Memorial University of Newfoundland

Faculty of Engineering and Applied Science

ENGI 6861 - Project

Computer Architecture of Wearable Technology (Draft)

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Executive Summary

The executive summary for this report will be handed in as part of the final draft. It would make no sense to complete the executive summary at this point, as not all the content has been finished yet, and it would make no sense to attempt to summarize an incomplete report.

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1 Introduction

Wearables as defined by Technopedia are technologies that are worn on the body that contain various sensors that can record health and fitness information, or take movement input data in real-time [1]. The market for this technology has expanded rapidly in recent years, with the wearable market being worth $19 billion in 2015, and expected to expand to $57 billion by 2022 [2]. This growth rate can be attributed to the fact that it is a novel technology just getting past the early adoption phase, but this technology is also improving at an impressive pace each year. The 2010s have seen advances in lower-powered processors with a smaller footprint that allow wearable devices to become much more powerful. With improvements in small, powerful processors, it allows wearables to have more functionality, and focus less on designing the wearable around the electronics inside [3]. Clearly, this demonstrates the design requirement for low-power and small components to architects of wearable technology.

While there are many types of wearables on the market in present-day 2019, this report will focus on two types of wearable technology: smartwatches, which record movement data for health and fitness purposes; and virtual/augmented reality (VR/AR) headsets and head-wear, which process movement data in real time for immersive digital experiences.

2 Smartwatches

2.1 Background

The most popular type of wearable in 2019 is the smartwatch [4]. Smartwatches are devices worn on one's wrist, equipped with sensors, and in some cases wireless communication capability for syncing data to a smartphone. They have rich operating systems (OS), on-board processors and memory, and come in a wide range of varieties from basic to high-end, with different specialized models in between [5].

2.2 Typical Specifications

Modern smartwatches typically have similar components to computers, albeit at a much smaller scale. They have an OS, which is most cases is proprietary to the manufacturer (i.e. watchOS for Apple); a single- or dual-core processor ranging from 80MHz to over 1.2GHz depending on the type of watch; up to a gigabyte of memory; battery life ranging between 18 hours to over a week; and depending on the watch - sensors to measure heart rate, fitness statistics, and atmospheric pressure [5].

It is simple to build a system that can accommodate all the required features of a smartwatch using normal computing components, however the challenge with a smartwatch is weight, size, and power consumption, as it needs to fit comfortably on the wrist, and be able to record data for at least an entire day on a single charge. This means all components must be lightweight, and energy efficient. According to ARM, the most necessary optimizations are using small data memories, using slower clock speeds, and choosing a silicon process technology that will offer the lowest possible power consumption, meaning the biggest design trade-off when designing smartwatches is between performance and

power consumption [6]. To examine these trade-offs, two popular smartwatches will be analyzed for the architecture decisions that went into their design and manufacturing.

2.3 Analysis of Examples

Two popular examples of smartwatches are the Apple Watch Series 5, and the Garmin Forerunner 235, both shown below in Figure 1. These devices are priced quite differently, carry different levels of functionality, and are therefore targeted towards different market segments. Shown below in Table 1 are prices for the watches listed above [7] [8].

(a) Apple Watch Series 5 [7]

(b) Garmin Forerunner 235 [8]

Figure 1: Smartwatches discussed in this report.

Table 1: Smartwatch Prices

Watch	Price (CAD)
Apple Watch Series 5	529.00
Garmin Foreruner 235	319.99

Clearly, these watches come at different price points, target different segments of the market, and of course come with different architectures for accommodating the necessary features in each model. This section will cover each of the watches shown above in greater detail.

2.3.1 Apple Watch Series 5

2.3.1.1 Background

The Apple Watch Series 5 is the newest iteration of smartwatch from Apple Inc., released in September 2019. Priced at $529, clearly this is considered a higher-end smartwatch, fitting in with Apple's other product lines (iPhone, iPad, and Mac). This watch has all-day battery life, a touch screen, voice call, GPS, compass, and music streaming capabilities, as well as the ability to run thousands of apps from the Apple App Store, made specifically for the Apple Watch [9]. This device is made for Apple users, as it requires an iPhone to make use of all its features. Its operating system is the Apple-designed watchOS.

Much of what makes the Apple Watch quite appealing is the variety of sensor technology that can track much of your health and fitness data. This sensor technology will be discussed, along with other computer architecture components in this section.

2.3.1.2 Hardware and Functionality

An innovation brought on by the Series 5 is the always-on display, a first for Apple Watch. An always-on display is not ideal for a device wanting low-power consumption, especially a high-resolution screen with a high refresh rate like the one on the Apple Watch. However, this new model incorporates a low temperature poly-silicon and oxide (LTPO) display which reduces the refresh rate of the watch's screen from 60Hz to 1Hz, the minimum frequency for the always-on display to accurately display the time [9]. This is a clever way to reduce power consumption by reducing frame rate when the watch is not being used interactively.

The processor and System in Package (SiP) at the core of the Apple Watch Series 5 is Apple's S5 chip, shown below in Figure 2. This is the fifth iteration of their custom-designed smartwatch chip where the entire system is fabricated into a single component with a footprint of about 40mm. This SiP includes some the sensors that come with the Series 5, including its GPS component and magnetometer (compass) [9].

Figure 2: Apple S5 Processor [10]

The Series 5 incorporates other sensors whose data is processed. These sensors are an electric heart rate sensor, which constantly monitors heart rate, and can perform an electrocardiogram (ECG/EKG) almost as accurate as a single-lead EKG [11]. Data from this sensor can be monitored and programmed to alert the wearer if there is any abnormal heart activity. The watch also uses its microphone to monitor noise levels, and alerts the user when current noise exposure could pose a risk for long-term hearing damage.

Arguably the most important sensor on a smartwatch with fitness tracking capabilities is the accelerometer, which actually tracks the motion patterns of the watch itself based on acceleration forces [12]. Data from GPS, accelerometer, heart rate monitor, and your own personal health data (height, weight, age) are used together to give you valuable insights into your workouts. The Series 5 comes with pre-programmed sports like cycling, running, swimming, and yoga, amongst others. In running activities, the watch tracks and can display your calories burnt, your pace, your heart rate, your distance, cadence, and elapsed time [13]. Having this data displayed in real time on your wrist, and available for analysis after the run is something that makes this device so valuable, as it helps people stay motivated and quantitatively monitor their improvements.

2.3.2 Garmin Forerunner 235

2.3.2.1 Background

If its name wasn't obvious enough, the Garmin Forerunner 235 is first and foremost a runner's watch.

2.3.2.2 Hardware

2.4 Smartwatch Summary

3 Virtual/Augmented Reality

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