High Fidelity UI Design of Smart Fridge

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INTRODUCTION

Modern appliances are probably the most representative improvement of industry and technology. Their meaning is not just confined to improving the life quality of individuals, but also has reshaped our society. According to research (Université deMontréal [1], the emergence of appliances has liberated women from housework to the workforce in the mid-20th century, which helped build equality between men and women, and also made a giant leap in social productivity. But currently, although they have profoundly impacted our lives and society, their functionality seems to have reached a limit. Luckily, the idea of the internet of things(IoT) can change such a situation. IoT simply means connecting everything to the internet, so the internet data center can collect the data and provide more services to the user. The existing appliances already have so many benefits for us and society. By using IoT, those appliances can act as intelligent assistants, which will further impact the overall community. Take refrigerators as an example; by connecting them to the internet, we can remotely control the temperature, monitor the food condition, record food consumption, and provide a healthy diet. Therefore, a problem is also raised here, how do we interact with such an intelligent refrigerator? The answer is that we need a brand-new user interface that can bridge users and the refrigerator, so the interaction in between can become smoother and more convenient.

RELATED WORK

So far, we can clearly see the idea of a new generation of appliances, but we still have no idea what kind of user interface should it be? Starting from the perspective of function, our UI should contain the basic function of the refrigerator, like adjusting the temperature. On top of that, the UI can also visualize the storage inside the fridge. However, that should not be all of the functions we have. Some article[2] points out that some people like to use the fridge bulletin boards to publish messages to other people who live with them, also some people use the top of the fridge to place some other things like plate, flowerpot or container, and some are having a difficult time in organizing the refrigerator. Some of the existing UI only provide the basic functionality of the refrigerator[3]; however, for developing an appliance UI that can enhance our user experience, we should also consider how can this UI assist users in many different cases when they are using the appliance, which means we need to do a situated study with our users, to see what are the possible features we can add to our UI.

In another perspective, Relevant research[4](Corcoran, 1998) suggests that users expect these new technologies should allow them to control their appliances remotely, in four ways:

- A web browser from a PC or pad
- On their mobile device, like phone, smartwatch
- using a TV set, remoter
- a personal organizer (AI) connecting to their appliance through the internet

The research also points out users expect such a user interface running across multiple devices can maintain a uniform style, which ideally has no buttons or additional hardware, so it can work on other devices, like phone and PC. In our case, the refrigerator can be totally controlled by a single touch screen, and also by choosing to implement it as a web app, so we can smoothly transit the UI into other devices that can open browsers. However, such a UI system has not yet reached the perfect standard and there is an issue with it.

There is a problem with the touch screens on appliances is the weak feedback to the user. When a user is using the appliances, the physical buttons, like knob switch, membrane button, or toggle switch, can provide them with strong physical feedback; such feedback is usually made up of sound, friction and pressure. Strong tangible feedback is an important factor when the user is choosing their appliances[5](Fujiwara et al., 2018). In comparison, touch screens can only provide very limited feedback to the user; for solving this issue, we need to consider how our user interface can enhance the feedback.

Research from Arizona State University[6] (Arizona State University, nd) suggests we should add a well-designed sounds system into our UI. Whenever a user is using the appliance, these sound systems can dynamically respond to them. The research defines a well-designed sounds system as; first, each sound in the system should convey certain information to the user, like warning, success or failure. If a sound can't carry any meaning, then it is unnecessary. Secondly, the sound system should sound comfortable and match the purpose of the appliance. Just having a sound system in the UI is not sufficient. The UI visual design is also important, website development usually represents CSS animation. A great UI animation can help the user construct a mental model about how the system is working, and it furtherly strengthens the feedback of the things the user is interacting with[5]. For example, in our case, one animation we can think of is using a dynamic pop up navigation bar to transit users' attention from an icon to its detailed description.

Some of the existing solutions we have seen on smart refrigerators[7] have wonderful animation, but the sound system is lacking; therefore, some users may wonder if the refrigerator is responding to them when they are configuring the refrigerator. Another existing solution we found is haptic, some refrigerators[7] use haptic to augment

the sensory feedback, haptic can provide a very strong sensation to the user, so users can really feel like the UI is responding to them[8].

In conclusion, designing the user interface for any appliance, in our case is, the refrigerator, should not just confine to the basic function of the appliance, we need to study our appliance's user and make the UI can satisfy their needs, and also we should consider how to let the UI maintain the same style running on multiple devices and also according to their usage, as well as how to design a sound system and the animation, so they can provide more feedback with their users. Those requirements make us need to think of some unique designs for the UI system on the refrigerator and also consider how we can integrate some currently existing elements from other UIs into it.

PROBLEM DESCRIPTION OR DESIGN CONCEPT

Nowadays, more and more people tend to eat less healthily. Students who are busy studying and spend most of their time at home are facing issues like obesity and a sedentary lifestyle. Research shows that college students tend to eat unhealthily [10], and this is due to a lack of time in selecting the food and also no time in learning how to eat healthier. Meanwhile, the research further points out that an unhealthy diet is also a factor that leads to fatigue, inattention, and other adverse side effects, which exacerbates their ability in the study and leads to even lower grades [11].

Similarly, in the working class, the national study found that the work environment is overwhelming with poor food choices which adds unnecessary calories to an employee's diet. To make matters worse, those are empty calories instead of nutrient-rich ones. Much of the food in the workplace is high in sodium, sugar, bad fats, and refined grains. Often, healthy options like fresh fruit and unprocessed food are in short supply [12]. As a result, people would find it hard to acquire an abundant source of nutrients.

In order to hear the details of how they describe the problem, we decided to get in touch with them. We decide to contact and interview our classmates to find the students' opinions and gain feedback from the working class by posting in forums and interviewing our families and friends in careers.

For the design concept, we decide to create a solution that will integrate into the users' life for the problem we discussed above. It should help the users to make an efficient and healthy food management process.

USER CHARACTERIZATION

In terms of age, people between 18 and 34 are our main target group. According to the research, 49 percent of people in this age group are concerned about the health of their food [13]. The improved refrigerator can meet their needs because it is designed to help people eat healthily.We recently had an interview with an engineering student who is experiencing an extremely burdened workload. He said he had 7 courses this semester and 5 lessons a day. It became usual for him to have two exams and three to four assignments due each week. Under this stressful workload, he said that he does not have enough time to learn how to make healthy food. When he was hungry, he simply used an air fryer to heat some fries and crispy chicken. He said that compared with spending time on studying cooking healthy food, air fries took less and less time to appease his hunger and make him quickly get back to his work.

People who are adept at cooking and are more receptive to new things use this new refrigerator with high proficiency. Because these people know more about food than others, their learning costs will be lower. They can also explore the functions of the new refrigerator through interest. This allows the refrigerator to be fully utilized.

A refrigerator is a necessary facility in the home. The gender of the users is often not fixed. Since food is a daily necessity, the smart fridge can be used by any gender. Our team had an interview with a busy white-collar, she said that: "This is an innovative idea that combines information like the state for the food and cooking recipes within a refrigerator. The refrigerator could automatically generate healthy recipes based on the food in the fridge. This brilliant idea saves the time that is spent on finding recipes by target users. On the other hand, I was curious about how the refrigerator records every food after shopping and how the refrigerator could notify me about the state of the food. I look forward to your team's next achievements!"

DESIGN

Our high-fidelity design is created based on our low-fidelity design we made back in assignment 2. With the help of the previous Figma design, aim to make a result that employs the design principles of visibility, attractiveness, consistency, and feedback.

For building the prototype, we chose to use HTML and CSS to create the web page and combine them with react.js. This is due to that: the web page is a great method to create a connection between the UI and the users since we can make various interactive features including icons and actions by them. Moreover, our high-fidelity design origins from our Figma prototype. Figma is an HTML-based design tool, and it is easy to transfer some of our elements in Figma to our high-fidelity design which is made by HTML and CSS.

As we discussed back in the previous assignment, our UI contains two modes: standby mode and active mode. The standby mode will be displayed while the user is not interacting with the UI. The standby mode is highly different from the original design. Our original design is a simple draft that contains all the needed information. We create our first vision of hi-fidelity design (as in figure 2) based on our original low-fidelity design (as in figure 1). However, after having a discussion with our TA and reviewing GUI design lectures in W6, we found its color unpleasant to look at and its layout made the data hard to understand. That's why we remake the standby mode by focusing on attractiveness and visibility. The background is replaced by a photo of a snow berg giving the user an expression of cold which is connected to the concept of the fridge and this kind of aesthetic appeal is more attractive

compared to the previous vision. We also redo the layout to make it clearer and easier on the eyes.

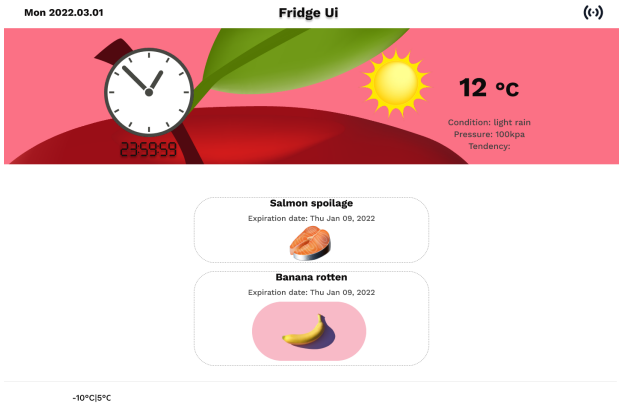

Figure 1. Low-fidelity Standby mode

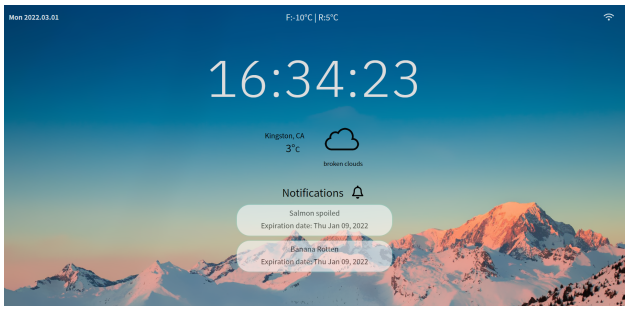

Figure 2. Hi-fidelity Standby mode

The active mode is based on the low-fid prototype. Our design focuses on presenting special information, including temperature modification, notification, recommendation recipes, and notepad, employing Visibility and consistency. First of all to make the UI easy to learn, use and remember by the users, we take consistency seriously throughout the active mode. Most of the components of this mode have similar shapes and colors to give an expression of they are similar elements to the users.

We consider affordance mostly in temperature and notepad, while we use high visibility controls such as a slider to adjust the temperature and the pad for typing notes (Figure 5). These controls are identical to the control in reality giving obvious perceptual clues to the user to lower the learnability of the UI. Most of the components in this mode are similar to our original design because our previous design is good enough to be displayed, but we re-do the food bar section in this mode. In the original vision, all the food items are on the left of the homepage, but we find that is not enough if it contains many food items in the fridge. We implement a secondary page that can see all the detailed information about every food item in the fridge, and you can open it by clicking the 3-dots icon at the bottom.

This notepad also greatly satisfied our target users, students, and working class. When we were doing the user evaluation, some of them told us that when they lived with other tenants, they liked to message each other with stickers on the fridge in the morning, such as shopping lists, trash removal, and kitchen management information. This can greatly reduce the embarrassment of direct communication with each other; as they think it is not easy to tell people to do things; but by using Notepad (as in figure 3), they can let people know about something without directly telling.

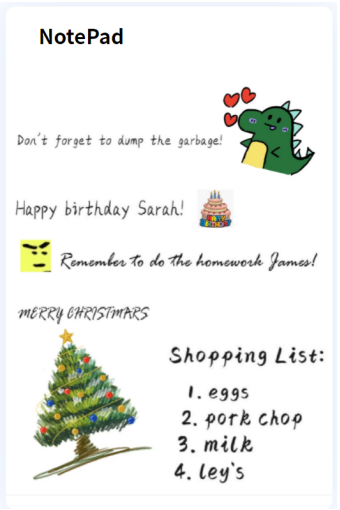

Figure 3. NotePad

At the same time, some workers and students return to home very late, and if they turn on the lights, it will affect other roommates; so they must use the refrigerator without lights in order to get the food in the fridge. So we designed a dark mode (as in figure 4) so that it won't glare at their eyes in the dark situation, and they can use the refrigerator without turning on the lights.

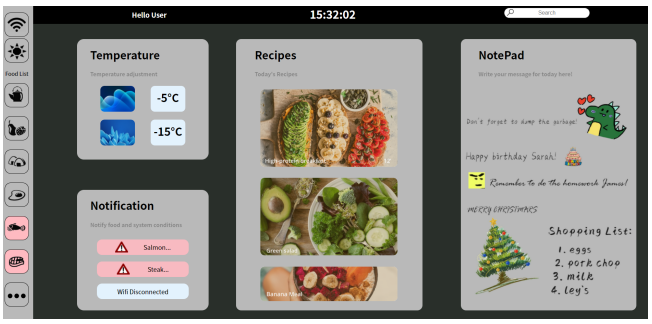

Figure 4. Dark mode

We also have considered the feedback during the UI design. When different components or buttons are clicked on the touch screen, users can hear different audio feedback from the UI. For example, we simulated the sound of lights turning on and off to let users know if they were turning on or off Dark mode. This tells users what they have done. Also, the different audio can let users know the function of different buttons. In order to hear the audio feedback immediately, we have reduced the latency of audio to meet user requirements. Therefore, users will have a strong sense of what actions they are taking.

After comparing the original proposal, we think that some parts of this report are different from the original proposal. The reason for this is that our original proposal is not perfect to satisfy users' requirements. One of their requirements is users' preference for straightforward interactions. According to the original proposal, although physical buttons as input devices can provide stronger tactile feedback, the touch screen as an interactive device

can not only provide user input to the system, but also the system can provide output to the user in the form of visual feedback. Therefore, to fulfill the demand for the touch screen, we focus on the visual feedback and reduce the tactile feedback. For example, in our Hi-fidelity design, when the user adjusts the temperature of the refrigerator, the value of the temperature changes with the slider. (Figure 5) This real-time visual feedback is a better method than using tactile feedback because in this case, visual feedback gives users a more direct user experience. Based on these, the changes to the original proposal are reasonable in our opinion.

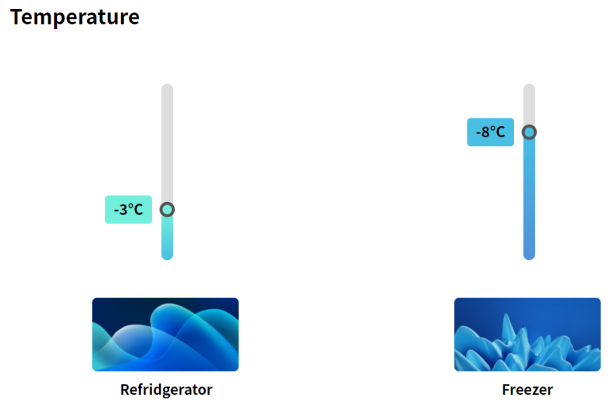

Figure 5. Temperature Adjustment

On the technical accomplishment, we implement interactive design through programming. This includes a synthesis utilization of HTML, CSS, and JavaScript. In addition, we use React to show our design to users. Therefore, we understand that it is very effective to choose different computer languages based on design.

HI-FI DEVELOPMENT

We have accomplished over 95% of the project as we proposed initially. Thanks to the help from the cutting-edge web development framework - React.js we have made astonishing accomplishments on the web browser. Since we are aiming at stimulating the idea of "smart fridge UI" on the web page, we do not include any hardware device except our pc device.

During our development, we have not met any significant bugs or errors. The only concerns that arise is the unexpected element layout and difficulty in aligning objects in the webpage. This is caused by non-standard coding structure and unfamiliarity of web developing language. Since none of us are professional web developers and none of us could write well formulaic code, the code inside the CSS file looks very messy which results in duplicate naming problems. For example, we have two different notification boxes on two pages. (as in figure 6) They have similar names and when we are declaring the class name of the sub-attributes, overlapping class names might arise. We have to make sure that each attribute should have its unique class name in order to keep each attribute independent from other irrelevant attributes.

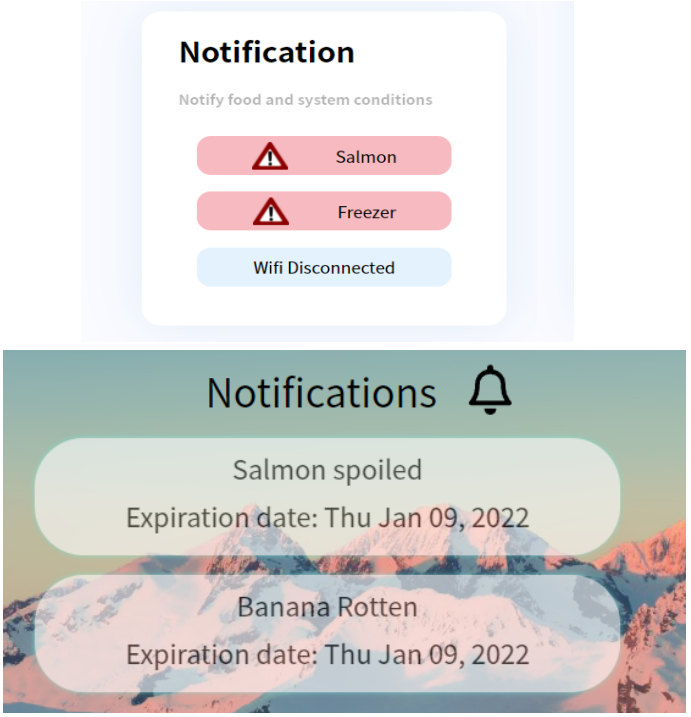

Figure 6. Notification Box in Standby mode (down) and Active mode (up)

There are some limitations that occur as well during development. Since there is only one of the people who is familiar with React.js, the rest of the team implement Javascript during the development. However, Javascript could not be directly inserted into React.js project. A function called "useEffect" is used to adapt the implementation of JavaScript. This could cause side effects like React.js takes extra time to operate [13] and it takes a bit longer to load for those attributes who apply this function.

There are several reasons why our product does not provide the operation of a true product. First of all, it is almost impossible for us to create an actual fridge user interface on a real fridge. The cost of either learning how to use proper programming language to code actual fridge UI or purchasing a fridge is tremendous. Thus, we can not integrate the full sound system effect into our UI, like convoying failure or success sound, as well as making our project to be compatible in every device.

Besides that, we made some animations based on the "hover" function from CSS. However, in terms of a user touch screen interface, there is no cursor that could be used to hover over icons or images to activate the "hover" animation.

As for the third party we have used in our development, we use Visual Studio Code as our main development environment. We choose HTML, CSS and JavaScript as our programming language and select React.js framework as well. All the amazing icons are found from a website called "font awesome" and we make some hand drawings in the notepad section.

Finally, we have successfully deployed React.js on Github page so our project could be automatically seen from a single URL. Please check our project by using the following link: https://blairli.github.io/smart-fridge/ Be sure to run this link using Chrome on laptop or desktop device, and also set the zoom view to 100% (default), as well as make sure to allow the web page to get your current location which our weather module need location information to generate weather report (as in figure 7).

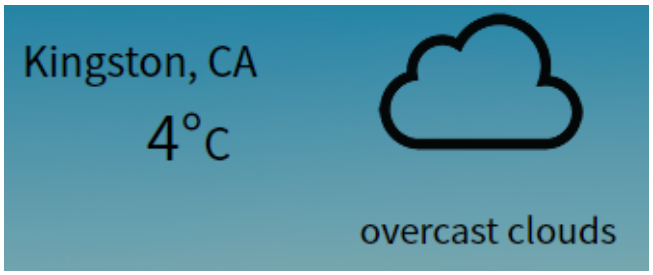

Figure 7. Weather report module

USAGE SCENARIO

Eva

College student

Age: 20

Gender: Female

Marital status: Single

Location: Kingston

Device(s): iPhone and MacBook

Eva's Scenario

Eva is a college student. She has just started her college life. She enjoys having fresh and healthy food. She loves cooking and tends to store a large amount of food to make sure she always has food to cook. She is not very good with complex electronics.

After she goes to college, she starts to spend most of her time studying, and both her lunch and dinner become disorganized due to the lack of time. Sometimes, she is confused about what or how much she has stored in her fridge since now most of her effort is used in studying. Sometimes, she cannot even remember some food she has in the fridge until it goes bad. She needs something that helps her to manage her foodstuff and keep track of her food in the fridge. She wants something that will constantly report the state of the food and notify her when the food is about to be rotten. For the UI, she asks for an easy and straightforward UI since she does not like complex Systems. She hopes to have a UI similar to her iPhone because that will make her easy to learn.

John

Engineer, workout enthusiast

Age: 27

Gender: male

Marital status: Single

Location: Toronto

Device(s): Samsung galaxy and an Asus with Windows 11

John's Scenario

John is an Engineer in Toronto. He is a fitness enthusiast who takes his diet seriously. He has a very heavy workload that makes him have to finish his dinner quickly at his house in order to leave enough time for him to rest. Moreover, John is a skilled engineer who is able to process large amounts of data and he is able to handle complicated systems.

John is looking for a system or UI to help him decide what to eat and how to eat. John always spends a lot of time deciding what kind of food he eats for dinner (ps. He usually eats a sandwich at the office for lunch) and spends even longer to come up with a receipt, after that he will calculate the energy of that receipt to make sure that it can be part of his healthy diet. John does not have very high requirements on the learnability of the UI since he is an engineer, and he is able to operate some very complicated Systems. However, he wants his UI to be good-looking and practical when he is not interacting with it, so the UI can also be a decoration in his house.

USER EVALUATION

Method

Customer evaluation and experience are undoubtedly the primary criteria for measuring product quality. Pre-market questionnaires also need to be designed. Our method is divided into three broad frameworks, namely target group, interview specifications and interview questions. First, we need to identify the users of the product. In terms of age, people between the ages of 18 and 34 are our main target group. People in this age group are mostly concerned about the health of their food, and their ability to accept new things is relatively strong. Once they understand the basic operation, they can quickly use it proficiently. Their learning costs are relatively low, they are also curious about new things, and they can make full use of the functions we designed for users. The gender of the user is not fixed, because the user of the refrigerator is not limited to a specific gender. College students and the working class are more suitable groups for refrigerators, they have the most exposure to refrigerators and are usually busy. Due to work or study pressure and other reasons, these people often eat irregularly, and it is normal to have one meal a day. The consequence of this behavior is that the body's intake of nutrients is lacking or unbalanced, which leads to a slow decline in physical condition unknowingly.

User interview specifications also need to be designed. The respondents are about 30 people, most of which are college students, followed by workers. Most of the interviews were conducted in libraries where students gathered, or coffee shops where workers gathered, where people generally had the patience and time to complete the survey. Considering that most users do not have the patience to complete a long survey and are resistant to a long interview, we will limit

the interview time to 7 minutes and no more than 10 minutes. Before the interview, we will inform the interviewee of how the information is collected and the purpose of the collected data. We will also, with the consent of the user, use audio or screen recording to store information for subsequent group discussion and analysis. Interviewee can choose whether the information filled in can be used for research and made public. When users agree to be interviewed and abide by these terms, we have two interview methods for users to choose from. The first type is face-to-face interview, in which a team member communicates with the user and shows the high-fidelity model to the user with the device. Meanwhile, information is collected by recording the communication content. The other is to send the survey chain to the user, and the user will complete the questionnaire and experience the high-fidelity model through their own devices. We will summarize and analyze the data received in the background through our platform.

The most important part is to determine the type of question and the underlying purpose of the survey. Our question needs to revolve around two core points, convenience and practicality. There are three levels of questions in the survey, and the content of the inquiry is also from shallow to deep. The first level is the collection of user information. At this stage, users will not see the high-fidelity model we made. Users can choose to skip, and the questions include the user's name, age, gender, whether they own a refrigerator, how well they know the smart refrigerator interface, how often the refrigerator is used, and expectations for refrigerator functions. These questions can help us understand how users relate to refrigerators and what they can expect from refrigerators. The second level is to show users our high-fidelity model. We will let users write their first impression of the product, including visual, functional and user experience. Users can interact with the interface and freely explore the features we have developed. The content of the answer is not limited, and it is completely written by the user. The purpose of this stage is to obtain the user's evaluation of our product, evaluate the feasibility of the product, and prepare for the subsequent upgrade. The final stage is to ask users about the problems they have with the refrigerator and to offer some suggestions for modifications to the displayed product. At the same time, we also need users to evaluate our products from the usability principles, which is learnability, ease of use, flexibility, and satisfaction. Then give our product a score. Five points are full and one is the lowest. This feedback allows us to avoid some existing problems when designing, and to upgrade and improve existing products.

Finding

There is no perfect product, good products are constantly updated and optimized. According to the survey, most users have already understood the concept of smart refrigerators. Different user groups have various comments on our products. Our high-fidelity prototype is fully interactive while meeting some of our user experience goals. But in contrast, when different users do unexpected operations, our system also has some unknown errors. In conclusion, the whole system is somewhat perfect, but there are still some defects, which will show in detail in the following paragraphs.

First, we will discuss some positive effects brought by the questionnaire and the discovery of user preferences. Most users feel that our system is very easy to learn, easy to use and has a strong memory in a short time. There are three aspects of user interest. The first point is that users are satisfied with the basic functions of the refrigerator. About 85% of them feel that the current functions can satisfy their use, and bring some convenience to their lives. These features include food details such as weight, calories, quantity, shelf life, etc. As well as the weather and time display on the standby mode of the refrigerator, it can help them quickly obtain time information when they are busy, or obtain weather information before going out.

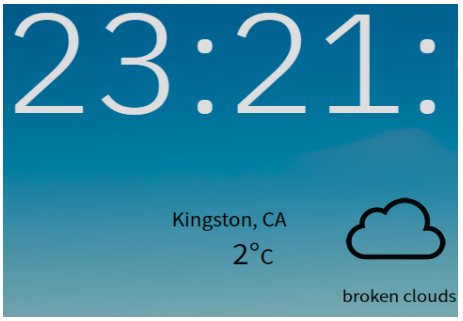

Figure 8. Time display and Weather report module

These details make users feel pleasurable and surprising. The second point is the interaction process with the refrigerator. Users can click on different modules to jump to different pages. Many people have highlighted the button that can be dragged in the temperature control module, the navbar that can display food details on the left side of the main interface, and Notepad on the right side of the main interface. Users are very interested in these three designs, some feel that this approach gives them a sense of engagement and satisfaction, and they find this design to be creative and entertaining.

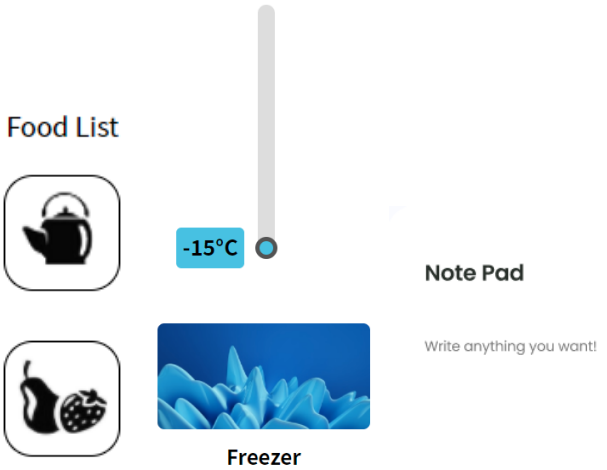

Figure 9,10,11. Navbar, Slide button, Notepad

The third point is the recipe module, which is important for many students to be able to make different dishes without spending extra time looking them up online. This module

makes users feel motivated. There are some individual users who mentioned the greeting of the main interface, which gave them a sense of being respected. In conclusion, compared with traditional refrigerators and similar products, our product does have strong targeted functions, which are important indicators of customer satisfaction.

This paragraph details some of the problems users mentioned and the improvements they hoped for. There are several situations. The first is that when the user has opened a page and clicks on other modules, the system will not close the current page but will overlap the two pages, and the operating system will get stuck if you do this multiple times. We didn't consider that users would open another page before closing one, which is a serious problem. The second is the display problem implemented by the standby mode page. Our time display is not very obvious and is not displaying seconds, which makes some users who need accurate timing for cooking feel very inconvenient. They need to spend extra time counting. Although this lack of design is not a serious fault, it is also an insufficient reflection of the user experience. The third point is notepad. Some users are not interested in the fonts, they felt that this kind of lifeless font didn't give people a sense of motivation and interaction, and the way they can only input text also makes them feel that their operations are restricted, and they are very dissatisfied with this. The fourth point is the dark mode. Some users hope that they will not be stimulated by the dazzling lights when they open the refrigerator at night to find things. The fifth point is that the standby mode interface gives users a feeling of immaturity. We guess that the use of colors is not skilled enough, and the mixture of various colors affects the user's visual experience. The entire interface does not have a prominent position, and each function occupies a similar position on the page. It is hard for the user to distinguish which is the main message the designer wants to convey to them. The sixth point is the display of food. Many users report that it is very troublesome and time-consuming to find the food in the refrigerator by sliding down the navbar on the left. It is hoped that a page can be displayed independently to display all the food and their detailed information. It seems to be very necessary, and it is also a reflection of our lack of comprehensive consideration.

In general, our users are more concerned about the functional problems, and there is not much mention of the visual problems, but this does not mean that we do not need to make a more attractive page, we should improve the user interface in the main process of improving the function.

Recommendations

Firstly, we adjusted the time display of standby mode, increased the displayed information, and enlarged the font, so that users could see the time more accurately.

Figure 12. Time display

Meanwhile, a panorama with single color was adopted as the background display, which avoided the chaotic use of colors and made the system consistent. Then, we made some modules smaller and gave titles to key modules to make it easier for users to identify key features. The second change is a bug fix for the display page. Now, when a user opens a page, even if they click on another module, the system will close the current page first to free up memory before proceeding to the next step. This change prevents the system from entering a deadlock state and is also more user-friendly. The third change is notepad, which now allows users to choose where to type fonts. The font styles can be either system-provided or handwritten, and users can add images or emoticons, making the notepad feel vibrant and interactive. The fourth change is the improvement of the dark mode. The system will not use a completely black background, but choose a combination of gray and black. This method improves the ornamental value of the page and facilitates the user to interact with the refrigerator comfortably. The fifth change is to change the display method of the food stored in the refrigerator. We have added a new page, which can be opened through the button at the bottom of the left function bar. Then there is a separate page showing the food currently stored in the refrigerator. Users can view more types by pulling down the sliding bar on the right side of the page. Expired food will also be marked in red to alert users.

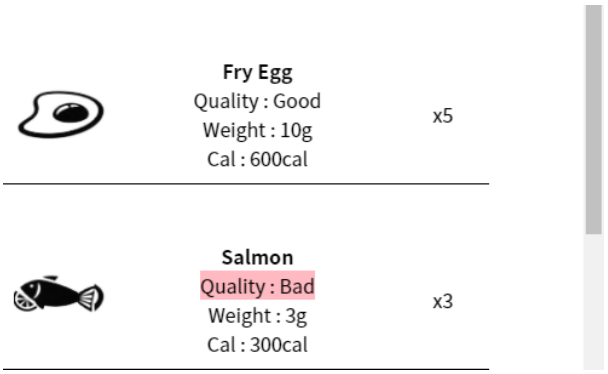

Figure 13. Food item display

DISCUSSION & REFLECTION

Developing a UI system that can enhance the user experience of using the refrigerator is our goal in this project; based on the further investigation of user evaluation and demonstration of the Hi-Fi prototype, we found a key insight from our interviewees that sometimes an appliance is more than an appliance, for example, a refrigerator can be used in ways more than the basic functions it provides, which we will discuss in the following paragraph. And by implementing the UI that can satisfy our users, we found key learning that can apply to all other appliance UI systems, “A good appliance UI should be able to integrate into the user's daily life.”

If we are able to start it again, the first thing is we will try our best to enumerate more cases on how people will use the refrigerator, as by reviewing the previous work we had, we found that we initially barely think about how our users will use our UI, and we only think about designing the UI itself, like how strong the feedback it can be, what design

style we should use and what color should pick; those factors can make our UI satisfiable in looking, but it will not be satisfiable in using. Until more user evaluation is done, we realize this issue, and we really start thinking about what the user really cares about in an appliance UI, as mentioned above, the answer is functionality. For example, in our case, some users like to leave messages on the refrigerator for late risers in the morning by using sticky notes, some would like to take some food from the fridge at mid-night and some need an accurate time control during cooking (more details in user evaluation). Thus, those requirements make us start thinking about how our UI can fit in those scenarios, then we design a hand writable notepad for writing and displaying messages, and a dark mode that can protect the user's eye during the night and we add a second unit after minutes when displaying the time.

As we did not realize this in the beginning, we can't find out more about such usage of the refrigerator and make them part of our UI system. Just with the current implementation, we revisit our previous evaluated users, all of them found very surprised that our UI can help them in those cases, and they all believe such a fridge UI perfectly fit their daily life; thus, it makes us further convinced that integrating the refrigerator UI into user's daily life is the essential key for enhancing the user experience. If we have more time to investigate more of these, our fridge UI can further satisfy our target users and even bring habits of using refrigerators from different users to others.

Besides the changes in key learning, if starting again, we will also spend more time using the CSS framework, as before this course only one of our teammates knew using web techs like React, CSS, and HTML. The rest of us spend tons of time learning and coding the raw CSS, JSX, Javascript, and HTML, we also pull off lots of issues using React-Hooks. But in the end, we found that using some CSS frameworks like bootstrap can reduce 90% of our workload, coding in CSS is difficult, and we have made lots of compromises on the design due to the inability in using CSS (more details in Hi-Fi development).

For designers of other appliance UIs, our advice is divided into two parts; in designing a UI system for the refrigerator, it is important to have great art design and provide tangible feedback, but a situated study on target users is also essential, without it, we can never know what target users want and how our UI system can satisfy them. Therefore, it is important to always spend time learning how your users use the appliances, and according to findings, making the appliances UI can also satisfy that or even better. So the user can feel the appliance UI fit in their life, which enhances the user experience of using an appliance.

In implementing the UI, due to our very limited experience in web tech, we will not suggest what tools are the best, but if using the CSS, remember to name class and id name differently, as following more CSS code you added, it will be difficult to adjust if you don't split them well in the beginning, in our case, we are forced to give up implementing some design due to this reason.

In conclusion, implementing the UI requires great team management skills on code, including version control, lower the function coupling; besides that, when designing the UI for a refrigerator, it is important to put the effort into studying the user, it is an essential step for making a great UI for refrigerators; as the specialty of the refrigerator, in development of the UI system, we should think how can our refrigerator UI integrates into user's life. This is also the design recommendation for other appliance UI designers.

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