# A fresh recipe for designers: HCI approach to explore the nexus between design techniques and formal methods in software development

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*Abstract*—Emerging companies involved in design and implementation of innovative products demand multidisciplinary teams to be competitive in the market. This need mainly exposes designers to extend their knowledge not only in User Interface elements of the design process but also in software methodologies to cover the lack of resources and expertise in start-ups. It raises the question of how designers can line up HCI techniques with best practices in software development while preserving usability and easy-to-use principles. To explore this gap, this paper proposes an approach which combines existing technology and methods by studying the nexus between HCI prototyping and software engineering. The approach is applied into a case study in the design of a virtual shop harmonizing the use of storyboards and the spiral. A comprehensive analysis is performed by using a Technology acceptance model (TAM) regarding with two variables:usability and easy-to-use. The present finding underlines the positive integration of HCI techniques and formal methods without compromising user satisfaction with a potential benefit for small companies in a formation stage.

*Index Terms*—human computer interaction, software methodologies, virtual shop, shopping on-line, information systems

## I. INTRODUCTION

To date, entrepreneurial ventures as design-center enterprises aim to a rapid prototyping of products in a scalable and sustainable approach [13] where during their formation stage there is no a correct skills balance in the workforce[4]. This fuzzy beginning leads to an ineffable pressure on designers to extend their knowledge to cover other software development areas to deliver quality products such as requirement analysis, implementation, testing and evaluation.

Particularly, designers are generally trained in user interface elements such as ergonomics, interaction design, multimedia, content [3] as well as usability principles such as learnability, operability and attractiveness which may causes a lack of experience in software development methodologies. Furthermore, current designing tools might not provide enough support to designers to have a complete understanding of the software process. In this context, one may be interested to know the feasibility of integration between Human-Computer Interaction (HCI) techniques and software methodologies so that designers can learn from best software practices while preserving HCI principles.

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Our contribution is a method to improve existing approaches by unifying a HCI process (storyboards) and a software development model (spiral) to enrich the capabilities of designers during the design process. The method is applied in the designing of a virtual shop and its evaluation is reported by using user testing reports which is also compared with the Technology Acceptance Model [7].The finding is positioned by Action Research (AR) as high application domain and low solution maturity, in which the results of studying the integration in HCI and software development aiming to solve an existing issue in a particular social setting[1].Overall, the evidence suggests that a design technique can be aligned with a software method; notably, when both are inherent iterative processes. Furthermore, the method's application result in a product with valuable degrees of usability and easy-to-use features. A priceless rewarding for designers and end-users.

The reminder of the paper starts by explaining the coverage of HCI and software development, related work, approach in action, prototype description and evaluation.

## II. BACKGROUND IN HCI AND SOFTWARE DEVELOPMENT

HCI can be defined as the process of analysis and design of interfaces between humans and computers [9], in others words the analysis and design of users interfaces. The process of design interfaces with HCI can be done iteratively with prototypes [6]. The use of prototypes allows to test early versions of systems with real users. A technique of prototyping are storyboards. A storyboard is a graphical depiction of the outward appearance of the intended system, without any accompanying system functionality. Although a storyboards technique provides more flexibility to the designer to focus on users tasks and UI graphical elements, there is a formal software methodology to complement the design process of prototypes such as rapid prototyping and the spiral model of software development.

A spiral model of software development involves a process expressed in a four-cycle plan [2]: define objectives, alternatives and constrains; evaluate alternatives, identify and resolve risks; develop and verify next-level product; and finally plan next product's phases. Hence, if a HCI process with a software model are defined in conjoint as process' techniques, it may be applied to improve the process of designing a virtual shopping interface.
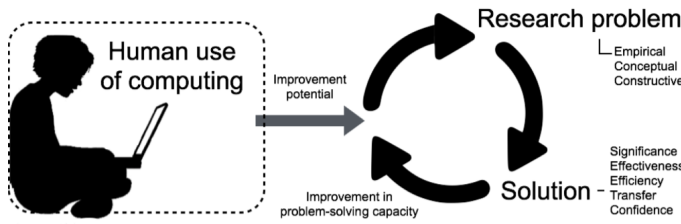
Fig. 1: HCI research as problem-solving



Fig. 2: Storyboard process

The role of HCI design has been explained by introducing the term "design" meant usability engineering as the the process of modeling users and systems and specifying system behavior such that it fitted the users tasks, was efficient, easy to use and easy to learn. [21]. During the design process, designers work with software engineers where this synergy leads to a set of useful skills such as navigation, typography, topography, visual hierarchy, color which is underlined as a creative design [23]. A process which is also different from an engineering approach. It is mainly because in a creative design, designers make a continuous process to fit user tasks by to looking and questioning at present the problematic while developers focus more on software specifications[8].

In terms of research methods and the ability to solve problems in human computing, HCI can be characterized as a problem-solving field (Fig. 1) [10, p. 5]. It involves "1) subject of inquiry, human use of computing; 2) research problems; 3) types of problem-solving capacity pursued; and 4) achievements in improving problem-solving capacity".

The designer invest time in understand the problematic as well as human and computer interaction. Later, this understanding causes la definition of the research problem divided in an Empirical(unknown phenomena), Conceptual(implausibility) and Constructive approach(no known solution).In this point, the designer can decide what kind of research problem is facing to provide a better solution; this solution defines heuristics aspects for contributing and assessing to the capacity's evolution in problem-solving such as significance, effectiveness, efficiency, transfer and confidence [10, p. 4].

Similarly, the concept of problem-solving in HCI can also be seen in Information systems as a research method known as Action Research (AR). It covers the result of scientific knowledge trough the study of the effects of an action taken which aims to solve an existing issue in a specific social environment [7].

Once, the role of HCI in research has been explored, it is necessary to focus on a HCI technique to solve human-computer issues. The storyboards' technique is described as a logical process which aims to describe the interaction between the user and the system over the time through the use of graphical elements - often sketches, and textual narrative- to reduce the cost of designing in a cyclical process to achieve user goals [6]. The storyboard process includes a two iterative process; make a design and then test and collect data (Fig. 1).

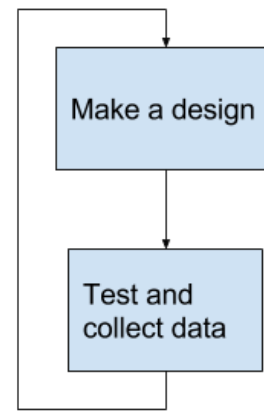First, the designer makes a design regarding with the user needs. Second, the designer evaluates the design, testing it with the user to understand the constrains and future improvements. All information is collecting by using formal interviews where the user expresses his level of prototype acceptance. Finally, the designer and user repeats the same process until the prototype meets user requirements.

This technique can be seen as an iterative helpful tool for rapid prototyping (RP) in the design process where many iterations are needed until the solution meets the user needs. Consequently, this concept can be extended by using the Information Systems (IS) prototyping method in Action research (AR) that includes not only the prototype design but also its evaluation in a cyclical process [7] (Fig. 2 and 3).

The mentioned process includes the following steps:

1) Diagnosing. To identify the main issues.
2) Action planning. To specify actions to solve or improve.
3) Action taking. To implement the action planned by an active intervention in the participating organizations.
4) Evaluating. To compile the evaluation of the results by study subjects and researchers.
5) Specifying learning. To identify new knowledge.

On the other hand, software engineering provides a cyclical methodology based on prototypes which is called the spiral model. A spiral model includes four steps: determine objectives, identify risks, development and testing, and finally plan the next iteration [2, p. 2].

Boehm states that the usage of this model is possible with one table per iteration with includes objectives, constraints, alternatives, risks, risk resolution, risk resolution results, plan for next phase and commitment. For instance, table 1 shows an example of the first iteration of this model for a TRW Software Productivity System.
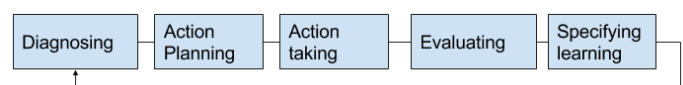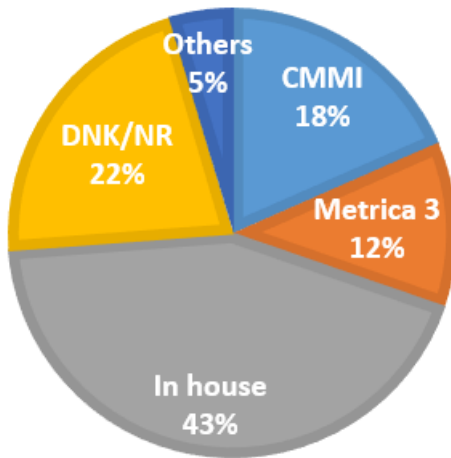


Fig. 3: IS prototyping model

Fig. 4: Main software methodologies

Designers need to know how users perceive systems or prototypes in order to understand how easy or difficult is the use of one particular technology. Many different models have been introduced in the research field of Information systems to evaluate the level of technology acceptance. In fact, the technology acceptance model (TAM) by Davis, Venkatesh [5] which aims to measure the degree of perceived usefulness and ease-of-use that a user has when using or interacting with some particular technology. As it is shown in Fig. 6, there are many developed models such as TAM2 [17], TAM3 [16], the Unified Theory of Acceptance and Use of Technology (UTAUT) [18], and UTAUT2 [19].

Every variation of the TAM model implies itself the user's behavioral intention against any technology. In detail, to understand the value of user behavior in TAM, two variables (usefulness and easy-of-use) are combined to define the user attitude which leads to the determination of the behaviors' degree. Then, this degree can infer the actual use of the technology. To extend it, a more precise forces' explanation which influence the perceived value of usefulness was given in TAM2; whereas, TAM3 focus on the easy-to-use perception. Similarly, an understanding of how the variables change over time was introduced in UTAUT, and its improvement UTAUT2.

## III. RELATED WORK

This sections reviews the HCI literature to understand historical, highlights and proposed solutions and more specifically, interactive systems regarding with HCI design methodologies and virtual shop designs.

The figure 4 evidences that enterprises prefer developing their own methodologies (in house) [12], mainly because high complexity and previous know-how for adopting the technology as luxury items that will now allow small companies to be competitive.

A well-known technology, UML is found with less than 1 per cent. Despite UML is recognized as a standard unified modeling language, it has been criticized for a lack of

notations and inconsistencies in semantic which impacts the learning curve for designers[15]. Even more, this technology might be a straitjacket for standalone enterprises because a rigid structure will rarely promote creativity and innovation being a vital element for small companies. Designers can not also be aware of testing and technology adoption of final products by end-users unless a formal evaluation method is included in UML.

Regarding with virtual shop designs, there have been some attempts to design a virtual shopping system such as the Design and Implementation of a Collaborative Virtual Shopping System. It considers a multi-agent support for collaboration activities including simulation and interaction processes to covers a more realistic shopping experience [22]. Furthermore, it was developed by using VRML systems, intelligent software and network technologies. Similarly, a vCOM and 3D system [14] that allows users to navigate in a virtual e-commerce world while interacting with real time agents. Puglia presented a multi e-commerce solution by the interaction of multiple users participating in a simultaneous virtual shop experience [11]. More closely, HCI has shown some research projects such as the virtual store layout with three layout components free-form, grid, and racetrack [20].

## IV. APPROACH IN ACTION

This sections aims to explore the design overview, market relevance and implementation. Overall, the designer follows the definition or steps of the spiral model seen in previous sections; then, he uses storyboards to create the prototypes and evaluate the design versions with end-users. Consequently, this evaluation will be extended by showing a technology adoption model.

### A. Overview

It was designed a prototype to test the concept of a virtual shop where the customer can interact by using a tablet and QR codes. As it was shown before, a spiral model is used as a software model containing as core component all other techniques such as the HCI storyboard technique (HST) and the TAM (technology acceptance model). The HST is used in every spiral iteration in the designing phase, it means that the designer focus on the UI elements of the interface by designing stories to understand the interaction between the user and the virtual shop. It is expected to reduce the complexity of the designing and the understanding of user behavior in the virtual shop usage. Then, the user tests the prototype and all information is collected by using surveys format, asking specific questions to clarify the requirements for the next prototype design. In the final prototype(release), the leader team will use a TAM approach to measure the level of technology adoption by the user.

It is expected that the HCI principles and techniques used in the designing phase will impact positively the user perception in usability and easy-to-use variables. The virtual shop
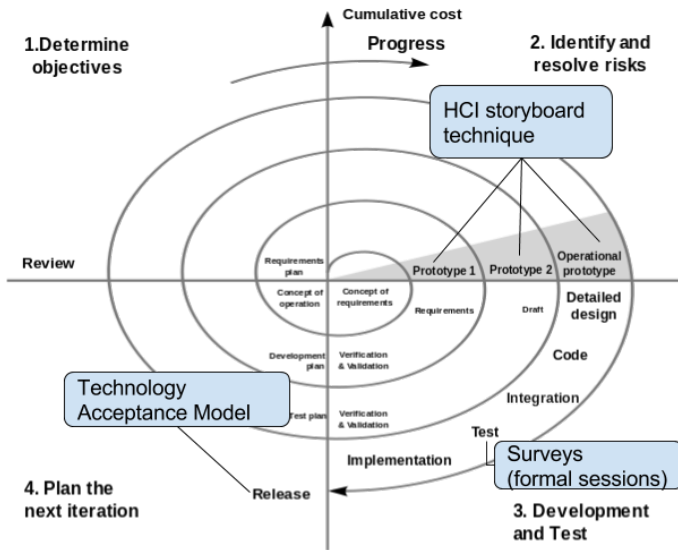
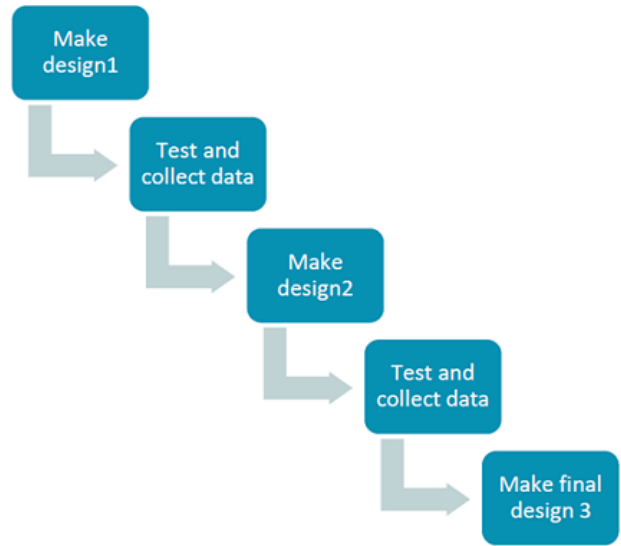Fig. 5: Spiral model in the virtual shop design



Fig. 7: Process to test the prototype

prototype supports these functions: select products, create an account, user login, do the payment and the delivery process. We are using the Woolworth's logo to show a familiar brand to the user.

The prototype focuses on two tasks:

1) Select three products and remove one product
2) Do the Checkout process (delivery info + payment + confirmation)

The prototype has two main interactive tasks:

1) The selection of products by using a products wall
2) The data entry of the purchase details

### B. Market relevance

It is an opportunity to test what big supermarkets in Australia are doing with new interaction methods to buy products. Woolworths has introduced the new virtual shop in 2012 which is working in Sydney. In addition, the demand of buying on-line is increasing in Australia. Customer behaviors are changing so that big supermarkets like Woolworths are making new ways to interact with the client as a Business to Customer model.



Fig. 6: Prototype

### C. Implementation

We made a prototype by using HTML, CSS and MySQL to publish the shop in our domain Based on the two tasks described previously, we followed this prototype plan:

1) Check the tasks requirements
2) Design the html interfaces.
3) Insert the products catalog with the most common products for students.
4) Publish the prototype.

The Fig. 7 shows the process to test the prototype.

The next subsections show the features that every design included which clarifies the main elements per iteration.

#### 1) Design 1:

**Spiral iteration 0**
To illustrate, a comparison table of iterations was made [2].
**Included**

- Select products and do the payment on line by using the tablet.

**Not Included**

- No navegation
- No instructions in the product's wall
- No buttons update & remove
- No prices
- No biometric login by eyes
- No paypal
- No email product description
- No best/last/ products

[2]http://juliangalindo.com/hci/espiralmethod/modeliterations.png

*2) Design 2:*

**Spiral iteration 1**

To illustrate, a comparison table of iterations was made (previously shown).

**Included**

- Select products by using QR codes on the products wall
- navegation
- Instructions in the product's wall
- Buttons update & remove
- Biometric login by eyes
- paypal
- Email product description
- best/last/ products

**Not Included**

- No prices
- No interactive videos about products

*3) Design 3:*
**Spiral iteration 2**

To illustrate, a comparison table of iterations was made (previously shown).

**Included**

- Prices
- Interactive videos about products

*D. Usability and user experience goals*

We focused on how users can interact with a new way of shopping so that we set these goals:

- How do users feel when they select products by scanning QR codes?
- How do users feel when they see products without prices in a WALL of products?
- Do users prefer selecting products by interacting with a tablet?
- Is the checkout process difficult?

Therefore, we set these goals:
**Tablet interaction**

1) Selection of products by interacting with a tablet
2) Selection of products by interacting with a products wall by scanning QR codes.
3) Change the products quantity in the shopping cart by interacting with a tablet
4) Do the checkout process including three steps; (delivery info, payment and confirmation) by interacting with a tablet.

**Products wall**

5) Look for products with and without prices showed in the wall.

6) Look for products with QR codes showed in the wall.

## V. STORYBOARD DESCRIPTION

*A. Stage 1*

In this stage a user wants to scan for a product in order to know about a description, price, or to buy an item. QR codes are printed below each product .

*B. Stage 2*

In this stage a user scanned an item and wants to see many other products. Also, the virtual shop will offer alternative products in order to give other suggestions to the consumer.

*C. Stage 3*

Once a product is scanned, the cart from virtual shop show the quantity, the price of the item selected through QR codes.

*D. Stage 4*

Sometimes, a customer will want to update the cart, for example, to add or remove the quantity of items and then proceed to the checkout .

*E. Stage 5*

The goal of this new type of service is to deliver the product as soon as possible the checkout is completed, so the customer will receive its purchase at home.

## VI. PROTOTYPE DESCRIPTION

*A. How did you make it?*

We use the following technologies:

- **CMS:** osCommerce to create the prototype (template and web pages) as the most suitable tool according to the storyboards and user requirements.
- **QR CODES:** We use an on-line generator tool to create the QR codes.
- **Tablet emulator:** We emulate a tablet access by using Tablet Emulator.
- **Physical device:** We use a tablet with an android system.

*B. Designs*

This section shows the three designs with their respective descriptions for every planned task.
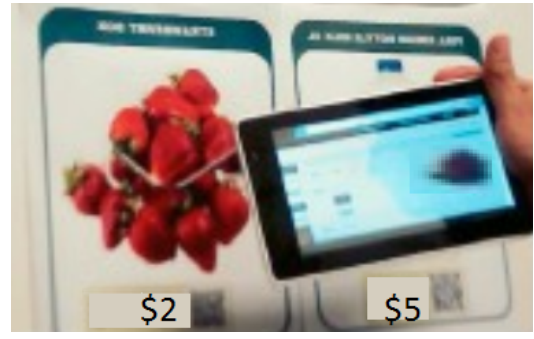
**Design 1**

Fig. 8: QR code inclusion in design 2



Fig. 9: QR code recognition in design 3

Task 1: Select 3 products and remove 1 product by using a tablet.

Steps:

1) Click in dairy products: The system shows all the products with images and the names .
2) Click in the milks image; the system shows more details about the product (price, description, and image) .
3) Click in add to cart button: the product is added to the shopping cart .
4) Selecting of the second product by following the same steps.
5) Selecting of the third product by following the same steps .
6) Deleting the last product.

Task 2: Do the Checkout process (delivery info + payment + confirmation).
Steps:

1) Click in the checkout button .
2) The user needs to login by creating an account and later on input the email and password.
3) The user needs to input information about delivery and payment .
4) After the user click in the continue button, a confirmation page is showed .
5) The user gets a confirmation email .

**Design 2**

This section will show the specific improvements between the design 1 and design 2.

1) The user could choose his products by using QR codes which are printed in a products wall (Fig. 8).
2) There is a navigation menu for each product page
3) The login supports a biometric process (eyes  login)
4) The checkout process supports PayPal
5) Special and popular products are showed in the right block
6) More details were included in the emails confirmation

**Design 3**

This section will show the final improvements between the design 2 and the design 3.

1) A product video was included.
2) Prices were included.
3) The user scans the QR codes by using its tablet (Fig. 9).
4) The selected product is loaded in the tablet automatically.

## VII. FIRST USER TESTING PLAN

### A. Describe the procedure of the user test

The user will be using the QR codes printed below a product; the main purpose is to scan them in order to buy the item or just to know the price of the scanned item. Hence, the satisfaction of the user is going to be analyzed through surveys.

### B. The tasks to be use in the test

- Scanning printed products in the wall.
- Flexibility to buy an item.
- Payments on line.
- Procedure to add/remove items.

### C. Who will be the participants?

There will be volunteers that tested this new innovated way to buy items. Volunteers were people representing a typical user that leaves work and go back home, but they do not have enough time to buy groceries.

### D. How data will be collected and record?

The main from to collect data is through QR codes, and these codes redirect the user to a virtual store that process the orders and record them in each account. In order to measure the user satisfaction, a survey was conducted to see the results according to the activities done when the volunteers bought an item.
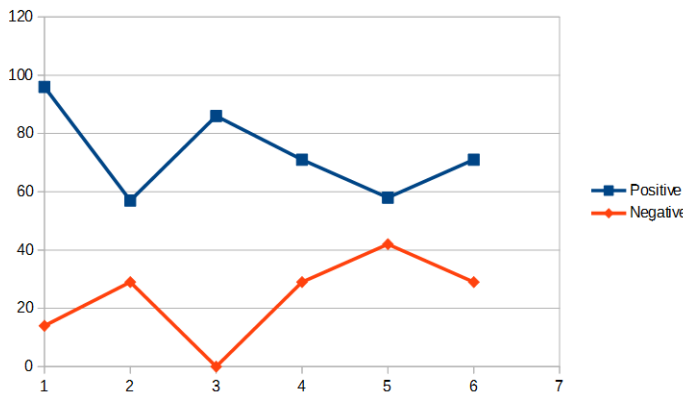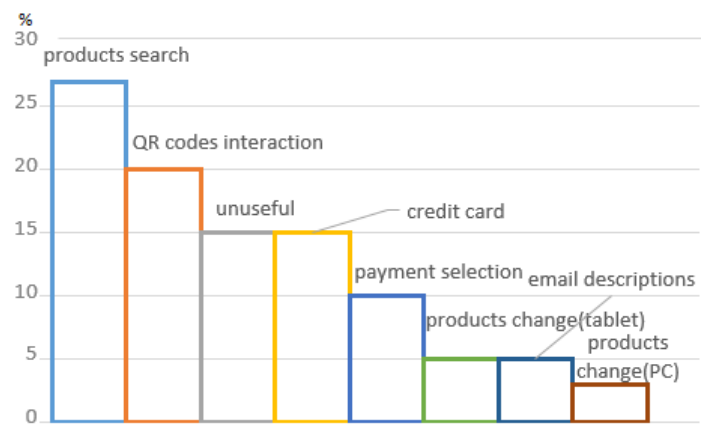
Fig. 10: TAM usability acceptance



Fig. 11: TAM easy-to-use acceptance

*E. Script for participant briefing and demonstrations*

1) A user sees the wall where the products are printed.
2) With his tablet / mobile, scan the QR code and the rice is displayed on the screen.
3) If the user wants to buy, he can click on add to cart.
4) Then the application precedes to checkout and delivery the product.

## VIII. FIRST USER TESTING REPORT

*A. What is the testing environment?*

A testing environment is a setup of software and hardware to perform a product. The environment used for this test was driven in a closed scenario simulating a bus stop station due that many people that do not have enough time to buy groceries this will be an alternative to improve their lifes quality.

*B. Testing results*

With the first survey, we understood that users prefer eye biometric method to login, want a description of the products in their email, want to see best-latest products and receive suggestions of other products in order to have a better combination.

*C. How the results may help to refine the designs*

With the results shown above, the second design will be improved according those users feelings about the procedures taken using QR codes. In addition, some improvements will be included in the second design.

## IX. SECOND USER TESTING PLAN

*A. Describe the procedure of the user test*

Once the user used his device to scan a QR code, now the measures are about the usability of the Virtual Shop. The tests are focused in the procedure of buying an item on the wall, the users satisfaction about the use and comfort of the usability of the process.

*B. The tasks to be use in the test*

- Scanning printed products in the wall.
- Flexibility to buy an item.
- Payments on line.
- Procedure to add/remove items.
- Checkout procedures.

*C. Who will be the participants?*

There will be volunteers tested this new innovated way to buy items. Volunteers were people representing a typical user that leaves work and go back home, but they do not have enough time to buy groceries in a store, so the target of this project are people who wants to buy groceries stuff and receive them at home.

*D. How data will be collected and record?*

The main from to collect data is through QR codes, and these codes redirect the user to a virtual store that process the orders and record them in each account. In order to measure the user satisfaction, a survey was conducted to see the results according to the activities done when the volunteers bought an item.

*E. Script for participant briefing and demonstrations*

1) A user sees the wall where the products are printed.
2) With his tablet / mobile, scan QR code and the rice is displayed on the screen.
3) If the user wants to buy, he can click on add button and add to the cart.
4) Additional security to login in the Virtual Shop is using the eye using biometric algorithms in the application.
5) Then the application precedes to checkout and delivery the product.

## X. Second User testing report

### A. Where is the testing environment taken?

Habitually, bus stations are crowded most part of the day-time, these tests were conducted in a similar situation, and the library was the indicated place to recollect data and also to test the performance and usability of the prototype.

### B. Who are the participants

Participants are the same group of users that used the first version of the Virtual Store in the same conditions but with more characteristics in the application. In addition, some others joined to the test for the first time in order to give us a feedback about the virtual shop.

### C. Testing results

With the second survey (See Appendix) we understood that users consider secure and fast eye biometric method to login, consider useful the description of each product purchased is sent to the email and prefer a video to have a clear description of an item.

### D. How the results may help to refine the designs

It is clear, according to the chart that users are more satisfied with the previous version due its easier way to modify the cart from the Virtual Shop. In addition, in the second version is added a biometric login with the human eye, it is safer and faster. However, the volunteers said that sometimes felt the need of a better explanation of an item. Sometimes new products can be released and no one can explain a specific item, so the new version of the Virtual Shop will be created in order to satisfy the users feedback.

### E. Evaluation

By following the TAM model, the team leader performed the usability, easy-to-use and action use by asking the user its experience with the final prototype and collecting the information. The following charts shows how high or low are the user perception in every variable:usability and easy-to-use. In this preliminary evaluation, users showed more positive evidence to adopt the technology across all user tests (Fig.10). In fact, users found a considerable degree of easy-to-use mainly at interacting with QR codes and looking for products (Fig.11).

## XI. Discussion and Conclusion

Based on the degree of usability and easy-to-use of the final design, it is possible to suggest that a formal software method can work in harmony with a HCI technique like storyboards. Designers will take advantage of this approach or method to

extend their capabilities in best practices in software development as well as design techniques. Overall, this integration was mainly evidenced because both techniques use a iterative model to achieve product goals. In storyboards, every stage was improved regarding with the previous version while the spiral model outfit a formal method where the designer creates every run to clarify and formalize all steps of the design process. Particularly, this method is highly recommended to startups in their formation stage where multiple roles demand synergy in designers to overpass lack of knowledge in the design process.

To follow a software methodology like the spiral model provides a more formal set of activities where team members can know exactly what to do and what the impacts are or potential risks in the interface for every prototype. Furthermore, HCI provides a helpful and easy technique to use where designers and users can meet their needs spending time in prototyping instead of developing. User testing reports helped designers to understand what are the most valuable requirements for the user while TAM releases a better understanding of user behavior. The assumption, "user will not change his behavior so that the usability of the technology will remains" can affect considerably the use of the virtual shop (final prototype) over time. It means that more considerations must be taken in order to run TAM iterations more frequently;for instance, while the user changes his perception the technology does too.

In spite of showing a positive technology adoption in a formation stage of a company, this research might be extended to cover other main aspects. For instance, the use of agile methodologies in conjunction with other HCI techniques. The study of the correlation between cost and benefit of using formal methods by designers. A more strict review of the impact in start-ups during the formation stage as a input to the next stage "Validation". to understand the degree of growth acquired. This research followed the assumption "designers are proactive employees to undertake new technology challenges"; however, the barrier or learning curve in formal methods may lead to a lack of enterprise resources.

## Appendix A
### Results of first survey

How often would you buy an item through your phone?

- 1 0 (0%)
- 2 0 (0%)
- 3 1 (14%)
- 4 4 (57%)
- 5 2 (29%)

Where do you want to see the price of an item?

- Below the product 2 (29%)
- Through QR Codes 5 (71%)
- Through a web page 0 (0%)

Would you need a guide in your shopping cart in order to see more products?

- Yes 6 (86%)
- No 1 (14%)

Do you agree to have a set of detailed instructions in order to guide to buy an item?

- 1 0 (0%)
- 2 1 (14%)
- 3 0 (0%)
- 4 2 (29%)
- 5 4 (57%)

How do you prefer to modify your cart to add or remove an item in your shopping cart?

- Labelled "Add" and "Remove" buttons 6 (86%)
- + / - symbols 1 (14%)
- Modifying directly quantity 0 (0%)

How do you prefer to pay the selected item?

- Credit Card 1 (14%)
- PayPal 4 (57%)
- Debit Card 1 (14%)
- Prepaid Card 1 (14%)

How do you prefer to login to the virtual store?

- Username / password 0 (0%)
- Eye biometric method 5 (71%)
- Email / password 2 (29%)
- Fingerprint biometric method 0 (0%)

Do you prefer a description of the products in your email?

- Yes 6 (86%)
- No 0 (0%)
- Choose at the moment of checkout 1 (14%)

What do you prefer to see meanwhile you buy an item?

- Best Product 1 (14%)
- Latest Product 1 (14%)
- Best - Latest products 4 (57%)
- Anything 1 (14%)

## APPENDIX B
### RESULTS OF SECOND SURVEY

It is easier for you to buy an item using QR codes?

- 1 5 (71%)
- 2 2 (29%)
- 3 0 (0%)
- 4 0 (0%)

Seems useful navigation bar in the application?

- Yes 4 (57%)
- No 2 (29%)
- Not important 1 (14%)

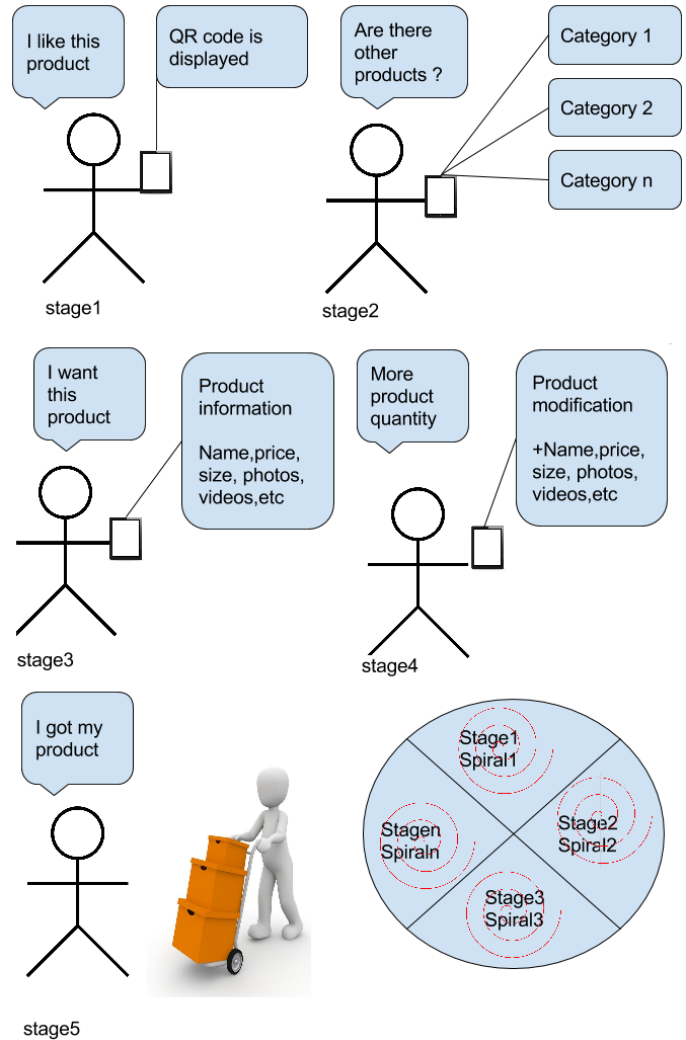## APPENDIX C
### STORYBOARDS PER STAGE AND SPIRAL ITERATION



Fig. 12: Storyboards per stage

## ACKNOWLEDGMENT

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