ECE-492
SENIOR ADVANCED DESIGN PROJECT
Meeting #3
Q1: Who is not on a team?

Q2: Which students/teams still did not select a topic?
ENGINEERING DESIGN

- You have studied a great deal of math, science, and fundamental technology, but probably have had limited exposure to creative and innovative design in a larger project.

- **Innovative Design** vs. **Methodical Design**
  - You need to balance effectively between these two.

- In general, without experience, you lack an innovation in your design.
  - So, you need to be involved in a number of innovative design projects to gradually gain experience.

- Design – is a new megatrend (!)
Design Process

- Design process
  - Steps required to take an idea from concept to realization
  - Develop a system that best meets the customer’s need

- Consider a hypothetical example: You are hungry and need to eat
  - You identify constraints: time, money, food, your tastes, nutritional values, your cooking knowledge, and skills
  - You brainstorm and come up with alternatives:
    - Dinner at home
    - Go to a restaurant
    - Buy something almost ready
  - You select one and decompose into a set of tasks, assign timetable, budget, tests, milestones

- Now consider building a machine/device/gadget
All technical solutions must be based on the background knowledge you learned

Math, physics, EE, CpE methods and practice must be embedded into your project – no exception

- This is particularly true during the design phase
- Make sound selection of system components, system parameters
- You need to demonstrate this in your:
  - Design Document
  - Design Review and In-Progress Presentation
  - Final Presentation of ECE-493

Ad hoc solutions are not acceptable (!)

Use simulations
Top-Down Design Model for ECE492
(Systems Engineering View)

Proposal Phase

Requirements Analysis
Operational requirements
Technical performance measures

Conceptual Design

Preliminary Design

Preliminary Experimentation Plan

Detailed Design

Experimentation Plan

Detailed Design Phase

Identification of Need

Research

Technology Development Application

Operational requirements
Technical performance measures
Elements of the Process

- **Identification of a need**
  - What are the needs of my customer?
  - You have to understand them very well

- **Research phase**
  - Understand the application domain, technology in that domain, existing solutions. You learn, learn, and learn.

- **Requirements Specification**
  - Development of an operational scenario(s)
  - Articulate what the system must do for it to be successful and be accepted by your customer
  - Requirements guide the entire project
  - When properly developed, provide flexibility for creativity and innovation in developing solutions
  - Define system interfaces with a user and an environment
Conceptual Design
- Many possible solutions to the problem are considered
- Creativity and innovation is encouraged
- Selection of the target solution

Design phase
- Two phases: Preliminary Design followed by Detailed Design
- Iterative process of developing a technical solution
- All major systems and subsystems are identified and described

Implementation phase
- Prototyping and Construction
- Different elements of the system are constructed and tested

System Integration
- All subsystems are brought together to produce a complete working system
- It’s time consuming
- Closely tied to the Testing phase
• Testing
  – Very important for checking system functionality at different implementation and integration stages
  – Frequently neglected and a cause for engineering disasters (still a problem in ECE-493)

• Maintenance phase
  – Maintenance and upgrade to include new functionalities
  – Design problems are corrected
STEP 2:
REQUIREMENTS SPECIFICATION

This step:

>- Includes one or more interviews,
>- Follows through the development of operational scenarios (Use Cases),
>- Defines External System Diagram, and
>- Ends on Requirements Specification

It is very important at this stage to work closely with your stakeholder(s)

Take it seriously so you can avoid problems and misunderstandings later on
Requirements Specification
Development Process

Customer

Customer Representation

Feedback

Develop System Operational Scenarios And Requirements

Technical Representation

Feedback

Constraints and Standards

Technical Community

Environment
The goals for the first interview are:

- To understand system operational coexistence with the environment, other systems, and the user
- To define basic system operations
- To define the first version of requirements

The team must carefully prepare questions for the interview:

- This usually is done after a brainstorming session at a team meeting
- Have the questions in writing (!)
- Do not show up for the interview unprepared – remember – you are asking questions
Question: How to define requirements?

Answer: From Operational Concept!

The system design process must start with an Operational Scenario(s)

Operational Concept: This is a user’s perspective of how the system is going to operate, step by step

- This results in Use Cases; they express mission requirements (of what the system is supposed to do)
Operational Concept

- It describes a typical scenario and other scenarios to handle by the system
- It describes the interactions between the system, its environment, external systems, and the user
- Scenarios do not include internal decomposition (!)
  - Again, you need to focus on relations with users and external systems (not on internals)
- Scenarios are developed around a specific goal (output of a system)
- Formulated using a graphical representation
- Scenarios should be developed along time lines
- Each scenario is represented by a Use Case
Elevator System Design: Sample Cases

External System Diagram

- Composite of scenarios from Operational Concept
- Shows your system interactions with external systems and user(s)
- If your system is defined as more than one subsystem, you can distinguish them separately
  - For example; a communication tower and a cell phone can be considered as separate systems
  - However, you should not overuse this options
- Can be used very effectively during your presentations to explain of what your project is about (!!!)
  - Use pictures and graphics to define external systems and users
  - Sketch interactions using lines
  - Annotate sequence of interactions if they improve understanding
Sample External Systems’ Diagram

Passengers

Elevator System

Requests

Feedback Info

Alerts

Alerts+Info

Maintenance System

Power System

Structural Support

Communication+ Service+Test
Requirements Specification

- Identifies those requirements that the design must satisfy
- Drives all subsequent stages of development
- Requirements describe the “whats” (not “hows”)
- Must be measurable and demonstrable
- Obtained through an interview with a user(s)

- Requirements analysis deals with tradeoffs and priorities in defining the final set of requirements
Requirements Categories

- **Mission Requirements**
  - Developed in the context of system relation within external systems and focused on the boundary of the system
  - They should be as design independent as possible

- **Operational Requirements**
  - Reflect a translation of the mission requirements into engineering terminology
  - Define a desired direction of performance
  - Specify minimum acceptable performance constraints
  - Define specific functions that the system must perform while transforming inputs into outputs
Operational Requirements

1) Input/Output Requirements
   - Sets of acceptable inputs and outputs
   - Interface constraints imposed by external systems
   - Eligible functions that match system inputs with system outputs

2) External Interface Requirements

3) Functional Requirements

4) Technology and System-Wide Requirements
   - Performance index thresholds, Technology, Suitability and quality issues, Costs, Schedule, Regulations and safety

- 'Wish List' Requirements
Writing Requirements

❖ Use proper language:

- ‘Shall’ - Indication of limiting nature of a requirement
- ‘Will’ - Statement of fact
- ‘Should’ - Indication of goals
Example requirements:

- “The robot **shall** navigate autonomously with the aid of landmarks in the specified environment”
- “The robot **will** operate for 1 hour on a single battery charge”
- “The cost of parts and material **should** be below $600”
- “The robot **will** have an average speed of 0.5m/s, and top speed at least 1m/s”
- “The system **shall** use the PIC microcontroller technology”
- “Peak power consumption **should** be below 3W”
- “The system **shall** be operated by an untrained adult”
- “The robot **shall** have a remote safety OFF-switch”
- “The system **shall** fit within 2x3x2in space”
CASE STUDY: Clock Timer

< Step 2: Requirements Specification >

(Separate set of slides distributed through email)
Summary: Requirements in ECE492/3 Projects

✓ Mission Requirements
  o Identify primary mission (and alternative missions)

✓ Input/Output Requirements
  o Define the basic operational input-output characteristic
  o Define system interfaces
  o List primary functions performed by the system

✓ Functional Requirements
  o Quantitative measures (objectives/parameters) the system must behave accordingly

✓ Technology and System-Wide Requirements
  o Restrictions on system components and geographical distribution
  o Regulatory and safety requirements
  o Technological restriction, etc.
STEP 3: CONCEPTUAL DESIGN

- A top-level design

- Exploration of many potential solutions and selection of one from them

- Use *creativity* and *judgment*
  - Creativity involves the generation of novel concepts
  - Judgment is applied to evaluate and select the best solution

- This step looks really simple but this is a false perception. Contrary, it can be very difficult.
  - It is based on previous experience – but you have to start somewhere
**Concept Sketching**

- It’s a simple first-step to jump-start your conceptual design

1. Start from taking three blank pages.
2. Use a single page to briefly sketch your solution/system, interaction with the user/environment, a way it functions. Look from a user perspective and operational functionality (!)
3. Use each page for totally different concept. Use imagination. Don’t be afraid of risky and innovative ideas. Refine them later – just sketch freely.
4. During refinement, redraw your concepts closer to the technical reality, available parts, main requirements, time frame, budget.
Conceptual Design in ECE492

- Based on a notion that Concept Sketching is best done individually
- Each team member should prepare three design sketches at refined level
- During a team meeting, all members show and explain their sketches
- Best sketches should be selected and discussed providing the feedback for further refinement
- Follow with the second refinement of best design sketches; this follow-up relies on smaller teams of 2 people
- Final team meeting is devoted to selecting the final design and alternatives
Strategies to Enhance Creativity

- **Have a questioning attitude**
  - WHY? HOW? WHERE?
  - IS THERE A BETTER WAY....?

- **Practice being creative**
  - Improve creativity by conscious effort
  - Keep thinking about your design throughout the entire day

- **Suspend judgment**
  - Early criticizing immediately dismisses ideas
  - Creative concepts can be developed by taking a concept and modifying it or combining it with other seemingly related concepts

- **Allow time**
  - The human mind needs time to work on problems

- **Think like a beginner**
  - New solutions often come from novices
  - Use knowledge during refining only
Novel combinations and adaptations of existing techniques:

- **Substitute** – Can elements be substituted?
- **Combine** – Can existing entities be combined in a novel way?
- **Adapt** – Can this be adapted to operate differently?
- **Modify** – What can be modified to provide a benefit?
- **Put to other use** – Are there any other applications of this system?
- **Eliminate** – Can a part(s) be eliminated?
- **Rearrange** or **Reverse** – Can elements of the system be rearranged differently?
Concept Evaluation

- Exercise engineering judgment, requirements and technical factors to derive the decision

- Initial Evaluation
  - Reject based on reasons a design may be deemed infeasible; i.e.,
    - Far too costly
    - Will take too long to develop/implement
    - Involves too much risk
    - Will not meet requirements

- Final Evaluation
  - Do it as a group
  - Carefully analyze strengths and weaknesses
  - Vote
CASE STUDY:
Clock Timer

< Step 3: Conceptual Design >
Summary: Conceptual Design in ECE492

- Execute conceptual sketching individually
- Develop a final sketch
- Extract a list of innovative/interesting design aspects that:
  - Make your project/approach interesting
  - Differentiate your project in a marketplace
For the Next Meeting

- Read textbook – Chapters 3 and 4
- Talk to your Faculty Supervisor
- Write a draft of Requirements Specification
  - Talk to your users
  - Define project motivation – in writing
- Start Conceptual Design
  - Run a brainstorming session

- **Homework for the next meeting:**
  - Bring hard copies of
    - Requirements Specification
    - Conceptual sketch
Final Project Selection Session

- You have to submit your Project Title Form today

- Now, we need to help students without an assignment to form/join a team