AEEM 6099 Systems Engineering & Analysis

Shopping Assistant System

Main Project - Milestone 2

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1. Project Description

This project proposes a shopping assistant system aiming to help international tourists achieve a better shopping experience in big malls like Super Brand Mall (SBM) Shanghai. A mobile system integrating with information service will be developed for assisting the international tourists to do shopping in big malls. Thus, the system will be able to provide convenience to international tourists and save their time on a tight shopping schedule.

2. Project Summary

2.1 Name

Shopping Assistant System

2.2 Team

Company “YY” (Service Solution Provider)

2.3 Customer

International Tourists (in big malls)

2.4 Problem to solve

International tourists usually have a tight schedule and waste a lot of time on searching right information, even lost their way in big malls as they are in a strange place surrounding by people who do not speak their native language. This project is aiming to improve the shopping experience of international tourists in big malls, like SBM Shanghai by making their shopping convenient and efficient. And the same solution could be applied to public places where the international tourists usually visit, such as airport, train station, and amusement park.

2.5 System-of-systems context

This project will develop a system for providing unique experience to international tourists, and will benefit big malls, airports, train stations who want to attract more international tourists, further, to improve the image of a tourist city.

2.6 Goal and objectives:

The goal of this project is to build a system to help improve the shopping experience of international tourists in big malls like SBM Shanghai by making their shopping convenient, time saving and energy saving. The system shall be easy to be interacted with to reduce the wasting effort caused by communication in different languages, finding the right information of desired product and service, finding the correct position of the store they want to go and carrying the heavy bags during long hour shopping.

3. System operational and maintenance function flows

3.1 Operational functional flow block diagram for the system

3.1.1 First level of operation functional flow

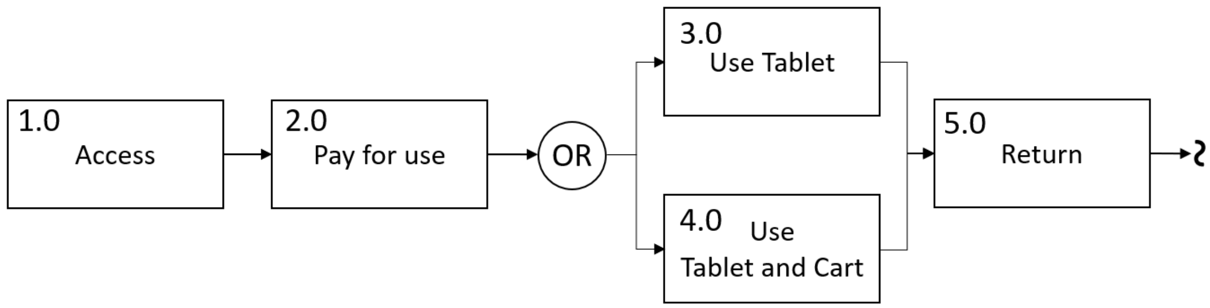


Figure 1: Operational functional flow block

Access

Sufficient amount of equipment shall be distributed in SBM Shanghai in order to give easy accessibility to users. In our plan, we will distribute 100~200 equipment including tablet computers and cart device at the major entries of the SBM shanghai. Considering some of the users will use tablet computer without the cart device, the ratio of amount of tablet computers to cart device is 1.5.

Pay for use

Users need to pay for using the equipment. Different payment methods will be provided to meet the various requirements from different users. The system shall provide methods of paying by mobile phone, credit card/debit card and cash. They could pay for use specific amount time, for example, half hour, 1 hour, 2 hours and 3 hours. Or they could pay for unlimited time until they return the equipment, but this payment only limited with using credit card.

Use tablet

Users could pay for only use the tablet computers, and the functions they will use will not include the cart device for carrying their bags. The tablet computer could be used for translation, searching product/service information and navigation.

Use tablet and cart

Users could pay for use both tablet computers and the cart device. The tablet computer will be used as a controller of the cart device. Thus, they are able to use the full functions provided by the system.

Return

Once users decide to end the journey, they shall be able to return the equipment easily. They could return the tablet computer at any exits/entries of the mall if they don't use the cart device. Or they could attach the tablet computer on the cart device and leave the equipment at appropriate spot in the mall, they are not required to return the equipment at the exits/entries of the mall.

3.1.2 Interact with tablet computer flow block

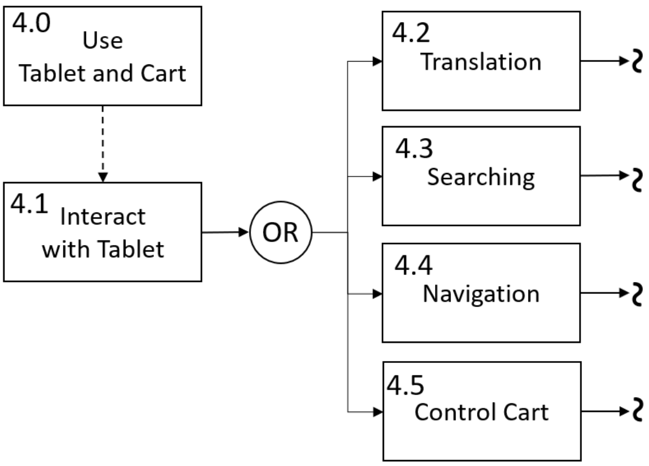


Figure 2: Interact with Tablet Computer

Once users start to use the table computer and the cart device, the first thing they need to do is set the language of interacting with tablet computer. The system will support major languages such as English, Chinese, French, Japanese, Korean. Then users could choose to use either the translation service, information searching service or navigation service. They could use the tablet to control cart device by turning on the automatic control or turning off the automatic control in order to manually control the cart device.

Translation

Translation service will provide service of translating product information, location information to the language they preferred. For example, when users need to know the items in the food menu, they only need to shoot the menu with the camera on the tablet computer. Or if they want to know what the clerk says, they could use the tablet computer to record the content and the translation service will translate the content to either text which will be displayed on the screen of the tablet computer or voice through the speaker on the tablet computer.

Searching

The information searching service is a fast way to obtain the information of product and service in the mall if the users do not know what product and service stores provide. The typical scenario is that when users want to buy a product but do not know which store has the product. They could use the searching service by simply typing the product or using voice input, all the products information including stores which have the product and price will be displayed on screen. Another scenario is if they want to try local food but don't know which one is good. The searching service will tell them all the local food options and the comments from other users.

Navigation

Navigation is the typical application used in current daily life, and in big mall like SBM shanghai, it is also useful to users who have tight schedule and don't want waste time on searching the location of the store. Once they decided which store they want to go, they could use the navigation service to find the position of the store in the mall, and the navigation service will plan a shortest path for them. They just need to follow the path displayed on the tablet screen, just like using google map navigation.

Control Cart

If users choose cart device to carry their shopping bags, they could use the tablet computer to control the cart device in automatic mode or manually control the cart device by moving the device around in the mall. The manually control is designed for difficult situations, such as when users want to go upstairs through elevators or in the narrow space where it is difficult for cart device to perform automatically move. By turning on the automatically control, the device will flow the users who carry the tablet computer as the cart device will keep a certain distance with the tablet computer by design.

3.1.3 Navigation service function flow block

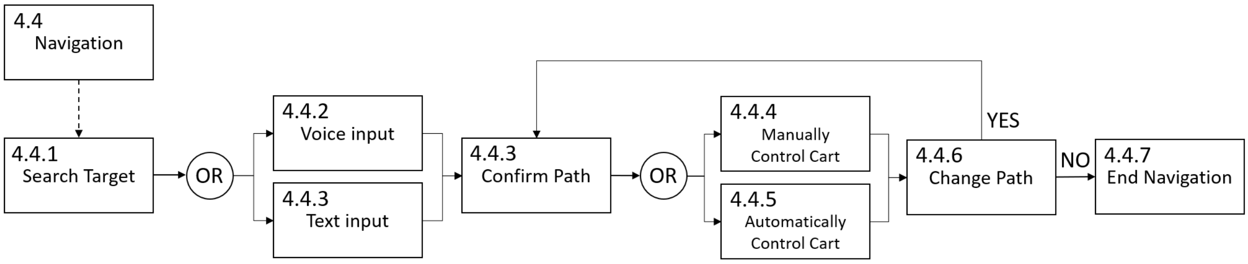
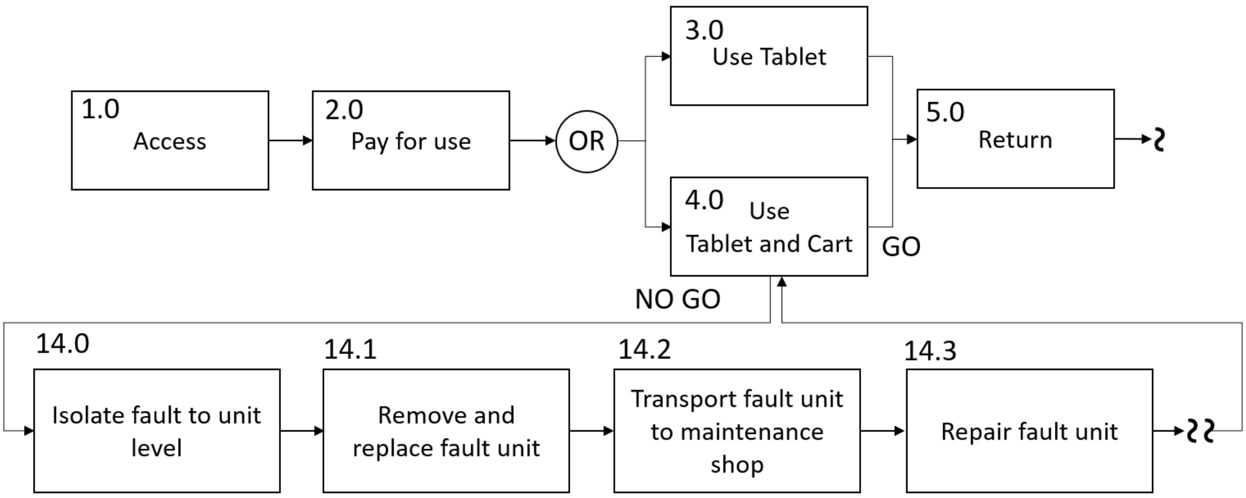


Figure 3: Navigation function flow block

The function flow of navigation starts from enabling navigation service, then users are required to search the target location in the mall either by voice input or text input. The service will display 1 or 2 paths on the tablet screen for the users depending on the traffic situation of the mall. Once users confirm the path, the navigation starts, users just need to flow the path indicated by the navigation service, and they could reach the destination. By controlling the cart device, they could choose automatically control mode or manually move the cart device. Due to the dynamic situation in the mall, the navigation service may update the path according to the position of users and the distance to the destination. User could choose to change the path or stay with the path they preferred at the beginning. Once users arrive the destination, the navigation service will end.

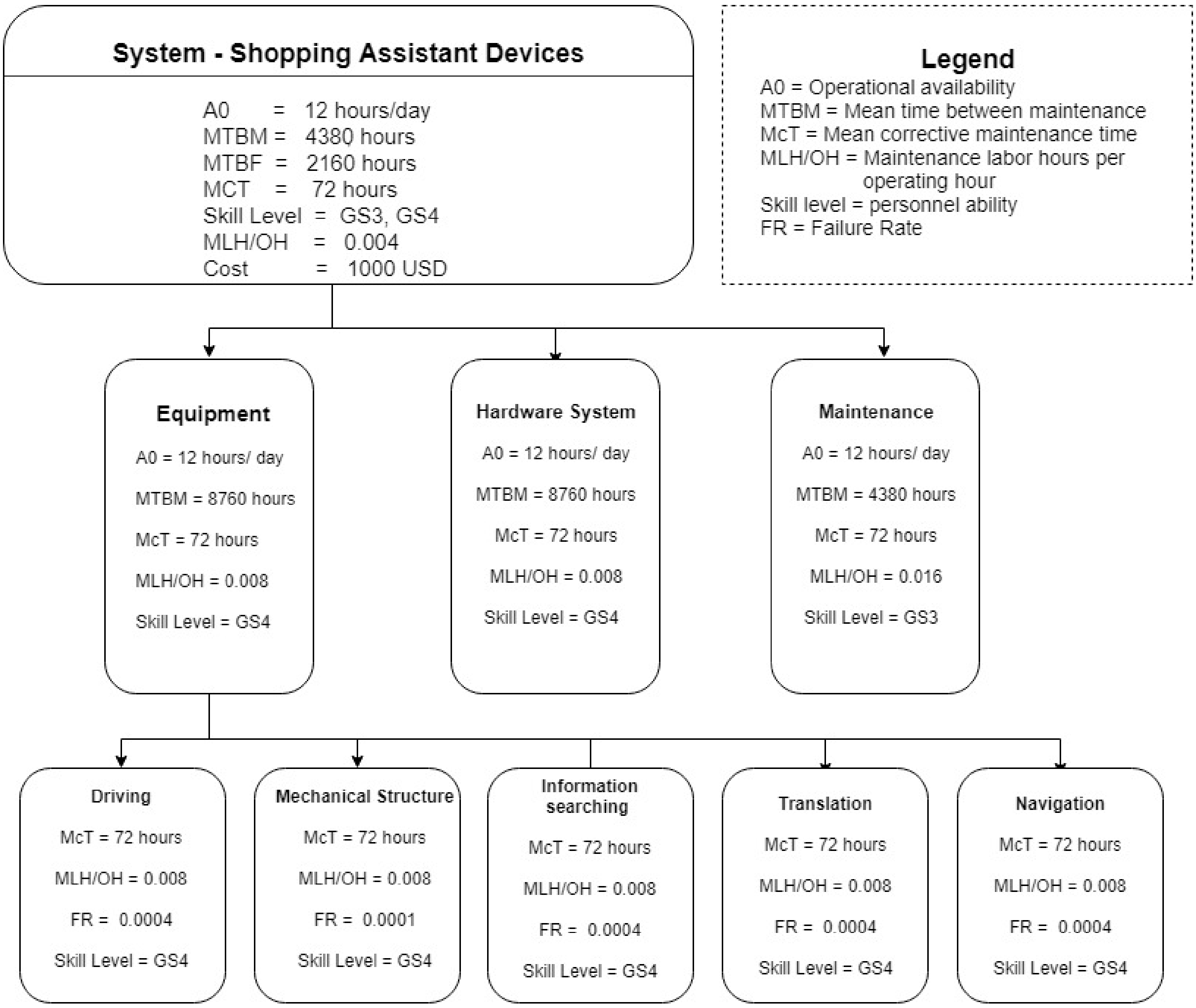
3.2 Maintenance functional flow block diagram for the system



During using the table computer and the cart device, there will be a possibility that the equipment is not functional. Then the issue will be reported to maintenance and support team. The maintenance team will inspect the equipment and isolate the fault to unit level. For example, if the battery is died, they will remove the battery and replace a new functional battery and transport the dis-functional battery to the maintenance shop and repair the battery. The same process will be applied to other units of the equipment if the units are not functional.

4. Technical performance measures

4.1 System requirements allocation diagram



4.1.1 Determine the top-level TPMs.

The top level of the system is defined in Level 1 in figure above. The criteria for the shopping assistant device to be considered are:

- The reliability MTBF: 2160 hours
- Maintainability MTBM: 4380 hours
- A0: 12 hour/day
- Information search & process time: 2s
- Cart (device) size: 10 inch * 20 inch* 30 inch
- Cart (device) weight: 8 pounds
- Cart moving velocity: 0.5m/s to 2m/s
- Cart payload: 20kg at least
- Cost: below 1000$/ea

4.1.2 Assign some top-level TPMs.

- The reliability MTBF - 2160 hours as it will guarantee 6 months' fully- functional use.
- Maintainability MTBM - The lifespan of the device is approximately 2 years and MTBM will be 1 years which means 4380 hours as it works 12 hour/day.
- A0: 12 hour/day - To guarantee the satisfaction of the customers' shopping experience, the shopping assistant device is available for operation as fully-functioning for at least 12 hours for one time's charging as the big mall usually open from 9:30 am to 9:30 pm every day. It is very important because fully-functioning operation must be guaranteed to provide all the services customers may need to use.
- Information search & process time: 2s - To guarantee the requirement device saving time for customers, the information search & process time of device will be less than 2 seconds using WIFI.
- Cart (device) size: 10 inch * 20 inch* 30 inch
- Cart (device) weight: 8 pounds
- Cart moving velocity: 0.5m/s to 2m/s
    - The device will be small and light-weight enough within 10 inch * 20 inch* 30 inch and 8 pounds to move easily and conveniently and the moving velocity will range from 0.5m/s to 2m/s to guarantee safety. Because the device could not

move much slower or faster than normal walking speed pf a person to guarantee both the requirements of saving time and safety as it may knock people when moving too fast.

- Cart payload: 20kg at least - To carry bags maximumly for customers, the payload will be 20kg at most. It is important to have large and suitable payload to satisfy the huge need of shopping.
- Cost: below 1000$/ea - Each device will cost below 1000$ totally to control the cost within the acceptable range to guarantee the benefits of our company and the continuous improvement of the products.

4.1.3 Allocate these requirements as appropriate to the second and third levels.

- The whole system can be divided into 3 parts based on the second level of the operational flow.
  - Equipment – Equipment is mainly divided into cart device and light-weight tablet computer. The performance measure of equipment is dependent on its fully-functional using condition which depends on the mechanical structure, interaction system and hardware. And the lifespan of battery within the system should be 3-4 years normally using. The expected lifespan of these equipment should be 5 years which is its operational availability and should be undergo scheduled maintenance every 2 years in its life cycle for which it has a McT for 3 days which gives it the MLH/OH of 0.008. So, it has a MTBM of 2 years and the skill level for this work is usually GS4 or higher.
  - Hardware system - Since the use of Hardware system mainly in WIF/BLE and security, it has a higher operation period between 2-4 years and has 3 days McT. Then MLH/OH is range from 0.004 to 0.008. The hardware system has the MTBM of 2 years usually. Skill Level required is GS4.
  - Maintenance - The major performance parameters of the maintenance will be the electric charge system. The system should be maintenance once a year and the McT is 3 days per maintenance which gives a MLH/OH of 0.016 and MTBM is 1 year (4380 hours). Skill level required is GS3.

- Based on Level III of the operational flow, the equipment of shopping assistant device can be classified as follows:
  - Driving – The driving system which driving the device automatically following the end-users.
  - Mechanical structure - The physical design of the device including the payload and driving controller.
  - Information searching – This belongs to interaction system which need big database and reasonable time response within 2 seconds.
  - Translation – This includes the multiple languages translation such as Chinese to English, Chinese to Japanese, Chinese to Korean, and Chinese to French translation and vice visa. Also, the system can provide voice translation as well as text translation on the screen. To improve the satisfaction of customers, it will also provide translation service through scanning the text and translating shown on the screen.
  - Navigation – This includes navigation indoor which provides both the voice navigation and map on the moveable device's screen between two spots.

5. Modeling and analysis of the system

5.1 Choice of analytic models

5.1.1 Develop the criteria

As design engineers, we have to develop the criteria that will be aid in selecting most appropriate computer-based tools and analytical models to analyze the system and verify the various system requirements. These analytical models/tools should be able to help us in the synthesis, analysis, and evaluation of the system that we are designing and the model we create must be adapted to the problem at hand and the output must be oriented to the selected evaluation criteria. The extensiveness of the model will depend on the nature of the problem, the number of variables, input parameter relationships, number of alternatives being evaluated, and the complexity of operation.

5.1.2 Address the considerations

1. the development of system operational requirements - This includes the reasonable response time, size and weight of cart device, system input (critical parameter) and also the lifespan of the system.
2. the maintenance and support concept - This includes the daily maintenance activity on the electric charge system to provide enough power of the device which could support 12 hours' fully-functional use after one-time charging.
3. the identification and prioritization of TPMs - These are the system specific parameters which aid in deciding the prioritization of TPMs of the system where we choose the interaction system model as the most important one in our project as it impact most here.

For our shopping assistant devices project, the system here contains three modules and due to its complexity, the criterions are established according to the nominal models that can be used for the system. We identify the proper design characteristics depending on the following three models: equipment requirements model, interaction system model, and maintenance system (electric charge system) model which show details as following:

Equipment system model

Should consider all the material of the cart device including the material covering the cart outside, the wheels leading the cart to build a lightweight cart with 8 pounds.

Should consider selecting the proper electric motor with right drive because:

1. It is essential to getting the performance which guarantee the velocity of 0.5 – 2m/s with 20kg payload condition to satisfy the customers' requirements.
2. The capacity of the motor to do work should approach the level which satisfies 12 hours' driving of device which require the enough horsepower.

Should consider the selecting of capacity of battery that can provide 12 hours' fully-functional use after one-time charging for every time maintenance.

Should consider the cost of all the materials selected range from a accepting price to limit the total value below 1000 USD.

Should consider the size of the cart device including the width, length, height and the size of all wheels to make the whole cart device range within 10 inch * 20 inch * 30 inch.

Interaction system model

Should consider the response time ranging within 2 seconds which the process starting from command received through touchable screen, transferring information to background, searching information from the database, transferring data into information and finally showing up the results on the screen or being output as voice.

Should consider the cost of the hardware using in the system which guarantee the total cost within 1000 USD.

Electric charge system model

Should consider the electric charge system provide enough power for device's battery to support 12 hours' fully-functional use after one time's charging.

Should consider the cost of electric charge devices within a appropriate range.

5.2 Validation of analytic models

5.2.1 Equipment system model

- Input:
    - weight of every components in cart device including materials and electric device like motor
    - horsepower and torque of the motor
    - cost of every component
    - capacity of battery
    - type of material and structure designing
- Output
    - the total weight of the cart device
    - the velocity and using time driving the cart device
    - the cost of cart device
    - average run time of the device
    - the size of cart device
    - payload capacity
- Parameters
    - the density of material covering cart assuming below 2.7g/cm^3
    - the thickness and length of material using to cover the cart device

- assuming 200 W DC electric motor with proper horsepower assuming and torque assuming
- wheel diameter assuming 2.3 inch
- the battery assuming capacity of 9Ah

We using mathematical models and CAD software to validate the expected output and if the results we get meet the requirements above, the analytic models successfully analyze and simulate the real situation and we can validate it a good analytic model.

5.2.2 Interaction system model

- input
    - network speed using normally WIFI
    - response time of touchable screen getting the command
    - response time of transferring information to background
    - response time of searching information from the database
    - response time of transferring data into information
    - response time of showing up the results on the screen or being output as voice.
    - MTBF of the system
    - cost of every hardware using
- output
    - total response time of whole interaction process
    - total cost of the hardwares
    - lifespan of the interaction system
- parameters
    - normally WIFI speed assuming 600 Mbps
    - the response time in every step of interaction

We build a analytic model to run the simulation and if getting the expected output within 2 seconds with only 1/100 failure probability, it can be shown that it's a good and efficient model and the input is successful.

5.2.3 Electric charge system model

- input
    - the voltage of electric charge system
- output
    - the lifespan of the system
    - the MTBF
    - the MTBM
    - the fully-charging time
    - the cost of the charging devices
- parameters
    - the rechargeable power supply assuming providing the 32 W rated charging
    - charging time within 4 hours

We use CAD software to model this electric charge system and if the fully-charging time is within 10 hours and give enough power charging to the battery, the system can be analysis to be successful.

5.3 Choice of CAD, CAM and CAS tools

The major part of the system is the equipment that end-user will interact with during their shopping in the mall. The equipment consists of a lightweight tablet computer, a cart device and the software applications embedded in the tablet computer for supporting the services like translation, searching and navigation.
Using CAD, CAM and CAS tools could help us design the physical equipment that meets the criteria in an efficient way and illustrate the data flow in the design phrase therefore to help us to design the efficient flow of data among the system.

5.3.1 CAD tools for modeling the physical equipment

In order to design a lightweight and appropriate shape of the cart device, we will leverage the CAD software such as Autodesk Inventor, Solidworks to design the 3D model for each part the cart device. By applying the specific configuration of the size, we are able to find the configuration of size and position in the cart device for other components, like wheels, actuators, and the platform of payload. So that we are able to select appropriate existing components in the market.

The CAD tools will also used to design a user-friendly cart device by considering the practical, fashionable shape of the cart device. As well as design the shape size of the tablet computer, in order to make it easy to be carried and attached to the cart device.

After each part of the equipment is designed with CAD software, we are able to assembly them together in the CAD software to see if every part is good or not to form a final equipment model. During this design process, we are able to address most of the problems in the equipment shape design and finally come up with a 3D presentation of the equipment with different views that can tells the details of shape of the equipment.

5.3.2 CAE tools for optimizing the weight and internal structure of the equipment

One we have a good shape design for each part of the equipment, we will use the CAE software to optimize the material as we are trying to design a lightweight cart device with maintain the stiffness with respect to the payload specification.

Giving the payload configuration and force may perform on the cart device, CAE tools can be used to determine the material of each part and simulate the typical scenario for using the cart and analyze the distribution of the applied force. Further we could reduce the material by redesigning the internal structure of each part of the cart device and make a material efficient design for the cart device.

5.3.3 CAM tools for prototyping the physical equipment

After we finish the initial design of the equipment, the CAM tools could be used to prototype the equipment, mainly focusing on the shape of the cart device. 3D printing and NC machining technologies will be leveraged in this phrase.

During prototyping, we could identify the parts that are difficult to fabricating or not material efficient. The prototyping with CAM tools could help us to learn the inefficient or bad design in the 3D model, therefore it will guide the redesign process so that we can address most of the problems in the manufacturing phrase before massive manufacturing.

With the prototype, we could assembly all the components into the equipment and build a functional prototype and test the whole equipment to validate our design for every part of the equipment.

With applying CAD, CAE and CAM tools, we could address most of the problems that may occur in the design process and therefore accelerate the design process and save the cost of design.

5.3.4 UML diagram for illustrating the information data flow

As the equipment will work with the hardware system and electrical system that distributed in the mall, and communicate with the information system, we could use UML diagram to illustrate the process of data interaction and communication, to understand the data flow among the system.

5.3.5 CAS tools for management of user behavior data and system data

CAS tools could be used to maintain the list of hardware devices, the electric charge system and the equipment. We will build a database to record and update the status of each hardware. This is the crucial part of maintenance and support. With this database, we could easily track each hardware device (BLE device and WIFI device), electrical charge system and the equipment (tablet computer and the cart device) during whole life cycle. That will make the maintenance work more straight forward, and also could help us to identify some problems in the system. For example, if we find some of the component does not work as expected or as their vendors promised, we might need to re-evaluate the component and replace with similar component from other vendors.

We will build another database for tracing the user' behavior, such as the mean time of using the system, the frequency of using specific service, and the feedback of using the system. So that we can understand the real situation by analyzing the data coming from real users. This will help us to improve the design in future.

5.4 Development of physical model

In designing the system, a physical model for cart device will be developed. This physical model will be used to validate the design and test the full function with integrating other existing components.

A physical cart device will be developed in early design process by using 3D printing or NC machining.

The physical cart device is the one of key part of the equipment that end-user will interact with. Despite of the software system, the physical cart device will be used to validate the criteria of size and weight, validate the integration/assembly of the equipment, the interface of the electric charge system and the communication with the hardware system.

By using different material to build the cart device for prototype, and assembly all the components to the cart device, including the actuators, the electric systems and wheels, we are able to tell the exact size and weight of the whole equipment, as well as the real feeling of maneuvering the equipment, this is a crucial part of validation and will reveal some problems that we are unable to find in design with CAD tools.

We also need this physical prototype of cart device to validate the interface of electrical charge system, to see if the device is able to charge with the plug of the electric system. In addition, we could address some problems in design of the electric system as the whole system has to fit into the environment of the mall.

We will move the physical prototype of cart device around the mall to test the internet connection and data transmission efficiency between the equipment and the hardware system which is distributed at the fixed spot around the mall. With this test, we are able to reveal the problems in data transmission, hardware distribution and information system, therefore we are able to redesign and fix the problems in the early stage of design process instead of letting some potential problems skip to the stage of using by real end-users.

6. Reference

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