Implementation of a Human-Centric GUI for Next-Generation Intensive Care Unit

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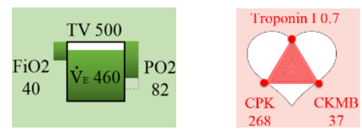
***Abstract*-- In the intensive care unit (ICU), the situations of the critical patients vary rapidly. To give the patient the necessary medical treatment, the medical staffs need to response in no time. However, making the diagnosis is not easy since there is tremendous information to be processed in ICU. In this paper, a prototype human-centric graphical user interface (GUI) based on ecological interface design (EID) is implemented by C# that is compatible with Microsoft Windows system. The human-centric GUI integrates the necessary information and will help the medical staffs to interpret them efficiently. The waveforms of artificial vital signs are displayed to show the variations of those signs instantly. Besides, the GUI can display the heart/lung/kidney indicators in radar charts to assist medical staffs aware of abnormal indicators in a visual way.**

I. Introduction

In the hospital, the intensive care unit (ICU) serves as a dedicated department to provide the critically ill patients the necessary intensive care medicine. Due to the extremely unstable situation of the critical patient in ICU, the medical staffs need to process large amount of complex information to understand the condition of the patients. The condition of the patient needs to be closely monitored by the medical staffs in order to perform the necessary emergency medical treatments to make their conditions stable. This leads the ICU to a high-pressure environment for the medical staffs.

To ensure the safety of the patient, one crucial issue is the correctness of the diagnosis which is closely related to situation awareness of the medical staffs in ICU [1]-[2]. Obviously, a correct diagnosis leads to an appropriate medical treatment. On the other hand, a wrong diagnosis may lead to the worst result - the death of a patient. The correct diagnosis needs the medical staffs handling various informations from different sources. However, integrating the tremendous information in no time is not easy, especially in a high-pressure environment. In the ICU, heterogeneous indicators are required to be interpreted by the medical staffs to understand the overall situation of a patient. Those indicators include the vital signs, the blood/urine examination results, and the medical images. Since the indicators are separated, the medical staffs need to obtain them from different sources. This effect makes the diagnosis more difficult.

Considering the above issues, a human-centric design based on the ecological interface design (EID) [3] is proposed in [4] for human-machine interface of next generation ICU. The EID aims to reduce the mental effort of the user for the complex systems. Thus, the cognitive resources of the user can be utilized for the higher cognitive processes. Fig. 1 shows the examples of the interface designs based on the EID concept. In Fig. 1(a), the state of the respiration is displayed. In Fig. 1(b), the risk of the acute myocardial infarction (AMI) [5] can be evaluated by the area of the triangle. Figs. 1(a) and 1(b) represent the respiratory system and the circulation system of the human, respectively.



(a) (b)

Fig. 1. Examples of EID: (a) respiratory system and (b) circulation system.

Based on the design in [4], the implementation of graphical user interface (GUI) for ICU is developed in this work. The vital signs, the heart/lung/kidney indicators and the medical images are integrated in one GUI. The human-centric display of those indicators offers the user a natural way to receive the necessary information for the diagnosis. Using C# on the Microsoft Windows system, the prototype GUI for ICU is implemented and demonstrated. The rest of this paper is organized as follows. Section II describes the prototype GUI implementation, and the conclusion is remarked in Section III.

II. Implementation of the Prototype GUI

According to the discussion in the previous section, our goal is to implement the human-centric GUI design for ICU to help the medical staffs monitor the conditions of the patients effectively. The GUI for ICU should integrate the necessary information to enhance the situation awareness of the medical staffs [6]-[9], and must be intuitive to help the medical staffs understand the indicators easily without interpreting the indicators exhaustively.

To develop the prototype GUI, the C# programming language with Microsoft Windows system is targeted. C# refers to an objected-oriented programming language with the elegant and type-safe features [10]. For the C# programming, the visual studio provides the programmers a user-friendly environment to develop the program. In addition, plenty of the resources and tutorials can be found in Microsoft Developer Network (MSDN) [11]. Those features make the combination of C# and Windows favorable for the implementation of the GUI of ICU in this work. In this paper, since it is not easy to obtain complete vital/medical signals from a person, we only use artificial signals/information to show the waveforms, numbers and images in order to test the prototype GUI functions in Fig. 2. Note that Fig. 2 is the screenshot of the

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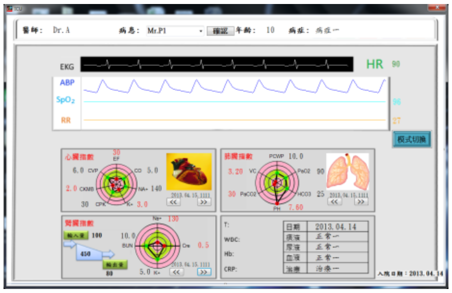

Fig. 2. Prototype GUI for ICU.

```
private void InitializeComponent()
{
   System.Windows.Forms.DataVisualization.Charting.Series series1 =
      new System.Windows.Forms.DataVisualization.Charting.Series();
   ...
   //Start of the codes for the radar chart display
      //Specify the attributes for the chart
         ...
      //Specify the background image
         chartArea1.BackImage="C:\\ICU\\chart1.png";
      //Specify the chart type
         series1.ChartType = System.Windows.Forms.DataVisualization.
            Charting.SeriesChartType.Radar;
      //Define the indicators
         dataPoint1.AxisLabel = "EF";
         dataPoint1.MarkerColor = System.Drawing.Color.Lime;
         dataPoint1.MarkerSize = 10;
         dataPoint1.MarkerStyle = System.Windows.Forms.
            DataVisualization.Charting.MarkerStyle.Circle;
         ...
      //Add the indicators
         series1.Points.Add(dataPoint1);
         ...
   //End of the codes for the radar chart display
   ...
}
```

Fig. 3. Simplified code for radar chart display in C#.

prototype GUI program. The heart and lung images in Fig. 2 are adopted from the clip arts in Microsoft Office.

Fig. 2 shows the implementation results of the prototype GUI. The GUI integrates three main areas into the main window: the basic information, the vital signs, and the heart/lung/kidney indicators. The top part of the GUI in Fig. 2 displays the basic information of the patient including the name of the attending doctor, the name of the patient, the age of the patient and the diagnosis of the patient. Using these informations, the medical staffs can have the basic understanding of the patient. Since the GUI is designed to accommodate the data from multi-patients, the medical staffs can choose the patient's name from the pull-down menu and the corresponding information will be displayed.

In the area of the vital signs, the waveforms of the electrocardiography (EKG), the blood pressure, the oxygen saturation, and the respiration rate are displayed as shown in Fig. 2. Since the vital signs change rapidly, displaying waveforms can let the medical staffs receive the immediate variations of those signs. In addition, the display of the 4-channel electroencephalography (EEG) signals can be activated by clicking the mode change button in Fig. 2 since the brain monitoring is expected in the next-generation ICU.

In the bottom part of the GUI in Fig. 2, the indicators are classified into three groups: the heart indicator, the lung indicator and the kidney indicator. For the indicators, different time points can be selected such that the medical staffs can evaluate the recovery progress of the patient by comparing the indicators at different time points. The indicators apply the radar chart for the visualization to help the medical staffs be aware of the patient's heart/lung/kidney conditions intuitively by observing the shape of the radar chart. In C#, the chart controls provide the capability of displaying various charts. Fig. 3 shows the simplified code for the radar chart display in C#. As can be seen, the radar chart type is specified for series1.ChartType. Accomplished with other attribute settings, the radar chart can be displayed through the C# program.

In the radar chart, the green zone and the red zone are used to specify the indicators in normal range and abnormal range, respectively. As can be seen in Fig. 2, the colors of the abnormal indicators lying on the red zone are changed to red to warn the medical staffs. For the heart and the lung indicators, the corresponding medical images are integrated with them. The thumbnails of the medical images are placed next to the radar charts. By clicking the thumbnails, one window will be popped up to show the enlarged medical image.

III. Conclusion

In this work, a prototype human-centric GUI based on EID for the next-generation ICU is implemented. The patient's basic information, vital signs and indicators are integrated in the prototype GUI. In addition, the GUI has the 4-channel EEG display function to provide the necessary brain monitoring for the next-generation ICU. To offer an intuitively way for the medical staffs' situation awareness of the heart/lung/kidney indicators, the radar chart is utilized in the prototype GUI. As a result, the prototype human-centric GUI can aid the medical staffs to process the information in ICU efficiently and makes the diagnosis and medical treatments easier.

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