Development and Test of a New Concept of Interactive Front Counter Designed to Enhance User Experience

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Keywords: Human-Machine Interface, Interactive Front Counter, Gestural Interface, Tactile Wood, Robotic Operating System, Modular Architecture, Tourism Application, User Experience.

Abstract: The front counter is the physical contact point between customers and service providers. By embedding technology in this piece of furniture in an aesthetic and an ergonomic design, surprising forms of interaction can be achieved. The combination of smart communicating devices and wood as the main material for integrated interfaces creates a unique atmosphere that can enhance user experience. This paper presents the design of an innovative, modular, low cost, interactive, smart front counter. This system provides customers with personalized information according to their profile, needs and tastes. At the same time, service and/or product providers can collect and visualize data concerning customers in real-time. With the contribution of professionals in woodcraft manufacturing and industrial design, a prototype of interactive front counter integrating a tactile wooden board, a gestural interface, and a wood screen has been developed and tested in the enotourism context with a group of 75 people. The counter was positively evaluated. Results show that the interaction with such a system can provide an attractive and valuable support for both customers and service providers.

1 INTRODUCTION

A front counter is a particular piece of furniture. It materializes the very first contact point between service and/or product providers and customers in most of the touristic, commercial, industrial, administrative, public, or private entities. In front of the counter, customers do not always have a precise idea of what they are looking for: some would like to be guided and advised by experts, without commercial biases, others may be reticent and shy and would prefer not to reveal their needs and constraints. Behind the counter, there are service and/or product providers willing to improve their position and visibility: the range of offerings becomes wider and wider, customization is the main trend and they have to survive in a world full of competitors. The front counter is therefore the physical interface between these two worlds and it can be pictured as the playfield of a "quest".

In addition, the spread of internet technology changed the way customers look for information: the challenge for them is to find the product or the service that fits the best to their needs, personality, or budget (Bell & Patterson, 2011). Therefore, the challenge for providers is to be able to assist customers in their requests and needs, drawing attention to the products and services they can provide. This "journey", in terms of customer's emotional involvement, plays an equally important role than the goal itself. Time has also become an important gauge. In a world where connections are here and now, waiting is more and more unacceptable: the positive perception of waiting time represents another critical issue for providers (Liang, 2017).

In this context, user experience plays a key role. User experience is defined by ISO (ISO, 2019) as the "*user's perceptions and responses that result from the use and/or anticipated use of a system, product or service*". Included in the definition are user's emotions, preferences, perceptions, and comforts "*that occur before, during, and after use*". The interactive behavior and the functionalities offered by a system can have a strong impact on user experience, a concept that remains dynamic, context-dependent, and subjective (Law, 2009). Technologies offer opportunities to a wide range of people to undertake various activities in different contexts. The goal of the activity directly helps to establish the requirements for technology design and integration, but the design can influence the way activities are performed,

D'Attanasio, S. and Sotiropoulos, T.
Development and Test of a New Concept of Interactive Front Counter Designed to Enhance User Experience.
DOI: 10.5220/0010142001620169
In *Proceedings of the 4th International Conference on Computer-Human Interaction Research and Applications (CHIRA 2020)*, pages 162-169
ISBN: 978-989-758-480-0

changing sometimes the nature of the activity itself (like smartphones) (Benyon, 2013). Then looking for a service or a product can become a more meaningful operation, involving learning.

The system we describe in this paper is the prototype of a new concept of interactive front counter aiming to enhance user experience for customers and to supply the provider with a useful tool to improve their service. The concept has been introduced in a previous work (D'Attanasio at al., 2019) and a state of the art of interactive and modular systems based on smart furniture has been presented.

A more recent work derived from the EU-funded research project REACH (Rongbo et al., 2020) proposes the concept of a modular interactive furniture system for elderly people. The main idea is to integrate stand-alone smart furniture into a larger framework, providing connection, and global data analysis. In this application, sensing aims to achieve prevention, to facilitate intervention system (sensing-monitoring-intervention) and to encourage physical and mental activities. The system is an intelligent interface among elderly and caregivers.

The reason we are interested in smart furniture is that our system is composed of physical interactive communicating modules. Krejcar et al. (2019) define smart furniture as "*designed, networked furniture that is equipped with an intelligent system or is controller operated with the user's data [...] Smart furniture needs to have the ability to communicate and anticipate user's needs using a plurality of sensors and actuators inside the user's environment, resulting in user-adapted furniture*". Frischer et al. (2020) point out the need for smart furniture to be flexible, low-cost, easy to buy, and install. These definitions have driven our research.

The state of the art has greatly inspired our design, but we could not find a work addressing all the aspects as our system does. First of all, our concept focuses on the front counter as a physical entity, as a piece of furniture, whose aesthetics and ergonomics are important. Our system must be nice to see and practical to use and, to reinforce this aspect, design professionals actively contributed to the work. The system must also be scalable and modular to adapt to different physical layouts and configurations, according to the provider's needs. Moreover, the concepts must flexible enough to be adaptable to various contents and applications, anywhere, and in any situation where a front counter is needed. These constraints have a huge impact on our technical choices, as it will be explained later. The integration of existing multimodal interfaces contributes to achieving a unique experience for the customer and an affordable product for the provider.

To optimize integration, the modules composing the system are designed from scratch considering material selection and fabrication and assembly procedures. This step is performed in close collaboration with a professional woodworker specialized in counter manufacturing. In our previous work, we already pointed out as wood-based interior products improve customer touch experience (Bhatta et al., 2017) and have positive physiological effects (Ikei et al., 2016). In more recent studies, Burnard and Kutnar (2019) present a test experiment to validate the hypothesis that the use of wood as the material for furniture, i.e. bringing nature indoor, reduces stress response and improves stress recovery.

In the next paragraph, we will briefly recall the basic concept of the interactive front counter, detailed in D'Attanasio et al. (2019). We will then describe the prototype, with a major focus on the developed interfaces, and on the system architecture. We will also present and discuss the results of a test performed on 75 people interacting with the system.

2 THE CONCEPT

Our concept of the interactive counter is illustrated in Figure 1. It consists of an interaction area. Within the area, the customer position and trajectory can be tracked and several modules can be found. Their number depends on the customer flow and on the services to provide. Each module, which can be duplicated if necessary, provides a specific service. Modules are independent but nevertheless connected pieces of furniture. They are parts of the same interactive front counter system.

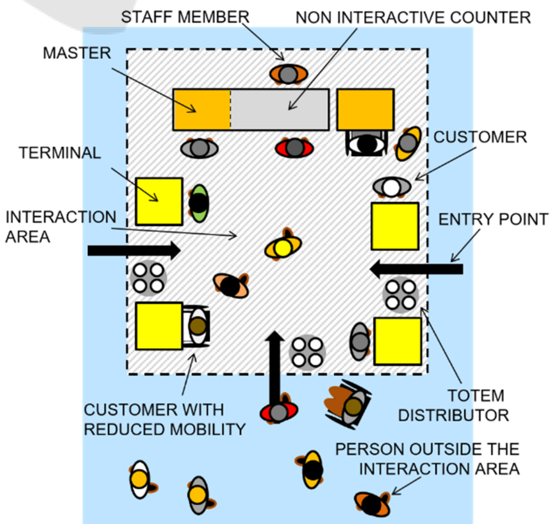

Figure 1: A schematic description of the concept.

This system includes two types of modules: the master and the terminal. The master is the module that the customer has to visit first. It allows the setting of preferences by means of a questionnaire. Each customer profile is associated with an agent, a unique physical and digital entity. The agent is a physical badge, called totem, and that has to be collected by the customer from special containers when entering the interactive area. Within the software control system, agents are digital identification variables storing customer's profiles.

Services are provided by terminals and are personalized for customers having visited the master. Because the context of the project is the tourism field, examples of service are the discovery of local products according to the customer's taste, or the discovery of cultural activities and events. All modules are interactive, have a similar console-shape, and are accessible to disabled users. In the next section, we will describe the prototype that we have developed.

3 MATERIALS AND METHODS

The current prototype is composed of two modules, a master and a terminal, described in detail in the following sections.

Figure 2: The design of the master is shown on the left. The picture of the prototype is shown on the right.

3.1 The Master

The master is depicted in Figures 2. The module consists of a "wood screen" of about 65cm width and 40cm height, where images are projected from behind as shown in the schematic view of Figure 3.

The transparency of wood is obtained by a board of PMMA (polymethyl methacrylate) covered by a 0,6mm wood veneer layer. The user can interact with the screen using a gestural interface. Two linear arrays of 60 programming RGB LEDs (WS2812B) at the base of the totem pedestal and on the top of the screen provide visual feedback.

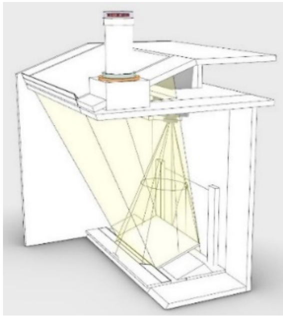

Figure 3: The schematic view of the projection area inside the master.

3.1.1 Gestural Interface

Several works demonstrate the successful implementation of gestural interfaces. The hand gesture is considered as a natural method of interaction (Ibraheem & Khan, 2012). To simplify the interaction and to lower the cost, we developed a gestural interface mounted at the bottom of the screen made of an array of distance sensors. We also wanted to achieve a contactless interaction, as it is nowadays critical to avoid virus transmission. The idea is to detect only three gestures: selection, shift right, and shift left. Because we wanted to make use of well-known gestures like the one used for smartphone interaction, we choose the sweep right and left to encode the corresponding shift right and left. The selection is performed by leaving the hand on the array several seconds. Each gesture has visual feedback given by a particular LED animation, that indicates the recognition of the gesture by the system. These gestures allow navigation through the questionnaire that is projected on the screen.

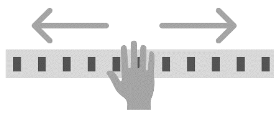

Figure 4: The sensor array of the gestural interface.

On the prototype, we integrated IR distance sensors because this technology can be covered by a transparent or colored layer of common Plexiglas without altering the measurement. This aspect is fundamental to assure the robustness of the system for maintenance (in particular dust), and for aesthetical and easy integration in the module. 11 sensors have been placed at 5cm of distance to cover 50cm of length as showed in Figure 4. It is possible to divide the array into "areas" to be able with one array to select items of a multiple-choice questionnaire and to reserve an area for the “back button”.

3.2 The Terminal

The terminal is depicted in Figures 5. The service proposed by this module is the discovery of the production of wine in a certain region. The module consists of a tactile wooden board (birch has been used) representing the region of Occitanie in the South-West of France. The map of the region has been engraved using a laser printer. As illustrated in Figure 6, four areas have been identified, as main wine production lands. When touching one of the areas, visual feedback is given by an array of 50 LEDs on the top of the board and a connected bottle, that can be grasped by the customer, allows the visualization of the different wines produced in that area.

Figure 5: The design of the terminal is shown on the left. The picture of the prototype is shown on the right.

Another array of LEDs is positioned at the base of the totem pedestal, as for the master. The bottle showed in Figure 7, is made of the neck of a real glass bottle and a body manufactured by a 3D printer using black ABS material.

A Samsung A10 smartphone is embedded in the body. An application on the smartphone allows navigation through the information available by sweeping and touching. In this way, for each type of wine, it is possible to obtain information about the grape variety, best years of production, flavor, dishes, and cheese to taste with. The application interacts in real-time with the tactile areas.

3.2.1 Tactile Wood

Capacitive sensing technology has been widely and successfully used for contact and even gesture detection. A variety of certified devices is available on the market (Wang, 2014; Davison, 2013). We used the CAP1188 for our prototype because this sensor has built-in Python and C libraries allowing easy integration and software sensor settings. Depending on the surface of the area, different sensor sensitivities and thresholds must be set. Sensitive areas are painted with a conductive paint ELECTRIC PAINT™ from BARE Conductive. The board of birch wood has a thickness of 2cm and is simply placed on the board where electrodes are painted.

Figure 6: The engraved map is showed on the left; on the right, the four interactive areas are highlighted in grey.

Figure 7: The connected final bottle is on the left. The CAD design of the body is shown in the middle. The bottle switches on during interaction (on the right).

4 THE TOTEM

The totem is depicted in Figure 8. This object is the physical representation of the agent, the entity that is assigned to a customer during his/her visit at the interactive front counter. This version of the totem has deliberately quite big dimensions (the cylinder shape has a diameter of about 10cm) because it materializes the will of the customer to be involved in the experience.

Two technologies have been integrated into two versions of the totem. The first one is active RFID (we implemented Pozyx solution). An emitter is positioned inside each totem and continuously emits

RF waves, detected by four fixed external beacons. Therefore, it has to be alimented by a battery. The precision of the system is about 10cm and depends on the position of the beacons (relative distance and height). As the position of the totem can be tracked in real-time, it is possible to automatically switch modules on when the customer approaches them. The downside is that the distance of the modules from the beacons has to be measured and recorded into the system.

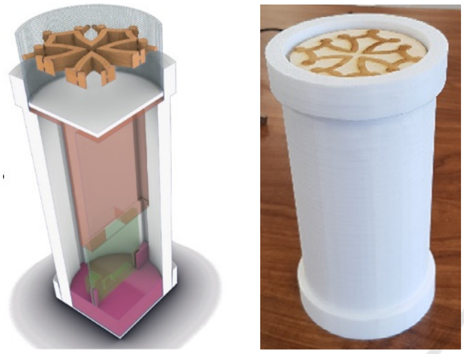

Figure 8: The CAD design of the totem is shown on the left. The emitter and the battery are positioned on the bottom. A picture of the totem, made by a 3D printer, is visible on the right. On the top, you can see the cross of the Occitanie region engraved on a wooden board.

As a consequence, modification in the layout of the counter (position of the modules) cannot be done without measuring and recording the distance again. The emitter battery must also be recharged and inductive chargers are mounted under each module pedestal as well as in the containers.

The second technology is passive RFID (we implemented MIFARE RC-522 reader). This technology is widely used today to label almost any product. The emitter main component is an antenna, called tag, that can fit in a small and cheap plastic badge or on a sticker. The tag must be at a few centimeters of distance from the reader to be detected. The advantage with respect to active RFID, besides the price, is that there is no need for a battery and the design of a totem that customers can keep (and eventually re-use) is possible. To switch modules on, the totem integrating the tag must be placed on the pedestal.

5 SYSTEM INTEGRATION

Our front counter integrates a processing unit in each module and a processing external unit acting as the main controller of the whole system. For security reasons and to obtain robust behavior, units are connected using a local wireless Ethernet-based network (Wi-Fi). The main controller can be then connected to the Internet for data management (storage, analysis, and access). That means that the front counter has a distributed architecture. Besides, modules can be added, reconfigured or updated, in terms of integration of new hardware (sensors and/or actuators) as well as in terms of control algorithms. That means that the front counter has a modular architecture. Modules are also stand-alone systems, working in parallel and at the same time as other modules. Real-time interaction with customers and providers and real-time system responses are also needed.

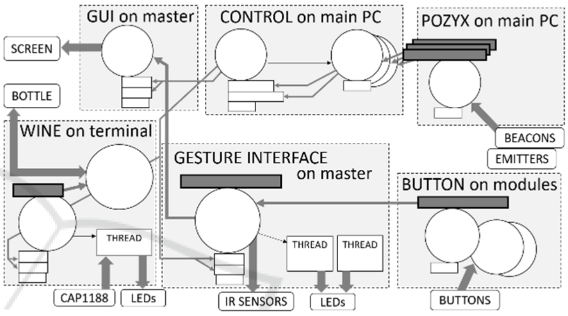

Figure 9: Architecture of the ROS control system. Circles are nodes, grey boxes are topics, white boxes are services or threads (when indicated).

These system requirements are the reasons for the choice of ROS Robotic Operating System as the middleware for the software architecture. Originally designed and developed for robots, ROS is meant to provide a powerful and flexible framework for complex, modular, distributed, parallel, and real-time systems. The ROS architecture of the front counter is shown in Figure 9. ROS nodes, contained into packages, are programs, coded either in Python or C++, that execute simultaneously. They exchange data through topics: when a message is published in a topic, the node subscribing to that topic is immediately warned and the corresponding call-back is executed (a call-back is the function associated with a topic). For example, the node managing the gestural interface publishes in real-time the detected gestures (commands). The node GUI (graphical user interface), which subscribed to the corresponding topic, reacts to commands updating the projected images. If the technology of the gestural interface is modified and the gestural interface node is updated, the only constraint for the node is to produce the same type of message. The stop or the start of a node does not affect the other nodes. Nodes also provide services that can be directly called by other nodes. For example, we used services to start and stop (switch on/off) modules when a new totem, with a new ID, (identification number) is detected. The main principle of the developed architecture is that the totem ID is responsible of the generation of a new node agent. This node, containing the user profile, subscribes to services provided by modules and generates the switching on and off of the modules when the user approaches them with the totem.

6 SCENARIO AND TEST SETUP

The prototype of the interactive front counter has been tested with a group of people. After the presentation of an early version of the prototype in December 2019 at a public event about technology in tourism, we observed that our concept gathered a lot of interest, in particular by the community of enotourism (or wine tourism). That is the reason why for the test we developed a scenario about wine and spirits. The Covid-19 pandemic forced us to organize the test at our University instead of a wine cellar. The system was installed in our laboratory and we invited students and colleagues (not aware of the project) to test it. The setup is showed in Figure 10.

Figure 10: Picture of the test setup.

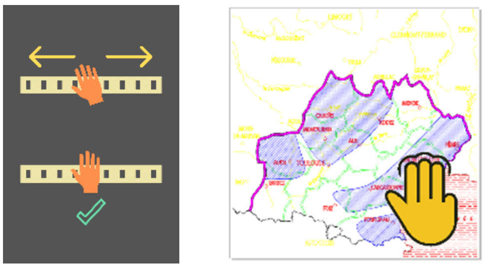

Figure 11: Signs installed on the master (left image) and on the terminal (right image).

The following scenario was presented: "you go to a wine cellar to buy a bottle of wine, the cellar-man is not available and a sign invites you to grab a totem and to head for the master". After which people were left alone to interact with the modules, and the only explanation they received were the signs showed in Figure 11. The master proposed 3 levels of questions, offering multiple answers. The first level was the language spoken, English, French, or Spanish (see Figure 12). According to the language selected, the rest of the interaction (on the master and the terminal) respected the choice. Then 2 other levels of questions were proposed (inspired by the website of the store "Esprit Dégustation", that can be found at https://www.esprit-degustation.fr/).

On the terminal, area selection and wine visualization on the bottle were possible, as explained in the previous section.

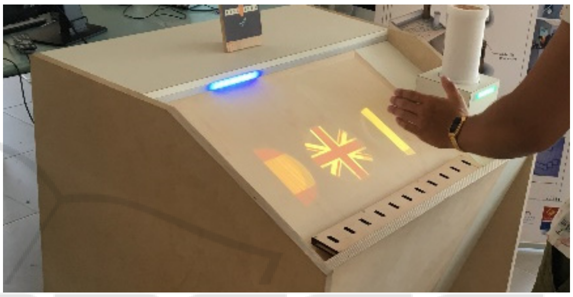

Figure 12: Example of language selection. In this configuration, to select the Spanish language, the user has to perform a swipe right gesture, as only the image in the center is selectable.

After a first interaction, an explanation of the mode of interaction was given and a second interaction was performed. All participants were asked to fill a 5-point scale questionnaire (Law et al., 2009) and to answer some questions. The graduation of the scale was: "--", "-", "o", "+", "++". The reason of the choice of this graduation (instead of 1 to 5 graduation) is that it is widely used for activities evaluation at our University and people are used to it. The evaluated items were the following:

1. Evaluate intuitiveness of the master (time spent to understand alone the working principle);
2. Evaluate intuitiveness of the terminal;
3. Evaluate ease of use after explanation;
4. Do you feel that the system can provide decisional aid?
5. Do you prefer to wait for the cellar-man and look around or to use the system in the meanwhile?
6. Evaluate the aesthetic of the modules (shape, color, material);
7. Evaluate the ergonomics of the modules (dimensions, ergonomics of gestures);

8. Evaluate the totem (shape, dimensions, aesthetic);
9. Would you like to receive this type of service in your favorite wine cellar?

A word to express the feeling after the experience was asked. The following words were proposed to answer to the first question: difficult/troublesome, unpleasant, boring, amusing, enjoyable, surprising.

We didn't base the questionnaire on standard tools, as the UEQ questionnaire proposed by Schrepp et al. (2017), because we wanted to focus on specific features of our system during this preliminary test.

7 RESULTS

75 people tested the system during one day, 36% of women, 64% of men. 20% of them had no scientific background and 20% of them had never visited a wine cellar. All of them are users of a personal computer in their daily life. The following table shows the age distribution.

Table 1: Age distribution of people: the first row indicates the age span, the second row indicates the percentage of people corresponding to a span.

<25	25-35	35-45	45-55	>55
53%	9%	20%	11%	7%

102 words were globally given, as some people gave two words. The most recurrent word was "amusing" with 42% of occurrences, followed by "surprising" (33%) and "enjoyable" (25%). People were also encouraged to comment the overall experience. The graphic of Figure 13 shows the overall results concerning the 9 items of the questionnaire described above.

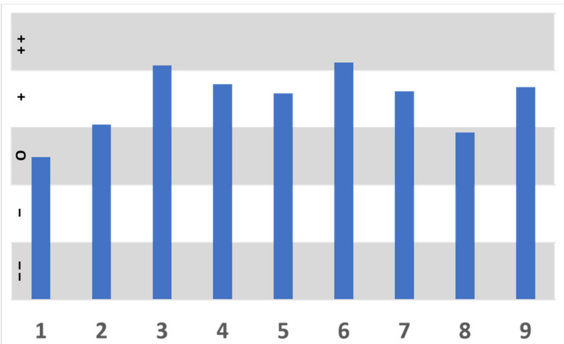

Figure 13: Results of the questionnaire. Each column of the graphic is the arithmetic mean of all evaluations of the item, obtained after the conversion to a 1-5 numerical graduation (1 corresponds to "--" and 5 to "++").

8 DISCUSSION

The first evaluation of the interactive front desk is very encouraging. Submitted to a public of 75 people discovering the system for the first time, most of the items evaluated are in the positive range. In addition, the user's comments provided a feedback difficult to analyze but very interesting for a qualitative evaluation of our system. The lowest evaluated item (in the "o" range) is the intuitiveness of the gestural interface. With the sign as the unique explanation, people had quite often a hard time to understand the working principle. Many of them tried to touch the wooden screen and did not notice at all the array of sensors on the bottom of the module. The selection gesture must be improved because unintentional selection is often triggered.

The interaction on the terminal is considered more intuitive. The problem here is the understanding of the fact that the bottle interacts with the map and that it can be grasped. On the other hand, after explanation, everybody found the interaction very easy to perform (item 3 is one of the best evaluated). The connected bottle was well appreciated: the fact of already having in the hand the object that the customer is looking for has been considered a clever choice.

Another item with medium evaluation is the totem. This medium evaluation is the result of a mean over a very spread result (from hate to love!). Almost everybody understood alone that the totem had to be positioned on the pedestal and the majority of users understood that the connection between them and the system was materialized by this object. The fact itself of carrying an object to be recognized by the system was well accepted and even preferred to identification by a camera (facial recognition was proposed as an alternative), considered too "invasive" even if performed under laws on privacy. The idea of using a bottle-shaped totem was suggested by several persons.

Finally, the aesthetic of the modules was very well evaluated because "wood provides a feeling of authenticity".

9 CONCLUSIONS AND FUTURE WORK

The paper presented the design of an innovative interactive front counter, that consists of an interactive area where communicating aesthetic and ergonomic wood modules are placed. Modules integrate different types and technologies of human-machine interface. Wood has been used as the main material, because of its authenticity. A prototype integrating two modules, a master and a terminal, has been developed and tested with 75 people, receiving a very positive feedback. Tests also contributed to identify some leads for future work. First of all, interfaces must be improved. The gestural interface must be improved: formal methods to select the appropriate gestures and to validate the design have to be implemented, as the one proposed by Vatavu (2019). A "back button" must be implemented. A work on the tactile wood has already begun to design a matrix-like tactile board. The idea is to obtain a universal board, easily configurable and programmable, for any application. Moreover, in the context of Covid-19 pandemic, alternative contactless methods for selection and/or automatic integrated sanitizing devices have to be studied. From the aesthetic point of view, customization of modules and of the totem according to the environment and the application is also demanded. Finally, a second version of the prototype with a third or even a fourth module (for example a pedagogical module explaining the steps of winemaking) has to be developed, completed with real contents, and tested in a real environment.

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