Embedded Systems

Theory

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Abstract

The course delves into Embedded Systems, covering their characteristics, requirements, and constraints. It explores hardware architectures, including various types of software executors, communication methods, interfacing techniques, off-the-shelf components, and architectures suited for both prototyping and large-scale production.

In terms of software architectures, the course examines abstraction levels, real-time operating systems, complex networked systems, and the tools and methodologies used for code analysis, profiling, and optimization.

Students will also learn to analyze and optimize hardware/software architectures for embedded systems, focusing on managing design constraints and selecting appropriate architectures. Key topics include estimating and optimizing performance and power at various abstraction levels, project management, and designing for reuse.

Additionally, the course addresses run-time resource management and includes case studies to illustrate trade-offs based on application fields and system sizes.

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CHAPTER 1

Introduction

1.1 Introduction

Embedded systems are characterized by their ubiquitous presence, low power consumption, high performance, and interconnected nature. These systems are commonly utilized in four main application contexts:

- *Public infrastructures*: safety is a primary concern to prevent potential attacks, and in some cases, latency is also crucial. Examples include highways, bridges, and airports.
- *Industrial systems*: reliability and safety are the predominant concerns. Key industries utilizing embedded systems include automotive, aerospace, and medical.
- *Private spaces*: this includes control systems for houses and offices.
- *Nomadic system*: these systems involve data collection related to the health and positions of animals and people, requiring both security and low latency.

In the future, embedded systems will evolve in several key ways:

- *Networked*: transitioning from isolated operations to interconnected, distributed solutions.
- *Secure*: addressing significant security challenges that impact both technical and economic viability.
- *Complex*: enhanced by advancements in nanotechnology and communication technologies.
- *Low power*: utilizing energy scavenging methods.
- *Thermal and power control*: implementing runtime resource management.

Usually, we process useful data locally and send the relevant data to the cloud less frequently. This approach conserves energy, thereby extending battery life. Due to time constraints, developing a device from scratch is often infeasible, so we typically collaborate with eco-alliance partners. The design process involves a multidisciplinary team, as it integrates multiple domains of expertise. The first prototype resulting from this design phase is called the Minimum Viable Product (MVP), which is the initial sellable version of the product.

1.1.1 Technological problems

Applications are expanding rapidly, pushing the need for mass-market compatibility and integrating into all aspects of life, which in turn drives up volumes. As technology evolves, the scale of integration grows, supported by new materials and programming paradigms. However, finding a balance in this progress is complicated by several factors. CMOS technology is reaching its physical limits, and the cost of developing new foundational technologies can often be unaffordable. Additionally, the power and energy demands create significant barriers, as does the exponential proliferation of data. Transitioning from invention to innovation is proving difficult, and the design methodologies in use today heavily exploit human effort—though this reliance on human ingenuity is, in some ways, a fortunate necessity.

Vertical applications Vertical applications requires various technologies to work ad desired such as sensors, computing units, storage, communication elments, and so on. Energy and power dissipation have become even more problematic with the introduction of the newest technology nodes, exacerbating existing challenges. Dependability, which encompasses security, safety, and privacy, is now a major concern. At the same time, the growing complexity of systems is reaching nearly unmanageable levels. Despite this, complexity continues to rise, driven by applications that build upon increasingly interconnected systems of systems.