Accessibility, UX Metrics and Gamification Approach in Embedded System

Kanisius Karyono, Andrey Andoko, Ellianto

Abstract— Embedded systems are developed to help people living a better life. Gamification approach in the system can also become the tool for people living their precious life. These systems require a friendly interface to help people able to use the system properly, especially disabled people. Better system experience and ease of use are among the parameters which are important but difficult to measure. In this work, we also propose a simple way to measure UX metrics based on the time needed to be able to access and properly use the system. The user is given the blind test for the new interface and the elapsed time is measured as the parameter for understandability. The faster the user understands the system interface the better the UX/UI score. Many smart cities policies also considering many applications that are specially developed for impaired people. However not many 'ordinary' embedded system that is developed with the consideration that their user might be having some degrees of disability or impaired. Small changes in design which require only little effort, like adding 'beep', could improve the user experience aspects, especially for a disabled user. Gamification can also trigger people to interact more with the system.

Index Terms—Gamification, Metrics, User Experience, User Interface.

1. INTRODUCTION

Many designers already developed special devices to help disabled people living their precious life. These devices are very popular because modern electronics and embedded systems are less expensive. Intelligent devices play important roles in daily life. It is the role of engineers to make it easier to use the devices. The efforts have to be done in the final product so that it can be easier to use without a heavy manual.

Initial thinking about accessibility was already mentioned before the 17th century. People considered that they are two kinds of people who are normal and impaired [1]. The location of the control interface must remain in the exterior of the device. Marketing today still think the same by making more profit from making an easy solution out of the complicated things.

In 2001 WHO made a new terminology by stating that human has a different amount of abilities instead of normal and impaired. The software inside the embedded system can be programmed so that the user interface is easier to use even for impaired people. The user interface should be carefully designed to cope with different human perceptive levels even for a normal user. A normal user can be ill or in a hurry so that he cannot concentrate to use the devices. The designer should really spend time thinking how hard this user interface may be for the person who has been impaired or have lower perception level. More accessible design should be beautiful and desired by end users if the devices are made visually good and easy to handle [2].

Symbols and logic of embedded systems are usually hard to learn for common people or nontechnical people. Many embedded designers are also implementing their design with a very limited level of accessibility due to the cost or the difficulties to employ a better user interface. The simplest example is the consideration to limit the number of buttons in the design of the embedded design. One button can be used to generate the short or long impulse to give a different kind of inputs. However, this kind of approach will generate unfriendly user Interface or worse user experience.

This research is intended to gain better User Experience (UX) / User Interface (UI), using the simple tool for comparison among alternatives of designs and the possibility to embed the gamification approach. Authors propose a better approach so that the embedded designer will be able to create a better design for the user by the means of metrics so that the design can be easily compared and scored. The result will also give benefit to impaired people so that the design can be more compatible with impaired people.

2. EMBEDDED SYSTEMS, IOT AND SMART CITY

The goal of the embedded system is to make it invisible from users and integrate with the surrounding. The technology complication can be made disappears in the environment providing user-friendly interaction paradigms. The environment will support natural interaction and people can be surrounded by a huge number of small computers without the users have to be experiencing difficulties. Even minor subconscious user actions might unintentionally trigger the sensors [3]. Embedded system is one that has computer hardware and software embedded in it as one of its most important components or can be defined as dedicated computer-based systems for applications. The goal of this system is to entirely hide their presence from users and smoothly integrate them within the surrounding context (technology fades out or disappear, seamless interaction paradigms). This needs hardware and software co-design and integration in the final system.

In the Internet of Things (IoT), sensor and actuators are blends seamlessly with the environment, information is shared across various platforms, can be in the form of mobile applications. Most of the loT related projects will focus on games, tourism, and advertising. The loT creates

Revised Manuscript Received on April 15, 2019.

Kanisius Karyono, Engineering and Informatics Faculty, Universitas Multimedia Nusantara, Tangerang, Indonesia (karyono@umn.ac.id)

Andrey Andoko, Engineering and Informatics Faculty, Universitas Multimedia Nusantara, Tangerang, Indonesia (andrey@umn.ac.id)

Ellianto, Engineering and Informatics Faculty, Universitas Multimedia Nusantara, Tangerang, Indonesia (elianto@student.umn.ac.id)

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

enabling environments in assistance in building access, transportation, information, and communication.

The Web of Things (WoT) is a vision where smart objects are integrated with the Web. Self-management is become important, which is the loT can manage its own operation without human intervention. Rural application platforms are meant to be used for executing applications required for providing different e-services, self-help services relevant in the rustic areas [3].

Although embedded systems offer many advantages, the embedded systems have some serious limitations as well, especially on the platform and system. There are plenty of definitions of embedded system and in most generic terms; an embedded system is one that has computer hardware and software embedded in it as one of its most important component [4]. It is a dedicated computer-based system for applications or product. Another factor which is more important than the technical things in Smart City is the adoption of services that are born from people's real needs. This can be designed through interactive, dialogic, and collaborative processes. People rather than technology are the true actors of the smart urban. The participatory innovation ecosystem will elaborate on citizens and communities to be working with public authorities. This knowledge will be beneficial to knowledge developers. This interaction will result in a user-centered approach. The output of this process is a model where most citizens will agree on these models. The process of accessing the facilities can be defined properly and the people can have the freedom or ability achieving their basic needs in order to sustain their quality of life.

In IoT, sensor and actuators are blended with everyday life without user visibility in any platform. The most common solutions are embedding mobile applications as the user interaction core which developed for a specific application. The application usually does not offer the best interaction between the user and the surrounding environment. This is how loT would make interaction possible with a greater range of services offered in Smart cities. The interaction can be in the form of using one or more interactions using voice recognition, objects, people and sounds. Most loT of related projects had been focused on games, tourism, and advertising. loT allows the users which connected to the internet to extract information for making the more human-related approach of smart cities. The uses of smartphones also allow the application to be easily developed for better accessibility resources for impaired users.

3. DISABILITY SUPPORT

Based on the 2010 data, the population estimated to be 6.9 billion with the percentage of about 15% of the world's population are considered to be living with a disability based on the 2004 data from World the Health Survey and Global Burden of Disease. This means that over a billion people including children are estimated to be living with a disability (also declared by the World Health Organization in 2011). The report also revealed that 110 million people have very significant difficulties in functioning, while 190 million have a severe disability. The disability inferred for conditions such as quadriplegia, severe depression or blindness [5].

The Internet of Things will be able to offer people with disabilities the assistance and support they need to achieve a good quality of life and allows them to participate in the social and economic life like a normal people. Assistive loT technologies are powerful tools and helper to the user to increase independence and improve participation. Therefore, the purpose of this paper is to analyze how people with visual, hearing and physical impairments can interact with and benefit from the loT. The loT creates enabling environments by offering people with disabilities assistance in building access, transportation, information, and Connected home devices are expected to comprise 25% of all Internet of Things devices shipped this year, according to BI Intelligence, a market currently valued at $61 billion and expected to jump to $490 billion by 2019 [6]. Many of the new loT applications are focused on comfort and security aspects. These applications certainly add a level of fun, comfort, and convenience for all users. The applications take on a whole new level of importance when used by a disabled user. Examples of home technologies:

For visually impaired people or have low vision, home automation applications allow the user to gain control easily of appliances. The environment control like the home thermostat can also be set by just one touch of a button on a smartphone. However, the compatibility of these applications should be solved and also integrated with the smart phone's screen reader or other accessibility features.

For people with mobility issues, this system allows the user to control things especially the appliances which physically difficult to reach, such as lights switch and door locks.

For people who have hearing difficulties, this system is capable to improve health and security aspects. For example break-in notification, devices alerts can be redirected through the user's phone in the event triggered by sensors.

Smart home technology also allows children or older adults to monitor their daily routines and put alert if necessary. The biggest barrier is to ensure the system having the compatibility and accessibility needed when developing new products and services. Accessibility must be a consideration at each stage of the development process. At a minimum, all parties involved in the development of loT devices and applications should commit to addressing the principles of universal design. Input from the disability community will be beneficial to the development of the Internet of Things. This will lead to more independent living, more personalized care, more flexibility and mobility and better employment and education outcomes.

4. AMBIENT INTELLIGENCE

Technology has begun to take place in every aspect of people's life. The artificial intelligence is now being integrated into the system to form an ambient assisted living. The major parts of the system employ the accessibility, usability and learning. This major role makes the interfaces becoming more and more important. Future interfaces are able to adapt themselves to changing personal situations. It means that the system is capable to adapt to individual and fulfill the individual needs.

This is a difficult task since elderly people often have insufficient knowledge of the possible technical solutions available and are usually unaware of their increasing disabilities. This new and advanced system require late learning, the learning needed by elder people to learn to use the system properly. Still many of today's elderly people especially in Europe are away from modern IT systems and even worse, they are afraid of using them. When referring to the support of elderly people, lifelong learning is not just a catch phrase. It is a chance to promote learning, through their lives especially for the elder to be able to use new technology. The new and ambient technology offers us both the challenge and the opportunity to support elderly people by assisting them to participate in the information society. One possibility of reaching these goals is by the application of user-centered design methods to involve elderly people in the development from the very beginning.

The important things about the good embedded systems are a system that provides a consistent user experience [8]. Many users would easily recognize a device running interface. If the device is designed well enough, there will be built-in function features utilization rather than additional actuator. Controlling devices via gestures will also be popular. Adaptable and adaptive user interfaces for disabled users are also becoming more popular [9].

5. GAMIFICATION

Gamification is a process for integrating elements of the game in an assignment or activity, to increase participation [10]. The main purpose of gamification is to motivate and support users to perform tasks desired by the gamification designer [11]. Gamification provides experience or an activity that makes users involved more in the activity with an additional internal pull factor [12].

Gamification began to be widely used in applications that are not actually related to games to increase UX (user experience) and user involvement [13]. Gamification is also widely applied to serious fields such as in the demographic area [14], to increase user loyalty to non-profit institutions [15], even to the exact and structured fields such as software design [16].

There are common factors in each of the objectives of the gamification design which is increasing user motivation, especially internal motivation [17]. The most important thing in the design of gamification is that the problem being verified must be clearly understood by the system developer. If the problem is not clearly understood, gamification will not give the desired effect. Failing to do so, will reduce the potential or the results it produces. One of the contributing factors is the developer's ignorance of the needs of the verified system. For example, manipulating users to perform tasks that are truly unwanted by the user or incentives are given are not in accordance with the desired form of the user [18].

Gamification is among a new science that is developing rapidly. Gamification can provide motivation; strengthen user involvement by strengthening positive activities from users. More than 50% of organizations will manage their innovation process by involving aspects of the gamification of their business in 2015 [19].

Special gamification applications in the health sector are currently very limited. New research is focused on personal applications, for example, to encourage the user to walk [20]. This application integrates data generated from the step counter FitBit device, which is used to move the game and the user is given a special score to be contested.

In the field of energy consumption efficiency or energy conservation, there are also many gamification applications that are implemented by focusing on saving energy at home [21]. This application is generally intended to educate people so that they pay more attention to their energy consumption. This platform of gamification is generally based on smartphone applications, web-based applications, and computer applications. Gamification is done by providing a level of understanding of energy conservation that is contested between users. Up to now, not many gamification done for public facilities. Applications that are found generally perform gamification on personal devices. The elimination of equipment provided by users has resulted in the measurement of the value of user participation to be more objective. Users do not need to provide tools, install or provide a special computer to be able to use it.

The staircase gamification prototype has been developed at UMN. RFID cards are used to login and select the type of sound that is available in the application [22]. Piano Stairs prototype was inspired by the creation of previous stair projects in Italy [23] and Sweden [24]. This tool is usually placed in urban centers such as malls, city parks, stations, schools, and universities. In an experiment at the Odenplan subway station in Stockholm, Sweden, this project was successful because 66% of pedestrians preferred to use stairs rather than escalators. However, the cost of making this tool is very expensive, reaching AUD $ 50,000 [25]. Subsequent research was conducted by a group of students named IDEO Labs in 2011 who used IR sensors and Arduino Mega 2560 in the development of this application. The results show that IR LEDs cannot work reliably because the 16 pairs of sensors installed require very complex calibration. To maximize the applications that have been made, they finally replaced the IR sensor with proximity infrared sensors which cost more than five times the price of the previous sensor [26].

6. DISCUSSION

A. Accessibility and UX Metrics

The Accessibility must become a consideration at each stage of the development process. All parties involved in the development should commit to uphold the principles of universal design. One possibility of reaching these goals is by the application of user-centered design (involvement of the users from the very beginning of development). The effort to make it become standard is not simple. This standard should involve a lot of parties. More common symbols, icons or graphics to be used will result in a more user-friendly environment.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

Small changes or fixes in design could improve the user experience aspects. Lesson learned was the use of more than one media for alert results in a considerable level of support and compatibility for supporting the disabled user. The simple media tested in this research are the use of additional sounds for example in the form of beep sounds, which can be deployed using as simple as the buzzer/speaker will lead to better user experience and the possibility for devices to be used by the disabled person without help. Another form of media which is tested is the additional vibration. This feature is easily be implemented using a smartphone vibrator or unbalanced small DC motor.

A more advanced function such as text to speech module or speech to text module can be a killer application for the disabled since this function requires also advanced devices. The application will be still limited.

The proposed metric from this work is based on duration time. The parameters consist of the duration based on the fastest, most likely and slowest activity durations called three-point measurement. The calculation formula is shown in equation (1).

Weighted average = (fastest time + 4X most likely time + slowest time) / 6 (1)

The testing scenarios can be selected according to the requirements, for example, the minimal interaction like Blind Test which the user knows nothing at all about the system. Brief User Manual or Short References can also be provided, for example, the one-page manual supplied in printer product. Short Briefing/Movie can also become alternative or good user education tools instead of boring Full User Manual. Another tool which might be needed is the Complete Movie System Manual as the most complete and easy approach for the user to understand the system. The chart shown in Table 1 shows the example of function testing map used to test the UX/UI factor for certain function.

Table 1. The example of the scenarios used to test the function

	Time (in Minutes)				
Function	Blind Test	Brief User Manual	Short Briefing/Movie	Full User Manual	Complete Movie
Function 1	x		y		z
Function 2	x	y		z	
Function 3					

The evaluations of the function in the design are generated by these embedded projects in UMN. The function and UX being tested are Auto Parking System, Alter Rate (Music Playlist Changer based on the Heart Beat Sensor), Voice-controlled Lighting & Media Player, Smart Plant Monitoring System, Matrix LED using NodeMCU, Indoor Guidance Robot made by the students of UMN

B. Gamification

The gamification, in this case, is used to attract people to use stairs instead of elevators. In terms of structure, building B has 5 floors. 1st and 2nd floors are used for libraries, 3rd floor is used for classrooms, laboratories and student lounges and 5th and 6th floors are for laboratories. The 2nd-floor library is accessed via stairs in a different location. The stairs will connect level 1 to 3, 5 and 6. In this building, the stairs are not the only access, because there are 2 elevators each with a capacity of 15 people. Thus, this location is suitable for conducting gamification research. People who accustomed to using elevators, being attracted to use the stairs from the 1st floor to go to floors 3.5 or 6.

Before the installation of gamification, the users of the stairs are 1,508 people with a standard deviation of 431. This data was obtained during normal use or during regular lecture days. Data during holidays or at the time of the exam are not considered valid data because the activity will experience a difference from normal days.

On the first day after the gamification was installed, the number of people using stairs reached 3,708, far higher than the average user. But in the following days, stairs users decreased back to normal. The average number of people using stairs after gamification was installed as many as 1,463 people with a standard deviation of 866.

The author also conducted a survey to get perceptions from users of this gamification. The survey results showed a slightly different matter. From 40 users surveyed, 50 percent of the respondents had the urge to use the stairs. The survey results also show people's interest in using the stairs as indicated by the reduced percentage of people who rarely use the ladder from 50% to 42.5%. From this questionnaire, it can be concluded that in fact, this gamification is quite interesting for humans to use stairs, but to make respondents change their habits they still need more interesting effort or gamification [27].

From the results of the calculation of the data and the results of the questionnaire from 40 respondents, it is shown that gamification by using the sound has attracted the interest of people to use the stairs which can be seen from the declining number of people who rarely use stairs. However, this gamification has not been able to make respondents change their habits as evidenced also from the results of a questionnaire which shows that only 50 percent of respondents get the intention to use the stairs regularly. The attraction of users only occurred on the first day and then back to normal after the curiosity was gone. This gamification approach still requires the use of other methods or more interesting gamification to become effective.

The decline in the following days is likely caused by:

- Stairs are used by the same people so that after trying to fulfill their curiosity, they are back to the original behavior of using an elevator.

- The tone of the sound will sound good when it is played (up and down), but on the gamification of the stairs, the tone will sound in sequence because people will tend to pass the stairs directly. So after trying, people will tend to go back to use the elevator. Gamification with this type of sound has not produced enough influence in changes in the behavior.

- Inaccuracies in reading data on people counter because the behavior of passing stairs together should have been taken into account. Due to the weakness of the infrared sensor, there is a possibility of inaccurate calculations if the presence of people walking through the sensor is exactly parallel.

CONCLUSION

The evaluation process of analyzing UX/UI on the embedded system will result in better user experiences. The awareness of the embedded system designer will be increased using this kind of evaluation process. This process can also be iterated to improve the compatibility of the system to be used by impaired people.

This work evaluates the use of a simple metric to measure the level of UX/UI, based on lime elapsed to learn the new interface. The user is given the blind test for the interface and the elapsed time is measured as the parameter for understandability. The faster the user understands the system interface the better the UX UI score. The tools use three-point of Measurement based on the duration needed for novice users to understand the UI or the system and being able to use certain functions or applications. The metric will measure the experience using fastest, most likely and slowest activity durations. The faster the duration achieved the better UX/UI level for the application no matter the users are, normal people or people with disabilities.

From the gamification point of sight, the process carried out has caused the desire of people to try to use the system, but not to shift their behavior. This study shows that to modify the behavior of users who seek comfort, there should be enough attraction by gamification elements. Otherwise, users only want to use the new system under curiosity, then return to the original activity or comfort.

REFERENCES

1. Esa Hakkinen. Accessibility in Embedded systems. EWTEK University of Applica Science. 2005
2. P. L.. Emiliani. C. Stephanidis. Universal access to ambient intelligence environments: Opportunities and challenges for people with disabilities. IBM Pp 608-619
3. Pallab Dutta. et. AIL A Comprehensive Review of Embedded System Desten Aspects tor Rural Application Platform. International Jurnal of Computer Applications (0975-888 1), Vol 106. No 11, 2014, pp 39-44
4. Ramirez, Alejandro R. Garcia, et all. Towards Human Smart Cities: Internet Of Things tor sensors impaired individuals. Computing. 2017. volume 99. number |. pp 107-126
5. Mari Carmen Domingo. An Overview of The Internet of Things For People With Disabilities. Journal of Network and Computer Applications. vol 35, 2012. pp 584-596
6. G3ICT. Internet of Things: New Promises for Persons with Disabilities, AGSict Business Case White Paper Series. 2015
7. Kleinberger. et. All. Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces. Universal Access in Human-Computer Interaction. Ambient Interaction: 4th International Conference on Universal Access in Human-Computer Interaction, UVAHCI 2007 Held as Part of HC! International 2007 Being. China. Tals 22-27. 2007 Proceedings. Part I. 2007. Springer Berlin Heidelberg. pp 103-112,
8. Nikhil Chaudari. et. All. ALED System to Provide Mobile lol Assistance lor} dderdy ind Disabled, International Jurnal of Smart Home vol 10 no 8. 2016. pp 35-50
9. Stephanidis, C.. et all. Adaptable and adaptive user interfaces or disabled users in the AVANTI project, Intelligence in Services and Networks: Technology for Ubiquitous Telecom Services: 5th International Conference on Intelligence in Services and Networks, Belgium, 1998, Springer Berlin Heidelberg, pp 153-166.
10. Merriam-webster, E. (2010). Merriam-webster Dictionary. Retrieved 2 9, 2015, from Merriam-webster: http://www.merriam-webster.com/ dictionary/gamification
11. Deterding, S. (2012). Gamification: designing for motivation. In Magazine interactions Volume 19 Issue 4 (pp. 14-17). New York, USA: ACM.
12. R.M. Ryan, C. R. (2006). The motivational pull of video games: A self-determination theory approach. Motivation and Emotion, Vol 30(4), 347-363.
13. Deterding, S. D. (2011). From game design elements to gamefulness: Defining gamification . the 15th international Academic MindTrek Conference: Envisioning Future Media Environments (pp. 9-15). Tampere, Finland: ACM.
14. Jonna Koivisto, J. H. (2014). Demographic differences in perceived benefits from gamification. Computers in Human Behavior, Volume 35, 179-188.
15. Elizabeth A. Freudmann, Y. B. (2014). The Role of Gamification in Non-profit Marketing: An Information Processing Account. Procedia - Social and Behavioral Sciences, Volume 148, 567-572.
16. Oscar Pedreira, F. G. (2015). Gamification in software engineering – A systematic mapping. Information and Software Technology, Volume 57, 157-168
17. Burke, B. (2014). Gamify: How Gamification Motivates People to Do Extraordinary Things. Brookline, USA: Gartner, Inc.
18. Sebastian Deterding, M. S. (2011). Gamification: Using Game Design. Conference on Human Factors in Computing Systems (pp. 2425-2428). Vancouver, Canada: ACM.
19. Juho Hamari, J. K. (2014). Does Gamification Work? -- A Literature Review of Empirical Studies on Gamification. 47th Hawaii International Conference on System Sciences (pp. 3025-3034). Hawaii : IEEE.
20. Rachel Gawley, Carley Morrow, Herman Chan, and Richard Lindsay (2016), BitRun: Gamification of Health Data from Fitbit® Activity Trackers, ICST Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2016, Springer (pp 77-82)
21. Daniel Johnson, Ella Horton, Rory Mulcahy, Marcus Foth (2017), Gamification and serious games within the domain of domestic energy consumption: A systematic review, Renewable and Sustainable Energy Reviews 73, Elselvier (pp 249–264)
22. Riski Safaat, A. A. (2015). Laporan Skripsi, Rancang Bangun Gamifikasi Piano Stairs Menggunakan Sensor Ultrasonik dan Teknologi RFID. Tangerang : Universitas Multimedia Nusantara.
23. JackRives147. (2009, 12 25). Piano Stairs in Milan. Retrieved 2 9, 2015, from Youtube: http://www.youtube.com/watch?v=0Mn2JLD_nZ8
24. Volkswagen. (2009, 09 22). Piano Stair Case. Retrieved 2 9, 2015, from The Fun Theory: http://www.thefuntheory.com/piano-staircase
25. Nguyen, P. (2010, 2 9). Piano Stairs Art Project. Retrieved 2 9, 2015, from FUTURE MELBOURNE COMMITTEE: https://www.melbourne.vic.gov.au/AboutCouncil/Meetings/Lists/CouncilMeetingAgendaItems/Attachments/7567/6.2.pdf
26. Akasaka, R. (2011, 9 8). Musical Staircase. Retrieved 2 9, 2015, from IDEO Labs: https://labs.ideo.com/2011/09/08/musical-staircase/
27. Andrey Andoko, Kanisius Karyono Ellianto, Dampak Gamifikasi Tangga Interaktif untuk Mengubah Kebiasaan Manusia Studi Kasus Universitas Multimedia Nusantara, Jurnal Ultima Computing, Desember 2018.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication