Development of a customized software for collection and analysis of data form patient monitors-a preliminary study

A Report for the Project work

conducted through cooperation of the Department of Information Technology, Government Engineering College, Barton Hill, Trivandrum and Sree Chitra Tirunal Institute for Medical Sciences and Technology

by

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CERTIFICATE

This is to certify that the report entitled **Integrated Monitoring System and Prediction Tool for Outcomes after Neurosurgery** submitted by **Gowri Arunsha** (TRV19IT029), **Ron Regi Zacharia** (TRV19IT045), **Suryanarayan Menon A** (TRV19IT055) & **Vinayak Naveen** (TRV19IT058) to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech. degree in Information Technology is a bonafide record of the project work carried out by them under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

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DECLARATION

We hereby declare that the project report **Development of a customized software for collection and analysis of data form patient monitors-a preliminary study**, submitted as part of a project done through collaboration of the Department of Information Technology with Sree Chitra Tirunal Institute for Medical Sciences and Technology, is a bonafide work done by us under the supervision of **Mr. Rajeev A, Mr. Manoj G. S** and **Dr. Smita V**.

This submission represents our ideas in our own words, and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources.

We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the Department and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma, or similar title of any other institution.

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Abstract

Effective anaesthesia management in neurosurgery operations necessitates real-time monitoring of hemodynamic parameters, depth of anaesthesia, and ventilatory parameters. It is critical to maintain adequate mean arterial pressure (MAP), as low MAP has been associated to unfavourable outcomes such as stroke and myocardial infarction. The Bi-spectral index (BIS) is used to monitor the depth of anaesthesia, with greater BIS values suggesting awareness and lower values indicating deeper anaesthesia. Gas monitors measure oxygen and carbon dioxide levels, as well as anaesthetic minimum alveolar concentrations (MAC). Low MAP, low BIS, and low MAC values (double/triple low) are related with higher morbidity and death. Blood pressure must be kept within cerebral autoregulation limits, and the occurrence of EEG quiet during surgery, along with low anaesthesia levels, has been associated to postoperative problems. For effective analysis of neurosurgical anaesthesia, customised software is required to combine and analyse data from numerous patient monitors. This initiative investigated the viability of developing such software to aid in the meaningful analysis of neurosurgical anaesthesia.

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Chapter 1

Introduction

The intraoperative anaesthetic management influences the patient's recovery and long-term clinical outcomes after a neurosurgical procedure. Maintenance of optimal hemodynamic, depth of anaesthesia and ventilatory parameters in the perioperative period are the key factors in maintaining cerebral blood flow and oxygenation and thereby improving postoperative outcome. In order to maintain these parameters in their optimal range, various real time patient monitors are employed during a surgical procedure.

The hemodynamic parameters are captured in real time with a pressure transducer attached to an invasive arterial line connected to the patient's artery. The mean arterial pressure (MAP) is an important hemodynamic indicator that needs to be maintained within an optimal range during the entire surgical procedure and post-operative care. The volatile anaesthetics evoke dose-dependent hypotension because they act as vasodilators and bring down myocardial contractility. The typical value of MAP is around 85 mmHg, but values vary according to the selected surgical procedure and the patient's comorbidity. It is reported that low intraoperative MAP might increase the risk of stroke, cause myocardial infarction and increase patient mortality [Chang HS 2000, Lienhart 2006).

The depth of anaesthesia is commonly monitored with the help of electroencephalographic (EEG) analysis. One of the electroencephalographic methods known as the Bi-spectral index (BIS), developed by Kearse et al., uses advanced signal processing methods to provide numerical values in the range of zero to 100 to indicate the hypnotic level of the patient (Kearse 1994). A value of 100 indicates full alertness, and values less than 40 indicate deep anaesthesia, whereas BIS values in the 40 to 60 range denote surgical plane anaesthesia.

When gaseous anaesthetics are employed to induce sedation, their potency is characterised by their minimum alveolar concentration (MAC), which is the alveolar partial pressure at which 50% of patients move in response to a skin incision (Sessler et al. 2012) Gas monitors are used to monitor the inspiratory and end-tidal levels of oxygen, the end- tidal level of carbon dioxide, and the MAC of inhaled anaesthetics. Even though MAC varies according to the selected anaesthetic, the MAC fraction characterises the relative dose of the selected anaesthetic agent. The initial dose of the selected anaesthetic agent is calculated based on the targeted MAC, and then the dose is adjusted to maintain optimal hemodynamic conditions.

Sessler et al., in their landmark study, showed that triple low, a combination of low MAP, low BIS value and low MAC number, intraoperatively is associated with a high probability of mortality and morbidity (Sessler et al. 2012). Other studies showed that even the double low, the combination of low MAP and low BIS, is an independent risk factor for mortality and morbidity. In a study by Maheswari et al., the presence of prolonged concurrent double low increased the incidence of mortality after cardiac surgery (Maheswari et al, 2017). The double low was also found to be a risk factor for the development of postoperative delirium (POD), which itself is a risk factor for mortality. A study by Chan et al. showed that maintaining higher BIS values during anaesthesia is protective against the development of POD (Chan et al, 2000). In addition to the hemodynamic variables, respiratory parameters such as hypocapnea (low CO2) for prolonged periods have been associated with poor outcomes in patients with brain injury.

Neurosurgical procedure requires strict control of blood pressure at a higher or lower limit of cerebral auro-regulation, depending on various illness conditions such as subarachnoid haemorrhage (SAH), raised intracranial pressure, endoscopic surgeries and resection of vascular tumours and arterio-venous malformations. The presence of hypotension has been identified as a predictor for poor outcome in patients with traumatic brain injury and in patients with SAH. Also, the anaesthetic depth maintained can vary according to different conditions. For example, conditions such as raised intracranial pressure as in intraoperative brain bulge and the application of neuroprotection during vascular surgeries require the maintenance of deeper planes of anaesthesia. The presence of EEG silence intraoperatively has been linked to the development of POD and postoperative mortality, though recent studies have shown that the presence of EEG silence along with low anaesthetic levels is the main risk factor, revealing an inherent susceptibility or frailty as the causative agent rather than the presence of EEG silence alone. Thus, it is clear that a complex relationship exists between multiple patient parameters during the surgery and anaesthesia. In order to correctly interpret this complex relationship between the three important patient parameters, viz:- MAP, BIS and MAC, data from individual patient monitors needs to be collected, integrated and analysed at a single point.

In SCTIMST hospital multiple patient monitors are employed to capture these vital parameters from a single patient. For meaningful analysis and interpretation of the combined effects of these patient parameters, it is imperative that this information be collected, integrated and analysed on a single computer. As there is no ready-made software available on the market, to collect and analyse these patient parameters which are spread across different monitors from various manufacturers, a purpose-built software needs to be developed. In this work, we aim to develop a customised software to collect and analyse data from two different patient monitors, the BIS monitor and a patient haemodynamic monitor. Due to shortage of time, only preliminary studies on the patient haemodynamic monitor was carried out.

Chapter 2

Proposed System

The proposed s ystem for collecting and analysing data from different patient monitors is shown in the figure [2.1]. The required data from the Operation Theatre (OT) is collected from a BIS monitor, a patient haemodynamic monitor and an anaesthesia monitor. When the patient is transferred to the Intensive Care Unit (ICU), after completion of the surgical procedure, MAP data is collected from a patient haemodynamic monitor, which is installed in the ICU. All of the monitors are connected to a centralized computer through suitable interfaces like a network switch or an USB port. Customised pieces of software are developed for each monitor for extracting the relevant data from the monitors. Then the extracted data is stored in a database for analysis. Separate software modules are needed for analysing each type of the collected data. Prior to the data analysis, an event is defined for each parameter. An event is occurred when the any of the parameters (i.e MAP or BIS or MAC) is reached below a specified threshold value in its magnitude and is it is exceeded a certain duration of time (see fig 2.2). After specifying the event associated with each parameter, the stored data is processed with the help of the concerned software module to generate an event list. The individual event list is compared with the clinical outcomes using a regression analysis module for building an event/clinical outcome relationship model. Due to the shortage of time, data collection and analysis from the BIS monitor and preliminary studies on the collection of data from the patient haemodynamic monitor are addressed in this report (highlighted in grey colour in fig 2.1).

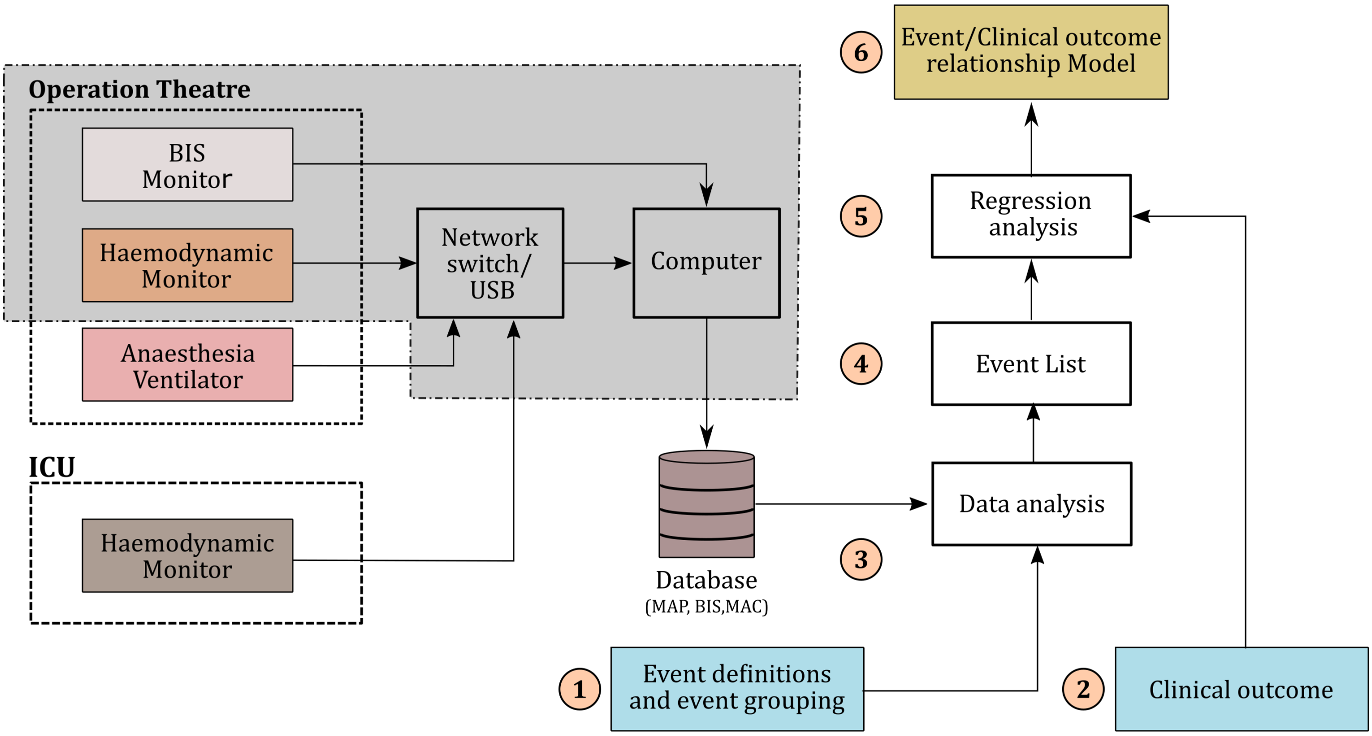

Figure 2.1: The proposed system for collecting and analysing data from different patient monitors

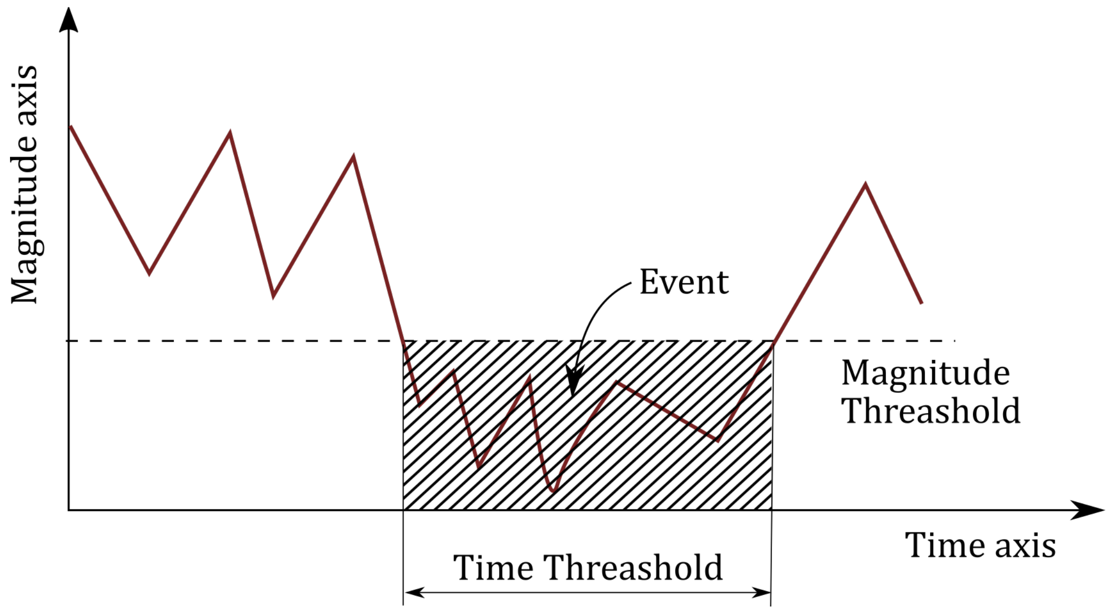

Figure 2.2: Event specifications for parameters. An event occurs when a parameter reaches below a specified value in magnitude and for a specified duration in time.

Chapter 3

Data Capture from Bispectral Index Monitor

3.1 Introduction to the BIS Monitor

The BIS monitor, as thoroughly researched and technologically analysed by Bard in [2], is a ground-breaking development in the field of medical monitoring. The Bispectral Index (BIS) monitor, which is based on the merger of neuroscience and digital innovation, offers a novel technique to measuring and visualising the complicated neurological condition of patients undergoing anaesthesia and sedation. The BIS monitor offers doctors with a quantifiable measure, the BIS value, by analysing the electroencephalogram (EEG) data acquired by this instrument. The BIS value acts as a quantitative depiction of the patient's degree of awareness and reaction to anaesthesia. This combination of physiological understanding and technical accuracy enables healthcare practitioners to make educated real-time decisions, assuring appropriate anaesthesia management and improving patient safety across a variety of medical procedures.

3.2 Data Collection

Our focus for the software developed focussed on the BIS monitor, which monitored a wide variety of parameters. The rigorous data gathering method included timestamp information, which allowed us to not only trace the chronological evolution of the anaesthesia process, but also permitted linkage with other significant events throughout the surgery

The average BIS values were an important measure of the overall depth of anaesthesia attained throughout the surgery. We acquired vital information regarding the patient's degree of awareness and responsiveness to the anaesthetic medications employed by analysing this critical measure. We also documented the minimum and highest BIS values seen during the procedure. These extremes provided a more detailed view of the anaesthesia variations, allowing us to pinpoint important points and potential obstacles throughout the procedure.

To ensure the validity of the BIS data, the Signal Quality Index (SQI) was used, which offered useful feedback on the accuracy of the BIS measurements. Accurate and consistent BIS readings are key for making informed decisions during anaesthesia management, and the SQI functioned as an important quality control parameter in our data gathering procedure.

We also looked at data from electromyographic activity (MG) and suppression ratio (SR). We were able to quantify muscle activity and its potential consequences for anaesthesia depth by analysing MG, whereas SR data offered insight on the adequacy of anaesthesia suppression during surgical stimulation.

We also logged the BIS monitor's average impedance values. This parameter supplied vital information on electrode contact quality, ensuring precise and reliable BIS measurements. Furthermore, BIS Bispectral Trends (BISBITS) were meticulously examined, providing vital insights into the trends and patterns of BIS values over time, allowing us to better understand the dynamics of anaesthesia depth during the surgical operation.

Finally, we included the average burst suppression measure in our data collecting efforts, which assessed the proportion of time the patient's brain activity was suppressed under anaesthesia. This measure allowed us to assess the amount of anesthesia-induced unconsciousness, which was useful for regulating anaesthesia dosage and ensuring patient safety.

3.3 User Input

Users interact with the system by providing specific information, including the location of the data obtained from the BIS monitor, as well as the start date and end date of the desired analysis period. Additionally, users input the start time and end time to narrow down the focus of the analysis.

Furthermore, users are prompted to set a threshold for the average BIS value, which plays a significant role in identifying relevant events within the data. The minimum duration for an event to be considered as significant is also a vital input, as it helps filter out minor fluctuations from more significant occurrences.

To accommodate different data formats, the system allows users to specify the desired file format for the analysis results. Users can choose between the widely used CSV format or the SPA format, ensuring compatibility with various data processing tools and software.

By collecting and incorporating these user inputs, the system operates efficiently, enabling seamless analysis of patient information from the BIS monitor data and generating meaningful insights in response to specific queries and requirements

3.4 Output

The output of our study was a visually informative and comprehensive graphical visualization that depicted the collected BIS (Bi-spectral index) information plotted against the timeline of events during the neurosurgical procedure. This visualization was instrumental in highlighting the dynamic changes in BIS values throughout the surgery. Variations in the BIS values were clearly denoted through distinctive blue lines in the diagram, enabling a quick and intuitive understanding of the fluctuations in anesthesia depth.

Our program allows for user input to improve the usefulness of the visualisation. Following particular user instructions, significant occurrences during the operation were highlighted in red on the graph, with the duration of each event clearly specified. This feature gave a clear and succinct picture of crucial points during the procedure, assisting in the identification of significant moments and potential obstacles that might impair the patient's anaesthesia experience. During the surgery, this assists in identifying crucial moments and possible obstacles that may impair the patient's anaesthesia experience.

The graph provided useful quantitative information in addition to the graphical display of events and BIS values. It includes the total number of events marked throughout the procedure, providing a vital tally of significant occurrences. Furthermore, users may enter an average BIS threshold, and the graph would display this threshold correctly to aid in analysis and decision-making. Another important element that customers could change was time tolerance, which allowed them to tailor the visualisation to their individual needs.

Overall, our graphical visualisation, together with user input options, provides a complete and user-friendly platform for analysing anaesthesia depth dynamics, highlighting crucial events, and measuring the impact of altering BIS values during the neurosurgical process. This sophisticated technology significantly aided in the optimisation of anaesthesia management, eventually leading to better patient care and results.

3.5 Visualisation Algorithm

3.5.1 toCSV.py

The main objective of this program is to convert data from a specific "spa" file format into a structured CSV format, which makes the data easier to use and analyze. The code does this through a series of planned steps. The first definition, spa_to_csv, contains the conversion process. This function takes three parameters: **folder, out_file**, and an **optional filename**.

When the program is executed, the **"spa" file** that has been provided is opened, and its contents, including the header line with the dataset's metadata, are read. The number of columns is determined by analyzing this header line. The index of a specific data label, "AVGBIS," within the header is then specified by the code. This index is necessary for meticulously deleting essential data from each row.

Data conversion is then accomplished by the code through the creation of a new CSV file in write mode. As it cycles over the rows of the "spa" file, the "—" delimiter is used to separate the data values. Each row's timestamp value and the value for the "AVGBIS" index, which stands for a specific data metric, are extracted. The rows of the CSV file are then arranged based on the values obtained.

After processing all rows and closing the CSV file, the procedure returns the location of the recently created CSV file. The code's modular design and parameterization make it simple to include in the broader project process, enabling accurate and speedy data conversion for use in analysis and reporting.

3.5.2 bisVizApp.py

In the pursuit of user-friendly data analysis and visualization tools, this project endeavors to create an interactive **graphical user interface (GUI)** application using the **KivyMD framework**. The primary objective of the application is to provide users with an intuitive platform for effortless data exploration and analysis. Central to this endeavor is the design of a clean and organized user interface. Built upon the KivyMD framework, the GUI employs a vertical **BoxLayout layout** that ensures a visually appealing presentation. The inclusion of a prominent project logo further enhances the user experience, establishing visual branding within the application.

To enhance the usability of the application, interactive elements have been thoughtfully integrated. The application enables users to define precise time intervals through buttons that trigger specialized MDDatePicker and MDTimePicker dialogs. These dialogs facilitate the selection of start and end dates, along with corresponding start and end times. The chosen time values are meticulously captured and processed, setting the stage for further analysis. Moreover, the application caters to varying data analysis requirements by allowing users to input personalized threshold values. Through labeled input fields, users can adapt the ”BIS Threshold value” and ”Time Threshold value” to their specific analytical contexts, thereby ensuring flexibility in the insights derived from the data.

A key feature of the application lies in its streamlined file management capabilities. Users have the option to manually input filenames or paths for CSV or SPA files, simplifying the process of data selection. Additionally, a dynamic ”Choose File” button launches an MDFileManager, facilitating seamless navigation through the file system and enabling users to effortlessly identify and select their desired data file.

The culmination of the application’s capabilities is observed in the initiation of data analysis tasks. By invoking the **bisviz function**, users can harness the power of their input parameters, including date ranges, threshold values, and file paths, to commence data analysis tailored to their requirements. This user-centric approach bridges the gap between raw data and valuable insights, demonstrating the symbiosis of user interface design and effective data analysis tools. In conclusion, the developed GUI application exemplifies the convergence of design and functionality, offering a versatile solution that empowers users to interact with and comprehend their data seamlessly.

3.5.3 Bis_visualize.py

Biz_visualize.py forms a pivotal component of the project, contributing to the analysis and visualization of the dataset. It commences by importing essential modules, including **CSV**, **matplotlib.pyplot**, and **numpy**, thus establishing the groundwork for data manipulation and visual representation. The program is structured around two core functions; namely bisVal_csv and plot_bis.

The bisVal_csv function encapsulates the data processing phase. With inputs encompassing start and end dates, threshold values, and a filename, this function efficiently reads the designated CSV file. It then applies specific conditions to ascertain events within the dataset, based on "AVGBIS" values dipping below a defined threshold for a specified duration. Consequently, the function outputs a range of critical event-related details, including event count, start and end positions of each event, and an array of timestamps.

Complementing the data processing function, the plot_bis function embraces the realm of data visualization. By employing the **matplotlib** library, this function transforms the processed data into an informative graphical representation. The graph, intricately designed to illustrate timestamps against "**AVGBIS**" values, encompasses shaded regions delineating each event's temporal span. Furthermore, the plot is enriched with a threshold line, delineating the threshold value, and a text box presenting pertinent information like event count, threshold value, time tolerance, and initial timestamp.

3.5.4 Bisviz_interface.py

At the outset, the code strategically imports vital functions from external modules, including **spa_to_csv**, **plot_bis**, and **bisVal_csv**. These functions serve distinct purposes, encapsulating functions for data format conversion, event visualization, and event value computation. This modular approach not only enhances code reusability but also underscores the project's emphasis on efficient and organized programming practices.

Beyond the integration of functions, the code establishes a seamless connection with the operating system to ensure context-aware file management. By accessing the current working directory, this feature promotes a dynamic environment for data processing and provides streamlined access to necessary resources.

The crux of this code lies in the **bisviz function**, which serves as the driving force behind data analysis and visualization. This function adeptly processes user-provided inputs, encompassing variables such as time thresholds, file formats, and specific data ranges. It dynamically adapts these inputs to ensure precise analysis and presentation. Impressively, the function demonstrates versatility by accommodating SPA-to-CSV file conversion when needed, a testament to the project's adaptability in handling diverse data sources. With finesse, the bisviz function orchestrates the creation of insightful visual plots, solidifying the project's capability to extract meaningful insights from raw data.

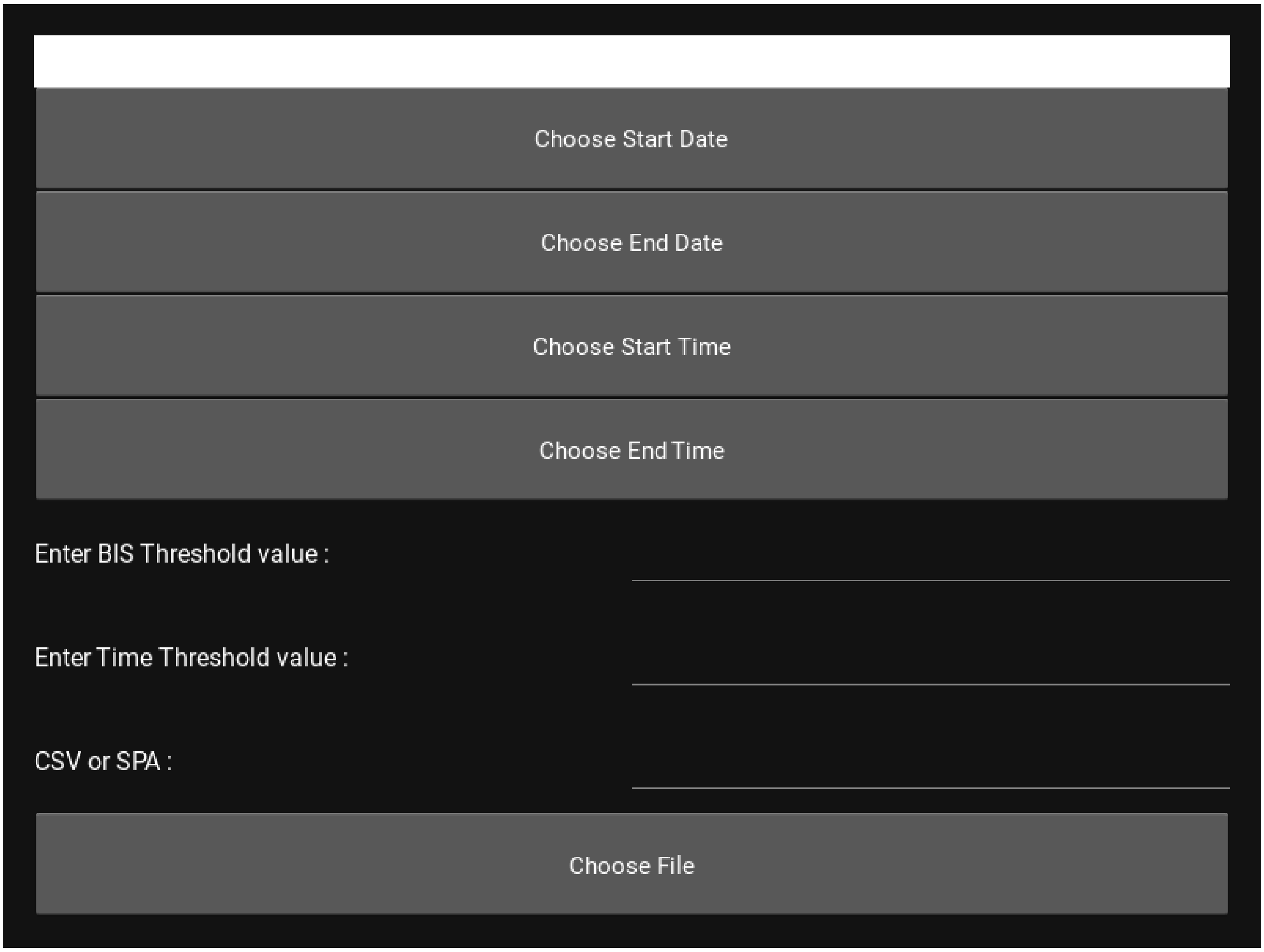

Figure 3.1: User Input

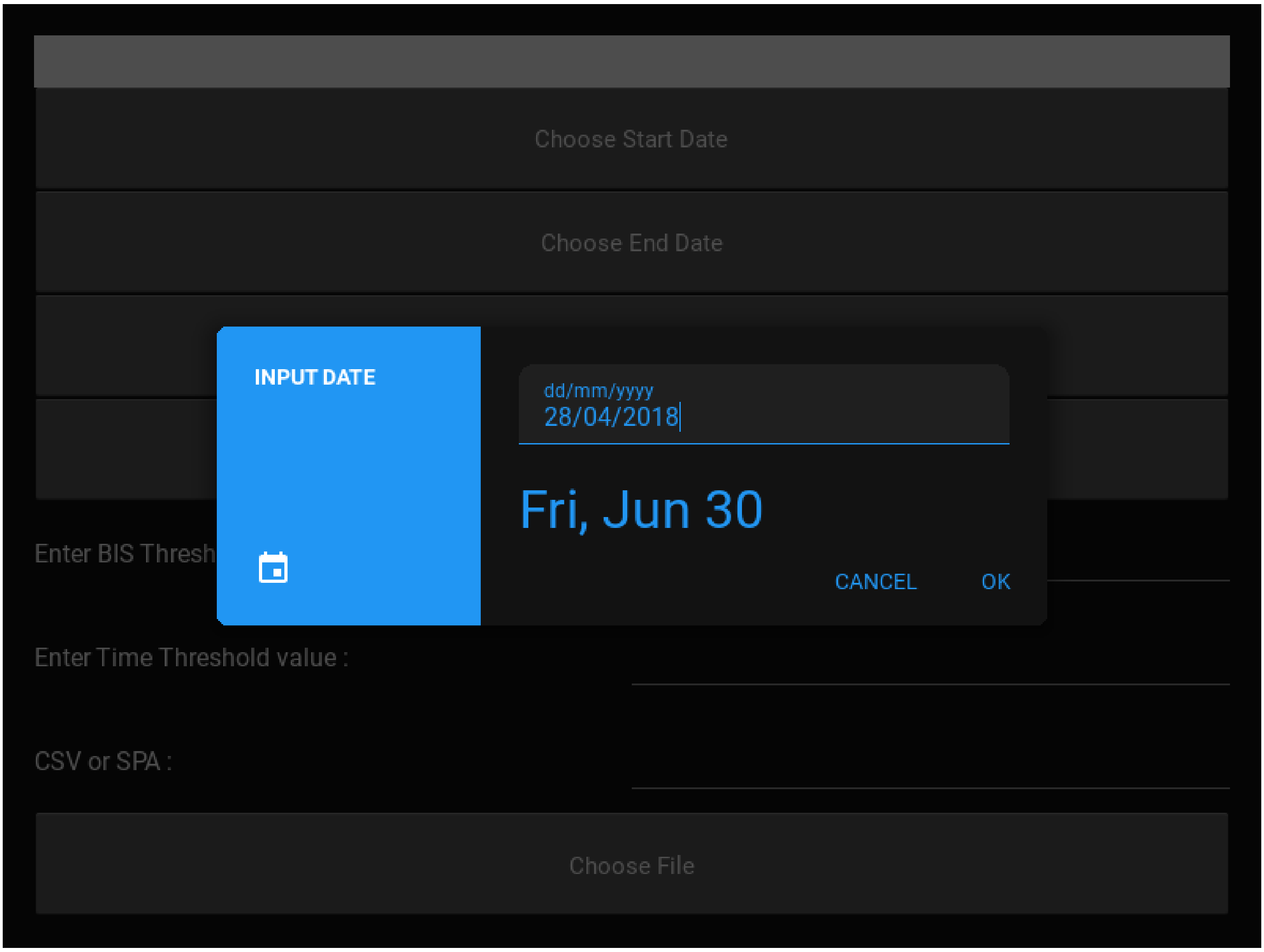

Figure 3.2: Input Date

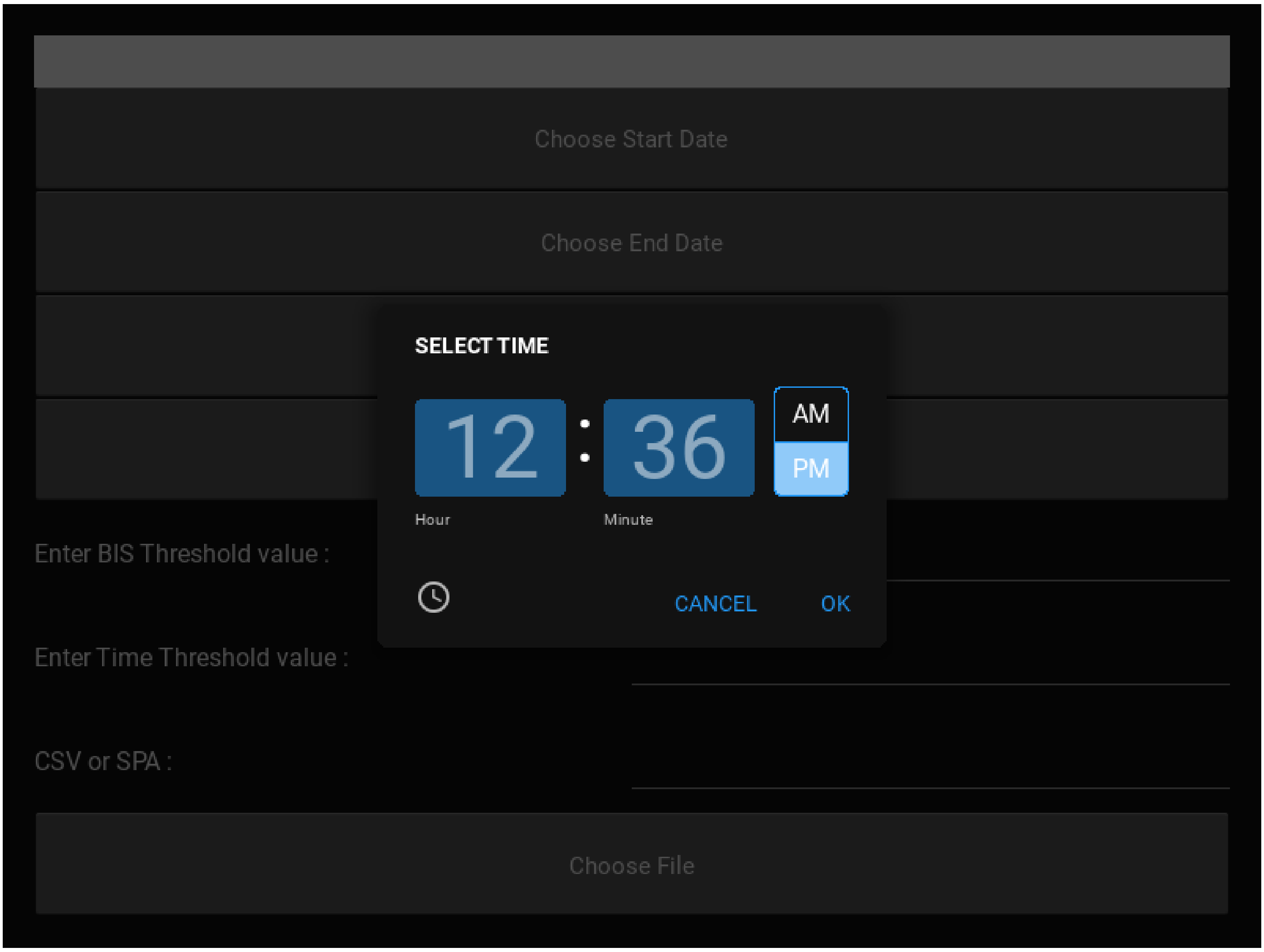

Figure 3.3: Input time

Figure 3.4: Input time - Part 2

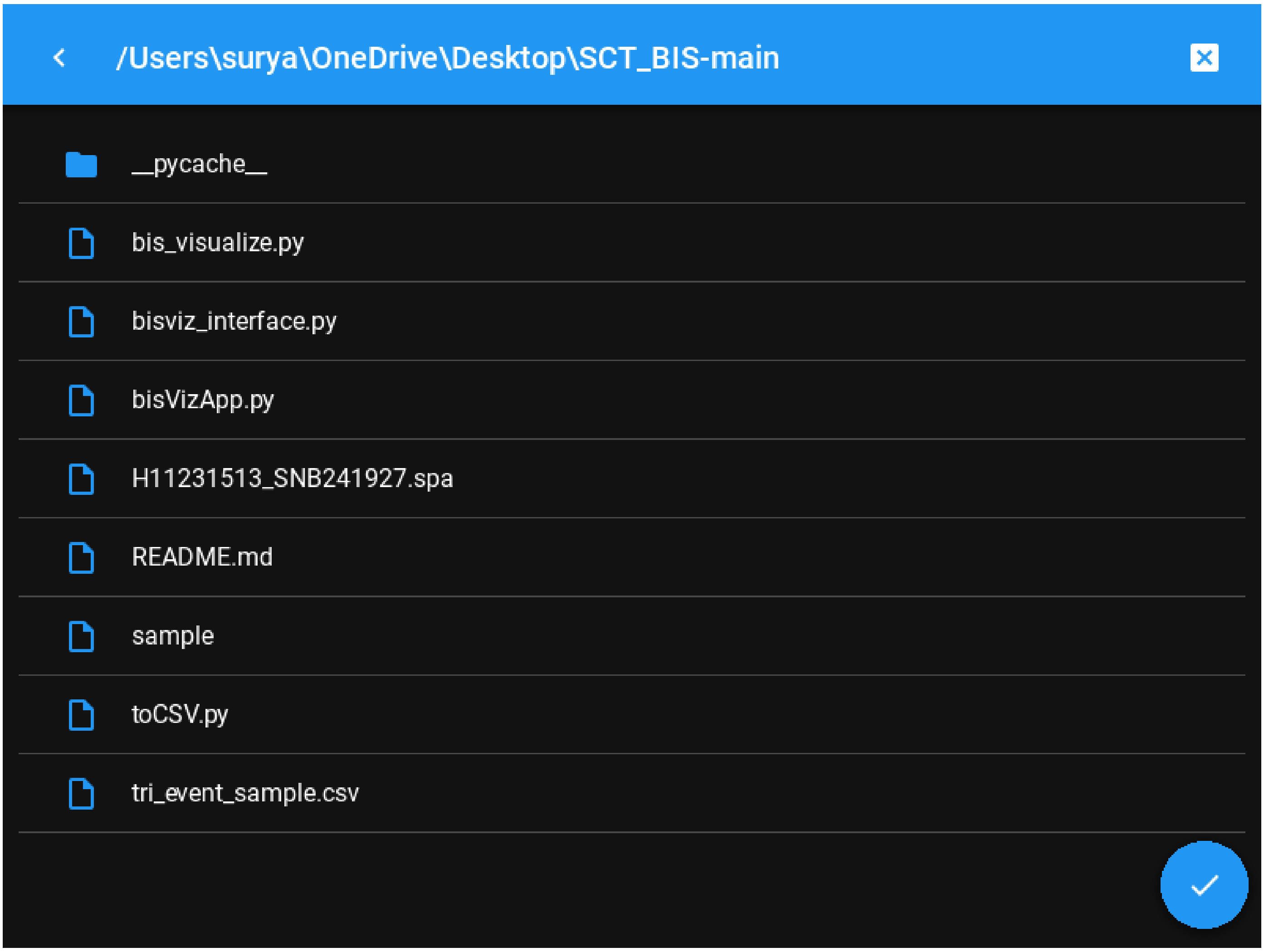

Figure 3.5: Input location of data

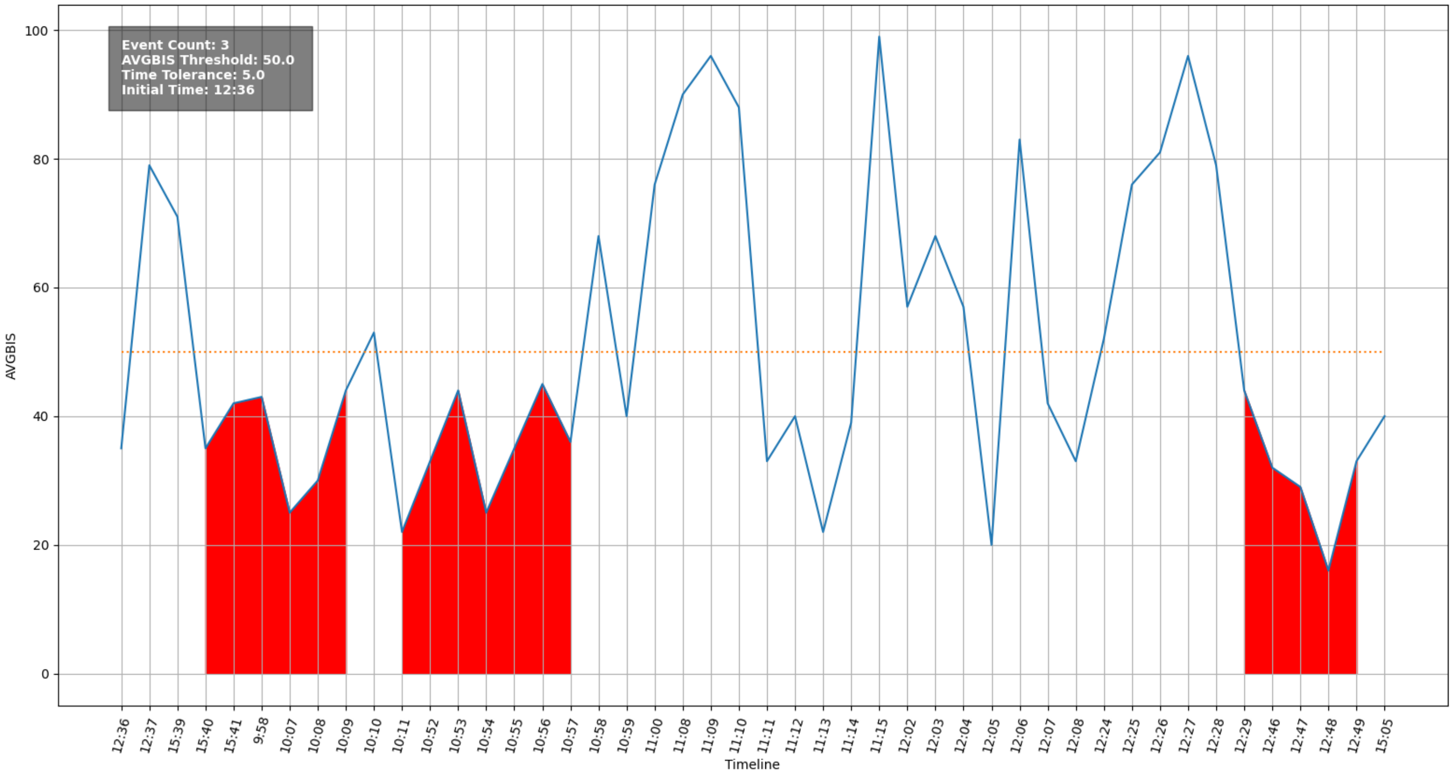

Figure 3.6: Significant Events

Chapter 4

Data Acquisition using Phillips Intellivue Monitors

4.1 Introduction

Philips Intellivue monitors have transformed how intensive care units (ICUs) manage and use enormous amounts of high-frequency data from numerous medical equipment. These cutting-edge monitors serve as central hubs, gathering data from a variety of ICU equipment such as heart monitors, ventilators, infusion pumps, and physiological sensors. This unified data collection gives a full real-time picture of a patient's vital signs, trends, and responses to treatments. The capacity to aggregate and show such huge amounts of data in a logical and understandable manner is crucial for doing live analysis and assisting medical professionals in making fast, educated choices.

Collecting this data in an online format is critical for its optimal use in analysis. Real-time access to patient data is critical in the fast-paced setting of intensive care units (ICUs) to support swift decision-making and timely treatments. Medical experts may rapidly access and understand data captured and stored in an online format, enabling realtime study of a patient's status and reaction to treatments. This instant access to high-frequency data is crucial for spotting small changes or patterns that may be suggestive of significant developments, allowing for earlier diagnosis of issues and more proactive patient management. Furthermore, an online data format enables easy 17 integration with modern analytics and machine learning algorithms, hence increasing the potential for in-depth analysis and predictive modelling, ultimately leading to improved patient outcomes and better overall ICU management.

4.2 Data Transmission Protocol Dialogue

The protocol dialogue between the Philips IntelliVue display and the Computer Client is depicted in the diagram below. The dialogues follow a request/response messaging pattern, which means that one party sends request messages and the receiving party responds with response messages. To be more explicit, the Association Request Message received by the Client will initiate a new conversation, and if the monitor accepts the association, it will return an MDS Create Event Report Message after a positive Association Result Message. When the association is successfully formed, the dialogue will go to the Data Export area, as illustrated. The client will send many Poll Data Request Messages to request data during these interactions, and the required data will be stored in the Poll Data. The dialog can be ended after sending an Association Release Request Message and receiving an Association Release Result.

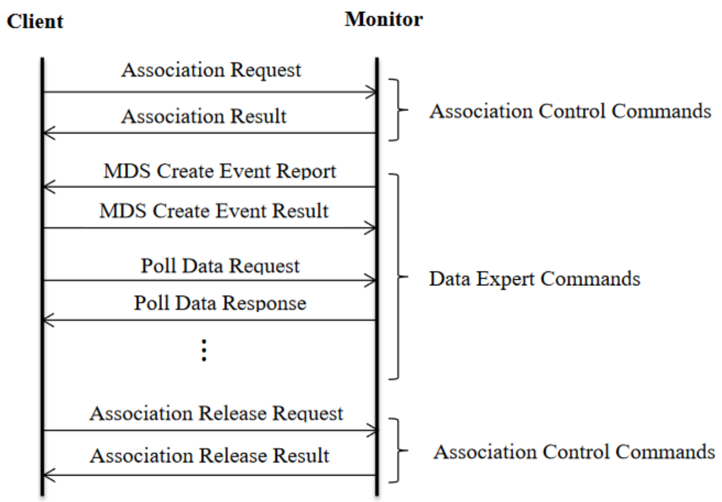

Figure 4.1: Protocol Dialogue

The following are the different components of Association Control Commands:

1. **Association Request Message**: The Computer Client initiates an Association Request message to the IntelliVue monitor when a new association needs to be

established. This message includes essential information about the requested protocol and the corresponding protocol options.

2. **Association Response Message**: In response to receiving an Association Request message, the IntelliVue monitor sends an Association Response message to the client, confirming the successful reception and interpretation of the Association Request. This message serves as an acceptance of the association.

3. **Refuse Message**: In cases where an error is detected in the Association Request message or the association cannot be accepted due to an ongoing association process, the IntelliVue monitor sends a Refuse message to reject the new association request.

4. **Release Request Message**: Should the users intend to terminate the existing association, they send a Release Request message from the client to the monitor. The Release Request message does not include any variable data.

5. **Release Response Message**: Upon receiving a Release Request message, the IntelliVue monitor sends a Release Response message to confirm the association's termination. The client then parses and verifies the response to ensure the successful release of the association.

6. **Abort Message**: The IntelliVue monitor automatically generates an Abort message to terminate an association without requiring further confirmation. This message is typically employed in specific system configurations, such as when an association times out, prompting the monitor to send an Abort message.

The following are the different components of Data Export Commands:

1. **MDS Create Event:** The MDS Create Event holds paramount importance as it encapsulates both the software and hardware configurations of the IntelliVue monitor. Accurate parsing of this message by the Computer Client is essential to obtain critical insights into the system configurations.

2. **MDS Create Event Result:** The MDS Create Event Result serves as a confirmed operation corresponding to the MDS Create Event message. Once

received, the Computer Client parses this message to ensure the successful configuration of the monitor, verifying that all settings align with the intended specifications.

3. **Single Poll Data Request:** Upon establishing the Association and receiving acceptance from the monitor, the Computer Client can issue a Single Poll Data Request message. To execute this operation, the MDS Create Event message and the MDS Create Event Result message sequence must be completed. This method enables the retrieval of IntelliVue monitor device data in a single response message.

4. **Single Poll Data Result:** As a response to the Single Poll Data Request, the IntelliVue monitor sends the Single Poll Data Result message. This message encompasses the requested data, allowing the Computer Client to process and interpret the received information accordingly.

5. **Extended Poll Data Request:** The Extended Poll Data Request provides the Computer Client with access to various types of data, including numerics data, wave data, and alarm data. Moreover, this feature allows for periodic Poll Replies, eliminating the need to send a Poll Request each time. By setting timers for each type of data requested, the Computer Client can enable periodic Poll Replies, ensuring a more streamlined data retrieval process.

6. **Extended Poll Data Result:** When the IntelliVue monitor receives an Extended Poll Data Request message, it responds with single or periodic Extended Poll Data Result messages. To extract the specified data from the Extended Poll Data Request message, the Computer Client employs a parsing algorithm, interpreting the data according to the specific data structure for each type.

7. **Specifying Objects in the Poll Result:** To specify the desired wave or numeric objects within the Poll Results, Get and Set operations are employed. In the absence of a user-defined priority list, the monitor returns Extended Poll Result messages based on the default priority list contained in the internal priority table, in accordance with the current system configuration. However, a new user-defined priority list can replace the default priority list, allowing

for more customized and purposeful retrieval of wave and numeric data. This enhancement enables the IntelliVue monitor to furnish data that precisely aligns with the specific needs of the Computer Client.

A detailed guide to each of the above sections along with structure and additional data citations can be found in [3].

4.3 Open Source Data Capture Solution - VSCapture

VSCapture is an open-source software developed to capture vital sign data from medical monitoring devices. This project report provides a detailed overview of the Program.cs file, which serves as the entry point for the application. The Program.cs file is a crucial component of the VSCapture software, acting as the main driver of the application. It orchestrates the execution of functions defined in other classes, utilizing three key modules - Class1, Class2 and Class3. VSCapture aims to efficiently collect, interpret and analyze vital sign data, ensuring real-time access and facilitating prompt decision-making in intensive care units (ICUs) and Operation Theatres(OTs).

The Program.cs file of the VSCapture software plays a critical role in establishing and maintaining connections with the IntelliVue monitor, retrieving essential vital sign data, and ensuring seamless communication between the software and the monitor. By handling various association messages, wave data requests, and poll data exchanges, the Program.cs file optimizes the vital sign capture process, facilitating real-time analysis and supporting medical professionals in making informed decisions for improved patient care and monitoring. The following sections will serve as a documentation of sorts for the code present in the Program.cs file within the Github repository for VSCapture [5]

4.3.1 CommandLineParser and User Input Handling

A CommandLineParser object is used to read command-line arguments. This allows users to input specific parameters, such as connection mode (RS232 or LAN), directly from the command line. The user's choice of connection mode is then obtained with "["mode"][0]" being extracted from the CommandLineParser. If the mode argument is not provided, the application prompts the user to enter 1 (RS232) or 2 (LAN) to determine the connection type, ensuring seamless configuration.

4.3.2 LAN Connection and Communication

After connection mode is chosen by user, the VSCapture application utilizes IPEndPoint and UdpClient, inherent C# classes, to enable LAN (Local Area Network) communication. The IPEndPoint class helps establish a network connection by defining an IP address and a port number (24105, which is the default for Philips Intellivue Monitors). This setup ensures seamless data transmission between devices within the LAN environment.

The "connectviaLAN()" function is responsible for initializing the VSCapture application and collecting vital sign data. This function first parses command-line arguments to determine the connection mode. If interval information is not provided, the user is prompted to enter the desired time interval for data collection, which is essential for subsequent data storage.

4.3.3 Singleton Pattern and UDP Communication

Within the Program.cs file, the "_MPudpclient" object is implemented as a singleton class, created through the "getInstance" method. The singleton pattern ensures that only one instance of the object exists, optimizing resource usage and providing default settings for UDP communication. Additionally, Class1, contains a constructor that initializes default values for the vital sign data collection process. The IPEndPoint() method, a part of the UDP communication module, facilitates data exchange by creating an object based on an IP address (created using IPAddress.Parse()) and a specified port number (24105).

4.3.4 Connection Indication and Wave Association

1. **Connection Indication:** The "IPAddressRemote" string variable is used to store the IP address of the monitor assigned by the Dynamic Host Configuration Protocol (DHCP) or entered by the user manually. If the "IPAddressRemote" is not null, it indicates an existing connection to the monitor. In such cases, the attributes of the "_MPudpclient" are set for the specific monitor. These attributes include the monitor's IP address, Device ID, MQTT (Message Queuing Telemetry Transport) URL, MQTT topic, MQTT user and MQTT password. Utilizing these assigned values, the application establishes a connection to the monitor using UDP (User Datagram Protocol).

2. **Wave Association Request and Reply:** Upon successful connection to the monitor, a Wave Association Request is sent, which is defined in Class1. The "MPclient" uses UDP Client Server programming and the built-in "Send()" method to transmit data for the request. The output file directory is saved at the current directory. Subsequently, the Association Reply is received from the monitor using the "Receive()" method, the data is stored in a byte array buffer, and then saved to a file.

4.3.5 MDS Event Report Request and Response

1. **MDS Event Report Request:** The MDS Create Event Report, a crucial message containing both the software and hardware configurations of the IntelliVue monitor, is received at line 447. This message provides vital system configuration information that the Computer Clients need to parse accurately. The received MDS Create Event Report is saved to a file at line 448. MDS Event Report Response

2. **MDS Event Report Response:** After processing the MDS buffer, the Program.cs file sends the result to the monitor, as mentioned in Class1 (line 453). The handling of this response is managed in Class1 and is a critical step in ensuring seamless communication between the VSCapture software and the IntelliVue monitor.

4.3.6 Poll Data Request and Response

To fetch data from the monitor, a Poll Data Request is sent. This operation is performed at line 459, utilizing threading to continuously send poll requests to prevent timeouts. The Class1 (line 357) defines this method, which waits for a set interval (nInterval). If the wait is longer than 0ms, the request is cyclically sent at a specified interval. If the wait is 0ms, the poll request is sent once. This approach ensures consistent data retrieval from the monitor. Poll Data Response

Lines 463 to 474 seem to be related to the reception of wave data from the monitor. However, further confirmation is required to ascertain its specific functionality and purpose.

4.3.7 Connection Maintenance and Poll Data Reception

To ensure the connection's continuity, line 478 checks if it is still active. Following that, at line 481, the Program.cs file begins to receive the poll data, allowing the VSCapture software to access and process the requested data from the IntelliVue monitor.

Chapter 5

Results and Discussion

The culmination of this project has yielded significant advancements in the domain of medical data analysis and visualization, particularly concerning the Bispectral Index (BIS) analysis and real-time data acquisition from medical monitors. The project was conceived with the primary intention of providing valuable tools to the medical staff at SCTIMST, empowering them to gain insights from data that was previously only momentarily accessible through monitors. The subsequent development of a dedicated visualization tool equipped with a user-friendly graphical user interface (GUI) has substantially fulfilled this objective.

The introduced visualisation tool stands as a testament to the successful realization of the project's initial aims. Its creation involved meticulous attention to detail and a comprehensive understanding of the complexities surrounding BIS Index analysis. The tool has proven to be an invaluable asset, offering medical professionals a seamless means of comprehending and interpreting the BIS Index data. The graphical user interface simplifies interaction, enabling users to effortlessly navigate through data, configure analysis parameters, and derive meaningful conclusions.

A pivotal aspect of the project was dedicated to the acquisition of real-time data from the Philips Intellivue Monitor. This endeavor was fueled by the fundamental goal of enabling the extraction of live data for analysis. The identification of a suitable open-source solution, the VS Capture software, emerged as a pivotal breakthrough. The software's capacity to capture live data from the monitor effectively bridged the gap between the monitor's output and the analytical platform, thus facilitating the project's core objectives.

A noteworthy focus of the project revolved around deciphering the intricate mechanisms governing data transmission from the monitor, which operates as a server, to a designated client system. Comprehensive documentation was curated for the driver classes of the VS Capture software, laying down a clear roadmap for future endeavors. This strategic step not only facilitates the continuation of the project's work but also serves as a valuable resource for future projects seeking to build upon the groundwork established.

The project has successfully achieved its envisioned outcomes, significantly enhancing the capabilities of medical staff at SCTIMST in data analysis and visualization. The integration of BIS Index analysis and real-time data acquisition has not only addressed existing limitations but has also positioned the institution on the forefront of innovative healthcare technologies. The developed visualization tool and the insights gained into data transmission mechanisms hold great promise for further advancements in medical research and patient care. As the project concludes, its impact reverberates within the medical community, forging new pathways for comprehensive medical data analysis and contributing to improved patient outcomes.

Chapter 6

Future Scope

An imminent option is to include real-time BIS (Bi-spectral Index) data capturing into VSCapture's live format. This interface would allow for the smooth absorption of collected data into our own digital processing systems, providing for quick, informed decision-making capabilities. VSCapture can play a critical role in optimising anaesthesia management techniques and increasing patient outcomes by employing real BIS data analysis.

Comprehensive documentation is required, as is the development of a specialised module through reverse engineering VSCapture. So far, the program.cs file has been used to document how the software works. However, its conversion into a module capable of providing the specialised use case remains unfinished.

Extending the software's capabilities to incorporate the collection of Patient Minimum Alveolar Concentration (MAC) data via an additional monitoring and data collection system appears to be a potential route. This improvement will help to a more comprehensive knowledge of patients' anaesthesia needs and reactions. The incorporation of MAC data into the prediction system will give it more information with regard to decisions it takes when it comes to patient outcome in Operating Theatres.

Chapter 7

Conclusion

The analysis and digital visualisation of bispectral index (BIS) data obtained by BIS monitors constitute a significant improvement in diagnosing and controlling patients' neurological states during various medical operations in the field of medical monitoring. Healthcare practitioners obtain insights on the degree of anaesthesia and sedation levels experienced by patients by analysing the signals received by the BIS monitors. This understanding allows for real-time modifications to anaesthesia delivery, guaranteeing maximum patient comfort and safety. We developed algorithms that convert BIS data into understandable graphical representations, allowing medical practitioners to quickly identify patterns, abnormalities, and significant occurrences. This convergence of medical knowledge and digital innovation works together to improve patient outcomes, reduce risks, and raise anaesthesia management standards in a variety of clinical settings.

Simultaneously, thorough documentation for the VSCapture programme grows as a critical component within the larger environment of software development. This documentation provides a comprehensive explanation of the software's architecture, functioning, and use. This documentation, by precisely explaining the platform's operating intricacies, enables developers to successfully connect with the product and allow for seamless growth in continuing on the foundation we have laid.

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