferences of peers within situations peers operate [17].

Some XML schemas are defined for describing contextual information of mobile networks, for example, activity, device status and reachability [18].

CC/PP (Composite Capability/Preference Profile) can be used to describe contextual information of service capabilities and user preferences. CC/PP is based on RDF. CC/PP, however, does not specify how contextual information can be stored [19].

E. Context-Aware Applications:

Context-aware applications can adapt their contents, functions, and interfaces according to the user's current situation. [20] Introduced some applications gaining big attentions worldwide and categorized them as:

- Location-Aware Applications:
  They are considered by [20] as the standard applications for the first stage of context-aware computing because the location is defined as the context. Location-aware applications offers functions or services to the users based on their physical location, for example, the application provides necessary information to the users as they enter or walk through specific areas, it can inform the user about current location on the map, nearby restaurants, notices about traffic condition, etc. the applications can also report a user's locations in any social network. Active Badge Location System, The tour guide, Personal shopping assistant are some of the popular location-aware applications.

- Social-Aware Applications:
  The growth of social media and advance in technology and mobile devices, the applications that are aware of social context are gaining big interest the last few years. Social context is defined as the context that can represent the interaction among people. It characterizes multiple users such as the social tie, social group or group dynamics [20].

F. User Profile

A user profile can be defined as the description of the users characteristics in particular his personal data (name, first name, age, address, contact, profession ...), interests, current purpose and the history of its interactions with the system, behaviors and preferences(a preference is an expression to prioritize the concepts the user is interested in) that can be obtained statically using questionnaires and interviews, or dynamically using machine learning and data mining techniques [21] [22].

4. *MYRESTAURANT*: A SMART RESTAURANT BASED ON IOT PARADIGM

The daily tasks of users concerned by our project require mobility and fairly high flexibility. Our choice of implementation focuses on the realization of several mobile applications as well as a desktop application for the manager that will be connected through a local network. Our system allows the connection of objects, namely a connected oven, a connected refrigerator, a connected hob and finally a connected table. Also, three mobile applications: one intended for customers allowing them to reserve a table outside the restaurant, another dedicated to the cook in order to supplement him in his work, and a third for the waiter to respond to customer requests. For the manager we have a desktop application to help him in managing the restaurant.

A. Motivation

IoT solutions are a simpler, faster and more efficient way to run a successful restaurant, the IoT will make any restaurant more efficient by:

- Maximizing equipment life cycles: the remote monitoring of all restaurant equipment and the detection of potential problems will help to avoid equipment breakdown and limit equipment downtime by anticipating maintenance.
- Food safety monitoring: it monitors the temperature and refrigeration nonstop and sends alerts when food is not prepared or stored in the preset parameters.
- Automated displaying system: it replaces the old way of printing orders which improves the communication between the restaurant employees and reduces waiting time by displaying orders immediately on a cook tablet.
- Also, it saves money from printing new catalogues for every change in the menu.
- Labor costs saving: changing restaurant operations from paper and manual processes into automated and digital solutions, save restaurant owners great amounts of labor costs.
- The connected refrigerator: each section of the refrigerator can be monitored and thermostatically controlled separately, this system can detect spoilage time and if pathogens are present. Also, it can monitor inventory levels, in order to send alerts to the chef or kitchen manager when the stock is low.
- The connected oven and hob: they offer remote control and monitoring which saves space and money since fewer staff is needed in the kitchen
- Inventory management: it helps with managing the cost of inventory. Restaurant managers can remotely and easily keep track of inventory, so it is adjusted according to daily orders, and whenever an item falls below the minimum limits, a replacement order is placed.
- Improved Guest Experience: one of the important motivation to have a connected restaurant solution is to deliver a unique dining experience for the restaurant guests making their experience more relaxing, efficient and effective than ever.

Using IoT solutions could help chefs and restaurateurs function in a way that increase efficient use of inventory and equipment, more quality control, better regulated food safety, and rises loyalty.

B. Presentation of The Solution: MyRestaurant

Restaurateurs are continuously striving to improve the quality of service offered to their customers and the internal functioning of their restaurants.

Basically, the idea is to create a sort of network between the different objects that can be found in a restaurant (table, oven, refrigerators and others) and integrate new technologies such as connected watches, smart phones and connected tables.

The most relevant needs are:

- Automate personnel management and the reservation services of tables.
- Automate and optimize inventory management by reducing the rate of expired products.
- Improve the staff working environment and communication between them.
- Decrease order preparation time.
- Build customer loyalty and knowledge of their gastronomic habits.
- Optimize the restaurant occupancy rate.
- Cost reduction.
- Supports clients before they arrive at the restaurant.
- Increase customer satisfaction by transforming wait time into leisure time and entertainment.

C. Strategy

In order to meet the needs listed above, we propose to create a restaurant management system based on IoT.

The restaurant will be equipped with connected objects and intelligent hardware.

- **Outside the restaurant:** A mobile application for the customer.
- **Inside the restaurant:**
  - The restaurant room:
    - Connected tables: 100% screen touch.
    - Application for restaurant management.
    - Connected object for restaurant waiters: The waiter will have a connected object on which he will be able to receive the chef notifications or calls from customers or the manager.
  - The Kitchen:
    - An application for the chef.
    - A connected refrigerator, a connected hob and a connected oven.
    - The appliances would be connected and synchronized to simplify the work of the chefs, thus reducing the preparation time of the dishes and increasing their quality.
    - The appliances in the kitchen communicate with each other and with the customer order management system; And they know at the same time as the chef the dishes to be prepared.

D. Architecture and Functionalities

The architecture of the proposed system is presented in Figure 2.
In the following, we present our system functionality.

1) The restaurant connected room system:

- Restaurant Manager's System: The manager will have an application that will interact with certain connected objects present in the restaurant. This application will allow him to be aware of what is going on in the restaurant and will also allow him to send messages to the staff of the restaurant.
- Restaurant customer system:
  - Outside the restaurant: The visitor can join the list of clients via a mobile application. First, the visitor must fill in a registration form to have an account to create a user profile that will contain personal information and gastronomic preferences, this profile will be updated as its orders.
    - The application has a geolocation option, which allows the customer to be directed to the nearest restaurant using its GPS coordinates.
    - Client can reserve a restaurant table, a list of available tables will be presented to him according to his preferences listed in his profile (smoking or non-smoking area, terrace, well-lit area or softened light area).
    - The client can also access all his personal information (gastronomic preference, food allergy, etc.) to view or modify it.
    - He can also access the restaurant's own information: photos, contact details, a summary of the menu with prices for dishes and desserts.

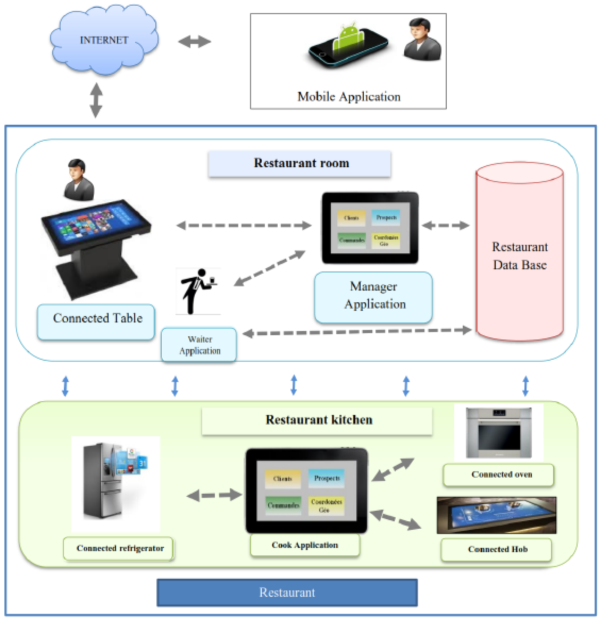

Figure 2. Global architecture

  - Inside the restaurant:
    - The customer will enjoy a meal around a connected table. These tables display electronic menus. The client will no longer have to wait for the menu card, the drinks card or a house slate (the restaurateur does not have to reprint or rewrite his card over the seasons). In front of a digital menu, the client selects and validates his order which will be sent directly to the kitchen. The digital menu proposed by the connected table adapts to the seasons (according to availability of fruits and vegetables).
    - Having data related to the menu choices of a restaurant subscriber (a subscriber is a customer who has an account), and thus his gastronomic preferences, the system uses this collected data to provide customers with personal recommendations in real time. Thanks to this, the customer can enjoy an adapted menu, accordingly dishes that could interest him. Restaurants can predict orders and better manage their food inventories, reducing their costs (less storage space, less food discarded).
      In the following, other services that the connected table may offer to customers:
    - During the waiting time for the preparation of the order, the connected table will propose to the client games and entertainment as a distraction for young and old.

- The client can track his order by visualizing the rate of advancement of his dish; Which is updated by the staff present in the kitchen.
- The client can also call the waiters to ask for additional cutlery or for other needs.
- The customer can also view the bill and note the service before leaving the restaurant.

2) The restaurant connected kitchen system:

- Chef's Application System: The chef has a touchscreen where he can interact with the connected table to provide information for the clients, such as the rate at which they prepare their dish (a percentage may be given). Through this application, the cook will interact with the waiter via his connected object (smartwatch), in order to notify him the end of the preparation of a dish so that he can finally serve it to the client. The chef's application will allow him to view the recipes of any dish and will give him the opportunity to add new personalized recipes to the restaurant database.
- Connected Refrigerator System: The connected refrigerator can give a preview of the elements it contains, it can also inform the chef about food that will soon expire so that he can use it in the preparation of his dishes to avoid waste. The connected refrigerator has an object identification system where each product is tagged by a QR code containing information about the product (name, type, expiry date), the refrigerator is equipped with QR reader that scans each product during the supplying.
  This system helps with the storage management and waste reducing by highlighting the products with the nearest expiry date.
- Connected oven system: The connected oven will interact primarily with the chef's system. He will be able to self-preheat for the next dish, to bake with information on the cooking temperature that the application of the chef communicates to him. The oven will also be able to inform the chef about the remaining cooking time and notify him when cooking time is finished. The screen of this oven is very intuitive and entirely touchscreen.
- Connected hob system: Like the oven, the hob will have the same functionality, except that the hob handles firepower and instead of temperature.

E. Connected Objects Interactions

Once in the restaurant, the customer will sit at a connected table and log in with his customer account, then he can choose between several features. The customer can consult a standard as well as a personalized menu, which recommends the most ordered dishes to the subscribers allowing him to select the dishes and to place an order; his order will be sent to the chef's application. The customer can consult at any time his order in order to modify it. The customer can track the progress of his order, a message is sent to the cook's application, the cook afterward returns his estimated rate which will be displayed to the customer on his connected table. Once the dishes are ready, the cook's application sends a notification to the waiter application asking him to take and serve the dishes to the customer and finally change the status of the order from (in preparation) to (Served). The client can also call the waiter from his connected table, that will trigger a notification in the waiter application. At the end of the service, the customer can note the service of the restaurant, this aims to inform the manager and thus improve the services.

1) Interactions of the Connected Table: Figure 3 shows the interactions between the connected table and other components of the system.

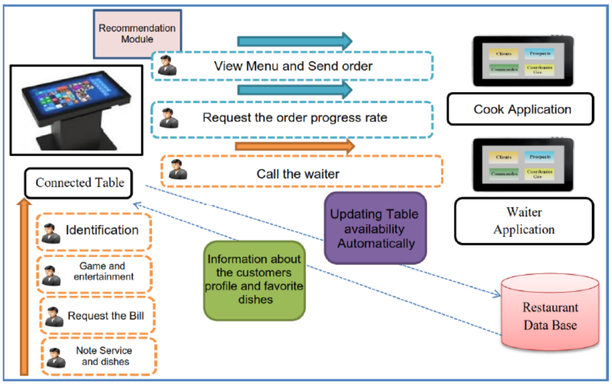

Figure 3. The connected table interactions

2) Interactions of the cook system: Figure 4 shows interactions between the cook application and other components of the system.

3) Interactions of the connected refrigerator: Figure 5 shows interactions between the connected refrigerator and other components of the system.

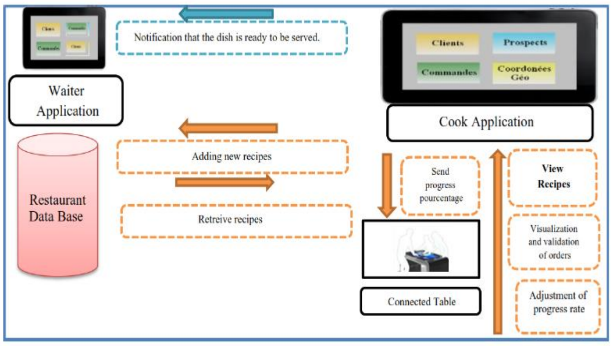

Figure 4. The cook system interactions

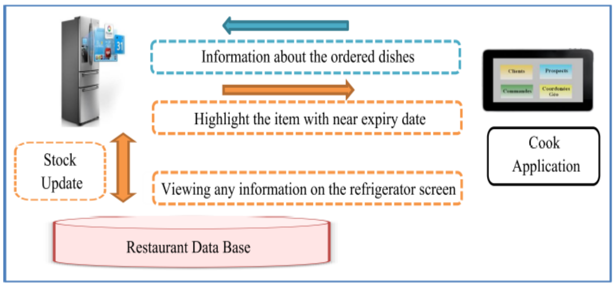

Figure 5. The connected refrigerator interactions

4) Interactions of the connected oven system: Figure 6 shows interactions between the connected oven and the cook application.

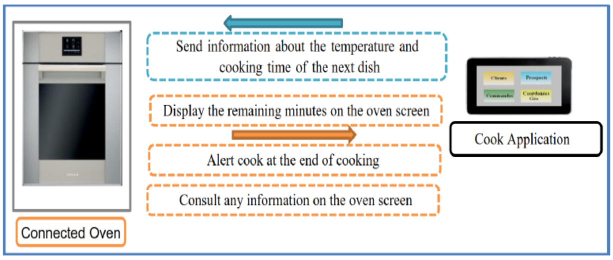

Figure 6. The connected oven interactions

5) Interactions of the connected hob system: Figure 7 shows interactions between the connected hob and the cook application.

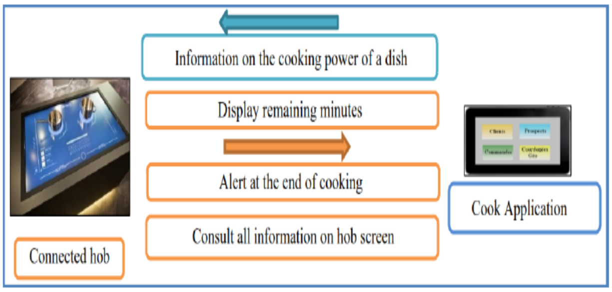

Figure 7. The connected hob interactions

F. Connected Objects Communication

Our system is composed of several connected objects that communicate with one another via the restaurant local network; each object is connected to the router of the restaurant and have its own IP address. The connected objects communicate with one another through messages contained in sockets. Our system uses a wireless local area network (WLAN) IEEE 802.11 as a communication protocol for data transmission between objects.

G. Context and user profile

The adopted context contains several components representing client-specific information. The context model has a multidimensional representation. That allows to create a concept hierarchy instead of independent unit fields.

The defined structure is flexible; thus, various characteristics can be extended thanks to the hierarchical character of the used model. The model is arborescence and is composed of one or more elements, each element contains one or more attributes (value, weight).

The user context is characterized by the following parameters: user identity, his preferences, type of terminal, localization, etc.

Various models for context representation were proposed, we chose CC/PP format to represent the context. CC/PP [23] is a W3C (*World Wide Web Consortium*) standard, which allows an expressive description of the environment constraints by using a general structure which takes a standard form for all users.

The suggested context allows to model the user and the service contexts by using a common vocabulary to represent the data for both entities.

The proposed model (Figure 8) is composed of four components:

- The client's profile: The profile component describes the client's preferences (his favorite dishes), his diseases as well as his allergies.
- Ordered dishes: This element describes the list of the ordered dishes by the client, as well as the number of times each dish was ordered. This information is used in the recommendation module.
- Terminal characteristics: This component contains all the details about the client smartphone, like:
  - Software characteristics: describes the software details of the client's smartphone such as the type and the version of the operating system and the navigator.
  - Hardware characteristics: Describes the material details of the terminal such as the size and the resolution of the screen.
- Localization.

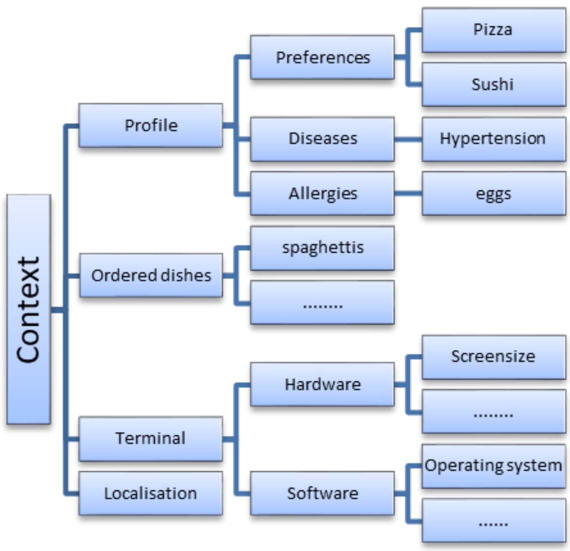

Figure 8. The context Model

The adaptation to the user context is integrated in two different levels of our system:

The first level, in the kitchen, there will be an adaptation to context supported by the characteristic of the automatic execution of services:

- When the cook receives an order, its application communicates some information to the oven and the hob that can be adapted in turns to the context (if the order requires a preheating or not, for example).
- When the cook receives an order, his application communicates some information to the connected refrigerator and depending on the context (foods needed to prepare dishes) the connected refrigerator recommends or highlights those whose expiry date is near.

The second level concerns the client of the restaurant. The context will contain information about the client and its profile (name, preferences, etc.); There will be an adaptation to the context supported by the characteristic of the presentation. The user profile is used to customize the menu. The interface of the menu will be dynamic and will adapt to the user profile and behaviors, recommending to him what will potentially interest him. It will focus mainly on:

- His habits and preferences: For example: the sequences of actions that he performs routinely on the interface and more precisely the dishes and drinks that he used to order in the restaurant.
- Ingredients to avoid: The client can be allergic to some ingredients in a dish (several people are allergic to fish, etc.), so the client is alerted.
- The context will contain also information about the client location; There will be an adaptation to the context supported by the characteristic of presentation. Depending on the user's location, a list of nearby restaurants is presented to him.

H. The Recommendation Module

We integrate in the connected table a recommendation module based on the use of a similarity measure.

Recommendation Systems (RS) are software tools and techniques providing personalized suggestions, and guide the user, within a large data space, to the resources which might interest him [24]. RS are usually classified into the following categories, based on how recommendations are made [25]:

- Content-based RS: these systems recommend items that are similar to the ones that the user liked in the past.
- Collaborative-based RS: these systems recommend to the active user the items that other users with similar preferences liked in the past.
- Hybrid RS: these systems are usually based on the combination of multiples recommendation approaches.

The proposed RS is a content-based recommendation system, it keeps track of the client order history to suggest or recommend to him similar dishes for his next orders. For this purpose, we use a similarity measure. The similarity is defined by the degree of resemblance between two objects. Indeed, any system having for goal to analyze or organize automatically a whole of data or knowledge must use, in a form or another, a similarity operator to establish the resemblances or the relations existing between the used data.

In general, a similarity measure is defined in a universe U which can be modelled using a quadruplet: (Ld, Ls, T, SF) [26]:

- **Ld** is the representation language used to describe the data;
- **Ls** is the representation language of the similarities;
- **T** is a set of knowledge about the studied universe;
- **SF** is the similarity binary function, such as:

$$SF{:}Ld*Ld \rightarrow Ls$$

A similarity measure is a function which satisfies the following properties:

$$\forall\, x,y \in Ld:\quad SF(x,y) \geq 0 \qquad (1)$$

$$\forall\, x,y \in Ld:\quad SF(x,x) = SF(y,y) \geq SF(x,y) \qquad (2)$$

$$\forall x,y \in Ld:\quad SF(x,y) = SF(y,x) \qquad (3)$$

In the same way, a dissimilarity measure is defined as a function DF which checks the following properties:

$$\forall\, x,y \in Ld:\quad DF(x,y) \geq 0 \qquad (4)$$

$$\forall\, x \in Ld:\quad DF(x,x) = 0 \qquad (5)$$

$$\forall x,y \in Ld:\quad DF(x,y) = DF(y,x) \qquad (6)$$

It is also possible to transform a similarity measure **SF** to a dissimilarity measure **DF** by using the following relation:

$$\forall x,y \in Ld:\quad DF(x,y) = S_{max} - SF(x,y) \qquad (7)$$

S_{max} is the maximum value which can be obtained by the similarity measure.

Several similarity measures were proposed in various applications fields, we cite:

- Similarity for textual data [27]**;**
- Similarity for intrusion detection [28];
- Similarity for Web services [29].

To compare two elements, we compare their values. However, when we have several attributes to compare, the previous method is insufficient. Therefore, we can use a similarity measure to determine the degree of similarity between two elements while considering all the attributes forming the elements.

The *Jaccard* similarity measure was used in [30] to evaluate the similarity between each previous client order and menu dishes to suggest or recommend to the client dishes according to his preferences.

Let **N** be a set of objects (documents, users, services…). Each object is described by **m** characteristics. Thus, for each object X is associated a binary vector ($X_1, X_2,\ldots, X_m$) such as:

$$X_i = \begin{cases} 1 & \text{if the feature } i \text{ exist in } X \\ 0 & \text{else} \end{cases} \quad (8)$$

$$\text{Where } i \in \{1,2,3\ldots,m\}$$

In our context, let **N** be a set of dishes. Each dish is composed of a set of **n** ingredients.

We define a threshold in order to present only dishes that have a similarity rate, with the dishes ordered by the client, higher than the threshold defined.

Let us note by:

- **a**: ingredients existing in menu dishes and also exist in the dishes ordered by the client.
- **b**: ingredients existing in menu dishes but not existing in the dishes ordered by the client;
- **c**: ingredients existing in the dishes ordered by the client but not existing in the menu dishes.

The *Jaccard* similarity measure used state as follows:

$$S = \frac{a}{a+b+c} \quad (9)$$

The similarity can be defined with a bipartite graph G(D ∪ I , E), where:

– D is the set of dishes on which we want to apply the similarity measure. We distinguish two types of dishes: the menu dishes and the dishes ordered by the client.

– I is the set of ingredients of the elements of D.

– (X, C) is an edge of G if the ingredient C is present in the dish X (in other word, the ingredient exists in the menu dish or exist in the dish ordered previously by the client).

Let G′({X,Y}∪I′,E′) be the subgraph of G generated by the two objects: X representing a menu dish and Y representing a dish ordered previously by the client. E′ includes the edges of G incident to X or to Y and I′ corresponds to the set of ingredients present in X or in Y. It is clear that the similarity degree of X and Y is proportional to the number of ingredients that they have in common. In the case of the graph of figure 9.b, the two dishes have exactly the same ingredients. We can deduct that they have a bigger similarity degree than the similarity degree of the graph (a) of the same figure.

We note that the subgraph G′ obtained in the graph of figure 9.b is a complete bipartite graph. The similarity between the two profiles is proportional to the degree of resemblance to the subgraph G′ of figure 9 (a complete bipartite graph).

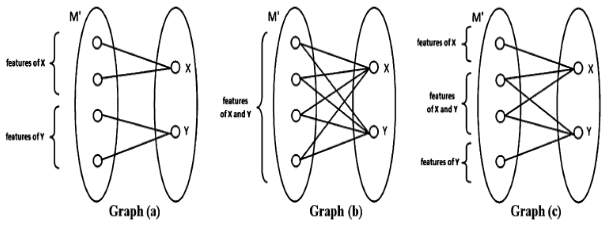

Figure 9. The bipartite graph G

After each order, the list of ingredients for each dish is retrieved and saved in the database as preferences. First, the recommendation system counts the number of ingredients which are shared between both sets, then counts the total ingredients of dishes in both sets (shared and not shared), then divides the number of shared ingredients by the total number of ingredients.

This operation is repeated with all existing dishes in the menu, and the dishes whose Jaccard index is the highest will be recommended to the client.

However, the Jaccard similarity measure presents some disadvantages. Indeed, we have noticed that the Jaccard measure checks only the existence of an ingredient in a dish, without considering the importance of the ingredient for the client (client's preferences).

So, we adapted the Jaccard measure in order to consider the importance of an ingredient for the client. The preference is represented by a weight associated to each ingredient.

The new similarity measure is formalized as follows:

- Let **P** be a set of objects (in this case an object is a dish). An object (dish) is described by **m** characteristics (ingredients) X= (X_1, X_2, X_3…, X_m).
- Let **X**= (X_1, X_2,…, X_n) be a dish belonging to **P** and (w_1, w_2,…,w_n) is a set of weights associated to each ingredient where $\sum_{i=1}^{i=n} w_i = 1$.

The weighted similarity measure ***WSM***: PxP →[0,1] is defined as follows:

$$\boldsymbol{WSM}(X,Y) = \frac{a*\sum_{i=1}^{i=a} w_i}{a*\sum_{i=1}^{i=a} w_i + b*\sum_{i=1}^{i=b} w_{a+i} + c*\sum_{i=1}^{i=c} w_{a+b+i}} \quad (10)$$

Where:

- X and Y are two dishes belonging to P;
- a is the set of common ingredients of X and Y;
- b is the set of ingredients existing in X and not existing in Y;
- c is the set of ingredients existing in Y and not existing in X;

To evaluate the weight of each ingredient, first we calculate the number of appearances of each ingredient in the dishes ordered by the client ($NbAppIng_i$). Then, we calculate the sum of the appearance numbers calculated previously $(\sum_{i=1}^{n} NbAppIng_i)$. Finally, we calculate the weight of each ingredient according to the following formula:

$$W_i = \frac{NbAppIng_i}{\sum_{i=1}^{n} NbAppIng_i} \qquad (11)$$

I. *Implementation*

Since the users concerned are nomadic users (they often move during the work) and their daily tasks require mobility and flexibility, our choice of implementation has focused on the realization of several mobile applications and a desktop application for the restaurant manager. These applications are connected through a local network.

MyRestaurant system consists on the one hand, of applications for connected objects, namely the connected oven, the connected refrigerator and the connected table; and on the other hand, three mobile applications: one for clients allowing them to book a table while being outside the restaurant, another dedicated to the chef in order to help him in his work and a third for the waiter that allows him to respond to clients' requests.

While developing *MyRestaurant* prototype, we used these development environments:
- The Wamp server (Windows Apache MySQL PHP): is a Windows Web development platform for dynamic Web applications.
- Android Studio: is a complete IDE for creating Android mobile app named Android Studio.
- Eclipse: is Integrated Development Environment (IDE) for Java Developers.

Regarding the Development languages we used: JAVA, XML, PHP.

Figures 10,11,12,13,14,15,16,17 present some interfaces of the proposed system.

Authentication interface: The application starts with the authentication interface represented by Figure 10. The user is offered two options, to log in to his account and, if he does not have an account, he can create one by registering.

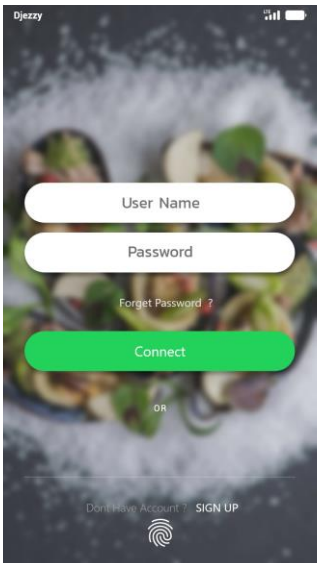

Figure 10. The authentication Interface

Home interface: After the authentication step, the application will display the home interface with a menu where the user is invited to choose an operation from among those proposed as shown in the figure 11.

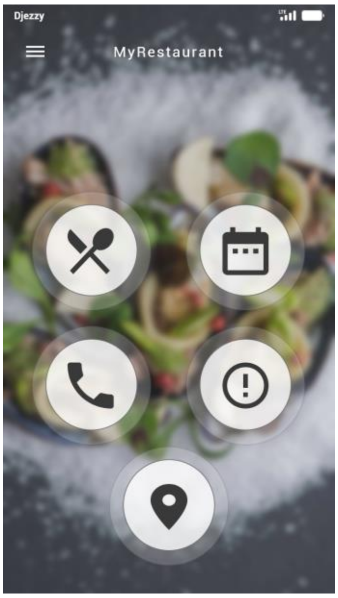

Figure 11. Home Interface

Restaurant Selection Interface: The interface shown in Figure 12 shows to the user a selection of the nearest restaurant depending on his location.

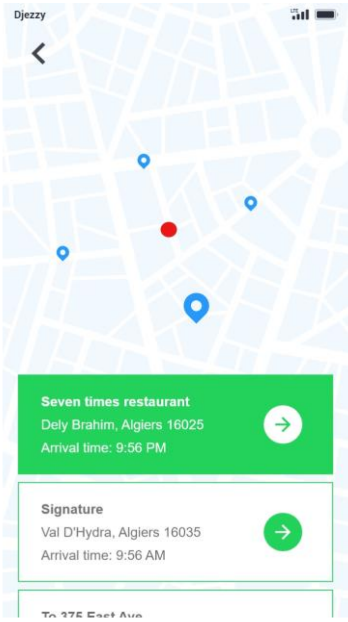

Figure 12. Restaurant Section Interface

Restaurant Menu interface: Figure 13 shows the menu that describes to the user the different dishes, drinks and desserts offered by the restaurant.

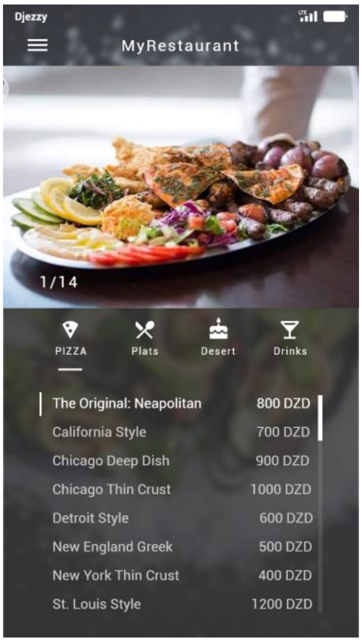

Figure 13. Restaurant Menu Interface

Table Reservation Interface: the interface shown in figure 14 allows the user to make a reservation outside the restaurant. He can change his preferences regarding the table's area.

Figure 14. Table Reservation Interface

The Connected Table Interfaces: Figure 15 shows the connected table home interface where the user can log in or create an account. Figure 16 is the connected table menu that displays the different options which are: displaying the restaurant menu and placing an order, calling the waiter, requesting the progress rate of the order, playing games and entertainment, requesting the bill, and finally give a review about the quality of service and food.

Figure 15. Connected Table Home Interface

Figure 16. Connected Table Menu Interface

The Cook Application Interface: One of the important applications of our restaurant is the cook application (Figure 17). The cook has the opportunity to add new recipes that can be attributed to new dishes in the restaurant. One of the most important features of this application is the orders management, the cook can consult all the tables orders, the list of orders sent by the connected tables of the restaurant room is displayed on his interface.

Each order contains a number of dishes, each one has a recipe. The cook can visualize the contents of each order then can choose to see the recipe of the dish to cook, he can also update the progress rate.

Once the cook mentions that the recipe is being prepared, the information on the temperature and cooking time is automatically sent to the connected oven application (if the dish needs to be put in the oven), so that oven preheat itself. Whenever the progress rate is updated by the cook, the customer is notified on his connected table of the new rate of progress of his order.

Once the order is ready the cook can notify the waiter from his application to serve it.

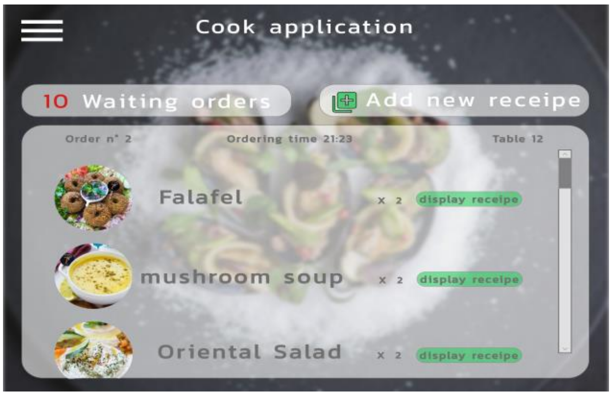

Figure 17. The Cook Application Interface

In the next section we discuss solutions that are implemented in the restaurant field.

5. RELATED WORK

Several solutions regarding connected restaurants exist in the restaurant industry, we chose to present these examples of connected restaurant applications in the list below:

- Chennai-based startup Strobilanthes [31] is installing wireless transmitters on restaurant tables that can hail waiters for drinks, service, or the bill, by sending alerts to internet-enabled watches strapped to the waiter's wrists. Software installed at each restaurant allows to manipulate connections between the transmitters and wristwatches to ensure waiters are not burdened during peak time. Tables can be added to relatively free waiters when traffic is light. This solution only improves guest's dining experience by making it easier for them to interact with service staff, but this solution does not handle any other part such as the kitchen restaurant, reservations outside the restaurant, and does not cover the part of the context.
- Grub Burger Bar [32], which operates restaurants in numerous US cities, has been installing a tag-based system with each new franchise it opens. This solution also improves the quality of service inside the restaurant dining room by reducing the waiting time but it does not automate the functionality of the kitchen, does not offer reservations outside the restaurant, and does not cover the part of the context.
- Luihn Food Systems [33], a Yum! Brands franchisee that operates over 75 restaurants uses a Quality Production Management (QPM) application that automates and streamlines food production. The application wirelessly networks each restaurant's cooking appliances and provides real time remote monitoring. Since its introduction, the application has improved labor productivity, increased sales and lowered costs.
- Au Bon Pain [34], a US-based chain with international franchises, has piloted a system of sensors in several of its restaurants that monitors usage of kitchen appliances such as ovens, toasters, walk-in freezers and heating and cooling equipment. Data is always accessible through mobile apps or a web interface.
- Powerhouse Dynamics [35] created new SiteSage Smart Kitchen module. This module enables wireless connection of ovens to the cloud-based platform, so that commercial kitchens can continuously and remotely monitor cooking temperatures to ensure product quality. The module also monitors refrigeration equipment and automates food safety reporting.

Luihn Food Systems, Bon Pain, Powerhouse Dynamics, are all solutions that improve the kitchen functionality by monitoring the usage of appliances and kitchen equipment, which will save time and money and automate food production. However, all these solutions do not improve the services inside the restaurant dining room, do not allow reservations outside the restaurant, and do not cover the part of the context.

- The Robot Restaurant: Twenty robots work at the Robot Restaurant in Harbin China, they can deliver food to tables, cook, usher and entertain diners. The restaurant opened in June of 2012, the robots have 10 different facial expressions (used to welcome, serve, and sing to diners), cook dumplings and noodles, seat guests, deliver food to the table, and there's even a singing robot to entertain diners [36].
- Tokyo smart restaurant: Is a popular restaurant in Tokyo that don't need waiters. Guests place their orders via tablet from their table and food passes by each table on a conveyor belt. Payment is also automated. Technology monitors how many people are sat and what they're eating. This information tells kitchen staff which dishes to prepare and how many new dishes they should add to the conveyor [36].

Both solution The Robot Restaurant and Tokyo Smart Restaurant improve guest's dining experience and kitchen functionality but do not cover reservations outside the restaurant, the recommendation system or the context.

Table 1 shows a comparison between *MyRestaurant* and the solutions presented previously. The criteria used in solutions comparison are: Context Management (CM), Recommendation System (RS), Connected Kitchen (CK), Dinning Experience (DE), Online Reservation (OR).

TABLE 1. SMART RESTAURANT SOLUTIONS

Criteria / Solution	CM	RS	CK	DE	OR
Strobilanthes	-	-	-	+	-
Grub Burger Bar	-	-	-	+	-
Luihn Food Systems	-	-	+	-	-
Bon Pain	-	-	+	-	-
Powerhouse Dynamics	-	-	+	-	-
Robot Restaurant	-	-	+	+	-
Tokyo Smart Restaurant	-	-	+	+	-
MyRestaurant	+	+	+	+	+

6. Conclusion and Perspectives

This solution presents a system based on the paradigm of the internet of things in order to create a connected restaurant. We considered the context management aspect by offering a dynamic adaptation of services; an adaptation to the context supported by the characteristic of the services execution and the characteristic of the presentation. We developed a prototype for our system *MyRestaurant*. This solution helps to increase customer satisfaction in terms of waiting time (the customer places his order directly on the connected table), the dishes are served hot (once the dish is ready, the waiter is notified on his application to take the order). Reducing waiting time to place an order and to receive it helps with reducing the occupancy time of the restaurant room which means the restaurant can receive more customers.

In this Paper, we choose the CC/PP format as a context model and we proposed a content-based recommendation module that is based on the use of a similarity measure. We adapted the Jaccard measure to our case scenario. The recommendation module is integrated in the connected table, it keeps track of the client order history to suggest or recommend to him similar dishes for his next orders.

As future work, we intend to design a communication system to enable the communication between the incompatible objects of the network. This system relies on implementing gateways between these objects to manage communication. A more sophisticated loyalty and recommendation system will improve this solution which will help maintain customers interests and meet their requirements, also meet the needs of restaurateurs.

Also, we intend to improve more the recommendation system in order to consider the customer's health status: for example, if he is diabetic then the system adapt the recipe to his needs (use an adapted sugar for diabetics or no sugar), or if the customer eats law fats or no salt...etc.

Finally, we plan to evaluate the performances of the system by measuring time optimization and client satisfaction.

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