Generic Patient Controlled Analgesic Infusion Architectural Model Description

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Contents

Chapter 1

Introduction

This document contains the documentation required to understand the the architectural model for a Generic Patient Controlled Analgesia Pump (GPCA) [AADL.zip]. Instructions on how to view and execute the model is provided in the Appendix A.

1.1 Document Purpose

This document shall serve as a ”readme” file for the architectural model of the GPCA system.

1.2 Intended Audience

The intendance audience for this document are researchers and practitioners who wants to understand the model. We are fully aware that others may disagree with our design, organization, style, and content; we welcome feedback and spirited discussion. We request that feedback on this document be directed to Mats Heimdahl at heimdahl@cs.umn.edu. It is strongly suggested that the reader first reads the requirements document prior to reading this document. It is also recommended that the reader is aware of the Architecture Analysis and Design Language (AADL) and the OSATE tool in order to understand the model.

1.3 Scope

The scope of this document is limited to details required to get a quick overview of the model architecture. It doesn't explain all the details of the model. The reader is expected to use this document as a guide in understanding the overall design of the model. This document provides some justification for certain design decisions wherever necessary. For details of the behaviorial aspects of each component, please refer to the Behaviorial Model section in http://crisys.cs.umn.edu/gpca.shtml. For verification using these models, please refer to the Verification section in http://crisys.cs.umn.edu/gpca.shtml.

Chapter 2

Overview

This chapter gives an overview of the Infusion System, providing a brief description of the system components and their high level functionality. Note that the descriptions in this chapter are intended as an overview for the model only, the requirements of the system are defined in a separate requirements document.

2.1 Infusion System Overview

GPCA Infusion system is a cyber physical system that controls the rate of infusion of analgesia and enables the patient to self-administer their own analgesic according to the programmed dosage of medication. Infusion pumps typically provide multiple modes of drug delivery. In *basal* mode, the drug is delivered at a constant (and usually low) rate for an extended period of time. In a *bolus* mode, the drug is delivered at a higher rate for a short duration of time to address some immediate need or to increase the drug delivery according to some therapy regimen. There may be multiple bolus modes. In *clinician bolus* mode, the drug is delivered at an elevated rate in response to a clinician's request. For example, the clinician may prescribe an elevated rate of infusion for a period of time at the beginning of infusion therapy. Further, in a PCA system, a *patient bolus* mode may be activated to deliver additional drug in response to a patient's request for more medication, typically to alleviate acute pain. The GPCA devices are usually built with capability to notify the clinician of exceptional conditions, for example, if the drug reservoir is running low or if there are air bubbles in the system.

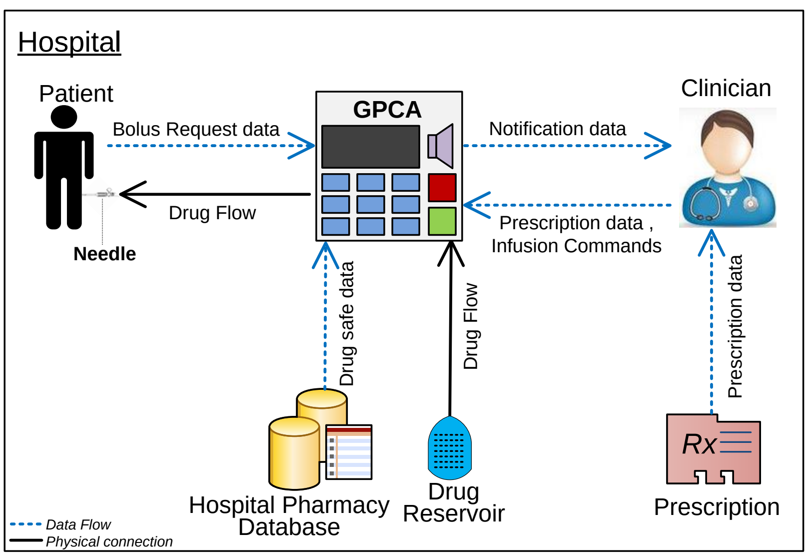

Figure 2.1: GPCA Infusion system.

The GPCA in its intended environment is illustrated in Figure 2.1. In an infusion system, the clinician operates the GPCA device, programs the prescription information, loads the drug, connects the device with the patient, and responds to exceptional conditions that occur during the therapy. The patient receives the medication from the device through an intravenous needle. The patient can self administer prescribed amounts of additional drug by requesting a bolus, a request usually done by pressing a bolus request button accessible at the patients bed. The hospital pharmacy database is a repository that stores manufacturer provided drug information. This typically includes ranges of values for various drug parameters that are safe for use in infusion therapy. The GPCA system has an interface to this repository for accessing this drug data that it used for verifying various infusion parameter values against the drug specific data from the repository to ensure that the programmed therapy regimen is within safe limits. The GPCA system has three primary functions (1) deliver the drug based on the prescribed schedule and patient re- quests, (2) prevent hazards that may arise during its usage, and (3) monitor and notify the clinician of any exceptional conditions encountered.

2.2 GPCA High Level Architecture

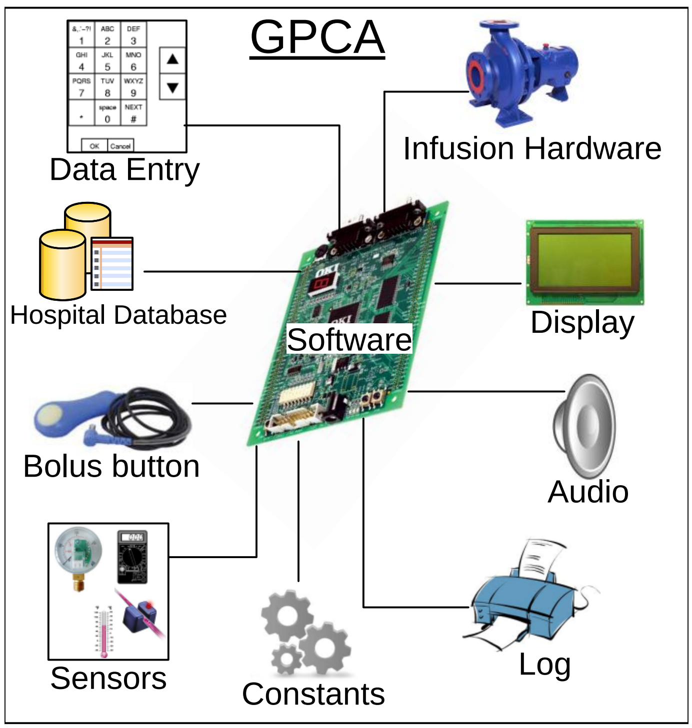

Figure 2.2: GPCA architectural components.

The architecture of a generic GPCA device is illustrated in figure 2.2. The architecture was prepared using publicly available user manuals and previous research efforts. This was useful to understand the inputs outputs between each component of the system.

Chapter 3

GPCA Device Architecture

As systems became more complex, it becomes necessary to decompose the system into subsystems for clarity and manageability. For the GPCA, we designed an architecture, in a way that partitions the behaviours of the system. The architecture of the model was chosen such that the model conceptually correlates with the requirements as well as make it easy to understand and maintain the model.

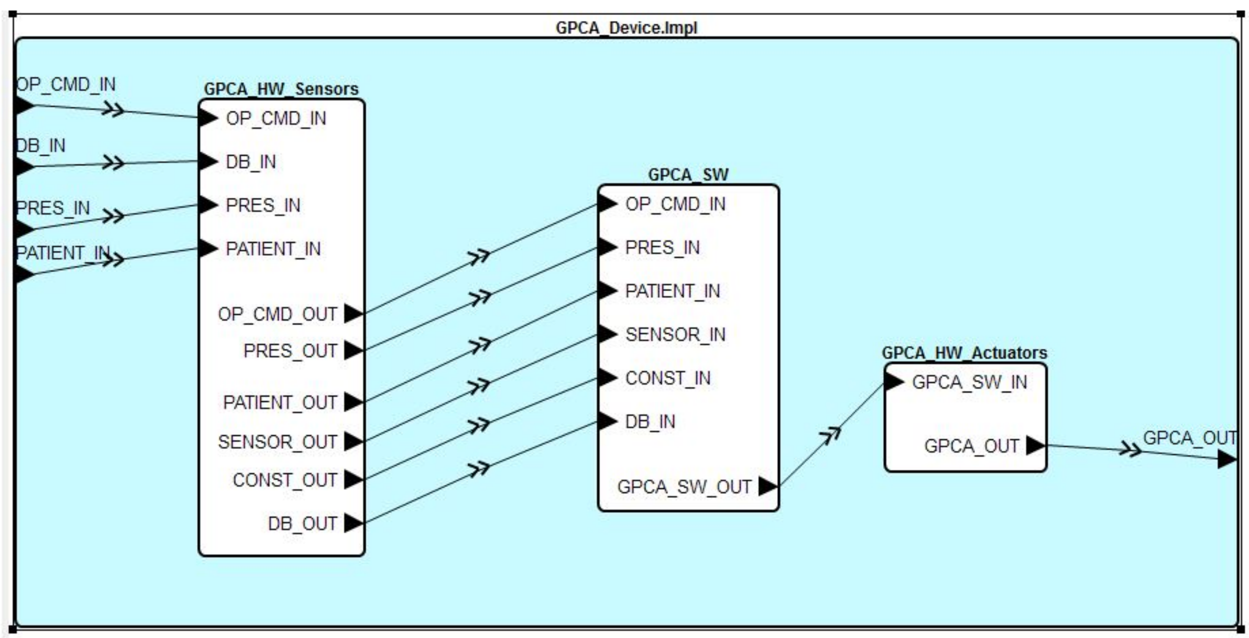

Figure 3.1: GPCA Device Architecture.

The architecture of a generic GPCA device as modeled in AADL is illustrated in figure 3.1. The Device architecture has sensors, software and actuators. For this modeling exercise, we grouped all the sensors illustrated in figure 2.2 as one system (GPCA_HW_Actuators.aadl). Similarly the actuators are grouped as one system (GPCA_HW_Sensors.aadl).

3.1 Inputs and Outputs

Inputs and outputs of the system as well as each component is defined in DATATYPES.aadl.

3.2 Software Architecture

This section describes the software system's (GPCA_SW.aadl) architecture and its components in detail, enough to help the users understand the design of the system.

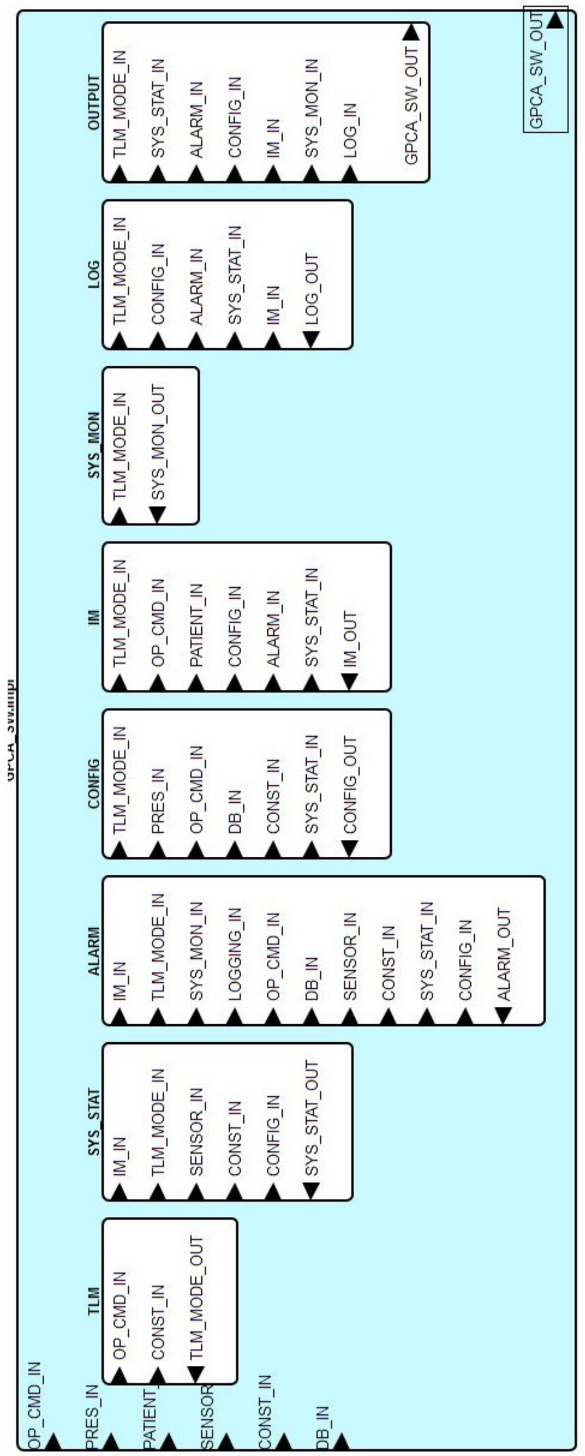

Figure 3.2: GPCA Software Architecture

The components of the software as shown in figure 3.2 are :

TLM - Top Level Mode Responsible for ensuring the system is switched ON, performing start up checks and shut down operations.

SYS_STAT - System Status Responsible for monitoring current state of the system and calculating the system status parameters such as remaining reservoir volume.

ALARM - Alarm Responsible for monitoring and notifying defined exceptional conditions.

CONFIG - Configuration Responsible for configuring prescription parameters.

IM - Infusion Manager Handles drug infusion commands and parameters.

SYS_MON - System Monitor Performs self tests at regular intervals of time.

LOG - Log Handles data logging.

OUTPUT - Output Selects a few component outputs to be represented as system outputs.

The components of the software were identified based on their high level functionality such that when logically connected that compositionally represents the entire system. The connection between the components depends on the flow of data between them as designed. This design is one of the many way that the system can be decomposed. We choose this design since it was easy to understand, maintain and formally verify.

The ordering of the components blocks is an architectural decision that is influenced by the expected behaviour of the components and system. The ordering was carefully planned by considering the dependency of each subsystem with others and their priority. For example, the alarm subsystem is placed before the infusion manager subsystem since the output from the alarm subsystem should be used by the infusion manager in the same step. When an air-inline alarm is raised, the system will stop infusion in the same execution step. If the ordering was different, then the system will stop infusion in the next step.

The subsystems are result of decomposition of the software system, hence the inputs to each component are a subset of the system's input and/or outputs of other subsystems within the system. The output of the overall system is a susbset of all the subsystem outputs that are relevant to be outputted.

Similar to the system inputs and outputs, each of the subsystem outputs are also defined in DATATYPES.aadl.

For details of the behaviorial aspects of each component, please refer to the Behaviorial Model section in http://crisys.cs.umn.edu/gpca.shtml

Appendix A

Appendix

A.1 Acronyms

GPCA Generic Patient Controlled Analgesic

HW Hardware

SW Software

A.2 Tool Tutorial

The tool tutorials and release information is available at http://www.aadl.info/

A.3 Instructions to download tool

Download latest version of OSATE http://www.aadl.info/aadl/osate/stable/2.0.3/products/

Download AADL.zip and UnZip into a folder of your choice.

- GPCA_Device.aadl - AADL file for the GPCA Device
- GPCA_HW_Sensors.aadl - AADL file for the GPCA hardware sensors.
- GPCA_SW.aadl - AADL file for GPCA Software Controller.
- GPCA_HW_Actuators.aadl - AADL file for the GPCA hardware actuators.