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Edge Computing in the IoT

Embedded Systems Design

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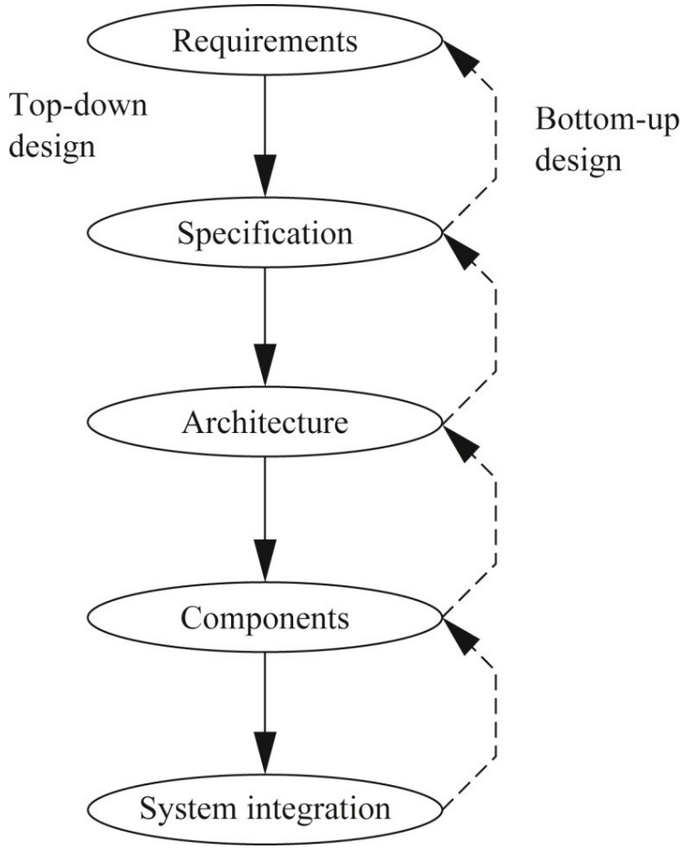
Embedded Systems Design Process



- At each step in the design process, we add detail:
  - At each step, we analyze the design to determine how we can meet the specification of the previous step
  - We verify the design to ensure that it still meets all system goals, such as cost and speed
- Separating out requirements analysis and specification is necessary
  - There is a large gap between what customers can describe and what the architects need to design the system
- Design is normally top-down, but we re-evaluate it bottom-up

Requirements

- Goal of this phase is to define the purpose(s) of the system and its main characteristics
- Actions of human users or other machines as they interact with the system
- A set of use cases that describe typical usage scenarios often helps in clarifying what the system needs to do

- **Functional requirements**:
  - What does the system do?
  - User interface(s)

Requirements

- **Non functional requirements**:
  - Performance: “speed” of the system
  - Cost: The target cost or purchase price for the system. Two major components:
    - manufacturing cost: components and assembly
    - nonrecurring engineering (NRE) costs: personnel and other costs for designing the system
  - Physical characteristics: The physical aspects of the final system can vary greatly depending upon the application
    - Size
    - Weight
    - Water/durst resistant
    - ...
  - Power and energy
    - Battery life
    - Power constraints
    - ...
  - Security
  - Reliability

Requirements - Example

Name	GPS moving map
Purpose	Consumer-grade moving map for driving use
Inputs	Power button, two control buttons
Outputs	Back-lit LCD display 400 × 600
Functions	Uses five-receiver GPS system; three user-selectable resolutions; always displays current latitude and longitude
Performance	Updates screen within 0.25 s upon movement
Manufacturing cost	$40
Power	100 mW
Physical size and weight	No more than 2″ × 6″, 12 ounces

Specification

- Goal of this phase is to translate requirements into more precise and specific form that will be followed by designers in the later stages
- The specification should be understandable enough so that someone can verify that it meets system requirements and overall expectations of the customer
- It should be unambiguous enough that designers know what they need to build
  - If the behavior of some features in a particular situation is unclear from the specification, the designer may implement the wrong functionality
  - If global characteristics of the specification are wrong or incomplete, the overall system architecture derived from the specification may be inadequate to meet the needs of implementation
- Specification languages, instead of natural language, may be used to provide more precise specification
  - e.g., UML

Architecture Design

- The architecture is a plan for the overall structure of the system
  - Will be used later to design the components that make up the architecture
  - It starts defining how requirements are implemented
- The creation of the architecture is the first phase of what many designers think of as design

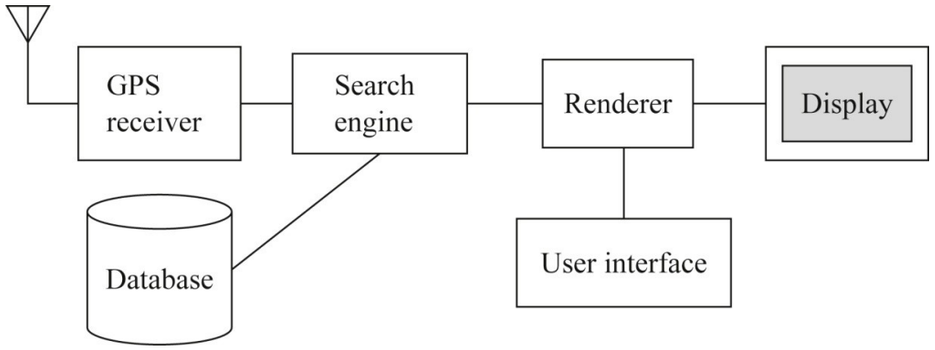
Architecture Design

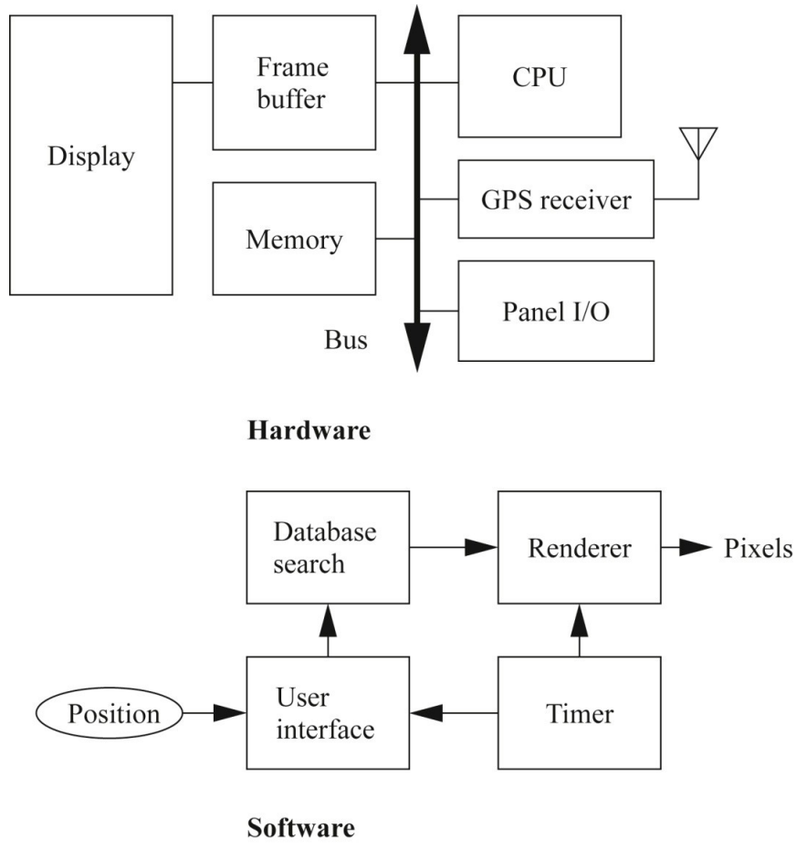
- General block diagram that describes the different parts of the system
  - Refined into one block diagram for hardware and one for software
- In case of multiple networked elements, we apply the same principle to the network architecture first and then to the architecture of each network element

Architecture Design

- Starting out with a system architecture and refining that to hardware and software architectures is one good way to ensure that we meet all specifications
  - We can concentrate on the functional elements in the system block diagram and then consider the nonfunctional constraints when creating the hardware and software architectures
    - We must somehow be able to estimate the properties of the components of the block diagrams
  - Some blocks are clearly hardware, some others clearly software
  - There are also modules for which the decision on whether to use hardware or software is made according to the requirements
    - Mixed HW/SW solutions are possible
- If the interfaces among different modules are specified in detail, the design of each module can proceed mostly in an independent way

Architecture Design - Example





Designing Hardware and Software Components

- The component design effort builds the components in conformance to the architecture and specification
- The components will in general include
  - Hardware: FPGAs, boards, sensors, actuators, ...
  - Software modules
- Some hardware and software components will be ready-made, some others will need to be designed and built
- Each component needs to be
  - Specified in detail
  - Designed
  - Implemented
  - Tested

System Integration

- In this phase, we put all the blocks, implemented independently, together
- This phase usually consists of a lot more than just plugging everything together
  - Bugs are typically found during system integration
    - By building up the system in phases and running properly chosen tests, we can often find bugs more easily
  - If we debug only a few modules at a time, we are more likely to uncover the simple bugs and be able to easily recognize them
    - Simulation – co-simulation
    - Use of artificial test vectors

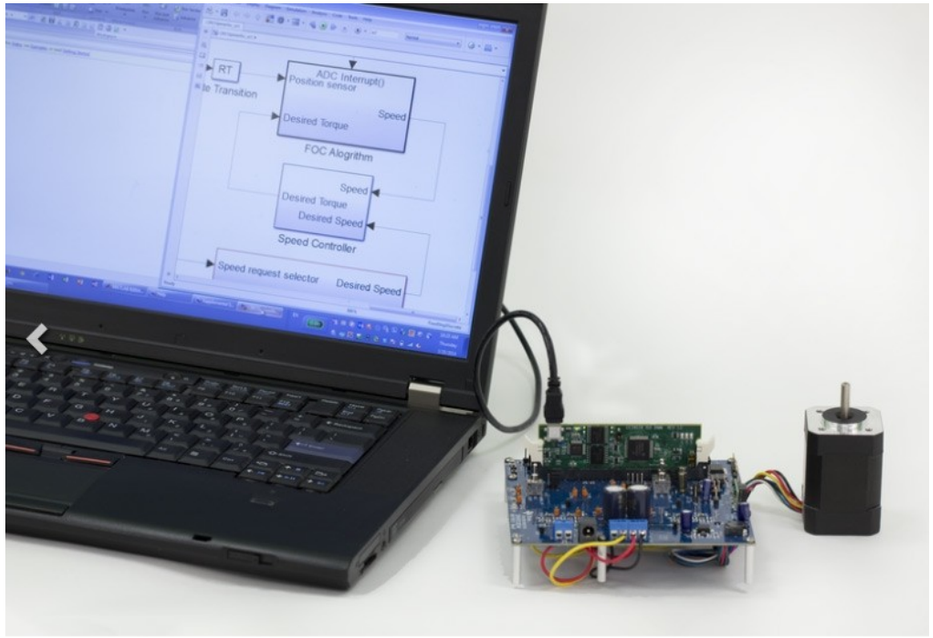
Simulation

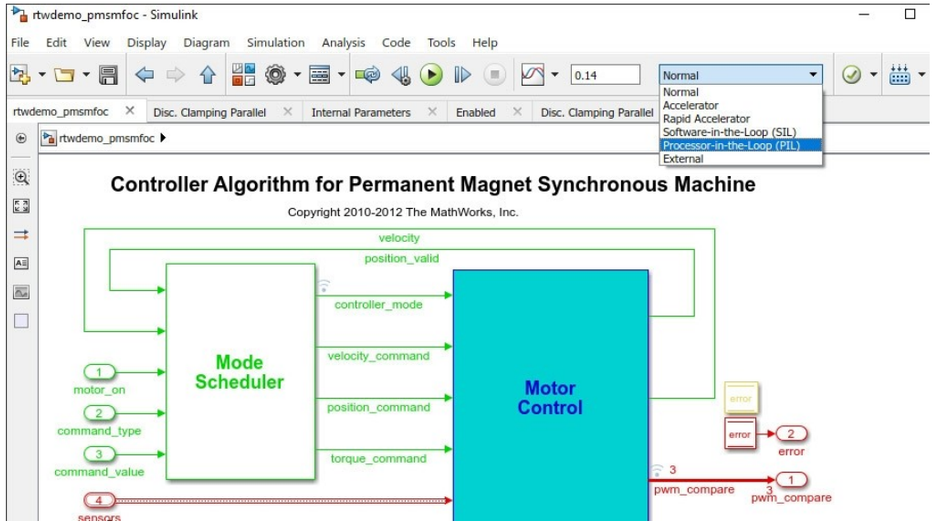
- Simulation of
  - The whole system
  - Building blocks
- Simulation can be used in different design phases
  - To verify correctness of requirements and specification
  - During the development of building blocks (e.g., algorithm development and tuning)
  - To test building blocks
  - To test the integration of building blocks before full integration takes place

Simulation

- We often rely on logged or artificially generated data
  - Input to a block provided by a simulated component that
    - Uses logged data, instead of live ones
    - Generates a fake output in accordance to specification
- Mix of real and fake blocks
  - Interfaces are the real ones
  - Hardware blocks may be simulated in software
    - E.g., a certain signal processing function is performed by a PC instead of a dedicated hardware unit

Example: Matlab Embedded Coder





https://it.mathworks.com/products/embedded-coder/features.html

Requirements and Specification Example

- Design a system that controls air conditioning in a house
- The system not only considers temperature settings by users, but also presence in the rooms, and learns habits of users as well

- Your turn:
  - Read the Requirements
  - Start drafting the high-level specification and the System Architecture