DESIGN AND IMPLEMENTATION OF A BUSINESS INTELLIGENCE DASHBOARD FOR SUPPORTING PALLIATIVE CARE

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Abstract

Palliative care is defined as providing relief from the symptoms and stress of the illness. Due to severe issues on the misdiagnosis of diseases and the shortage of professional clinicians in palliative care, the support of data visualization tools becomes of utmost importance. And to solve that, this project developed an off-line dashboard website designed for medical workers to improve the correlative interventions. To achieve this objective, firstly, current approaches were summarized systematically to specify the functions in our dashboard. Concretely, our dashboard would achieve five services: (1) multi-angle assessment of palliative care, (2) demographic outcomes display, (3) metabolic control, (4) conditions tracking and contrast, and (5) interventions tracking and contrast. And these can be presented through two modules: extraction of patient pattern and care process analysis. Next, five types of interactive charts were designed to realize the above functions integrated with Graphical User Interface. And then, we applied HTML5, CSS3, JavaScript, and ECharts techniques. As for the achievements, our work not only summarized the state of art, but also completed a new type of dashboard with original designs of multi-angle palliative care assessment, patient psychosocial and spiritual condition monitoring, and customized intervention modes for the specific patient pattern.

Index

Cap ťulo 1. Introduction

1.1 Project Introduction

1.1.1 Project Description

The project aims to design and implement interactive and analyzable data visualization tools based on the techniques of business intelligence for improving the palliative care provision. In detail, the whole task is expected to retrieve available data entities and then developed the web-based dashboard system to support palliative caregivers analyzing the care processes and adjusting interventions to improve patient conditions with suitable charts and efficient interactions.

The two key parts of the system emphasizing on are the context of palliative care and the dashboard itself. Palliative care is a comprehensive health care method, which helps patients associated with chronic disease to enhance the quality of their life through some interventions to relieve symptoms and passive states. And the dashboard is a kind of business tool for businesses to make the analysis of the data and get valuable deduction behind them through dynamic charts.

Overall, the significant meaning of this project is to support palliative care practitioners in observing the intuitionistic care data and explore the inherent association between patient status and interventions, which will be very conducive to improving the life quality of patients suffering from chronic diseases.

1.1.2 Project Objectives

The overall purpose of the project is to create an interactive and analyzable dashboard system designed for palliative care analysis. Considering the functionality and operability angles, the main objective to realize the dashboard is supposed to be split into several sub-objectives so as for clearer and more reasonable task execution.

From the perspective of functionality, the sub-objective is to indicate key analysis indicators and needed functions in palliative care based on doctors, nurses and other related researches to relieve symptoms and negative status of patients. The function needs to meet the general requirement of treatment analysis including different incurable and chronic diseases, as well as distinct patient and doctor characteristics. In addition, realizing analyzable charts and usable GUI is also a sub-goal. In dashboards, interactions are very critical parts linking users' desires to outcomes directly and effectively. Simultaneously, the user interface needs to satisfy some basic and high performances to guarantee normal functions and additional value for users' sustainable operation, e.g. correctness, responsiveness, and effectiveness.

1.2 Finished Works

In order to achieve the final goal, the general objectives need to be narrowed and divided into specific stages of the work. Since the most critical part of the objective is to implement the dashboard, with this concept, doing researches on skills and tools of dashboard technique and web programming is the basic step to construct suitable charts and layout of pages for the project.

In addition, to apply the data visualization technique into a palliative care background, investigating existed study or work associating dashboard to incurable and chronic diseases is the next stage of work. However, according to researches, the currently implemented systems with regards to dashboard tools were mostly on some particular disease types, such as diabetes, prostate cancer, head and neck tumor, and breast cancer, lacking the common and general palliative care dashboard module. Therefore, specific to these particular areas, we made a careful comparison between these used charts and interactions with different system functions and tested patients, and also summarized the requirement and key indicators for a treatment analysis.

After researching the existed work, the whole system's functional requirements of this project could be set out. The system has two main sections: firstly allow users to select specific patients to analyze on the basis of different patient conditions; then analyze and evaluate interventions through tracking patient key condition indicators in the care process. Patient condition indicators are classified into three sections: physical, psychological, and social to comprehensively assess patient status. Then, to realize those functions, the suitable charts were designed and implemented, consisting of bar charts, a nested pie and polar chart, line charts, a timeline chart and a gauge chart. Besides, effective interactions were linked between users and data or among charts, like zooming, tooltips, selecting, clicking, etc.

Then, the next stage of work was to program for the dashboard system. The project applied HTML5, CSS3, and JavaScript as the basic web programming languages and ECharts to support developing distinct charts. After encapsulating each chart calling functions, BootStrap was utilized to implement the responsive and user-friendly layout and beautify the user interface.

Finally, for user review in pilot testing, a suite of dashboard assessment key performance indicators were proposed. The assessment indicators were divided into two aspects: functionality and operability, which are in accordance with sub-objectives.

1.3 Current Achievement

This project is a totally new type of dashboard, which has not been realized before, designed directly for palliative care. And it has several features and contributions different from others, which can be shown in the following three aspects:

- **List of the state of art applying dashboard into palliative care.**

We investigated dozens of literature concerning dashboard design for chronic disease then compared the most relevant researches from the data source, techniques, functions, charts, and assessment dimensions. After that, we summarized eight effective functions and selected some of them to meet requirements in palliative care.

- **A new function of assessing palliative from multi-angle by stacked bar chart in our dashboard.**

Since palliative care is interdisciplinary care and previous research only evaluated it from different angles by the literal expression, this design helps medical workers directly know what treatments need to be adjusted through visual tools.

- **Emphasizing on new angles (psychosocial and social) to monitor patient conditions in our dashboard.**

Existed works majorly focus on monitoring patient conditions from the physical angle, but in palliative care, the psychosocial and spiritual pains are critical to be mitigated. So we used some scores to estimate and tracked them by line chart.

- **A dashboard design of using Extraction of Patient Pattern and Care Process Analysis modules to improve interventions.**

That design can let medical workers analyze and adjust their treatments to improve particular outcomes or fit specific patient features. And all functions in our dashboard are based on this thinking.

1.4 Report Structure

Chapter 2. Background- firstly demonstrates the state of art for palliative care, business intelligent dashboard, and web programming. Then the chapter summarizes the data source, functions, charts, assessment, etc. of dashboards with respect to other chronic diseases. Finally, it sets up the objectives and techniques in this palliative care dashboard project.

Chapter 3. Design and Implementation- based on required services of palliative care and existed dashboard systems researched in chapter 2, it puts forwards the designed five functions our dashboard will realize: (1) multi-angle assessment of palliative care, (2) demographic outcomes display, (3) metabolic control, (4) conditions tracking and contrast, and (5) interventions tracking and contrast. Then, it lists the data entities as the data source. After that, the chapter shows the design of charts and interactions in the dashboard, which will be implemented into two modules: (1) extraction of patient pattern, and (2) care process analysis with five interactive types of charts. And demonstrates designed the requirements of each module and GUI. As for the implementation section, this chapter reveals the materials and methodologies to let those designs meet our objectives.

Chapter 4. Results and Discussion- the result section displays the screenshot of our workable prototype, explains the functions and lists requirements met and not met. Then the chapter evaluates our dashboard by viewing satisfied and dissatisfied requirements put forward in Chapter 3. After that, we summarize the achievement and problems we met. At last enumerates qualitative and quantitative assessment ways for professional people to measure further.

Chapter 5. Conclusion and Further Work- summarizes the current work we tried to do, the main achievement of our project and some existed issues. The chapter also refers to the future work to polish my dashboard project at last.

Cap ŧulo 2. Background

2.1 Academic Knowledge Introduction

2.1.1 Palliative Care

Palliative care is a comprehensive and interdisciplinary health care method, which assists patients associated with chronic disease and other life-threatening illness, as cardiovascular diseases, cancers, chronic lung diseases, aids, diabetes, etc. to relieve the symptoms and enhance the quality of their lives (physical, psychosocial and spiritual areas) by means of early identification, assessment and interventions[1]. Ordinarily, this kind of care is able to benefit only patients like older people, but also their families, tacking comprehensive care of them through formal and professional caregivers, doctors, pharmacists, psychological counselors, and other front-line practitioners setting out customized interventions centered-on patients.

One characteristic of palliative care is its assessment complexity and interdiscipline since the care process pays close attention to physical, spiritual, social, cultural, and other dimensions[2]. Therefore, the interventions need to be identified into numerous categories: in the physical domain, indicators include chronic diseases conditions, symptom intensity, and ability to perform activities of daily living; in psychological and spiritual domains, cognitive functioning, anxiety, and mood disorders need to be considered; in the social domain, independence and social participation, and family and social support are indicators; in disease process domain, illness and prognosis understanding, and needs and preferences regarding treatment are critical[3].

Meanwhile, another obvious feature distinguishes palliative care from common disease care is that the final purpose of the former is not to totally cure patients, but to raise the quality of lives in the period between diagnoses and death since most of them will inescapably die due to their incurable illness. This term is easy to confuse with terminal care. However, terminal care begins when two physicians demonstrated patients were expected to live for less than half a year, which is negative and only makes the end painless, while palliative care can begin at any time after being diagnosed as a chronic disease being more positive and helping to extend survival time as well as optimize the quality of life[4].

Since population aging is a long-term trend and the incidence, and mortality of chronic conditions like cardiovascular diseases, cancer and diabetes affecting older people is increasing, there are considerable demands for palliative care services[5]. If current trends continue, the need for it will rise substantially over the next 25 years and died in care homes, homes, and hospices will almost double by 2040. Direct at this phenomenon, researches show that the number of hospitals offering palliative care has been increasing over the past 10 years. In 2008, 53 percent of all U.S. hospitals with more than 50 beds had palliative care teams; by 2015, that had climbed to 67 percent. Although a growing number of hospitals offer palliative care, fewer than half of all patients who need it (7% to 8% of all inpatients) actually receive it. Studies also showed that about 80 percent of Americans wished they could spend their last days in their own homes, but only 20 percent of people did[6].

There are two main reasons for the above issue. On the one hand, doctors' misdiagnosis of palliative care, such as over-optimistic prognosis, time pressure, or therapeutic inertia, leads to patients' inability to live according to their own wishes before their death, and excessive invasive treatment. On the other hand, there is a severe shortage of palliative care professionals, which makes it expensive and time-consuming to monitor severe patients manually.

Therefore, palliative care now faces several critical problems, which are very hard to solve merely by traditional and manual means. The accurate prognosis of patient situations is one of the most severe challenges, where now some machine learning means are tried to predict probable candidate patients, death time and severity of illness with the medical, psychological, and environmental information of patients at the time they are diagnosed. Moreover, the lack of professional caregivers to track situations, alert behavior deteriorating to status, and show care expertise is vital. Although patients and doctors can visit and call patients in teletherapy, the foreseeability and quick response capabilities to emergencies are still limited.

2.1.2 Business Intelligence Dashboard

Business Intelligence can be seen as a solution, which can extract useful data and clean up them from different enterprise systems, and then through the extraction, conversion, and loading, namely the ETL process, merged into an enterprise data warehouse, resulting in a global view of enterprise data. On this basis, appropriate query and analysis, data mining, online analytical processing (OLAP), data visualization and other tools are used to analyze and deal with it. Finally, knowledge is presented to managers to provide support for discovering value behind the big data and making decisions quickly to managers.

Typically, business intelligence systems can consist of three main modules: data integration and storage, data query and mining, and through the graphical user community (seen as Figure 1). Data integration and repository module are devoted to gathering, integrating, and storing data from heterogeneous sources. The data querying and mining module implement the longitudinal analytics algorithms to retrieve meaningful patterns in the big data and realize the specific functions in specific data groups. The dashboard will be designed to cover the different scenarios of use for each type of end-user, supporting the managers and policymakers to discover data, evolution, progresses and changes. In the clinical medicine area, researchers exploit visit-by-visit Decision Support Systems (DSS), which is a kind of business intelligence system to assist caregivers in defining therapeutic plans by analyzing clinical and home monitoring data[7].

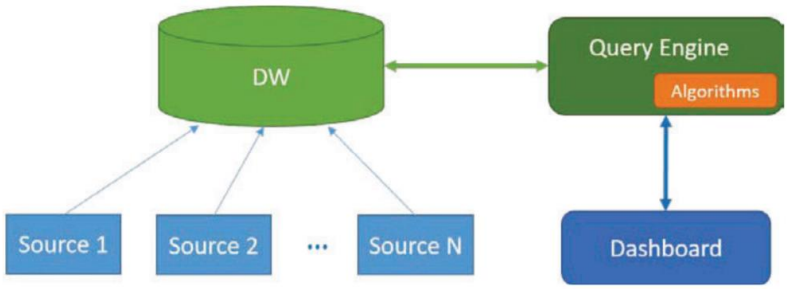


Figure 1. A Business intelligence system

Among those Business Intelligence tools, Dashboard is a data visualization module supporting manager analyses intuitionistic big data through a large amount of charts and interactions to create business value. In another way, it is an efficiently visualization tool showing enterprise the key performance indicators and the measurement of status with different compositions of chart modules. Conventional chart components include pie charts, dashboards, circles, specks, bubbles, radar, and maps for analysis. Moreover, digital dashboards may be laid out to track the flows inherent in the business processes that they monitor. And there are three main types of dashboard currently: stand-alone software applications, web-browser based applications, and desktop applications. Many internet companies also made out their customized dashboard solutions for business, such as Crystal Dashboard by SAP (Figure 2), BIEE by Oracle (Figure 3), and PerformancePoint by Microsoft.

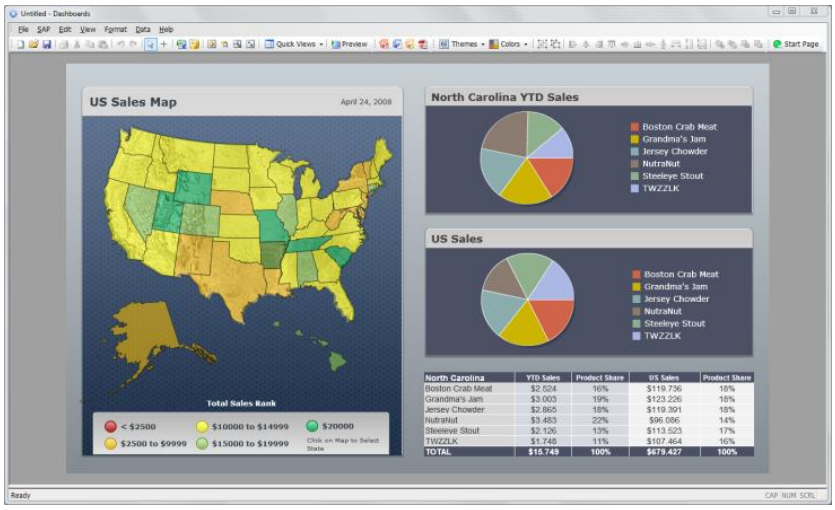


Figure 2. 'Crystal Dashboard' by SAP

Figure 3. 'BIEE' dashboard by Oracle

Also, good information design will clearly communicate key information to users and makes supporting information easily accessible. In order to design a dashboard these factors need to take into account:

- Responsive to the medium it is exhibited on (desktop, laptop, mobile, tablet)
- Types of visual charts to present single and crossed data

(a) Bar chart: It is to display one or more series of data and compare with various subjects

(b) Line chart: It is to track the tendency in a number of dependent data sets over a period of time

(c) Scatter chart: It is to represent the 3-dimension data set and judge the correlation between two variables

(d) Box plot: It is to provide key information about data location and dispersion arranging a group of data from large to small, mainly including six data nodes: namely its upper edge, upper quartile Q3, median, lower quartile Q1, lower edge, and an outlier. The functions are observing the outliers, skewness and tail weight, and data shape.

(e) Timeline plot: It is to record the significant events with the time developing.

(f) Area chart: It emphasizes the degree to which quantity varies over time and can also be used to draw attention to the gross trend, where the accumulation area chart and the percentage accumulation area chart can also show the relationship between parts and the whole.

(g) Gauge chart: It simulates the gauge unit on the car to monitor key performance indicators if lower or higher than the threshold.

(h) Bubble chart: It can be used to show the relationship between three variables. It is similar to a

scatter diagram in that one variable is drawn on the horizontal axis, another on the vertical axis, and the third variable is represented by the size of the bubble. The difference with scatter charts is that bubble charts allow an extra variable to be added to the chart to represent the size of the comparison.

(i) Polar chart: The X-axis of the polar map shows the circumference of the polar map, and the Y-axis shows the center of the circle to the top of the circle. It is used to compare all components by the center to the top of the items.

- Colour and shape of legends presented on a graph
- Spatial arrangement: place the most important view on the top left, then arrange the following views with the most important information following the top-to-bottom, left-to-right pattern.
- Colour palettes or voice reminds to be color blind friendly
- Efficient interactions conveniently supporting users requirements

Finally, to assess the quality of implemented dashboard, these are several key indicators:

- Simple and easy operation
- Minimum distractions
- Supports with meaning and useful data
- Applies human visual perception to the visual presentation of information
- Easy access by intended users

2.1.3 Web Programming

Web programming applies HyperText Markup Language (HTML), which specifies the format of the information displayed on a web page, identifies the images to display, embeds a descriptive language supported by other browsers, and specifies hypertext connection objects such as other web pages, JAVA, CGI programs, etc. As for web programming script languages, several popular techniques at present are PHP, JavaScript, Perl, Python, Java and JSP.

2.2 The State of Art

To investigate existed researches and works scholars and technicists have done related to this background, nearly 3000 papers searched were narrowed down to the most relevant and beneficial ten papers on the palliative care dashboard. This section will firstly, compare these existed work from the type of disease, data source, developing tools, dashboard functions, types of the chart, results and assessment criteria angles. Then summarizing their features into a comparative table, requirements and modules of dashboards designed to palliative care can be deduced then.

2.2.1 Methodologies Comparison

Up to now, the relevant research focusing on the palliative dashboard has been very few, and investigators have not set out professional and universal data visualization modules aimed at improving the analysis of clinical data and interventions with different requirements of physicians, doctors, caregivers and policymakers on palliative care. Therefore, to design a specialized dashboard system for palliative care, researches on improving care quality of different chronic, complex and incurable diseases and telehealth are strictly and objectively compared and summarized.

Literature[8] designed a dashboard system based on predictive modeling, longitudinal data analytics, and the integration of multi-sources data for detecting drug exposure patterns, assessing the risk of type 2 diabetes complications and analyzing clinical decisions. Thereinto, the impact of the clinical decision support component can be observed integrated with the doctor visiting frequency, the number of screening examinations, and the patient lifestyles. As seen in Figure 4, they created the traffic light plot displaying the metabolic control and complication risk assessment, where it used

red yellow and green to alert the value higher or lower than the threshold and the arrow aside presented the trend of recent two records; timeline plot to show temporal patterns for complications with critical events, where different colors represented various events; scatter plot was for representing drug purchase pattern; and pie chart, as well as bar chart showing population figures could select specific patients to overview the outcomes, where the reports could be drilled down when clicking the button.

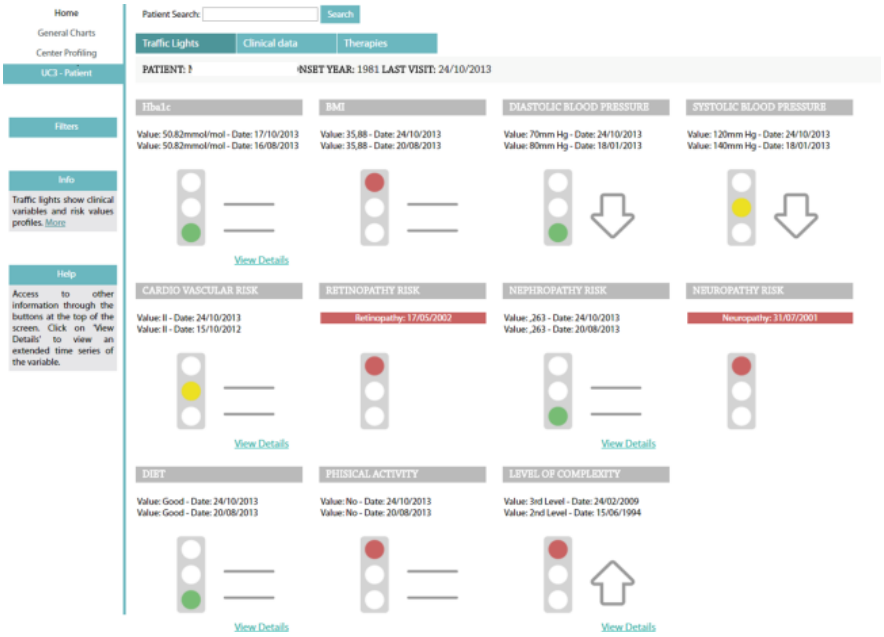
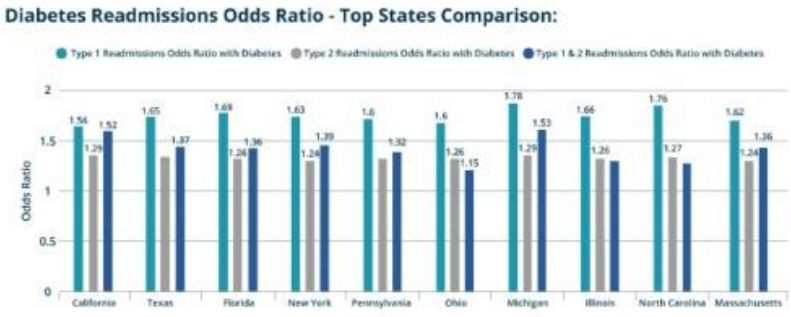


Figure 4. Traffic light chart showing metabolic control state

Another diabetes dashboard[9] let hospitals to examine the impact of diabetes on their all-cause readmission rates and financial implications if diabetes was present at the index hospitalization. And this system demonstrated data of diabetes readmissions quality metrics at a national level, which allowed analyzer to visualize the figure of each state and compare odds ratios for readmissions with raw clinical data. In Figure 5, the bar chart with the table was used to compare the readmission rate of different types of diabetes in various countries to the mean value, while the box plot (Figure 6) reflected the possibility of distinct influence factors.



Diabetes Readmissions Quality Metrics

State Name/ National	Type 1 Diabetes Hospitalizations (Oct 2015 to Aug 2018)	Type 2 Diabetes Hospitalizations (Oct 2015 to Aug 2018)	Type 1 & 2 Diabetes Hospitalizations (Oct 2015 to Aug 2018)	Type 1 Readmissions Odds Ratio with Diabetes	Type 2 Readmissions Odds Ratio with Diabetes	Type 1 & 2 Readmissions Odds Ratio with Diabetes
United States	364,300	10,988,647	33,753	1.66	1.27	1.36
California	24,747	820,241	2,462	1.56	1.29	1.52
Texas	22,941	874,457	2,475	1.65	1.28	1.37
Florida	22,617	771,482	2,601	1.69	1.26	1.36

Figure 5. Bar chart showing diabetes readmission ratio

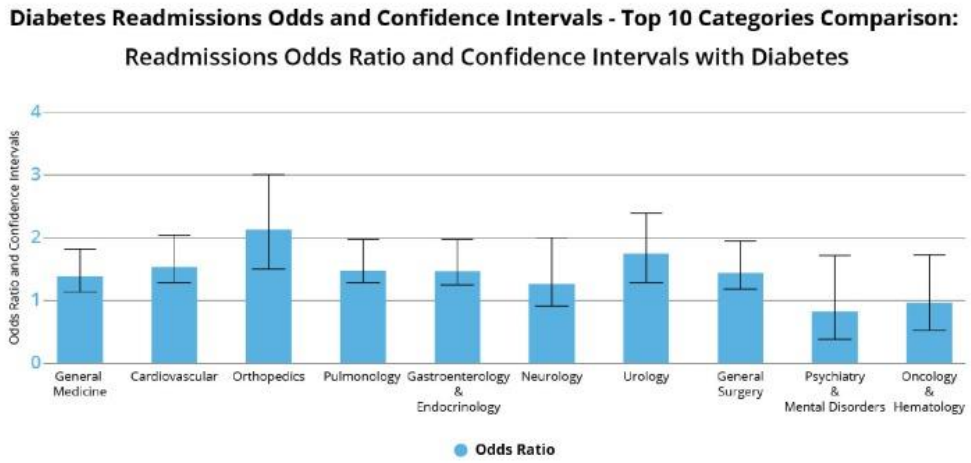


Figure 6. Box plot showing readmission rate and confidence intervals

Beside of these, a system[10] aiming at introducing self-collected health data from patients with diabetes into consultation was developed to assess the reliability of self-collected health data, list all collected data, and highlight medical situations that need to be investigated every day to improve the status of the patients. There, a bar chart was utilized for the distribution of some noticeable events in a day. A line chart was used to monitor diabetes contributors and others like glucose of patients with the range of recommended value as shown in Figure 7. And the multi-series chart could be zoomed by mouse clicking and keyboard input to see the some part and legends could be hidden when clicking.

Figure 7. Line chart monitoring daily influence factors in the blood

In addition, literature[11] identified the causal interconnection of the necessary metrics (patient, disease and therapy) for information assessment in head and neck tumor board participated by eight clinical experts with different levels of expertise in this field. Then it applied pie charts, which displayed their weight to analyze patient disease situations.

A dashboard for breast cancer[12] also did thorough research into improving interventions along the care process. Firstly, data were sliced by demographics, patient volumes, primary sites of surgery, grade, tumor size, histology and other parameters. Then analysis uncovers hidden patterns and

trends which provide insights towards improving treatment plans and better patient care. It used the bar chart to compare the death rate among different cancers and the influence possibility of distinct contributors. Pie charts represented the metastasis to different parts of the body. Then, the map displayed the geographic location of patients by race. The survival rate grouped by ages was observed by the box plot and the number of patients divided by races was seen in a bubble chart. The dashboard design is displayed in Figure 8.

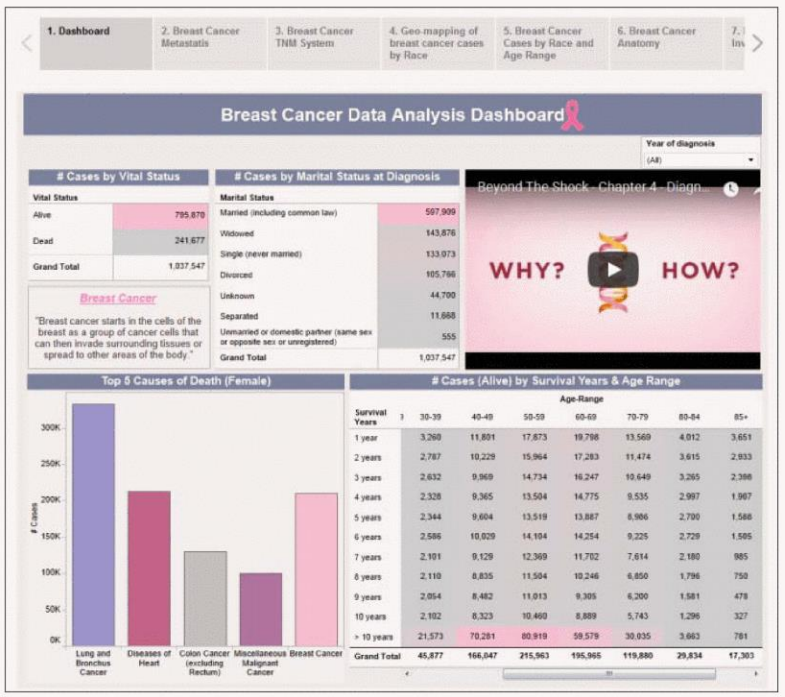


Figure 8. A breast cancer dashboard

As we see, Table 1 shows ten related work to the project. Among them, eight types of research paid attention to design and develop dashboards for diabetes, head and neck tumor board, breast cancer, prostate cancer these severe diseases, one research put emphasis on common disease and the other one was for palliative care in hospital at home. And other referred literature[13]-[16] for our dashboard are listed in the table.

Number	Type of Disease	Data Source	Developing Tools	System Functions	Type of Chart	Results	Assessment Measure
1	diabetes	(1) >1000 patients (2) two databases retrospectively over 10 years and prospectively for 6 months: the ICSM EHR and the local public health agency ATS (3) certified code for drug active ingredients, pharmaceutical company, and drug package features data	JS,HTML,CSS, Google Charts	(1) daily clinical decision support during follow-up consultations for clinicians and health care practitioners (2) periodic assessments of outcome on populations of interest.	(1) explore patients temporal data and assess the risk of developing complications or disease progression (a) metabolic control and complications risk assessment: traffic light chart, (b) frequent temporal patterns for complication: timeline plot (c) drug purchase patterns: scatter plot (2) overview the outcomes of the current treatments on the population of patients (a) select patients due to characters: bar chart (b) display similar clinical pattern: timeline chart, pie chart, bar chart	(1) a reduction in visit duration (2) an increase in the number of screening exams for complications (3) an increase in the proportion of patients receiving lifestyle interventions	(1) quantitative: constrast visit duration, screening exams for complications, interventions change between with and without system (2) qualitative: discuss usefulness, disease progression accurrency, patients population indicators
2	diabetes	Medicare Limited Data Set (LDS)in Centers for Medicare and Medicaid Services (CMS) administrative claims database, ICD-10 code for medical data	techniques in Dexur Research and Analytics organization, Python, HTML	examine the causes for diabetes readmission rates and financial implications	(a) compare readmission rate of different types of diabete among different countries bar chart + table (b) compare top 10 influence factors and possiblities: box plot (c)compare readmission odds ratio of diabetes in different hospital: bar chart	displays visual data for quick interpretation, monitors changes at a population level, and benchmarks facility data against local and national trends.	not mentioned
3	diabetes	patients' self-collected health data addition to their current HER (insulin intake, carbohydrate intake, blood glucose values)	Java Enterprise Edition 8，Java Server Faces 2.2, Glassfish5	(1) identify the needs of both patients and clinicians regarding relavent information (2) evaluate early prototypes and propose adjustments (3) develop prototypes based on the proposed adjustments	(a) distribution of noticable event a day: bar chart (b) display factors to influence the diabetes for monitor contributors to diabetes: combined line and bar chart (c)display everyday glucose in blood over time: scatter chart (d) display the sum or mean value of glucose or insulin: line chart	useful during consultations, especially for patients living in remote areas or those who are technologically interested,but disadvances are time consuming during consultation and not easy to use.	qualitative: based on expectation, usability (knowability, operability, efficiency, robustness,satisfaction, safety) and functionality
4	diabetes	participants had type 2 diabetes mellitus, were English-speaking, were aged 21 years or older,14 patients	using Apple Keynote	displayed and summarized 5 measures of patients' diabetes health status	(a) measure 5 diabetes related health status (blood pressure, A1c…): gauge charts	feasible but no usage record.	assess through validated metrics of task performance on 5 standardized tasks, semistructured interviews, and a validated usability satisfaction questionnaire.
5	diabetes	acquire parts of patient data from its lab	not mentioned	displaying all diabetes-related lab measures at one place for decision support	(a) display the most important lab values for Glucose, Renal Function, and Lipid Profile tests: gauge charts (b) display data of the lab values from the past and current visit: table (c)trends of lab measures: line chart	help physicians to make quicker decisions through this snapshot view	has not performed a full-fledged user evaluation
6	head and neck tumor boards	41 metric data includes patient metric,disease metrics,therapy metrics	not mentioned	display three distinct groups of metrics (patient, disease and therapy metrics) as well as set up specific recommendations	(a) display therapy recommandations: pie chart	provides a solid foundation for the essential future research on visualization, user experience as well as the benefits in patient outcome and user performance	qualitative: qualitative survey including eight clinical experts with different levels of expertise in the field of head and neck oncology
7	breast cancer	raw data from SEER cancer database	Tableau for prototype	display and compare breast cancer metastasis, incidence and mortality cases, survival rate by age, geograpgy, races to show the severity and regularity of the disease	(a) compare deadth between different cancers,and possibilities of influence factors: bar chart (b) display patient information: table (c) metastasis to different parts of th body: pie chart (d) geography location by races: map (e) survival rate of by age-range: box plot (f) patients number by races: bubble chart	confirmed the suitability and provided additional value based on information representation, but not user-centric.	not mentioned
8	prostate cancer	(1) patient-reported outcomes (PROs) for 60 patients (2) EPIC standard data to measure symptom severity and bother on a 0 to 100 scale for urinary, bowel, and sexual domains	Photoshop for prototype	illustrate trends in health-related quality of life (HRQOL) reported by patients following prostate cancer treatment	(a) show severity score of quality of life with different intervations: line chart	50 patients and providers rated pictographs less helpful than bar charts, line graphs, or tables and preferred bar charts and line graphs most.	including focus groups, interviews, advisory boards, and expertsreviews. 3 to 5 trained evaluators in critical review to inspect the usability of dashboard.
9	diseases with blood issue	from a RESTful interface that is tied directly into the database stores all of the data.	JS,HTML,CSS	(1) help healthcare providers and patients to better understand the various ailments that they might suffer. (2) provide insurance providers to track costs across the healthcare network.	(a) show metrics and sub-metrics leading to the disease, propotion and severity of the value: pie chart + polar area chart (b) display the relation of different metrics over time: parallel coordinates plot (c)display metrics over time: line chart	demonstrates the effectiveness of the application and the reactions of physicians and patients	not mentioned
10	telehealth disease in palliative care	from a RESTful interface that is tied directly into the database stores all of the data.	not mentioned	monitor well-being, pain, symptom and realize medication management, messaging, photo upload in rural areas of a telehealth community-based palliative care (CBPC) program.	(a) show patient information, days, recent events,well being: table (b) monitor well being: line chart	patient symptom burden and symptom are improved	(1) quantitative: quality data assessment collection tool and word cloud in application to show changes of symptom burden, documentation of advanced directives, and a hospice transition rate (2) qualitative: semistructured interviews with patients, caregivers, and providers demonstrated overwhelmingly positive experiences

Table 1. Existed Works about Dashboard for Palliative Care

2.2.2 Outcomes Summary

Through the above comparison and summary, we find that so far dashboards designed for general palliative care are very few. Current dashboard systems are merely in allusion to one kind of chronic disease, as we see in the table. To associate with the background showing the problems and requirements of current palliative care, we can summary these dashboards to develop data visualization modules focusing on palliative care indeed.

Despite there have been considerable efforts designing computer-based models to estimate long-term outcomes and identify the most efficient management strategies for chronic diseases, like diabetes and cancers, the business intelligence system as DSS often made out various functions considered distinct emphasizes of hospital managers and policymakers. Available business intelligence modules focused on different aspects: some of them developed with the purpose of enhancing personalized treatment and medication recommendations; others targeted the improvement of controlling key chemical substances in patient bodies; and there were others focused on the management of specific complications, such as diabetic foot, retinopathy, nephropathy, etc. Moreover, conspicuous efforts have also been devoted to offering evidence-based care centered-on patients, with recommendations tailored to the patient's clinical conditions and behaviors and to some clinical settings.

And these are some of the summarized functions and types of charts in existed work:

- **Metabolic control: traffic light, scatter chart**
- **Track quality of life: line chart**
- **Display critical events: bar chart, timeline chart**
- **Overview demographic outcome: bar chart, bubble chart**
- **Pathogenesis discovery: line, bar chart**
- **Prognosis of complication and survival time: timeline plot**
- **Readmission influence factors & possibility: box plot**
- **Disease metastasis regulation: pie chart**

With regard to the charts they commonly used, the bar chart, line chart, pie chart and gauge chart are verified to emerge with a high frequency. Bar charts usually display the distribution of daily treatments, diseases in different countries, readmission rates of different diseases, the possibilities of different indicators leading to disease, and treatment outcomes to find the same clinical patterns for patients. Line charts often track the chemical substances in bodies, wellbeing indicators and severity scores of the quality of life over time. Pie charts show the therapy recommendations, metastasis to other parts of bodies and sub-indicators leading to diseases. And gauge charts are special tools measuring the real-time health status indicators, like glucose, A1c, etc.

Besides, the colors and interactions in the dashboard design are also necessary. Red, yellow, and green represent the alert, reminded and normal value. Clicking the button can drill down the significant and valuable figures for further analysis; zooming chart by dragging the slider to filter out unrelated data and let users focus on more interesting ones; extracting wanted information by selecting the area by mouse or entering the scope by the keyboard.

As to the technical tools and programming languages, most of the dashboard use HTML, CSS, and JavaScript to develop. Many projects use tools as Google Charts or High Charts to support chart implementation. A few systems applied Java or Python to program. And other systems use Tableau, Photoshop to make the prototype of their design.

2.3 Material Selection

In this system, our dashboard considered and improved the first four functions in our previous

investigation (metabolic control, quality of life tracking, critical events display, and demographic outcome display). Then put forward a new function to assess whole palliative care from multi-angles, so that doctors could intuitionistically know which aspect needs to be improved in the care process.

As for types of charts, we applied stacked bar charts for assessing the treatment and demographic outcome display. Then we came up with a nested pie and polar chart for alerting the abnormal chemicals. To prove the design to perform these functions, Tableau was utilized for prototype making.

To select the most suitable programming materials, we did a thorough comparison. Since the mainstream programming languages for the web are Hypertext Markup Language 5, Cascading Style Sheets 3 and JavaScript, we used them to develop our dashboard web pages. And BootStrap technique was also used due to its high capacity to beautify the GUI and set up a responsive layout.

The most critical material is the technique to draw charts on the web site. We compared the most popular tools (HighChart, Google Chart, and ECharts) and listed their rankings in Table 2.

	Ease of Learning	**Big Data Expressiveness**	**Less Expense**	**CPU Utility**	**Chart Aesthetics**	**Freedom of Chart configuration**	**Chart Types Richness**	**Interaction Support**
HighCharts(SVG)	2	2	2	1	2	2	2	3
GoogleCharts(SVG)	2	3	1	1	2	1	1	2
Echarts(Canvas)	1	1	1	2	1	3	1	1

Table 2. Ranking of common chart development techniques

As we see, the first two are based on Scalable Vector Graphics (SVG), and the last is based on Canvas. Both of them are popular technology in HTML5 supporting 2D graphics display. However, SVG is suitable for statistic picture display, which draws charts by XML document description. Canvas is more adaptive for dynamically big data rendering, which generates charts by the JavaScript program. And after comparing these three techniques by eight dimensions, we eventually chose ECharts as our developing technique, due to its high performance on chart aesthetics, rich chart types and perfect interaction support.

Cap ítulo 3. Design and Implementation

3.1 Design

In our design, totally, the purpose is to improve the efficiency of interventions to relieve the pain as well as enhance the quality of life for patients. And in order to set out more accurate intervention modes, caregivers can group patients by whole care assessments or demographic outcomes. Thus, the suitable intervention modes are able to be summarized for improving specific aspects in the care process or particular patients with similar characteristics. Moreover, medical workers can also evaluate the effect of each intervention by reviewing its influences on different patients from physical, psychosocial and spiritual aspects. Then, we can say this design can support palliative care practitioners to set out more general and effective intervention modes for different patient patterns.

3.1.1 General Function

On the basis of Background, in order to improve the palliative care interventions, our dashboard system was designed for medical practitioners with those five dominating functions in two modules.

- **Extraction of Patient Pattern Module:**

(a) Multi-angle assessment of treatment

(b) Demographic outcomes display

- **Specific Care Process Analysis Module:**

(a) Patient metabolic control

(b) Patient conditions tracking and contrast

(c) Patient interventions tracking and contrast

And then, each function will be discussed below to explain the effects on supporting clinicians making decisions in palliative care.

3.1.1.1 Extraction of Patient Pattern Module

With the purpose of advancing previous palliative care treatments efficiently, first, we need to group the patients to identify different patient patterns. Then, the healthcare managers can set out specialized and effective treatments for patients within the same pattern based on their common status. The meaning of this module is to help medical workers know what outcomes will be improved when they adjust several interventions for the specific patient group.

To be exact, the patient pattern can be identified in line with various manners depending on specific clinician requirements. In our platform, it will allow two types of patient selection from the care outcome: multi-angle assessment of palliative care and demographic outcome display. Therefore, it will benefit clinicians to make more accurate and pointed evaluations and decisions for a large number of palliative care patients.

Therefore, this function will benefit clinicians to make more accurate and pointed evaluations and decisions for a large number of potential palliative care patients.

- **Multi-angle assessment of treatment**

The first method is to select patients by the comprehensive assessment of palliative care since it involves many fields to evaluate whether the whole treatment process and outcome are good, and the assessment of previous treatment is extremely valuable for the improvement of interventions. Thus, this function was put forward to let doctors set out pointed interventions for improving particular aspects.

And in our project, the assessment refers to these seven angles: the physical, psychosocial, spiritual, and service angles of patients, the psychosocial and service angles of patient relatives and the aftercare angle. Moreover, in each angle, there are many evaluation indexes. For instance, patients can estimate the service by whether they can contact medical workers quickly, whether doctors tell them about the merit and demerit of treatments, whether doctors explain the cause of illness and whether caregivers respect their life.

After reviewing these, users can pick up some patients with lower scores in some aspects and set out interventions direct to improve them.

- **Demographic outcomes display**

Besides, doctors can also adjust interventions by reviewing patient demographic outcomes. In other words, users can pick up patients to analyze by disease type, age group, severity degree, treatment mode, physician team, death place and other dimensions. In each selected patient group, doctors are able to set out the particular treatment modes according to the specific statistical regulations. For example, a series of interventions can be customized for the particular race.

Then, doctors can choose patients in this pattern, track the condition indicator and interventions in the whole care process. And also, if they want to ignore several patients in the same pattern or add patients from other patterns, the dashboard is also expected to allow users to select a customized group for analysis.

3.1.1.2 Specific Care Process Analysis Module

After medical practitioners selected specific patients in the pattern. They will analyze their care processes thoroughly to sum up their treatment path. And then compare these events to set out a series of effective interventions suitable for this particular patient pattern.

- **Patient metabolic control**

In this function, physicians can easily set out suitable interventions and identify complications of diseases for selected patients.

Since some chemical substances are also associated with the mental status of patients, tracking key chemicals for patients with different diseases can reflect their physical and psychological status. And caregivers can discover the relationship between specific substances and patients' mental or physical status, which indirectly supporting intervention adjustments by control chemicals in the body. For example, they can compare two types of lipid-lowering drugs by viewing the lipid level in the body and physical activity indicator of the patient.

And these key inner chemicals can be classified into different parts of patient bodies and recorded during the whole care process so that doctors can track the change and transfer of these chemicals. Then, it will also help doctors to make interventions to change some abnormal chemical levels with the relation between chemicals and pain of patients.

- **Patient conditions tracking and contrast**

As for clinic condition evaluation, the key indicators are in regard to physical, psychological, value,

social and other aspects, as palliative care is an ary care, where the condition can be measured by suitable scores. For example, Karnofsky Performance Status (KPS) estimates the activity ability, Numeric Rating Score (NRS) represents pain degree, Self-Rating Anxiety Scale (SAS) for anxiety degree, Self-Rating Depression Scale (SDS) for depression degree and Purpose And Meaning in Life (PIL) for life value.

From this function, the pain and symptoms can be estimated and tracked in the whole care process, so that caregivers can give interventions to improve patient conditions.

- **Patient interventions tracking and contrast**

The care process including patient condition and intervention tracking have been recorded since they stayed in the hospital. And this function records all critical treatments and events for selected patients. Doctors and health caregiver will track events like operation, medication, physical activities, diet, and psychological interventions. Both patient condition and interaction data are supposed to be longitudinal, so clinicians can be aware of adjusting treatments for patients in different stages of the disease based on their temporal features.

And caregivers can adjust their interventions in the future mainly from this part, after they do the analysis through adding and changing some interventions, then reviewing whether the pain of patients has been relieved. Then, it will support them to identify the most effective way to improve patient quality of life. Furthermore, within the same patient pattern, doctors can also compare the care process and discover the improper interventions in previous treatments.

By tracking the treatments and corresponding conditions of patients, clinicians can have an insight into the effects of several interventions, including whether the communication between patients and caregivers truly remiss the pressure and depression for patients and how long will the diet intervention make the effect. After discovering the effectiveness, responding time and the side-effects of the specific intervention, the manager can select the method more precisely and will not cause the complication. At the last, clinical policymakers can make out efficient and regular care models with different treatments depending on different disease stages for the specific patient pattern.

3.1.2 Data Source

In our data source, we leveraged not only the horizontal but also the longitudinal nature of clinical data summarized from multiple types of research and a set of hospital-level dashboard systems. Overall speaking, the total input data entities contained 17 attributes of patient basic profiles shown as Table 3, which helped to formulate customized and specialized treatment (patient ID, name, disease type, age, sex, nationality, birthday, religion, height, weight, BMI, marital status, education level, employment status, income level, smoking status, alcohol intake).

Patient ID	Name	Disease type	Age	Sex
Nationality	Birthday	Religion	Height	Weight
BMI	Marital status	Education level	Employment status	Income level
Smoking status	Alcohol intake			

Table 3. Patient profile data entities

Besides, in order to track every patient treatment process in general palliative care, we needed the process data for intervention recommendation and adjustment. The relevant attributes for therapy in our project were collected from 33 dimensions, which could be seen in Table 4.

Episode ID	Episode start date	Episode end date	Assessment date
Proposal date	Proposal status	Admission to hospital date	Actual discharge date from hospital
Expected discharge data from hospital	Discharge destination from hospital	Clinical unit stayed in hospital	Expected admission date to hospital at

			home date (HAH)
Actual admission date to HAH	Discharge destination from HAH	HAH healthcare scheme	Doctor urgent visit date during HAH
Doctor scheduled visit date during HAH	Doctor urgent phone call during HAH	Doctor scheduled phone call during HAH	Discharge date from HAH
Spiritual consultation date	Death date	Death place	Preferred death place
RxNorm prescription code	Prescription make date	Intervention type	Intervention date
Medical team assigned	Nurse ID	Physician ID	Social worker ID
Diagnose date	ICD9 diagnose code		

Table 4. Treatment process data entities

As for the automatic and real-time monitoring function, we measured patient key indicators in physical, psychological, and social areas. Therein, physical indicators included chemical substance amount in body, KPS and NRS scores. Chemical substance could be grouped by diseases it contributed to majorly as shown in Table 5.

liver	Aspartate Aminotransferase	Bilirubin	Alanie Aminotransferase	Alkaline Phosphatase
diabetes	Serum Albumin	A1C	BMI	Glucose
heart	diastolic blood pressure	systolic blood pressure	High-Density Lipoprotein	Low-Density Lipoprotein
bone	Calcium			
anemia	Hemoglobin Count			
Kidney	Creatinine	Blood Urea Nitrogen	Potassium	
WBC	Leukocytes			

Table 5. Chemical substance data entities

Other indicators included KPS, NRS, SAS, SDS, PIL scores to measure all aspects of patient situations. Karnofsky Performance Status (KPS)[17] measures Human functioning status calculated based on observable factors such as activity, activity, self-care, food and fluid intake, and state of consciousness, where scope is from 0 to 100 and the higher value means better status. Numeric Rating Scores (NPS) uses digital 0-10 to indicate the degree of physical pain. Self-Rating Anxiety Scale (SAS)[18] is a famous psychological scale used to measure the degree of anxiety and its changes during treatment, which scores from 0-80. Self-Rating Depression Scale (SDS) is a self-rating scale of depression in psychology, which is widely used in screening, evaluation of emotional state, investigation and scientific research of outpatients, which also scores from 0-80. PIL score displays the quality of life in palliative care. And other scores could also be used to measure in our system.

At last, to evaluate the comprehensive palliative care outcome of patients, we referred a set of indicators in a proved research [19], which considered physical and psychological aspects of patient, psychological aspects of patient relatives and aftercare aspects. Other literature[20] was also considered. All indicators are exhibited in Table 6 for 27 attributes.

Patient Physical Symptom	Patient Psychosocial Well-Being	Patient Spiritual Well-Being	Patient General Aspect	Relative Psychosocial	Relative Generic Aspect	Patient Aftercare
extent patient with obvious pain	extent patient with anxiety	extent patient indicate caregivers respect life	extent patient stay in preference location in last month	extent attention paid to relative psychosocial well-being	extent relative know patient death clearly	extent relative immediately get support after patient death
extent patient with fatigue	extent patient with depressed	extent patient has access to a counselor	extent patient know the cause of illness	extent relative feel they are treated well	extent relative perceived expertise of caregiver care	extent relative informed about possibility of aftercare
extent patient with shortness of breath	extent patient receive psychosocial support	extent to with patient has preparation for saying goodbye	extent patient know the contact of caregiver	extent relative have opportunity to be alone with patient		extent final discussion about care evaluation
extent patient with constipation	extent patient receive attention from caregiver	extent patient feel life worthwhile	extent patient know the adv & disadv of treatment			
extent patient receive physical support		extent patient died peacefully	extent patient asked decision about end-of-life care			

Table 6. Comprehensive outcome data entities

As you see, our data entities included both horizontal and longitudinal data, and how to combine them into charts to showing their single and crossed form and mining the hiding value inside the big data was a big issue of this project. In programming, these data entities will be shown in JSON format to maintain a common state for efficient transformation and revision by users.

3.1.3 Chart and Interactions

In order to obtain those five functions of our dashboard system enumerated in the *General Functions* of *Design and Implementation* section, several requirements are supposed to be satisfied in our chart and interaction design.

On the whole, our visualization module has two major modules: 1) Extraction of patient pattern and 2) Specific care process analysis. And the functions will blend in these modules. In addition, five types of charts: stacked bar charts, line charts, nested pie and polar plot, gauge chart, and timeline plot are designed to be applied. The stacked bar chart mainly realized the functions in the first module: multi-angle assessment of palliative care, and demographic outcome display. It allows users to formulate different patient patterns by treatment outcomes they want to analyze. And other charts are used in the second module, which deeply track and compare key indicators to adjust the

interventions for specific patients in accordance with their conditions. The nested pie and polar chart is able to monitor inner chemicals for discovering reasons for patient physical and psychological conditions. Besides, the line charts monitor and track conditions from different angles, while the gauge plot can alert for these conditions. Nevertheless, the most essential part is the timeline chart for reviewing and adjusting the interventions by observing patient condition changes before and after these interventions. Furthermore, dozens of interactions are added to support these effects include zooming charts inside and outside, selecting data by brush, mouse moving over to trigger other charts, clicking the button to download into the image, choose legends to display, etc.

So as to display the design more intuitively for modifying and evaluating the feasibility of the dashboard prototype, firstly a paper draft version of the design was created, then Tableau was used to come up with a digital version before the design was put into implementation for programming.

Next, based on the mock-up drawn with Tableau, we will list the requirements for charts and interactions to realize four functions within these two modules of the dashboard.

3.1.3.1 Extraction of Patient Pattern Module

- **Multi-angle assessment of treatment**

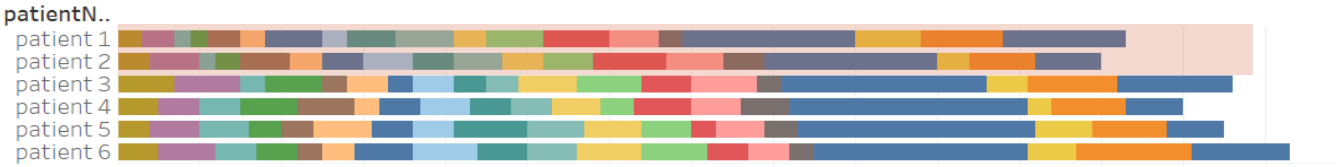


Figure 9. Stacked bar chart for selecting patients by multi-angle assessment

As we see in Figure 9, the stacked bar chart presents the general score of the palliative care process for each patient, which measures from patients, patient relatives and aftercare angles. The X-axis is the total score of each patient, and Y-axis is the patient ID. Then doctors or caregivers can use toolbox beside the chart to select an area covering data items, where Y-axis represent targeted patient ID for further analysis.

- **Demographic outcomes display**

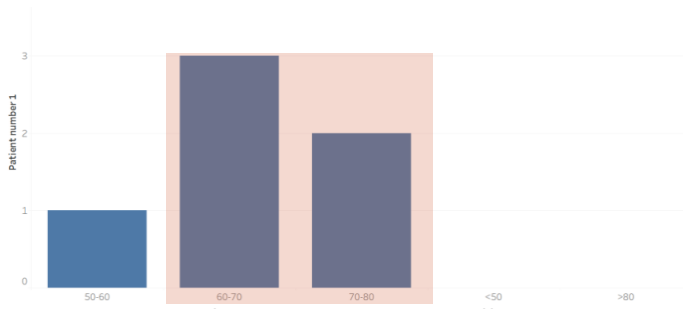


Figure 10. Stacked bar chart for selecting patients by different age groups

The bar charts can show patient groups by demographic outcomes shown in Figure 10. In the plot, the Y-axis is the patient number in each classification and X-axis is the group standard. For instance, we can identify patient patterns with different ages, severity of disease, disease type, death location, the care team and other dimensions. As well, the data of the specific group of patients can also be selected through the toolbox. Besides, users can also zoom or download the chart image to see and save their interested data.

Finally, all patients in selected the area in the first module will be saved in the page and when user clicks the button for further analysis of that customized patient pattern.

And these are some designed requirements to be realized in this module:

(a) Select patients in multiple ways according to user requirements.

(b) Avoid selection confliction of users within each chart.

(c) Display selected patients on the page to remind users.

(d) Allow to generating a customizable patient pattern by users.

3.1.3.2 Specific Care Process Analysis Module

In the second module, we will use four kinds of charts: line chart, timeline chart, nested pie and polar chart and gauge chart to record conditions and interventions in the process. Due to the limited function of Tableau, where the timeline chart and nested pie and polar chart could not be presented, we substitute them by Gantt chart and pie chart respectively.

- **Patient conditions tracking and contrast**

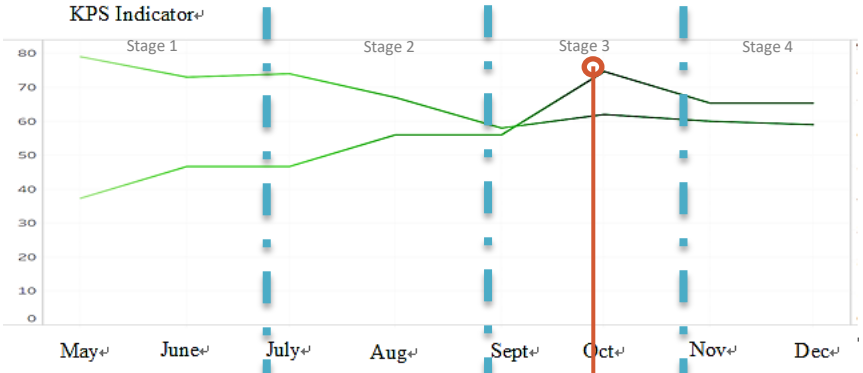


Figure 11. Line chart for tracking patient condition by KPS indicator

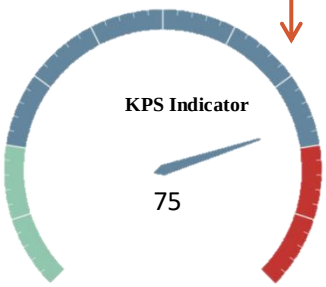


Figure 12. Gauge chart for alerting patient KPS indicator

A set of line charts shows the change trends of the physical, psychological and social indicators in care process (Figure 11). The physical indicator shows the KPS (0-100) and NRS (0-10) score; the psychological indicator displays the SAS (0-80) and SDS (0-80) score; the spiritual indicator exhibits the PIL (0-140) score. At the same time when the mouse is on the point, it links to nested pie and polar chart and gauge charts to show their information.

While the related indicator values with the same measuring date will be displayed in gauge chart on the right side to alert the abnormal indicator, seen as Figure 12.

- **Patient metabolic control**

Figure 13. Nested pie and polar chart for monitoring the inner chemicals

Corresponding chemical substance figures with the same measuring date as line chart will display in nested pie and polar chart (Figure 13). It divides chemicals (like calcium, systolic blood pressure, A1C, BMI, glucose) due to the contribution degree to the particular type of disease.

- **Patient interventions tracking and contrast**

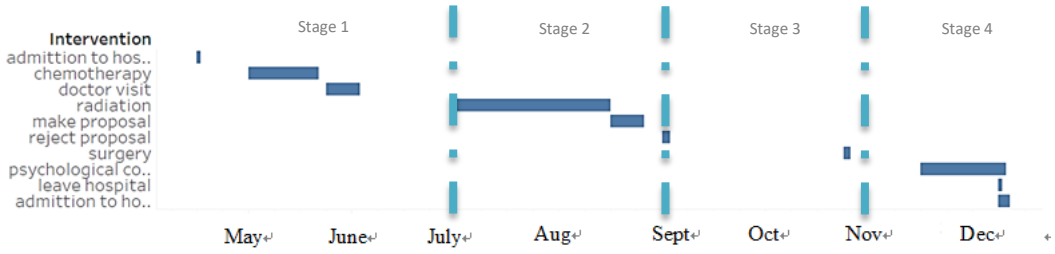


Figure 14. Timeline chart for tracking and contract patient interventions

Figure 14 is the timeline plot to record all events and interventions from diagnosis to the end of palliative care, which can be contracted with tracked indicators to see the influence and impact of these interventions to patient situations.

The requirements for this module are listed as below:

(a) Acquire patient pattern correctly from the previous module to analyze the process.

(b) Observe patient conditions in physical, psychological and value areas respectively for the care process.

(c) Different patients can be distinguished obviously.

(d) Mark different stages of disease in the process.

(e) Observe the intervention and patient condition correspondingly.

(f) Observe the chemicals and patient condition correspondingly.

(g) Identify the abnormal value of internal chemicals and conditions.

(h) Show key chemicals into different parts of the body to identify complications.

3.1.4 User Interface

The main page to display dashboard is divided into three blocks: navigation bar at the top, sidebar menu at the left side, and the content for charts at the right side.

- Navigation bar: It is designed to be at the top of the page and realizes the title demonstration and user information management functions. On the left side, the logo and brand of the project are put ("PC Dashboard"). And on the right side, the email and personal information settings of users are put, where messages are graded into various priorities for a quick glance and the user

can revise personal information and log out.

- Sidebar: It is the place to hold the menu, which navigates to different modules (dashboards, patient details, doctor schedules, and PC expertise). And the sidebar can be responsively hidden when window's size is too narrow for user-friendly layout.
- Content: the dashboard content will be put on this part, which has two display forms. The first one put Extraction of Patient Pattern and Care Process Analysis modules together in the main dashboard showing treatment processes of selected patients or all patients. And it can also jump to palliative care assessment and intervention record dashboard pages when clicking corresponding buttons. Each chart will be held in a panel to show their modularity.

The requirements for the GUI or whole dashboard module are listed as following:

(a) Zoom in and out interesting data.

(b) Choose factors of palliative care to display according to the user.

(c) Save interesting data for further analysis.

(d) Adapt element size and layout according to different personal computer monitor sizes and window sizes.

(e) Display charts and elements in the suitable size.

(f) Display charts with suited data and series amount.

(g) Realize the collapse and close functions correctly on the chart panel.

3.2 Implementation

3.2.1 Methodology Description

In our work, the development process of the dashboard module was on Visual Studio Code v-1.43.2, and the test browser to display the web pages was Google Chrome v-79.0.3945.117. As for the programming languages and tools, the technologies exploited to develop the GUI and charts in dashboard were based on Hypertext Markup Language 5 (HTML5), Cascading Style Sheets 3 (CSS3) and JavaScript. The communication between different components to exchange data was by JavaScript Object Notation (JSON) format. And all interactive charts in user interface were developed with the support of Apache Echarts tools, which were based on JavaScript language. The layout of the whole dashboard interface was created with BootStrap tools to realized organized and responsive elements. All languages and tools were chosen fully considered and discussed with the team in our laboratory named ITACA in Spain, which could be viewed in Figures 15 and 16.

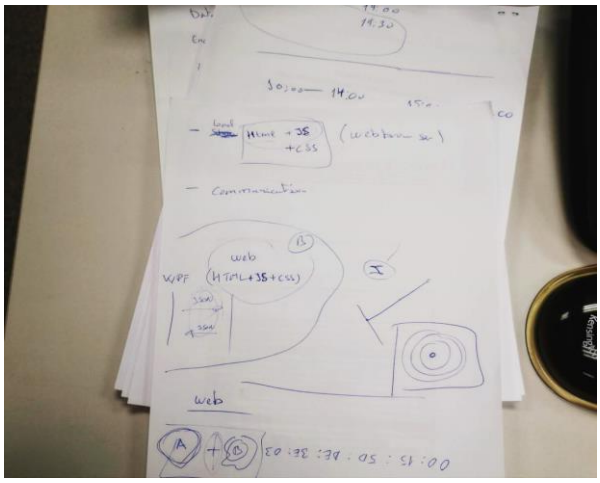


Figure 15. Drafts about dashboard design with tutors

Figure16. Working in ITACA laboratory of Spain

And the developing methodology followed the iterative approach. Since our dashboard is service-oriented, so as to achieving the overall sub-objectives and performing the majorly two services, an agile development process was exclusively used for this task, as evolution, changes, and adaptability were necessary, considering the continuous inputs provided by the team.

In the iterative approach, firstly the dashboard task was split into several subtasks: save analyzed data into JSON format on the client side to support off-line analysis, respectively show and add functions to each chart, append interaction in or between charts, implement GUI layout, integrate GUI with modules of charts, improve the style and responsive layout, and do a pilot test. These subtasks were then implemented in different iterated turns, where results would be tested and measured to check if achieving the milestones. The evaluation stages were performed by the developers and tutors in the team. If requirements were met, iterate the work in the next turn; if not, revise the code in the last iteration before step into the next iteration. When all sub-objects were decided to be satisfied and supported for the teammates, the dashboard then used in the test pilot. We stopped the iterative design process and selected the last prototype for assessment by different pharmacists, doctors, nurses, clinic policymakers, hospital managers, caregivers or others.

3.2.2 Project Framework

The whole file structure is shown in Figure 17, under our project ‘Dashboard for Palliative Care’, there are five folders (‘charts’, ‘css’, ‘image’, ‘lib’, and ‘pages’) and a file (‘index.html’). Our main dashboard page is put in ‘index.html’ file, which contains two modules we mentioned before to select patient patterns for customizing interventions. And this file refers to relevant JavaScript files to draw charts on this page. HTML5, CSS3 and JavaScript languages are used in it, where JavaScript languages perform the logic of the patient pattern selection method.

And the linked pages (‘patientDetails.html’, ‘outcomeAnalysis.html’, ‘interventionView.html’, ‘doctorSchedule.html’ and ‘PCExpertise.html’) are put under the ‘pages’ folder, which perform additional functions. ‘outcomeAnalysis.html’ is linked to the palliative assessment function in the first module of the main dashboard, which views various aspects of assessment by pie charts to observe each factor clearly for every patient. ‘interventionView.html’ is linked to the intervention tracking and contrast function in the second module, which displays the historical events for each patient by record lists and timeline charts. Moreover, ‘patientDetails.html’ shows all patient-relevant personal information and chatting records with the doctor to help doctors know the unique situation for patients. ‘doctorSchedule.html’ includes the calendar, to do list functions for reminding of doctors doing their daily activities conveniently. And ‘PCExpertise.html’ links to the critical news on palliative care in each hospital.

The style to display these pages are saved into .css files in ‘css’ folder homologously (‘patientDetails.css’, ‘outcomeAnalysis.css’, ‘interventionView.css’, ‘doctorSchedule.css’ and ‘PCExpertise.css’). And the Cascading Style Sheets of our main dashboard is saved in

‘user_interface.css’.

As for implemented functions to draw charts in the main dashboard page, we put functions to draw different charts in different JavaScript files of ‘charts’ folder. ‘stackedBar.js’ defines functions to draw the stacked bar chart for palliative care assessment and add the chart to specific panel in main dashboard page. And the input data of each function is also saved in these JavaScript files with JSON array format. ‘stackedBar2.js’ draws the stacked bar charts for demographic outcome display. ‘line.js’ displays the line charts for patient condition tracking from physical, psychosocial and spiritual aspects. ‘nestedPie.js’ draws the nested pie and polar charts to alert for abnormal chemical values. Besides, the ‘gauge.js’ displays gauge chart for alerting the abnormal condition values. And the ‘timeLine.js’ records all essential events by timeline chart in main dashboard. Apart from those, the ‘timeline2.js’ and ‘bar_pie.js’ contain functions to draw charts on additional ‘interventionView.html’ and ‘outcomeAnalysis.html’ pages. Thus, to draw charts on the main page, the data is passed into these functions as a JSON object, then append this chart container to specific panel on the main dashboard.

In our ‘lib’ folder, we put dependent libraries here, like BootStrap-3.3.7, FontAwesome-4.7.0, ECharts-4.0.2, and JQuery techniques. BootStrap beautifies the GUI of our dashboard, FontAwesome provides pretty icons in our GUI, ECharts support chart developing with dozens of configuration items to customize our charts in the dashboard, and JQuery helps query document elements and dynamically change them effectively.

At last, the ‘image’ folder saves many images with .jpg and .png format linked to pages.

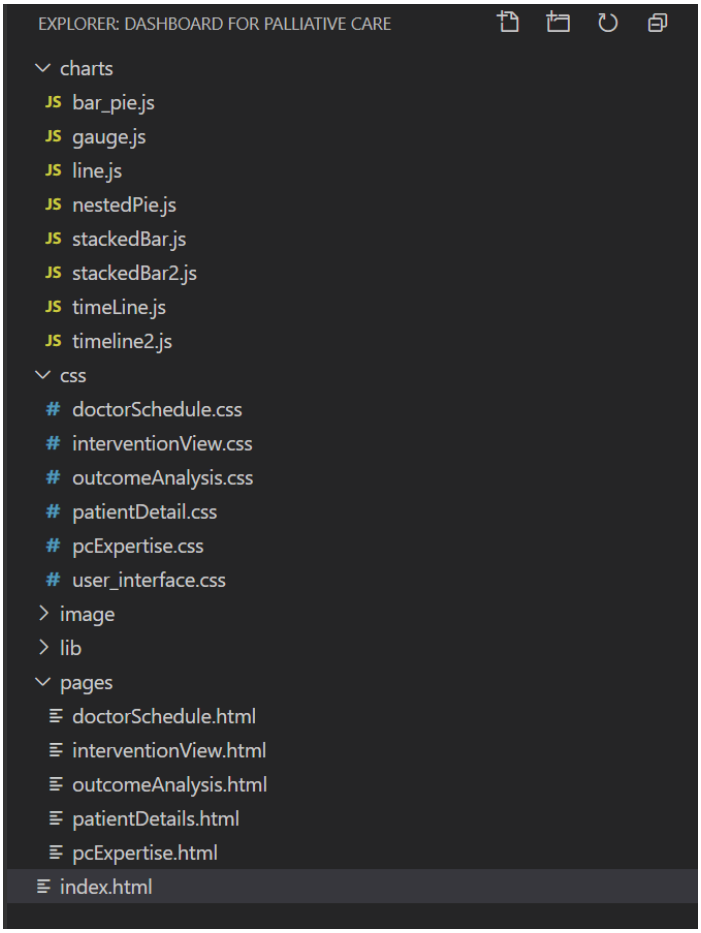


Figure 17. Project file structure

Cap ťulo 4. Results and Discussion

4.1 Results

4.1.1 Overall GUI

The user interface of the working prototype for our dashboard system is demonstrated in the following. The default web browser is Google Chrome. The main achievement of the system is the data visualization module and the GUI on the website contains three sections: top navigation, sidebar menu and main content. When selecting the 'Overall Analysis' function from the menu, the content will display the palliative care dashboard divided into two parts: 1) Patient Pattern Extraction and 2) Specific Care Process Analysis.

Among charts, the zooming in and out interesting data function is realized by inside and outside ways, the user can zoom with x-axis and y-axis slide bars, scrolling mouse inside the chart and select zoom tool in the toolbox. The legend of stacked bar charts, timeline chart can be clicked to add and delete according to the user. And the elements and charts are in the suitable size and position of the dashboard for conveniently obverse.

4.1.2 Extraction of Patient Pattern Module

Here, doctors can choose patients to review their care process from three methods: patient information table, palliative care comprehensively assessment and demographic outcomes (group patients by illness severity, age and death place). And you can see the example of choosing patient 001 (Nancy) and patient 003 (Herry) in the first module from Figure 18.

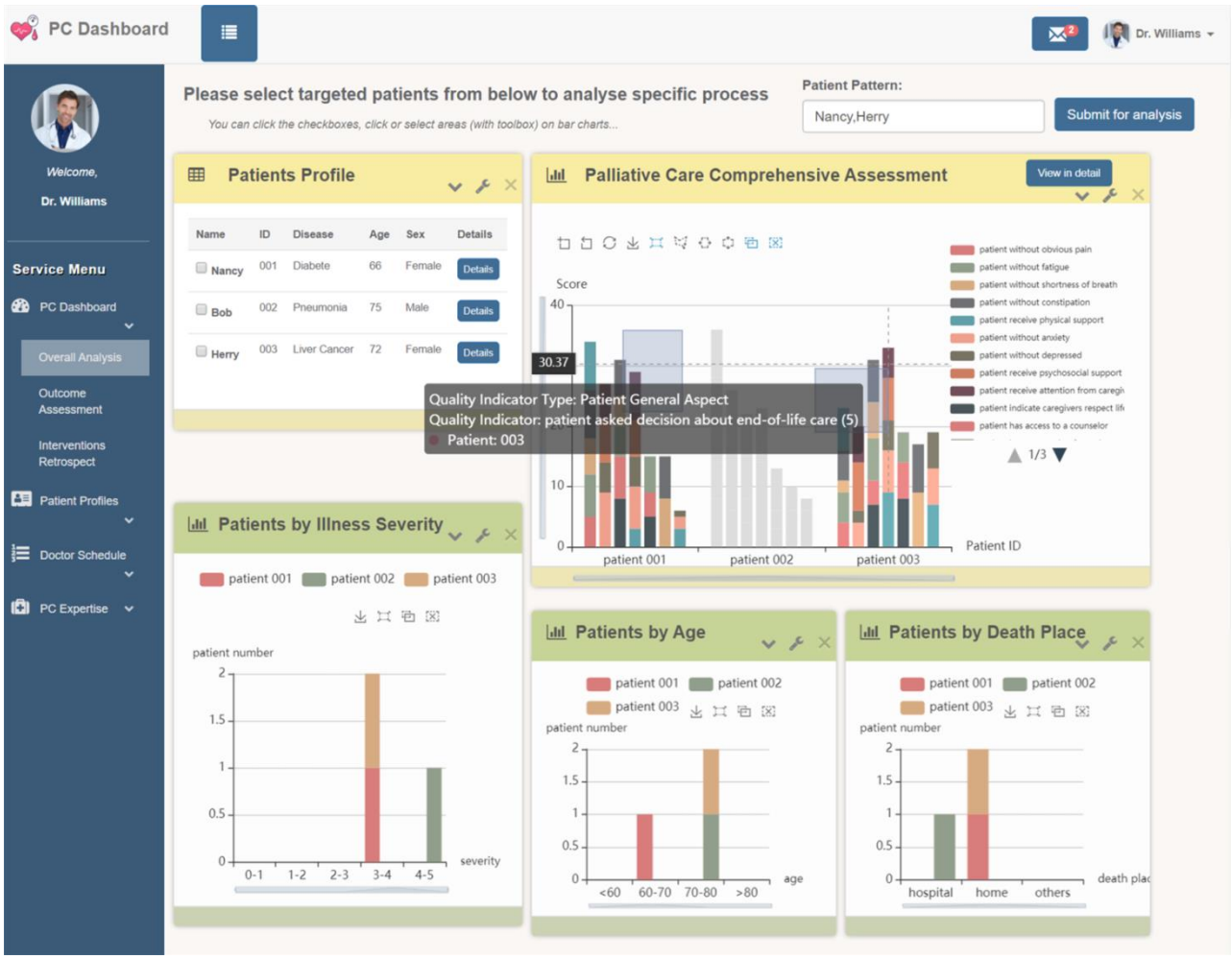


Figure 18. Patient pattern extraction part of dashboard

When the user wants to view patient detailed information, he can click the 'Details' button to jump to a patient profile page, which can be seen as Figure 19.

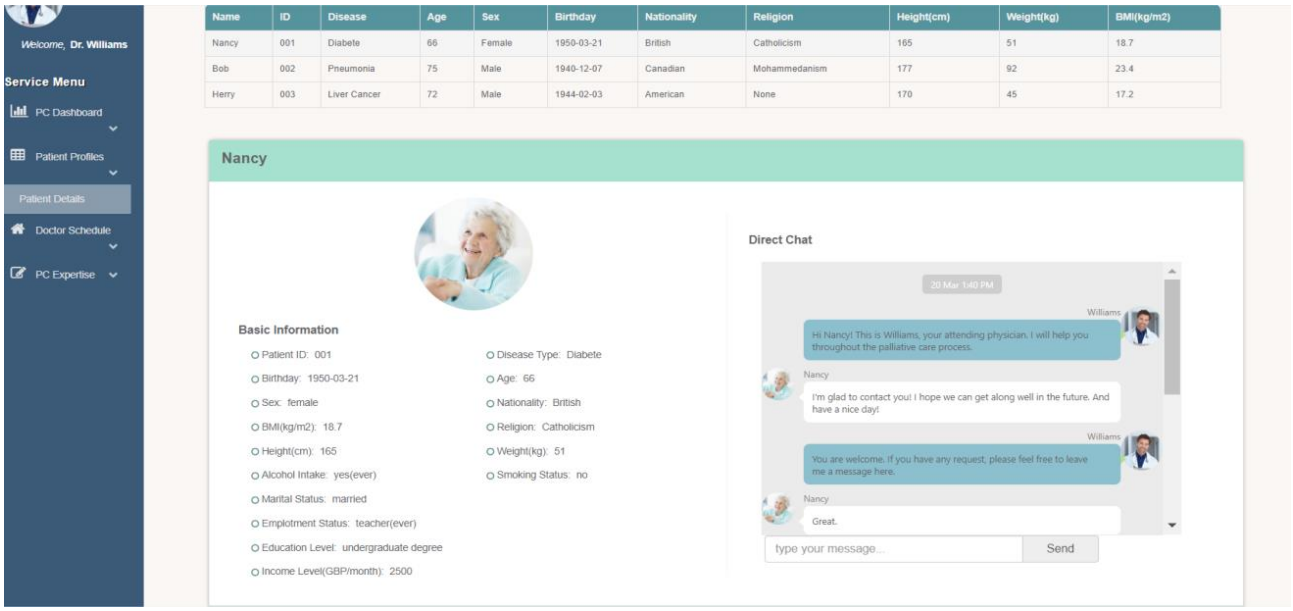


Figure 19. Patient profiles page

At the same time, when the user desires to choose patients from a comprehensive assessment chart, clicking the ‘view in detail’ button on the panel header can support observing clearly of patients’ care outcomes (Figure 20).

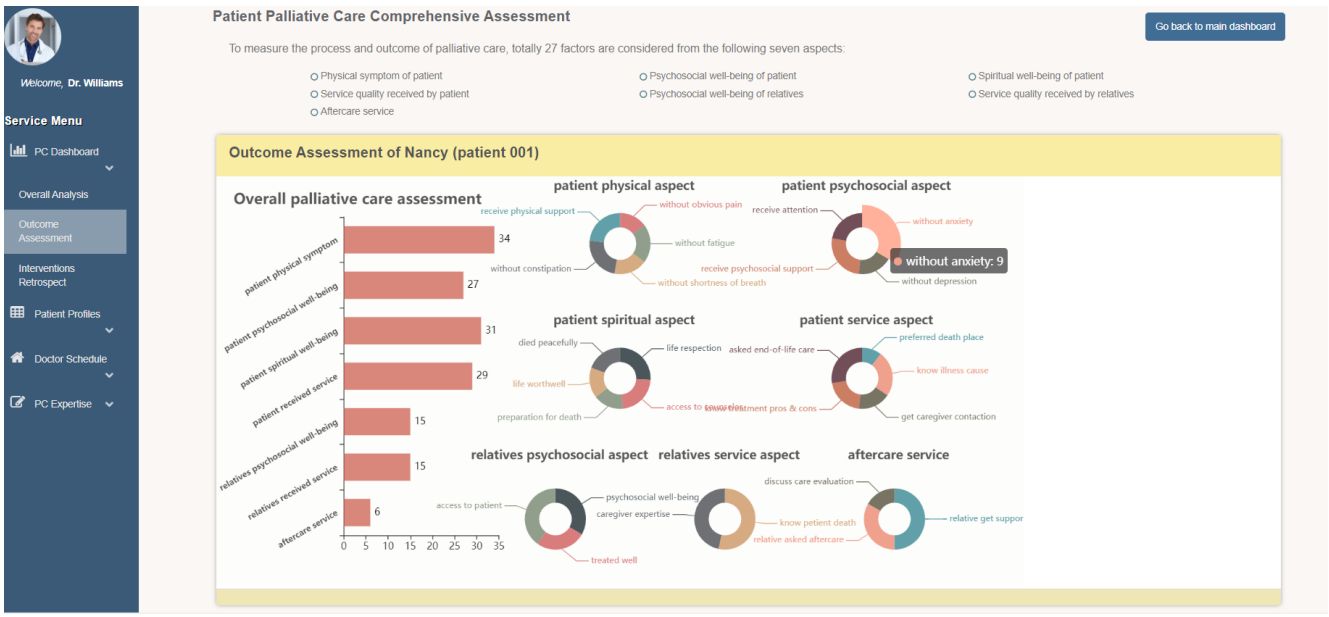


Figure 20. Patient outcome assessment page

We successfully support the user to select patient patterns in multiple ways. User can select patients through clicking on the checkbox in ‘Patients Profile’ table, or through clicking on patient item or brush area covering these items with the toolbox on ‘Palliative Care Comprehensive Assessment’ chart and other populational charts bellow to identify the pattern according to subjects of interventions they want to improve. Besides, the patients to be analyzed can also be canceled when clicking again on the checkbox or item of charts. To remind user the patients they have chosen, the input field at the top right corner will show their current selection.

Nevertheless, although selection inner one chart may not cause conflict, the conflict will generate when user selects across charts. So the project only supports selecting patient pattern through one method.

4.1.3 Specific Care Process Analysis Module

Figure 21 and Figure 22 display the ‘Specific Care Process Analysis’ module, which realizes recognizing familiar and critical intervention paths, analyzing effects of interventions on patient conditions and discovering effects of chemicals on patient status within the same patient pattern.

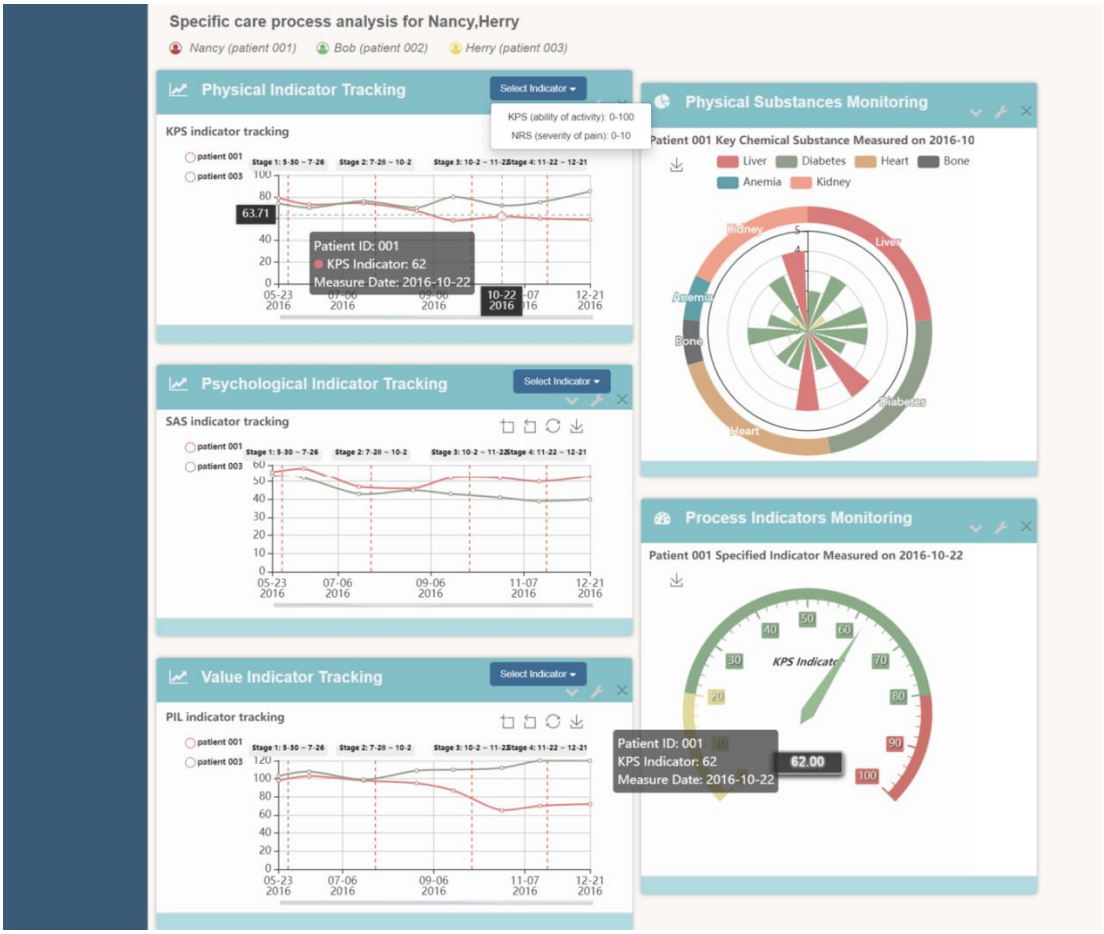


Figure 21. Specific care process analysis part of dashboard (1)

Figure 22. Specific care process analysis part of dashboard (2)

First, the retrieved patient pattern (patient 001 and patient 003) from the last module is displayed in the title of this module, and the selected patient process will be tracked from conditions and interventions parts. Different patient will use various color to represent. The top five charts represent the patient conditions, while two charts in the last row reveal the interventions and actions in care flow. Therefore, the interventions can be analysed and adjust according to the status of patient, which is the essential function to improve palliative care.

To measure the condition, the left three line charts respectively represent the physical, mental and value status. Moreover, activity status and pain degree can be selected to observe on physical status tracking charts, the anxiety and depression levels can be selected to display on the psychological tracking chart and the value towards life can be shown on value tracking chart. To be aware of the abnormal status of patients in care process the right-side gauge chart can be triggered when mouse moving on points of line charts. The gauge chart gives an alarm to doctors when patient has very poor condition and its pointer goes beyond the central range. In the same way, when the mouse is moving on points of line charts, the data representing key chemicals in the body will appear in the nested pie and polar chart on the right side. The outsider hollow pie chart displays the disease type correlated with chemical substance, while the inner polar chart exhibits the amount of those chemicals. So doctors can not only intensively focus on specific chemicals of patient's disease, but also pay attention to substance leading to other chronic illness, which helps to discover complications early. And when physicians find patient status is poor, they can quickly get the abnormal chemical substance and make prescriptions correctly.

To track the intervention and actions in palliative care, the left line chart at bottom records the doctor visit times, operation times and medicine tacking times every month; the right timeline chart at bottom displays every activitiy and intervention of patients in the course. The timeline chart marked with different stages of disease (dotted line) is conducive to compare and conclude the treatment mode for the specific patient pattern. Besides, based on their temporal features, clinicians can figure out the general solutions when patients are in there terminal of lives. For instance, the familiar activities in our data are admission to conduct at-home nursing and physical comfort. And users can merely display the interaction they interested by deleting the legend on the chart. These treatment records are placed just below patient status, displaying a distinct contrast by the timer shaft.

If the user wants to retrospect the interventions of patients in detail, he can just click the 'view in detail' button, which displayed and tracked previous intervention records as seen in Figures 23 and 24.

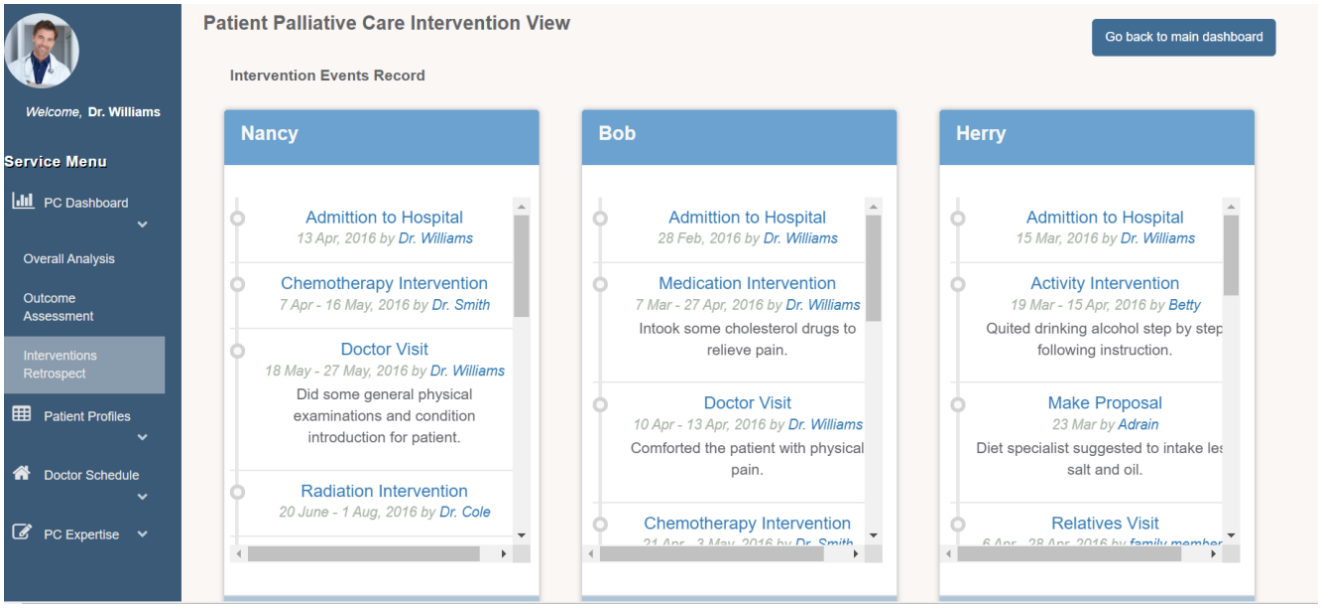


Figure 23. Patient intervention retrospect page (1)

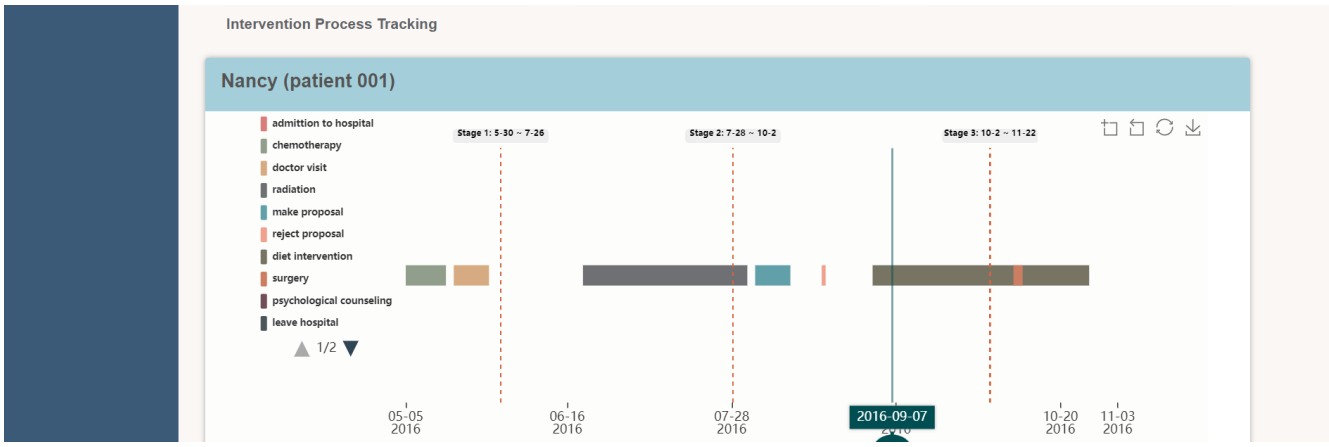


Figure 24. Patient intervention retrospect page (2)

The requirements defined previously are all realized well in this module.

4.2 Discussion

4.2.1 Requirement Completion

As we see, most of the requirements put forward in the Design section are implemented preferably as seen in Result section. As for functional requirements, for example, selecting customized patient groups by checkbox, tool box to add and cancel patients, displaying selected patients in the input field submitting to the second module, tracking patient conditions in physical, psychological and spiritual angles by choosing scores to display in line charts, alert abnormal condition by nested pie and polar chart as well as gauge chart, and set out general interventions by combining different treatments into one timeline chart. And the operability of requirements is also satisfied, like zooming inside or outside the charts, choosing legends to display, saving interesting data, displaying each chart in suitable place and collapsing the insignificant charts.

Nevertheless, there are also two requirements need to be improved. Firstly, the patient pattern now can be selected from one chart. If user wants to select patients from different charts to form the pattern, it will only show patients selected in the last chart. However, generally it is enough for users to select inside one chart, since each chart contains all patients. Apart from that, the responsiveness function has been realized mostly, but some panels are not very responsive considering the confliction when user collapses the panel.

4.2.2 Achievements and Problems

When it comes to the contribution of this project, it is a totally new type of dashboard designed directly for palliative care and has great distinctions from others. First, the state of art has been totally investigated, which helps others to know the situation and issues. We compared ten most relevant dashboard prototypes and summarized the most effective functions and charts. Second, we come up with a new function of assessing palliative from multi-angle by stacked bar chart in dashboard. Since previous research only evaluated palliative by literal expression, it may not let caregivers find the defective aspect quickly. Thus, this design can not only effectively discover the current insufficient, but can also let them set out intervention modes to perfect that. Third, existed works majorly focus on monitoring and alerting patient conditions from physical angle. But in our work, we emphasize on the psychosocial and social angles, which are the most significant and in great demand for palliative care. So it is also a breakthrough to associate these conditions with different scores then use charts to track and alert them. And the last characteristic is the design that let medical workers to analyse and adjust their treatments to improve particular outcomes or fit specific patient features. To realize that, we split our dashboard into patient pattern extraction and care process analysis modules.

However, there were also some problems I met. Due to the changed plan caused by the epidemic

situation, the previous database was not available, so I used some simulated but real data from the researches and existed dashboard systems and saved them into the JavaScript files on browser side. Then, our project is an off-line data analysed platform without any connection to local or remote databases. Besides, since there are few dashboards developed for palliative care and most are designed for treatments of chronic disease, the functions are not easy to be identified for our project. To solve that, first I investigated the current issues in palliative care that could not solve manually then reviewed on existed dashboards concerning chronic diseases. I selected the most suitable functions as well as charts, and created others to meet requirements in palliative care. And another problem was that the ECharts tool could not support some nested pie and polar plot as well as timeline chart in my design, so I changed the configuration items and added many other functions to make the desired interactions.

4.2.3 Assessment Methodology

Since the dashboard web pages need to be further assessed by interdisciplinary professional personnel including caregivers, doctors, pharmacists, psychological counselors, and other front-line practitioners, these are series of methodologies for them to evaluate this platform. And the evaluators are supposed to possess professional experiences and be chosen in a wide age range. In addition, the assessment of functionality and operability for dashboard will be divided into two methodologies: qualitative and quantitative way.

4.2.2.1 Qualitative Method

The qualitative way to measure functionality and operability:

- Functionality

(a) Extract patient patterns for drill-down analysis: the capability to select patients into group in accordance with user's requirement from care outcomes to care process discovery.

(b) Recognizing familiar clinic interventions and their temporal feature: the capability to set out effective and directed intervention mode for selected patient group in distinct critical stages. The ability to find inappropriate interventions for outliers by comparison of conditions among patients. And ability to let users be aware of patients going into their last stages of lives.

(c) Analyzing effects of internal key chemicals on patients' condition: the capability to identify complications from tracking chemicals and adjust prescriptions to control key substance in body.

(d) Discovering effects of different interventions on patients' status: the capability to deduct the reason for fluctuation of key condition indicators and adjust diet, activity or mental interventions to improve physical and psychological indicators.

- Operability

(a) Usability: user can understand, learn, and remember how to use the system.

(b) Efficiency: capacity of the system to quickly get desired information.

(c) Responsiveness: capability to resize and adjust layout according to different computer monitor sizes.

(d) Observability: capability to display charts in suitable size to observe.

(e) Robustness: capacity of the system to resist error.
(f) Satisfaction: capacity of the system to generate interest in users

4.2.2.2 Quantitative Method

The quantitative way to measure functionality and operability before and after the use of dashboard:

- Functionality

(a) Doctor visit duration (minutes)
(b) Doctor visit times
(c) Doctor call up duration (minutes)
(d) Doctor come times
(e) Physical activity intervention times
(f) Diet intervention times
(g) Medication intervention times

- Operability

(a) Responsiveness: time from making a request to generate all elements on web (second); improper displayed element number.
(b) Usability: time from tutorial end to user can operate whole functions correctly (minute).
(c) Satisfaction: frequency of using dashboard system (times/week).
(d) Efficiency: time from operating to get wanted information (second).
(e) Robustness: number of page error generated each operation.
(f) Observability: number of charts displayed in improper size or data amount.

Capítulo 5. Conclusion and Future Work

To sum up, the objective of our project is to identify requirements for the improvement of palliative care, then to design and implement chart modules in the dashboard system to satisfy those requirements. After researched on relevant works, we created a web-based and off-line dashboard system, which could support daily palliative care analysis through five functions: (1) multi-angle assessment of palliative care, (2) demographic outcomes display, (3) metabolic control, (4) conditions tracking and contrast, and (5) interventions tracking and contrast. These functions were implemented by two modules (extraction of patient pattern and care process analysis) with five types of charts and appropriate interactions among charts. Finally, after the initial assessment after the pilot test, we proved the functionality and operability for our dashboard system.

The future work of our project is to connect it to multi-source databases stored electronic health records to support on-line big data analysis. Then, the system will be tested and assessed on different devices and by different professional clinicians to view the feasibility and value in practical use.

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Second, I shall show my appreciation to another external tutor who supported me a lot on technical aspect of the project. He not only introduced the laboratory environment and equipment, but also gave me rich suggestions on the requirements of palliative care, tools to develop analysable charts and type of interactions we may need. Moreover, he identified some problems in my previous dashboard system, which helped to revise and polish the project effectively.

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Risk and environmental impact assessment

Since our dashboard project is a type of software engineering being of great risk of unpredictability, accurate assessment of its risk and environment impacts and set out risk management strategies before it is deployed are very essential.

As for environment impact, since the web pages need to store a large amount of data and process some logical functions, it will consume local storage and computing resources to some extent. The network delay may reduce user satisfaction, but it will not have big impacts on the normal completion of the GUI. In terms of risk assessment of our dashboard, we need to recognize factors leading to the randomness, variability and relativity from user requirement, charts and interactions design and technical quality aspects. Since we investigated a number of dashboards used for chronic diseases analysis, but did not asked and discussed with a professional palliative care practitioner about their requirement directly, there are inconsistencies between user requirements and system functionality. Besides, the needs of users will also change according to time and environment, which is inevitable and can cause a big economic lost and conflicts between doctors and patients when improper interventions are made with the support of our dashboard. The design problem can be caused by the capability and expandability, it needs to be used by various care givers and policy makers, and adapt to different browsers and monitors of personal computer. That decides the feasibility and friendliness for uncertain operating environment and limits its value. Finally, the risk can occur in codes or other technical error, which may be destructive to device. And the poor code style may lead to maintenance difficulties of product in the future giving rise to economic and equipment loss.

Therefore, to assess these risk and environment impacts, we apply risk factor calculation method to make the risk assessment table. This measure uses the product of likelihood (L) and consequence (C) quantitative numbers to measure the risk of failed completion for our dashboard project, where the former represents how likely the issue will occur and the latter means how serious the consequence will be. A point is that the likelihood level refers to the occurrence ratio if the risk is not managed effectively to be avoid. The following table shows main risks identified in our dashboard projects and how to manage these risks.

Risk and environment impect	Likelihood level(L)	Consequence level(C)	Score	Rating	Action
frequent user requirements changes	4	4	16	hign risk	reinvestigate requirements and design functions
device incapability for display	2	5	10	significant risk	change to computer and Chrome, Firefox and Microsoft Edge browser
poor page responsiveness	3	2	6	moderate risk	improve page responsiveness or change to suitable device
pages appear errors in charts or interaction when operating	2	4	8	significant risk	rewrite the code to repair project
function does not meet expectations	3	1	3	low risk	redesign functions
network delay to display pages when operating	3	1	3	low risk	move data and tasks to the server for storage and computation
interpersonal conflicts caused by improper intervention supported by dashboard	1	5	5	moderate risk	collect extensive data and design functions
The code is not easy to maintain and extend	3	0	0	no risk	/

Table 7. Risk Assessment Table

We can see, the highest risk is cause by the uncertainty and variability of user requirements, which gives rise to redesigning the project. And the incapability or other technical error causing the system may not work normally need to adjust in codes or device. Then the responsiveness impacts the comfort and satisfaction of user, but no fatal error. And if the functionality does not meet the expectation, we just need to refine some charts and interactions, since it is at low risk.

Overall, the above table lists all analysed risk and environment impact on enterprise economic, equipment performance and interpersonal conflicts for our dashboard project. When related personnel deploy the system should try to analyse and avoid that to control the loss at the lowest level.