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A low cost technique to evaluate usable product for small manufacturing companies: a case study on Garcia robot

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Abstract. A usability evaluation technique to evaluate user interfaces is introduces. The technique is effective and affordable for small manufacturing companies. By using this technique, an integration of users' feedbacks and some usability concepts, a product can be 3 times easier to use among potential users and more than 5 times easier to use among motivated users. In addition, the technique can be implemented with the company's employees as participants.

Keywords: interface, improvement, evaluate, deliver, result

1. Introduction

With search capability that provides instant results such as Google's search engine, it is still difficult to find a usable product on the internet. The problem is that many manufacturers are small and often lack resources to incorporate well researched usability results published in the literature into their product development effort [2, 3, 5]. Seventy percent of all U.S. manufacturers have fewer than 20 employees [12].

Many small manufacturing companies have well-define missions to design and manufacture user-centred products to earn profit and serve customers. Every product has specific purposes and often the goal of each product is align with the goal of the organization which is among the necessary requirements to develop a usable product [16]. An easy to use product can transform the users' lives, mentally and physically [15]. However, many companies fail to manufacture products that are easy to use due to lack of understanding or resources to integrate or extend proven techniques published in the literature. As a result, even with many years of successful manufacturing experience, many small manufacturing companies still fail to produce usable products. Case in point is the company Acroname incorporation that manufactured Garcia robot. Table 1 show that Acroname has 17 years of manufacturing experience. In addition, Acroname's mission is also aligns with its product's mission.

Table 1
Missions of Acroname inc. and Garcia robot [13]

Acroname	Description
Mission	To provide expertise, applications and high quality products in robotics. We aim not to just make money, but to advance our field with applications that benefit people.
Experience	Founded in 1994 and has relentlessly pursued our mission for over 12 years; reaching over 20,000 customers worldwide. We have experience working with groups as large as Intel, Microsoft and the US Government.
Garcia robot	**Description**
Mission	Professionals who need to focus on using a robot, not building or maintaining one, will quickly advance their research efforts with Garcia.

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2. Background

Many research papers provide techniques and principles to assist the design of user-centred products. For instance, [2] identified relationships among human experience, knowledge, and context of use. The relationships are then translated into design principles. Paper [17] investigated how to deliver result of usability studies so that designers can improve their design. The paper argue that understanding feedback from usability evaluations as arguments, and focusing on creating written feedback as well-structured arguments will help to improve the persuasiveness of the issues being presented.

Cushman provided guidelines for the design of various types of products such as handheld, portable, and transportable products [5]. An example of portable products included but not limited to a laptop computer and a personal radio. A user can carry a portable product for at least ten minutes without resting. A transportable product can be carried only for up to 125 meters by the user. Example of transportable products included a small television and a microwave. The paper provided recommendations for each type of product configuration to satisfy users' requirements.

Paper [7] reported that existing techniques for determining usability requirements may not be applicable due to practical constraints of certain projects. The paper discussed and developed tailored methods that can be used when such circumstance occur. User-centred principle was extended to develop user-centred method for product to the disable people [1].

Customers now also pay attention to after-sale service in addition to the product's low price and high quality [19]. Enterprise must be customers-oriented to be profitable in the long term. It is well known that in manufacturing systems, the customer needs are fed in into the design process. The choices made by product designer in the preliminary design stage affect 60% of all product life cycle costs (welce & Dixon, 1991).

Paper [3] studied how users' expertise and prototype fidelity affect usability result. The results of the study show that issues most frequently reported by expert users are efficiency and functionality. Subjective usability ratings are not really influenced by the type of prototype used.

Using the flow of the project shown in figure 1, a user-centred prototype may be generated.

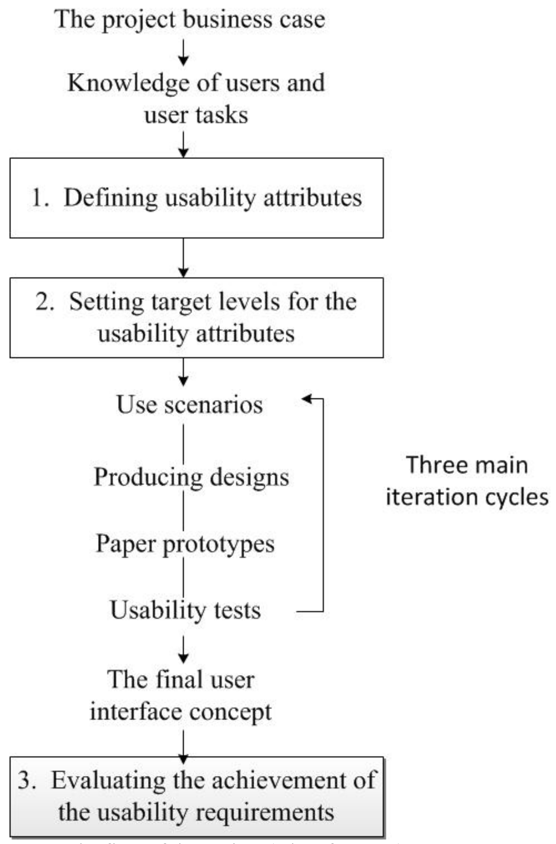

Figure 1: The flow of the project (taken from [7])

2.1. Usability goals

User-centred principles provide guidelines to develop a useful system or product in a way that is easy to learn, effective to use, and enjoyable from the user's perspective. Some of the usability goals [16] are tabulated in Table 2.

Table 2
Usability goals and definitions [16]

Usability Goals	Definition
Effectiveness	Measure of how well a user can perform a task.
Efficiency	Measure of how quickly a user can perform work.
Learnability	Measure of how rapidly a user can become productive.
Memorability	Measure of how well a returning user forms a mental model of the system and remembers how to use it.
Satisfaction	Measure of user attitudes, perceptions, feelings and opinions regarding the system.

2.2. Principles of user interface design

Principles of user interface design included [19]:

The structure principle: Design should organize the user interface purposefully, in meaningful and useful ways based on clear, consistent models that are apparent and recognizable to users, putting related things together and separating unrelated things, differentiating dissimilar things and making similar things resemble one another.

The simplicity principle: The design should make simple, common tasks easy, communicating clearly and simply in the user's own language, and providing good shortcuts that are meaningfully related to longer procedures.

The visibility principle: The design should make all needed options and materials for a given task visible without distracting the user with extraneous or redundant information.

The feedback principle: The design should keep users informed of actions or interpretations, changes of state or condition, and errors or exceptions that are relevant and of interest to the user through clear, concise, and unambiguous language familiar to users.

The tolerance principle: The design should be flexible and tolerant, reducing the cost of mistakes and misuse by allowing undoing and redoing, while also preventing errors wherever possible by tolerating varied inputs and sequences and by interpreting all reasonable actions.

The reuse principle: The design should reuse internal and external components and behaviors, maintaining consistency with purpose rather than merely arbitrary consistency, thus reducing the need for users to rethink and remember.

3. The propose method

Figure 2 illustrates the propose method.

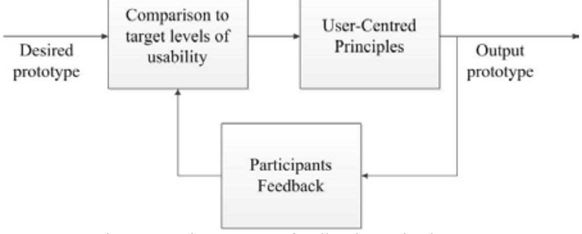

Figure 2: The propose feedback method

Comparing to figure1, figure 2 lies between boxes 2 and 3. As seen in both figures, the design is iterative. The user-centre design involves three important activities: early and continual focus on users and their tasks, empirical measurement of user behavior, and iterative design. To design a usable system, users' needs must be consider throughout the design, development and evaluation process. At a minimum, the following four phases must be conducted [16]:

1. Analyzing the context of use.
2. Defining the user and organizational requirements.
3. Developing a design solution to meet those requirements.
4. Conducting evaluations to test the design against the defined requirements.

3.1. Participants

The first experiment has two groups, Technical Group (TG) and Non Technical Group (NTG). TG has 23 hardware engineers, software engineers, and engineering technicians. TG participants work with software programs and hardware interfaces on a daily basis. The NTG, which has 15 participants, includes managers, secretaries, and accountants.

In the second experiment we have 32 participants in TG and 17 in NTG. Fifteen participants in TG did not participate in the first experiment. This provides a great opportunity to assess their feedback and then compare their responses in experiment 2 to the same group in experiment 1. Their feedbacks will show how much improvement is made by combining usability concepts with user feedbacks from experiment 1.

3.2. Procedure

The first question in both surveys is the same; it is used to compare the respondents' consistency. The first survey was completed in the first week of March, 2011. The second survey was completed in the first week of April, 2011. Prior to participate in the first experiment, participants were explained usability concepts. New TG which only participated in the second experiment was not explained about usability concepts.

Both the motivate users and potential users answer the questionnaire on a 1 to 5 scale: 1 for most negative impression, 3 for neutral, and 5 for most positive impression.

1. I have basic electronic knowledge such as LED and its purpose.
2. I can easily remember which LED at the front of the robot is for which device after 5 minutes of learning them. [Note: participants are given a list that describe each LED and the device that each LED represents according to their ordering]
3. If any of the cables inside the robot is disconnected, I would know how to connect them.
4. I can easily operate the remote control.
5. I can easily understand the graphical user interface about the battery's status.
6. I can easily understand the graphical user interface about the object's distance.
7. The blue, red, and white robots have good manipulations of visual objects.

3.3. Example

Suppose a prototype and it quality assessment is available as in Garcia robot as illustrated in figures 4-8. Quality assessment is tabulated in table 3. Quality of the prototype needs to be improved before manufacturing phase. Using the propose feedback method illustrated in figure 2, the following steps need to be taken.

1. Assess the prototype using the user-centred principles.
2. Improve the prototype by removing or minimizing the negativities.
3. Use the participants to rate the "improved" prototype.
4. If the target levels are met, the final prototype is ready. If not, repeat steps 1-3.

Only four prototypes are tabulated in table 4 to conserve space. See images in appendix for the input and the output prototypes.

Table 3

Input Figure	Principle	Comments (+) positive comment (-) negative comment
4	Structure	+Status indicators are grouped closely together.
	Simplicity	-Complication cause by using green, yellow, and red to denote functional.
	Visibility	-Poor contrast, yellow LEDs on yellow background is poor. -Power indicator status need to stand out among the LEDs. It should be the leftmost or rightmost.
	Feedback	-Using red, yellow, and green to represent functionality cause confusion.
	Tolerance	-Since red and yellow are used for functional electronics, result may be misinterpreted by user.
	Reuse	-Using red, yellow, and green to represent functionality mean inconsistency.
5	Structure	-Lacking label, any loose cabling can cause lengthy delay to fix.
	Simplicity	+Interfaces are keyed; the chance of connecting incorrectly is reduced.
	Visibility	-This image is the only known image that shows how to connect all interfaces and it has too much information. The image is also too small.
	Feedback	-There is no label to indicate which interface is for which electronic. This can causes ambiguity if multiple interfaces are disconnected at the same time.
	Tolerance	-Errors can be hard to detect if sensors are perceived to be connected properly.
	Reuse	-Difficult to replace damaged electronic because of the absent of labeling.
6	Structure	-The buttons are too small and too close to each other. Users with large fingers may have difficulty using this remote control.
	Simplicity	-Difficult to remember which key is for which function.
	Visibility	-Using numeric key to represent functionality is difficult to remember versus pictorial key.
	Feedback	-Difficult to remember which key is for which function. This may cause confusion because user may not be sure if the robot performs the correct function.
	Tolerance	-The user may inadvertently press 2 or more buttons at the same time.
	Reuse	- The user can quickly use the robot again and again without remembering the key if label marker is added.
7	Structure	+ The interface clearly displays battery status and some of the sensors' statuses.
	Simplicity	+The interface is simple to understand.
	Visibility	+Good contrast.
	Feedback	+ Good feedback for the battery status. – For the obstacle detection, user has no idea how far away the obstacle is.
	Tolerance	-User has no idea how far the obstacle is from the robot.
	Reuse	-User can read any voltage value.

Using the method presented in figure 2, the output of figures 4, 5, 6, 7, and 8 are figures 9, 10, 11, 12, and 13 respectively. The output prototypes are not the best possible prototypes, but they are improved prototypes based on the many constraints such as cost and time. If a table similar to table 3 is created for the output prototypes, the number and the severity of negative comment would be reduced.

4. Result

This section is divided into three subsections. The first subsection is experiment 1, the second subsection is experiment 2, and the last subsection is the improvement result.

4.1. Experiment I

After quantifying the first measurement on paper prototype, the following result is obtained based on participants' feedback. Sixty percent or more of the participants found that the remote and the distance feedback are difficult to use. Eighty seven percent of the participants in both group found at least one problem. Over fifty percent of participants in both group found two problems. Almost one in five participants found 5 problems.

Table 4
Preliminary measurement on user interfaces

Interface problem	Exp. I (percent)		Percentage of people reporting	Exp. I (percent)	
	NTG	TG		NTG	TG
Device status	20	35	1 problem	87	87
Hardware connection	53	9	2 problems	53	57
Remote usability	60	78	3 problems	47	52
Battery status	33	22	4 problems	40	26
Distance status	67	61	5 problems	20	17
Visual object	13	35			

4.2. Experiment II

After redesign using method illustrated in figure 2, the second measurement is obtained from participants. Only 24 percent of NTG and 12 percent of TG found the remote difficult to use. For distance feedback, only 6 percent of NTG found it difficult to understand. About 12 percent of NTG found four or more problems.

Table 5
Experiment 2's measurement on user interfaces

Interface problem	Exp. II (percent)		Percentage of people reporting	Exp. II (percent)	
	NTG	TG		NTG	TG
Device status	18	3	1 problem	64.7	22
Hardware connect.	41	6	2 problems	23.5	6.3
Remote usability	24	12	3 problems	17.6	3.1
Battery status	24	0	4 problems	11.8	0
Distance status	6	0	5 problems	11.8	0
Visual object	18	9			

4.3. Improvement

Table 6 and figure 3 show drastic improvement in only one iteration. The most surprising results are the elimination of battery's and distance's status problems from TG feedback. Also for TG, no participant report more than 3 problems. Using the propose feedback method, every prototype was improved except for the visual object. Thirteen percent of NTG found a problem with visual object in experiment I while 18 percent of NTG found a problem in visual object in experiment II. In contrast, TG found visual object to improve more than 300 percent.

Table 6
Improvement factor

Interface	Improvement factor		Percentage of people reporting	Improvement factor	
	NTG	TG		NTG	TG
Device status	1.1	11.2	1 problem	1.3	4.0
Hardware connection	1.3	1.4	2 problems	2.3	9.0
Remote usability	2.6	6.3	3 problems	2.7	16.8
Battery status	1.4	∞	4 problems	3.4	∞
Distance status	11.3	∞	5 problems	1.7	∞
Visual object	0.76	3.74			

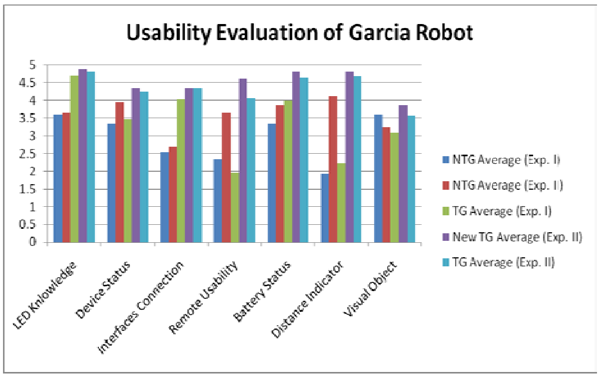

Figure 3: Usability evaluation of both experiments

5. Discussion

Reduced fidelity prototypes are suitable to predict product usability of the real product [3]. First experiment showed that 87% of TG and NTG found a usability problem with the robot's user interfaces. More than 50% from both groups found 2 problems (See table 4). However, after applying technique of figure 2, which can be done in-house, usability problems are reduced significantly. NGT found more problems than TG which agree with [3]. A small improvement found by NTG result in a much larger usability improvement found by TG. This result shows that a small manufacturing company can use a non expert and expert users' feedbacks along with usability concepts to improve their product. Getting employees involve in product development not only make them feel important, but also more innovative [11].

6. Conclusion

Both experiments show that respondents' feedbacks are very consistent as can be seen with their feedbacks on LED Knowledge. While learnability, maintainability, and usability improved in experiment II as compared to experiment I, visual object manipulation slightly degraded for NTG. This is not the case for TG. New TG rated the survey with comparable score to TG that participate in both experiments.

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Appendix

Figure 4: LEDs

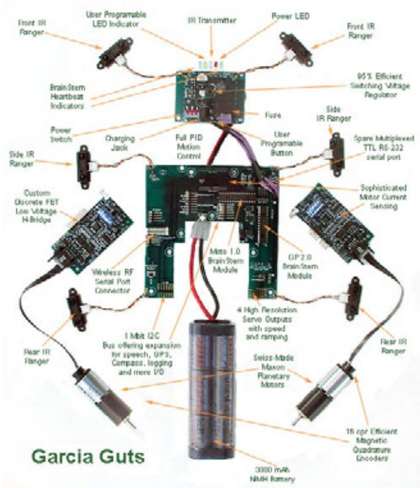

Figure 5: Electrical interfaces

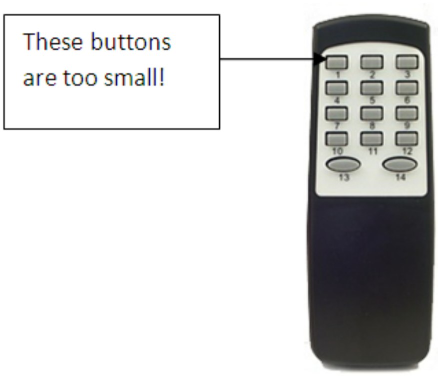

Figure 6: Remote control

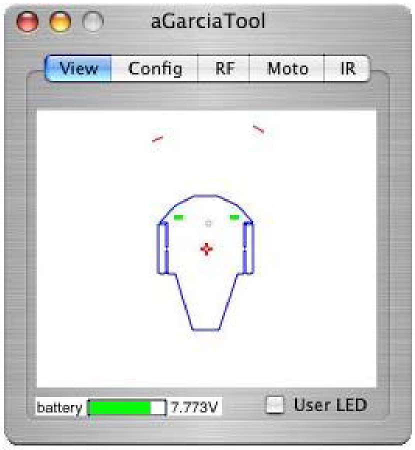

Figure 7: Computer interface display

Figure 8: Visual arrangement style

Figure 9: LEDs

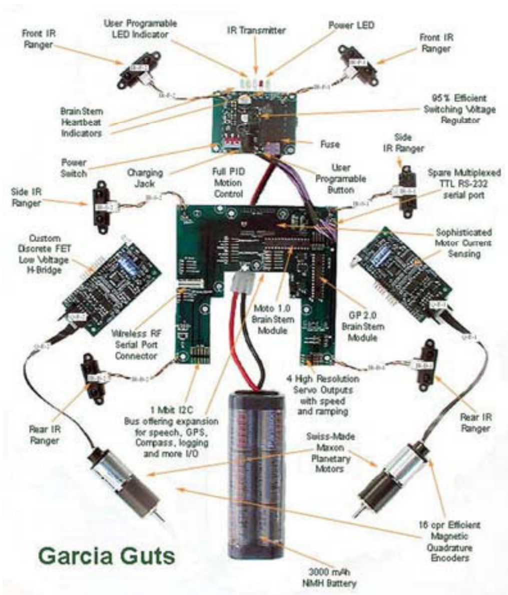

Figure 10: Electrical interfaces

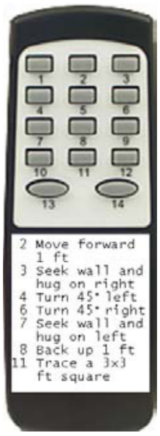

Figure 11: Remote control

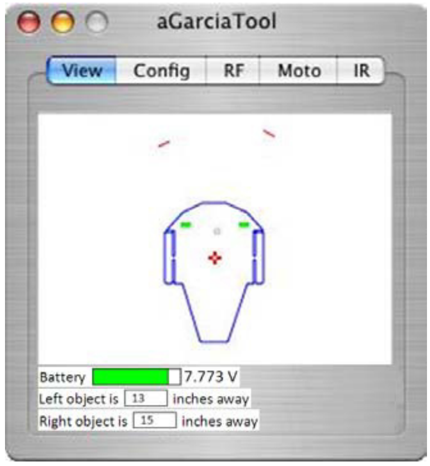

Figure 12: Computer interface display

Figure 13: Visual arrangement style