iCoff: Towards Building an Intelligent Coffee Plate System to Enhance Coffee Shop's Customer Experience

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ABSTRACT

Blossoming coffee culture give a rise to coffee shops in many cities around the world. In today's coffee industry, it is no longer customer satisfaction that is important but the customer experience. This work presents a development of an intelligent coffee plate system called *iCoff*, which aims at enhancing coffee shop's customer experience with a platform that allows a barista to communicate with a coffee drinker as well as enables the coffee drinker to learn more about his/her coffee, such as ingredients, temperature, and weight through an interactive coffee plate. This paper describes its hardware and software components as well as a preliminary user experience study result. It is an applied ubiquitous/pervasive technology in the context of coffee shop experience as part of our today's urban living.

CCS CONCEPTS

Human-centered computing → Empirical studies in ubiquitous and mobile computing

KEYWORDS

Intelligent coffee plate, Arduino application, coffee shop application

ACM Reference format:

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1 Introduction

Coffee culture is a somewhat new industry that is blossoming. Coffee shops are on the rise around the world. Recently, 21 out of 25 European countries reported an expansion in their coffee shop industry [1]. In Asia, it's been reported that the Chinese coffee market grew several times faster than the global average in the decade [2]. Thailand also witnessed the rise of coffee shops. In 2018, there were 8,025 coffee shops operated in Thailand, which was 4.6% increase from the previous year. Thailand's overall coffee market is worth 36 billion baht, of which 20 billion belongs to instant coffee, 1.2 billion baht is the premium market, and rest is other segments [3]. Thai people are becoming more into coffee that almost every small town, gas station, and village now drink and even grow coffee.

In coffee industry, it is no longer customer satisfaction which is important but the customer experience, along with the products or services, which carries a lot of weight in customers' final decision making [4]. Customer satisfaction is not the same as customer loyalty, i.e. whether the customer will come back and buy again. Thus, a satisfied customer does not equal a loyal customer [5]. Customer experience is a better explainer and antecedent of customer loyalty, which concerns everything in a company's actions and offering. Whenever customers buy a product or service, they always have an experience, which may be good, bad, or indifferent [6].

Coffee and service provided by the coffee shop therefore ought to be designed and aimed at improving customer experience. Services in a local coffee shop or even a high-end coffee shop like Starbucks normally include internet, electric power supply, music, food, and bakery. These are the services that most customers today are accustomed to. There is a need for a new and interesting service goes beyond these conventional services.

With the recent advancement in information technologies, we see that the ubiquitous or pervasive computing paradigm holds a great potential to provide a foundation for creating such service. To our knowledge, in the context of coffee shops, the pervasive computing has been applied to provide new solutions for wireless communication via a hotspot access control gateway [7], social interaction with table-top application [8], and shop queuing monitoring and estimation system [9]. To fill in the gap of pervasive computing application in coffee shops, we developed a system that integrates the concept of storytelling, i.e. an innovative way to engage customers to achieve their loyalty [10] and pervasive computing, i.e., user interaction as a service that allows the user (i.e., coffee drinker) to receive his/her coffee details (i.e., ingredient information) as well as a short message from barista through an interactive coffee plate, namely *iCoff*. Our development contributes to the body of knowledge of pervasive computing with our system design and implementation, combing the hardware and software components to build a prototype that is fully functional and tested in real-life coffee shops.

2 System Overview

Many people care of what they consume everyday due to various reasons, such as health concerns, dietary, or simply just a curiosity. Would it be nice to know the ingredient of your cup of coffee and related details? How about its current temperature and weight while you're drinking it? Many coffee drinkers would appreciate these information, and this additional service that enables the coffee drinkers could potentially enhance their coffee experience. So, we developed an intelligent coffee plate or *iCoff*, which is simply a plate for serving coffee that also carries the information about the served coffee i.e., ingredient along with the sensory component that reports the state of temperature and weight of the coffee that is still in the cup waiting for the drinker to finish it. A short message written by the barista who proudly makes that cup of coffee can be delivered to the drinker via the plate, which can be a word of encouragement, cheering, or motivation.

The *iCoff* is simply a platform for delivering information based on sensory as well as non-sensory data. It consists of both hardware and software components, which can be divided into two main parts; writer and reader. Writer part consists of hardware and software that enable data writing mechanism i.e., inserting information into the plate, such as ingredient and short message. On the other hand, reader part drives the information reading mechanism i.e., displaying the inserted information and sensory data such as temperature and weight of the coffee. The system overview of *iCoff* is shown in Fig. 1. The barista inserts the coffee's ingredient information and a short message (if wanted) using the writer's user interface (UI). The inserted information will be transferred from the writer UI and be stored in the cup using an NFC (near field communication) tag attached under it via the writer's sensor, which is built with a NFC/RFID (radio frequency identification) module for writing data into the NFC tag. The cup is then placed on our intelligent plate (reader's UI) built with NFC/RFID module to communicate with the NFC tagged cup, temperature and weight sensors, and touch-screen display to visualize the information stored in the cup and allow the user to interact with the graphics such as clicking an icon for more information about some ingredient.

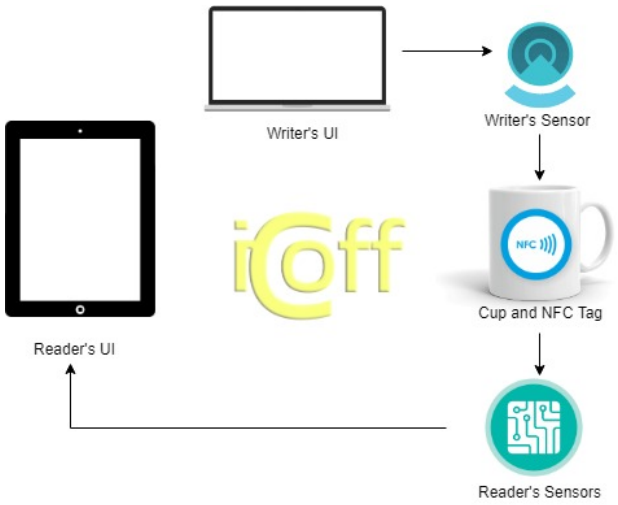


Figure 1: System overview of *iCoff* that consists of information writer's and reader's components

2.1 Data Writer Components

There are two main components of the data writer part; sensor and UI. Writer's sensor serves as a bridge between the writer UI and the NFC tagged cup, which is basically our data storage. So, the goal here is to recognize the NFC tagged cup and to be able to write new information or data into it. Writer's UI serves as a channel for the barista to insert the data or coffee information into the cup.

2.1.1 Writer's sensors. For serving as a bridge of data communication between the writer's UI and the NFC tagged cup, the writer's sensor is built with a PN532 NFC/RFID Module V3 for reading from and writing to the cup, which connects with an Arduino Uno R3 for controlling and supplying power to the PN532 NFC/RFID V3 module, as shown in Fig. 2.

The connected hardware is then placed inside a case to be ready for the use. Figure 3 shows the hardware and its case, while Fig. 4 shows the case with the hardware enclosed. Since the Arduino board needs a power supply, the side of the case

was drilled to create an exact hold for its power jack. On top of the case, there is a label 'Place Here' which indicates the location where the cup needs to be placed on for the writer's sensory hardware to recognize and write information into the NFC tagged cup (Fig. 5).

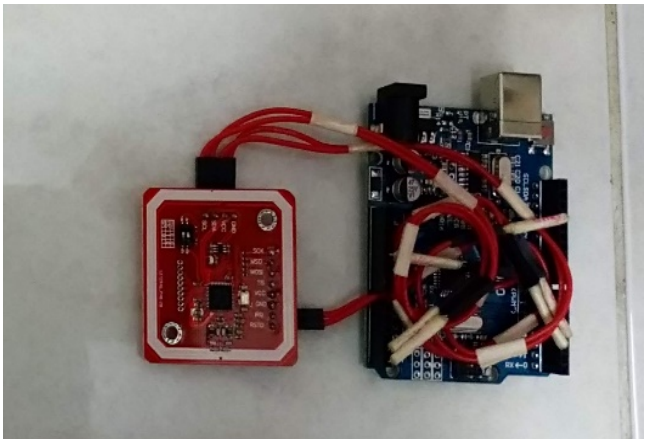


Figure 2: Components of the writer's sensor, which consists of a PN532 NFC/RFID V3 module (red board), connecting with an Arduino Uno R3 (blue board)

Figure 3: Writer's hardware and its case

Figure 4: Writer's sensor case ready to be used

Figure 5: A snapshot of NFC tagged cup

2.1.2 Writer's interface. Writer's UI was developed using Processing[1], which is a development environment and computer language (built on Java) for programming interactive visual graphics. Processing is widely used for developing interactive tools, such as [11]–[15].

Figure 6 shows a snapshot of the writer's UI where the user (i.e., barista) selects the ingredient information from the dropdown menu, including types of coffee, types of beans used, bean's origin, types of milk, and sweetness level. Barista can also write a short message for the coffee drinker by typing into the 'Message To Customer' box.

Figure 6: A snapshot of the writer's UI

To communicate the information entered by the barista to the cup and later to have the data read from the cup, we used a sequence shown in Fig. 7 as the data format. Each information is

[1] https://processing.org

separated by a dash line that includes; menu (coffee type), sweetness level, bean type, milk type, bean's origin, and message.

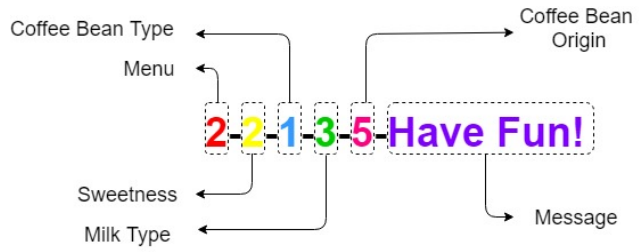


Figure 7: Format of data sequence used for writing to and reading from the NFC tagged cup

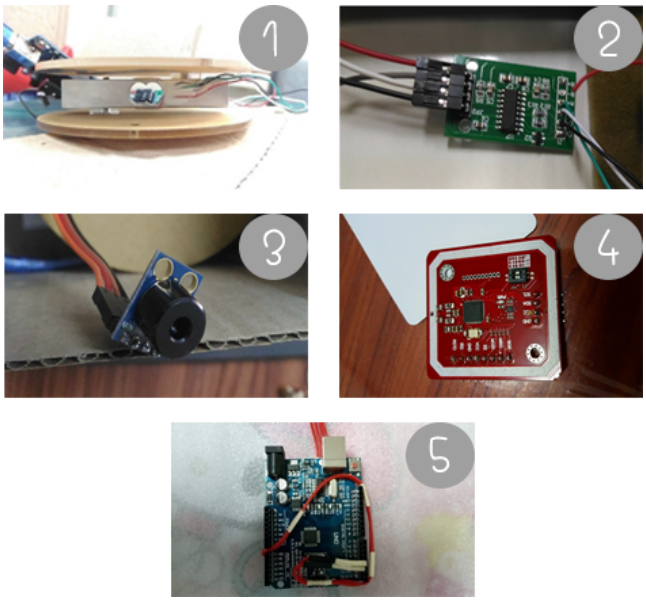


Figure 8: Reader's sensory components; (1) weight sensor (load cell) with base kit, (2) HX711 weight sensor amplifier dual channel module, (3) Arduino GY-906 infrared temperature sensor module, (4) PN532 NFC/RFID V3 module, and (5) Arduino Uno R3

2.2 Data Reader Components

Once the information from the barista is stored in the NFC tagged cup, the cup will then be placed on the plate for serving to the customer (coffee drinker). The plate is where the information or data is read and displayed, so the plate serves the reader as well as the UI. In addition, the plate itself can also produce data concerning the served coffee i.e., temperature and weight. Therefore, here we explain the sensory components of the plate (as reader's sensors) and its UI.

2.2.1 Reader's sensors. Sensory items include a weight sensor (load cell) built with base kit and used with HX711 weight sensor amplifier dual channel module, which consists of an amplifier and a precision 24-bit analog-to-digital convertor used for Arduino compatibility. Our weight sensor here can take up to 25 kg. For temperature sensing, we used Arduino GY-906 infrared temperature sensor module because its small size and low cost. Its measuring temperature range is -40C – 125C, which is suitable for coffee cup.

For data communication, we used PN532 NFC/RFID V3 module to read data from the NFC tagged cup. Lastly, an Arduino Uno R3 was used as a CPU here to administer the whole reading and related tasks for the coffee plate. All reader's sensory components are shown in Fig. 8.

2.2.2 Reader's user interface. The coffee plate itself serves as the UI where the user (coffee drinker) can observe information about the served coffee on the plate as well as interact with the graphics by clicking on some icons on the touch-screen interface. All connected reader's sensory components shown in Fig. 9 were to install inside a case – i.e., the coffee plate, which was specially designed and built. The plate was designed to have two main key areas; display area and cup placement. For the display area, we used a CSC Wisebook W803T Wifi tablet with an 8-inch screen and 210.5mm x 122.5mm x 7.9mm dimension. The cup placement area was allocated with a 5cm-radius circular space on the plate. Figures 10, 11, 12, and 13 show the sketch design of the coffee plate with its dimension, empty plate, sensory and display components placed inside the plate, and a final appearance of the plate that is fully functional.

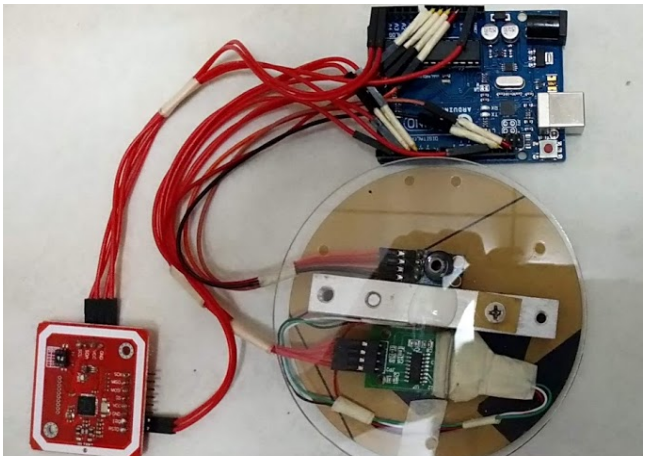


Figure 9: Connected reader's sensory components

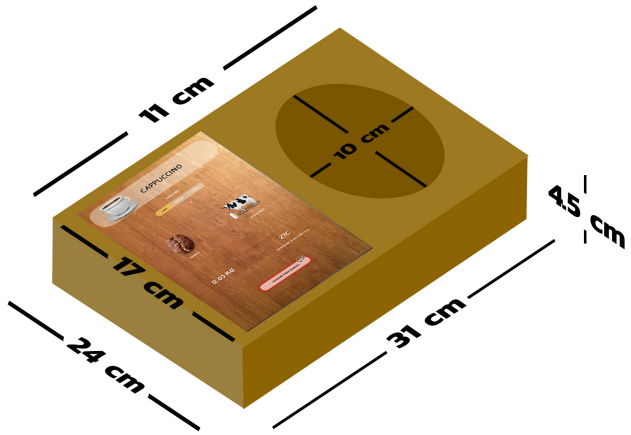


Figure 10: Sketch design of the coffee plate

Figure 11: Empty coffee plate, without sensory

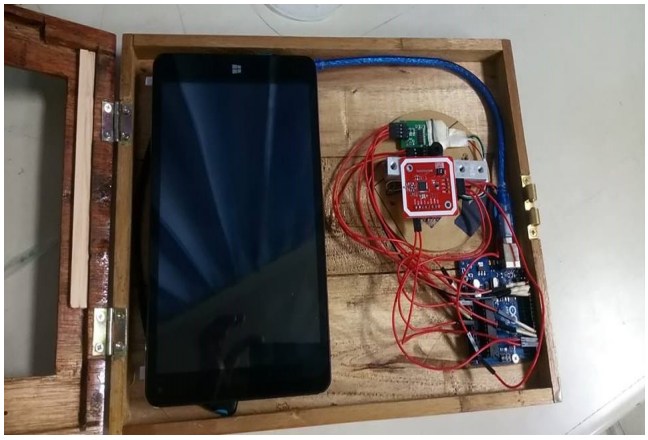


Figure 12: Coffee plate with all hardware components

Figure 13: Coffee plate in use (with a coffee cup placed on top)

The coffee plate's UI was built with Processing for user interactability. The customer (coffee drinker) is served with a cup of coffee placed on our *iCoff* plate. On the display area of the plate, the customer will see the information about the served coffee. More details about the coffee beans used and milk type can be seen by clicking on the bean's and cow's icons. The current temperature of the coffee cup is reported on the display so that the customer is aware of the dropping temperature of the coffee. Likewise, the weight of the coffee is measured and reported on the display. In addition, the customer can click on the 'Message From Barista' icon to see whether there is a message from the barista and find out what it is said. This messaging feature was developed to hopefully create a nice and cute way for social interaction between the coffee shop and its customers – adopting the product personalization concept for increasing customer royalty and hence enhancing customer experience. Figure 14 shows a snapshot of the plate's display section and it indicates the interconnected data communication links of the plate.

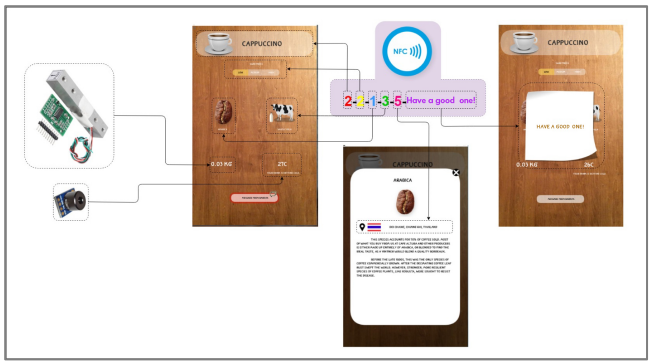


Figure 14: Interconnected links of data communication of the *iCoff* plate

3 Experimentation

To ensure the accuracy of our sensory components, we conducted preliminary experiments for testing temperature

sensing and NFC communication performance. For temperature sensing experiment, we examined temperature measurement with different cup's materials and thickness, including glass, ceramic, and paper cups, as shown in Fig. 15. We measured percentage differences between the actual temperature measured by a thermometer and the one from the *iCoff* plate. The experimental result is shown in Table 1, which suggests that the accuracy varies with the thickness of the cup regardless of the material.

Figure 15: Pictures of the cups with different materials and thickness used for temperature sensing experiment

Table 1: Experimental result of temperature sensing with different cup's materials and thickness

Cup material	*Thickness (cm)*	*Actual temperature (C)*	*Sensed temperature*	*Percentage difference*
Glass	1.20	55.81	47.61	15.27
Ceramic	0.50	58.61	52.02	11.91
Ceramic	0.35	60.33	58.32	3.39
Glass	0.25	56.55	55.78	1.37
Paper	0.10	61.78	61.25	0.86

Furthermore, we tested the NFC connectivity between the plate and the cup to see if the NFC-tagged cup is readable at different distances from the plate. As we wanted to use a cover material on top of the plate for a good appearance of the plate, so we tested the readability of the cup with and without cover material. We also examined different types of cover materials. The experimental result is shown in Table 2. The result suggests that the cup should be within 3.5 cm from the plate without cover material. We've tried using a thin wooden platter, plastic sheet, copper sheet, and aluminum sheet as the cover material. In our opinion, the wooden platter has the best appearance as it artistically looks well with the whole wooden case. We finally decided to use the wooden platter as it allowed the NFC connectivity while other materials like copper and aluminum sheets that were though thinner and having similar appearance (with brownish tones that look similar to the wooden case's color shade), they didn't allow the NFC connectivity. Another material that was tested was a plastic sheet that was friendly for the NFC connectivity but it didn't have as nice appearance as the wooden platter.

Table 2: Experimental result of NFC communication with and without cover material

Cover material	*Thickness*	*NFC communication*
None	1.0 cm	Yes
None	2.0 cm	Yes
None	3.0 cm	Yes
None	3.5 cm	Yes
None	4.0 cm	No
Wooden platter	0.35 cm	Yes
Plastic sheet	0.30 cm	Yes
Copper sheet	0.10 mm	No
Aluminum sheet	0.30 mm	No

4 Demo

For the demonstration purposes, a video clip showing how the developed *iCoff* system works is available at: https://youtu.be/285tQqoZE0E.

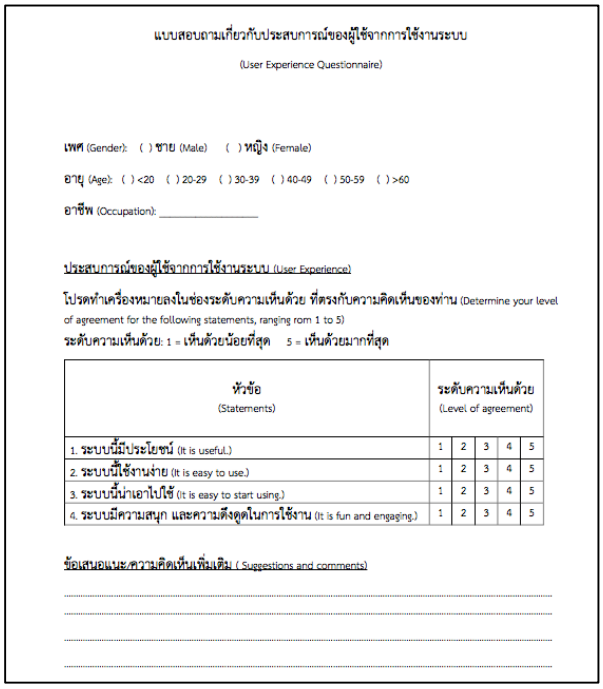
5 User Experience Study

To evaluate the developed *iCoff*, we put it into the test by the real users by conducting a user experience study. Each user was asked to use *iCoff* and then asked to answer a questionnaire (shown in Fig. 16). The survey questionnaire was designed base the Theory of Four Elements of User Experience [16], which askes to the user to rate their level of agreement with four different statements concerning the user experience with the system that include:

1. It is useful.
2. It is easy to use.
3. It is easy to start using.
4. It is fun and engaging.

There are 40 participants in total that include 20 males and 20 females, which is a mixture of ages and occupations. Each participant was asked to give a rating of agreement level to the four statement where the rating score is a 5-likert scale where 1 means the lowest level of agreement and 5 means the highest level of agreement.

Overall, the users gave the highest rating for the system being fun and engaging at 4.82, followed by being easy to start using (4.64), then being useful (4.58), and lastly being easy to use (4.20). The overall result is shown in Fig. 17. This suggests that the users appreciate the fun and engaging aspects of the system, however there is still a need for improvement especially the aspect of the system being easy to use. One of the comments from the users was "*The system should come with a user manual. It's a little bit difficult to know how to use it. I'm not sure where I can or cannot click on the plate*". Thus, a user manual can clearly be an additional part of the system in our future development.



แบบสอบถามเกี่ยวกับประสบการณ์ของผู้ใช้จากการใช้งานระบบ

(User Experience Questionnaire)

เพศ (Gender): ( ) ชาย (Male) ( ) หญิง (Female)

อายุ (Age): ( ) <20 ( ) 20-29 ( ) 30-39 ( ) 40-49 ( ) 50-59 ( ) >60

อาชีพ (Occupation): _____

ประสบการณ์ของผู้ใช้จากการใช้งานระบบ (User Experience)

โปรดทำเครื่องหมายลงในช่องระดับความเห็นด้วย ที่ตรงกับความคิดเห็นของท่าน (Determine your level of agreement for the following statements, ranging rom 1 to 5)

ระดับความเห็นด้วย: 1 = เห็นด้วยน้อยที่สุด 5 = เห็นด้วยมากที่สุด

หัวข้อ (Statements)	ระดับความเห็นด้วย (Level of agreement)				
1. ระบบนี้มีประโยชน์ (It is useful.)	1	2	3	4	5
2. ระบบนี้ใช้งานง่าย (It is easy to use.)	1	2	3	4	5
3. ระบบนี้น่าเอาไปใช้ (It is easy to start using.)	1	2	3	4	5
4. ระบบมีความสนุก และความดึงดูดในการใช้งาน (It is fun and engaging.)	1	2	3	4	5

ข้อเสนอแนะ/ความคิดเห็นเพิ่มเติม (Suggestions and comments)

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Figure 16: User experience study questionnaire

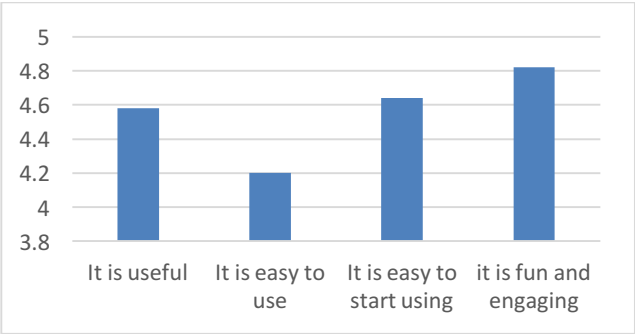

Figure 17: Overall result of the user experience study

When separate the users by gender, the result in Fig. 18 shows that both genders gave similar rating to all user experience aspects, except for the aspect of being easy to start using which was higher rated by the male users (4.77 compared to female's 4.50). The ranking across all aspects is remains the same as the overall result. One of the female users commented that "*It's interesting. I like its idea, but its look should be improved. It should look more artistic.*" Another female who was a barista said "*It's a cool idea. I think it'd take some time for me to get used to it (entering information to the cup). Can you make it easier to enter information? I'm afraid that it could slow down the service especially when the shop is busy*". This suggests that the appearance and quick data communication mechanism are among those to be considered in our future development.

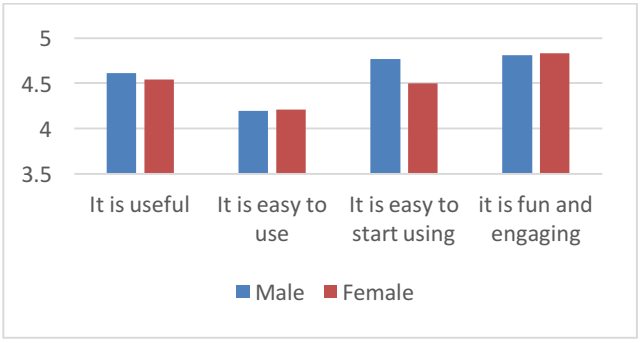

Figure 18: Result of user experience study when grouped by gender

When separate the users by age, there were 4 users who were younger than 20, 24 users who were 20-29 years old, 11 users who were 30-39 years old, five users who were 40-49 years old, and 6 users who were 50-59 years old. The result in Fig. 19 shows that the users in the youngest age group gave the highest rating to the aspect of the system being easy to use (4.50), while the users in the 20-29 age group gave the highest rating to aspect of being fun and engaging (4.79), 30-39 age group users gave the highest rating to the aspects of being useful and fun and engaging (4.92), 40-49 age group users gave the highest rating to the aspect of being fun and engaging (5.00), lastly the 50-59 age group gave the highest rating to the aspects of being useful and fun and engaging (5.00). This suggests that most users across all age groups appreciated the aspects of *iCoff* system is being useful and also being fun and engaging, especially those who over 20 years old who are mostly regular coffee goers. One of the comments from a user who was 52 years old was "*I like it. I makes my coffee shop visit more interesting and also makes me want to learn more about coffee.*" Another comment from a 48 year old customer was "*It makes me want to come back and order different coffee next time to learn more about different types of coffee*". This suggests that we are on the right track in terms of using the storytelling concept to add value to the coffee and create the customer royalty.

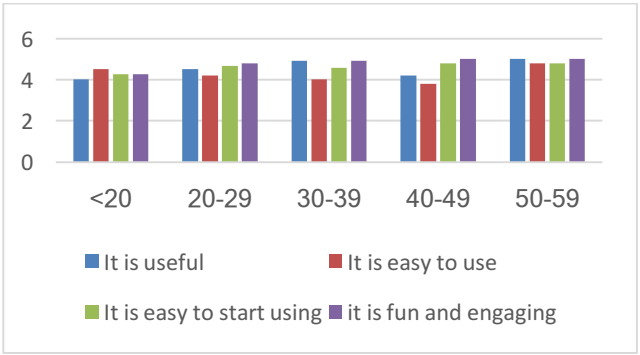

Figure 19: Result of user experience study when grouped by age

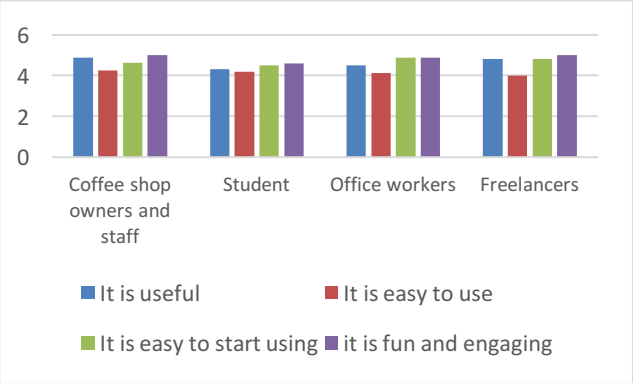

Figure 20: Result of user experience study when grouped by occupation

When separated by occupation, there were 16 coffee shop owners and staff, 20 students, eight office workers, and six freelancers. The result in Fig. 20 shows that the coffee shop owners and staff gave the highest rating among other occupations to the aspect of the system is being useful as well as the aspect of being fun and engaging. Students gave slightly lower ratings compared other occupations to all aspects. One of the coffee shop staff commented that "*I think the shop can benefit from it. It still needs an improvement in its appearance design. Its functionalities could also be improved with more exciting features and user instructions*". A coffee shop owner commented that "*It's an exciting new service that we could have in our shop, however it may be costly at the same time to have several iCoff plates*". A coffee shop customer who was a freelancer and regular coffee goer commented that "*I would definitely use it. It looks interesting and fun to use for the first timer, but I'm not sure if this plate would attract people to use it over and over again. Unless there are more information or perhaps feature or something that makes people want to interact with it again and again.*" These are very useful and constructive comments from the participants, which suggest ways to improve our system in the future, which may include new designs for the plate and UI, new attractive features e.g., gamification, social interaction, social media, and so on.

6 Conclusion

This paper presents a development of an intelligent coffee plate system called *iCoff* that aims at improving customer experience in a coffee shop, which is a key for customer royalty. Its design and development were inspired by the concept of storytelling and pervasive computing. Storytelling has been shown to be an innovative way to engage customers to achieve their loyalty, while pervasive computing is applied to create user interaction as a service that allows the user (i.e., coffee drinker) to receive the coffee details (story) as well as a short message from a barista through an interactive coffee plate. The *iCoff* system allows the barista to insert the coffee information such as coffee type, milk type, and beans used as well as a short message for the customer into a serving cup. The inserted information will then be processed by the plate, which is equipped with sensors that allows the customer to see the information about the served coffee as well as its current temperature and weight.

Our system's sensory components were tested in preliminary experiments. A user experience study was also conducted to evaluate the system from the aspect of its usability. Overall, the users highly perceived its usefulness and its aspect of being fun and engaging. There were many useful and constructive comments from the study's participants, which suggest for more artistic design of the plate and user interface appearances, as well as an addition of user manual and social interaction features. These are among many to be considered for our future development.

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