Team Project: Developing and testing a simulator of the Tandem t:slim Insulin Pump[1]

Project Plan due Mar 17th

Project due Tue Apr 8th

Project plan and team work submitted **individually** on Brightspace. **Mandatory design-code reviews** will be **individual** starting on Fri Apr 11th. The scheduling details will be announced the week before and the project review-demo times will be arranged between you and your assigned TA. The implementation and testing are to be in C++ using the Qt framework on the course VM (COMP3004-F24). You are required to use GitHub: make sure your repository is private and that you provide access to your assigned TA. You are encouraged to check your progress on a weekly basis with myself and the TAs. Do not wait until the last minute.

Deliverables (6 parts)

- **Project plan**
  - team responsibilities and schedule
- **Use cases**
- **Design documentation** – structure and behavior
  - UML Class diagram
  - UML Sequence diagrams for scenarios covering normal and safety operation, to be determined
  - UML State machine diagrams
    - For any control entities
  - Textual explanation of your design decisions that can include references to any conversation with your TA or myself to clarify requirements or check your documentation artifacts.
- **Implementation**
  - Source code of your Qt C++ project that builds and runs on the course VM (COMP3004-F24.ova found at https://carleton.ca/scs/tech-support/virtual-machines/
  - Execution of tests based on the above scenarios
- **Video:** record a video of running your simulation through the above specified scenarios
- **Requirements traceability matrix**

Objectives

- Analyze requirements based on provided material and develop the corresponding use case model.
- Develop a software architecture that supports data collection, processing, and visualization.

[1] Project specification developed by Vishal Parag Parmar.

- Test your implementation.
- Relate the modeling, design, implementation and testing through a Requirements Traceability Matrix.

Fig 1.

Tandem t:slim X2 Insulin Pump
Left - Insulin pump UI screen
Right - Insulin pump with infusion test tubing

Project overview

The goal of this project is to develop an interactive software simulation of the t:slim X2 pump in Qt/C++. This simulation will replicate essential pump functions, enable the recording and visualization of usage metrics, and incorporate algorithms to analyze weekly patient data for actionable insights into glucose control. To ensure high software quality, the project will emphasize comprehensive unit testing and GUI-based testing.
In today's rapidly advancing healthcare landscape, virtual medical device simulations act as an essential bridge between theoretical knowledge and practical application. By emulating the operation of sophisticated medical equipment in a controlled and risk-free environment, these tools provide users with valuable hands-on experience, eliminating the need for direct access to physical devices. This approach not only enhances skill development and safety but also builds greater confidence and understanding in the use of advanced medical technologies. The Tandem t:slim X2 Insulin Pump is a system designed to deliver precise insulin dosages for effective diabetes management.

Detailed Steps for Simulating and Interacting with the t:slim X2 Insulin Pump with Control IQ Technology

1. Getting to Know Your t:slim X2 Insulin Pump

To begin interacting with the t:slim X2 insulin pump, users need to familiarize themselves with its primary interface and core components. The pump's home screen is the central hub where users can monitor insulin delivery, battery life, and CGM (Continuous Glucose Monitoring) data. Located in the upper-left corner is the battery indicator, which provides real-time updates on the status of the pump's rechargeable battery. Opposite to this, the insulin fill gauge in the upper-right corner displays the remaining insulin in the 300-unit cartridge. The "Insulin on Board" (IOB) indicator shows how much insulin is still active in the body from previous bolus injections. The home screen also includes key navigation buttons such as the bolus button, which directs users to the bolus calculator, and the options button, which provides access to insulin delivery settings, alerts, and system configurations. Users can quickly return to the home screen by tapping the Tandem logo from any screen within the pump.

2. Getting Started

Before the pump can deliver insulin, users need to ensure it is properly set up and ready to function. First, the pump must be charged using the provided USB cable, with the battery indicator showing its progress. Turning the pump on involves holding the power button until the startup sequence is complete, while turning it off or putting the screen to sleep can be done via the options menu. The t:slim X2 features a touchscreen interface that enables users to navigate between various screens easily. For security, a PIN-based lock screen can be set up to prevent accidental inputs.

3. Insulin Delivery Settings (CRUD Personal Profiles)

The t:slim X2 insulin pump allows users to customize and manage personal profiles that cater to different daily needs, such as varying basal rates during sleep or exercise. Users can create a new profile by navigating to the personal profiles section and entering critical settings like basal rates, carbohydrate ratios, correction factors, and target glucose levels. Each profile can be named based on specific routines, such as "Morning Routine" or "Exercise Mode." Once created, profiles can be reviewed and updated as needed. For example, users might modify a profile to increase basal insulin delivery during high-activity periods or adjust carb ratios for a large meal. If a profile is no longer needed, it can be deleted to streamline options. The CRUD (Create, Read, Update, Delete) model ensures that personal profiles are flexible and easy to adapt to users' changing requirements.

4. Manual Bolus

Delivering insulin through a manual bolus is a critical function of the t:slim X2 pump. Users initiate a bolus by accessing the bolus calculator via the home screen or bolus button. They can enter their current blood glucose level and carbohydrate intake manually or have these values pulled automatically from the CGM. The bolus calculator then suggests an appropriate dose based on programmed settings such as insulin sensitivity and target glucose levels. In cases where users need more or

less insulin than suggested, they can override the recommendation by manually adjusting the dose. The pump also supports extended boluses, where insulin delivery is spread over a longer period, and quick boluses for immediate correction of high glucose. Users can cancel or stop a bolus mid-delivery if needed, ensuring flexibility during treatment.

Determining how much Bolus to provide is determined through real-time data reading by Control IQ technology. As explained in this video

https://www.youtube.com/watch?v=tKvFGC7RRFI&ab_channel=TandemDiabetes

The simulation should allow for generating, reading, and graphing of data.

5. Starting, Stopping, or Resuming Insulin

Managing basal insulin delivery is an essential aspect of the pump's functionality, and Control IQ technology simplifies this by dynamically adjusting delivery based on CGM feedback. To start insulin delivery, users must select a basal rate from their active personal profile or manually configure it through the options menu. Once set, the pump continuously delivers insulin at the specified rate unless interrupted. Stopping insulin delivery can occur either manually or automatically when Control IQ technology detects low glucose levels (below 3.9 mmol/L). During such events, basal delivery is suspended, and the event is logged in the system for future reference. Resuming insulin delivery involves restoring the previous basal rate or switching to an updated profile when glucose levels stabilize.

6. t:slim X2 Insulin Pump Information and History (Data Storage)

The t:slim X2 insulin pump maintains detailed records of insulin delivery events, which users can review to track their treatment progress. The system logs information such as basal rates, bolus injections, insulin duration, and correction factors. By accessing the current status screen, users can view recent events like the time and amount of the last bolus, changes in basal rates, or alerts triggered by CGM readings. This data is crucial for identifying patterns or irregularities in glucose control and can assist healthcare providers in optimizing treatment plans. The stored history allows users to trace back specific events to understand how insulin was administered during different situations.

7. t:slim X2 Insulin Pump Malfunction (Error Handling)

To ensure safe and effective use, the t:slim X2 pump includes mechanisms for detecting and handling malfunctions. Common issues such as low battery, low insulin, or CGM disconnection trigger alerts that inform users of corrective actions. For example, a low battery warning might prompt users to recharge the pump, while an occlusion alert could suggest checking the infusion site for blockages. The pump's error-handling system automatically suspends insulin delivery during critical

failures to prevent incorrect dosing. Additionally, logs of errors and malfunctions are maintained, allowing users and healthcare providers to troubleshoot issues effectively. For severe issues like pump shutdowns, the system provides guidance on restarting or contacting support if necessary.

[1] https://www.tandemdiabetes.com/en-ca/home