Hardware and Software Implementation of an Artificial Pancreas System on a Mobile Device

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ABSTRACT

In this work, an artificial pancreas (AP) system, implemented on a mobile device is described. The proposed AP platform integrates hardware (insulin pump, glucose monitor, various sensors for vital signs and physical activities) and software (closed-loop control algorithm, sensor fusion, data storage and remote server access) components via smartphone that is running a dedicated Operating System designed for AP systems. Interfacing with this OS and custom application development steps are presented. Closed loop operation is demonstrated with case studies.

KEYWORDS
Activity Trackers, Artificial Pancreas, Bluetooth, Closed Loop Control, Type 1 Diabetes

INTRODUCTION

Research on artificial pancreas (AP) systems promises significant improvement for Type 1 diabetes patients’ daily lives and it is expected to impact millions of patients (Turksoy, Quinn, Littlejohn, & Cinar, 2014a; Turksoy et al., 2014b; Turksoy et al., 2014c; Cobelli, Renard & Kovatchev, 2011). A major component of the AP system is a closed-loop control algorithm (Farmer, Jr., Edgar, & Peppas, 2008; Thabit & Hovorka, 2012), which aims to keep the glucose levels within acceptable margins by infusing insulin or suggesting carbohydrate intakes. However, glucose concentration (GC) variations are not easy to predict, since its reaction to past stimulus can be rather slow. Additionally, GC and insulin sensitivity are affected by various metabolic and physical activities, which can lead to hypoglycemia episodes. Some studied cases are post-exercise hypoglycemia (depending on its type and intensity, may be reached at a faster pace), nocturnal hypoglycemia or stress. Therefore, GC predictions require not only a continuous monitoring of GC, but also additional vital signs to identify the patient’s state. Proposed additional measurements are galvanic skin response (GSR), heart rate, breathing rate, energy expenditure (EE), vigorous activity and sleep state.

The ultimate goal of this research is to develop an artificial pancreas: a portable, autonomous system that a person with diabetes can carry during their everyday life. The proposed platform...
includes traditional components highly used by diabetes patients: a glucose sensor (for continuous GC monitoring) and an insulin pump (to infuse basal insulin and insulin boluses on demand). Since the algorithm relies on key vital signs (such as heart rate or breathing rate) as well as activity parameters (acceleration vectors or galvanic skin response), fitness sensors are also included. Furthermore, the proposed AP system is designed to provide a remote monitoring of the person, by medical professionals or family members (to access their real-time data). Hence, a dedicated server-AP system interface is also necessary. Figure 1 shows the hardware and software components for the AP platform.

Our previous work (Martinez, Oruklu & Cinar, 2015; Lazaro, Oruklu & Cinar, 2015) presented the initial framework for the multi-sensor AP platform, with especial emphasis on the server communication. In this work, we focus on the embedded system; mobile device and the host applications. Section II introduces the Operating System (OS) installed on the smartphone, its Graphical User Interface (GUI) and its default functions and capabilities. Section III describes the implementation of the closed loop algorithm and sensor fusion operations. Section IV presents the necessary steps for integrating additional sensor devices to the proposed AP system. Section V concludes the paper.

**AP PLATFORM**

**Mobile Device: Diabetes Advisory System (DiAs)**

A dedicated Operating System (OS), DiAs is used as the host for the AP system. DiAs (Keith-Hynes et al., 2013) is a Diabetes helper platform, developed for Nexus 5 by the University of Virginia (UVA)’s Center for Diabetes Technology. The mobile device on our platform is based on DiAs. User interaction is enabled by the same GUI, allowing different operating modes. The AP system is comprised of multiple devices, such as a Dexcom glucose sensor (Dexcom), a Tandem insulin pump (Tandem) and a Zephyr Bioharness 3 chest band (Zephyr). Another critical feature is the remote monitoring server...
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