Design Process Overview

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'87

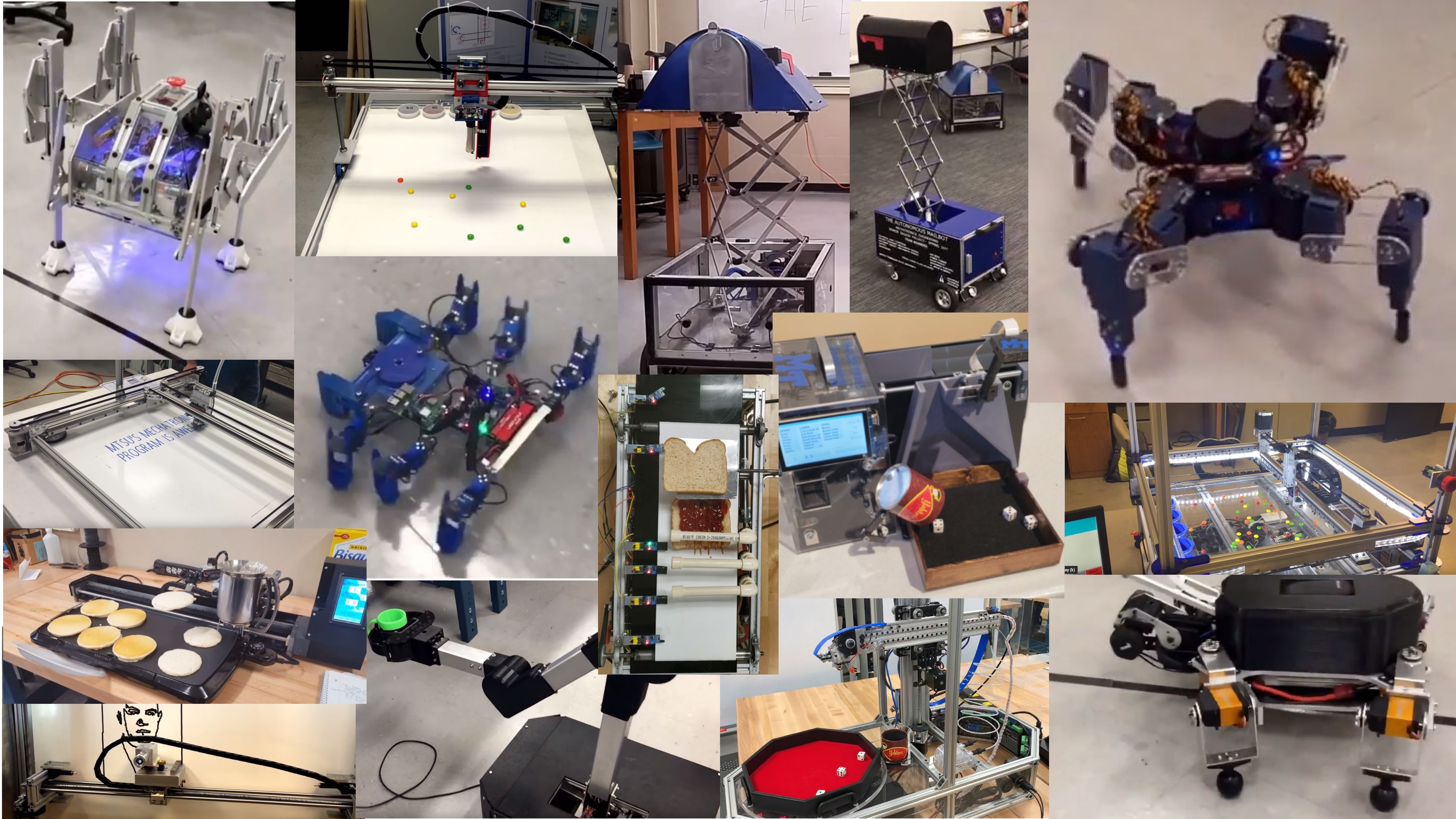
'09

'13

'15

'19

Mentored about 40
senior design projects

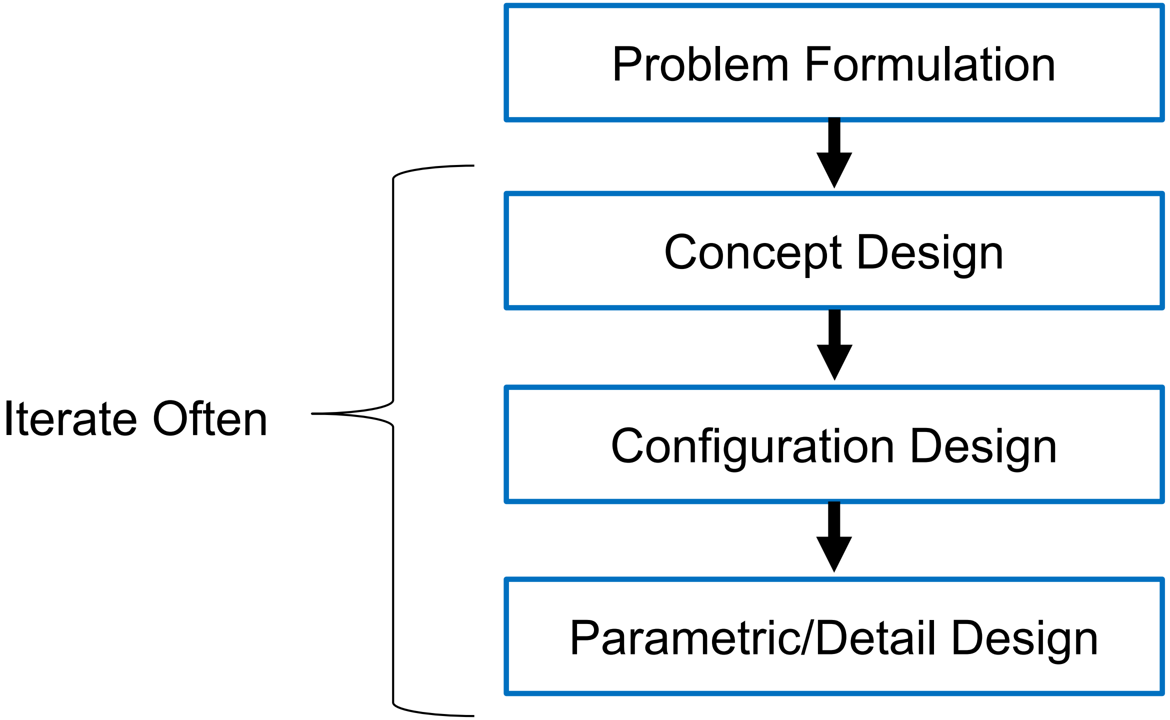

THE AUTONOMOUS MAILBOT

Senior Design Advice

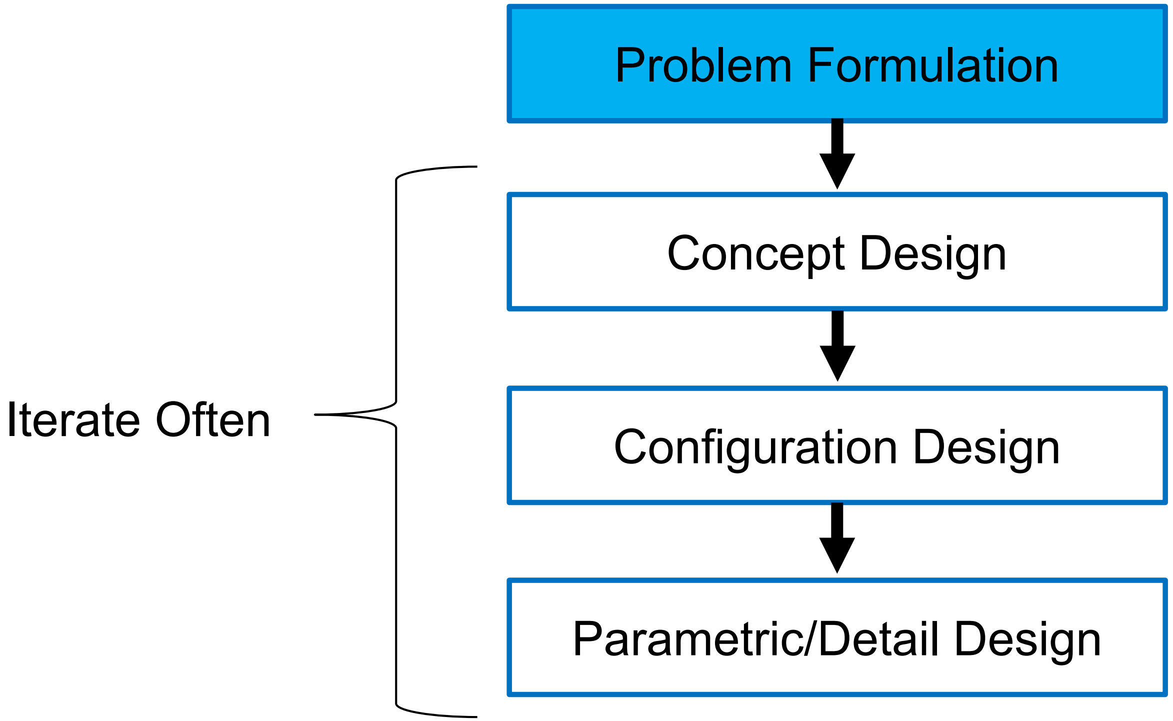
<u>Here is some of what successful teams do:</u>

- ❑ there is a clear project manager and technical lead
- ❑ each person works in an area of strength
- ❑ each team assigns multiple people to one major area (mechanical design, electrical, programming, controls, hydraulics, pneumatics, etc.), but there is a clear lead for each part of the project
- ❑ the team has a process for dealing with conflict
- ❑ the team has a process for making technical decisions
- ❑ the team engages in a non-engineering activity early in the term (i.e., goes out to eat, goes bowling, etc.)
- ❑ the team has excellent documentation and communication skills

Design Fundamentals



Design Fundamentals



Design Fundamentals

Problem Formulation A phase in the design process in which customer and company requirements are determined and engineering design specifications are prepared

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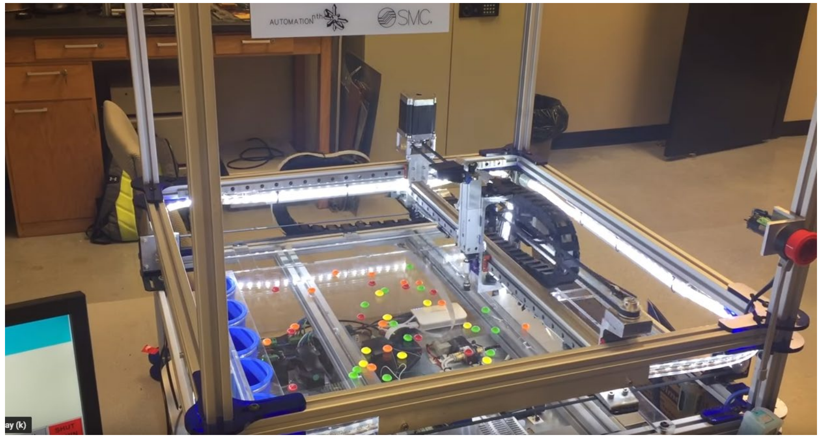
Problem Formulation A phase in the design process in which customer and company requirements are determined and engineering design specifications are prepared

- Clearly define the problem at hand (in your own words)
- Problem statement should be solution independent
- Design problems are often ill-defined, and the team should work with the customer for clarity
- Iterate on the problem statement until everyone is clear

Design Fundamentals

Problem Formulation



Which problem statement is the most helpful?

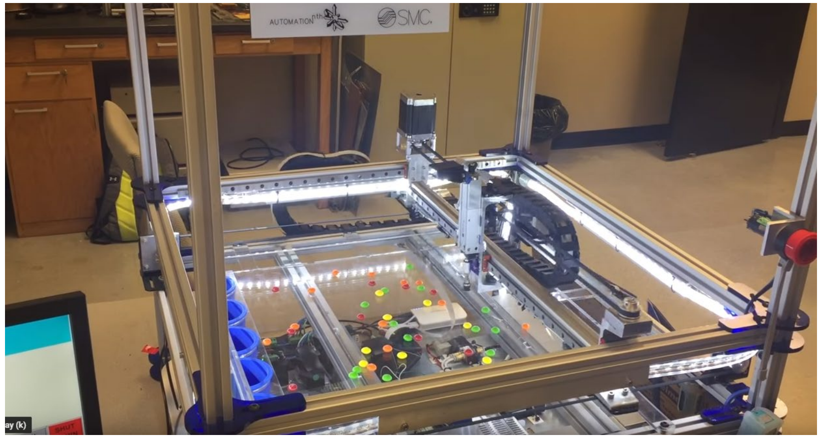
A) A two DOF belt driven robot must be designed to sort skittles by color

B) A system must be designed to sort skittles by color

C) An autonomous skittle sorting machine should be designed which sorts skittles by color, costs less than $1000, fits into a 2 ft by 2 ft area, provides an easy to use GUI, and is safe to maintain and operate

*robot developed by seniors at Middle Tennessee State University.

Design Fundamentals



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Design Fundamentals

Functional Requirements Functionals requirements should be identified to specify what the product should do

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EX. Consider the design of a bicycle

Subfunction	Weight
Transports riders	50%
Steer bike	25%
Support riders comfortably	10%
Absorb road shocks	15%
Total	100%

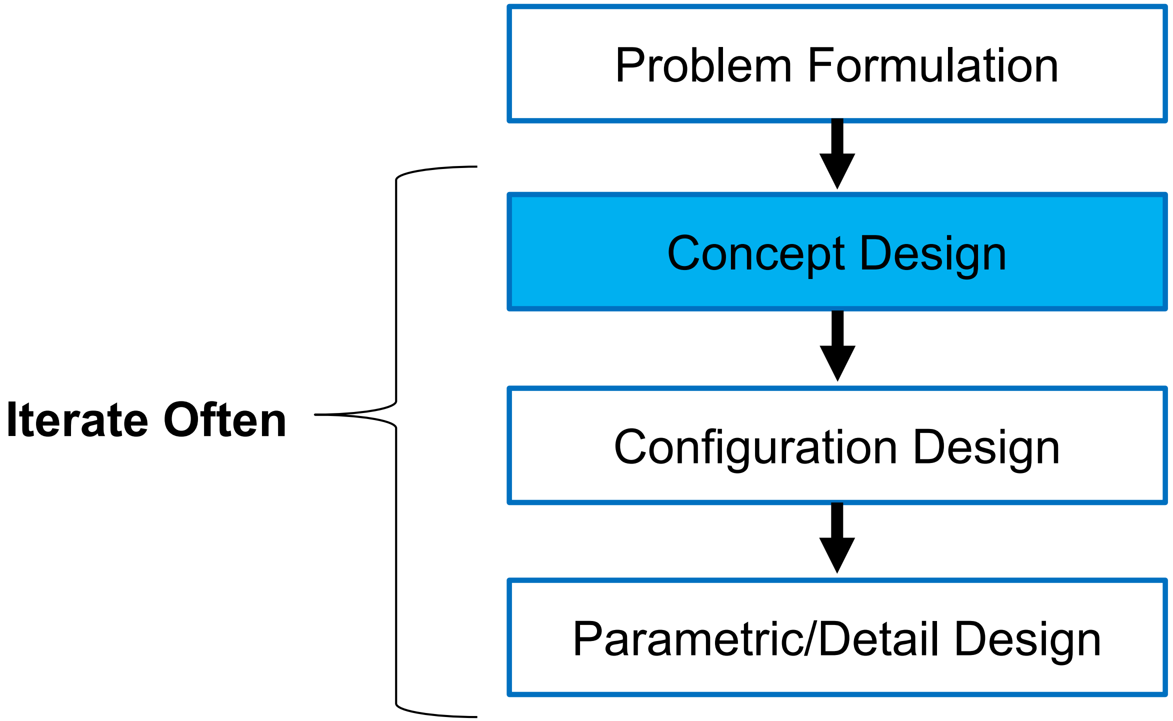
Design Fundamentals

<u>**Functional Requirements**</u> Functionals requirements should be identified to specify what the product should do

EX. You could fill out this table for your team

Subfunction	Weight
?	?
?	?
?	?
?	?
?	?

Design Fundamentals



Design Fundamentals

Concept Design Part of the design process when alternative design concepts are generated and selected for further development

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- Design Concept: The abstract embodiment of a physical principle, material, and geometry
- Design concepts should be developed INDEPENDENTLY
- Questions to consider:
    - Will the concept be manufacturable?
    - Will the concept work in the desired operating location?
    - Does it meet marketing requirements?
    - Does it meet the minimum performance requirements?

Design Fundamentals

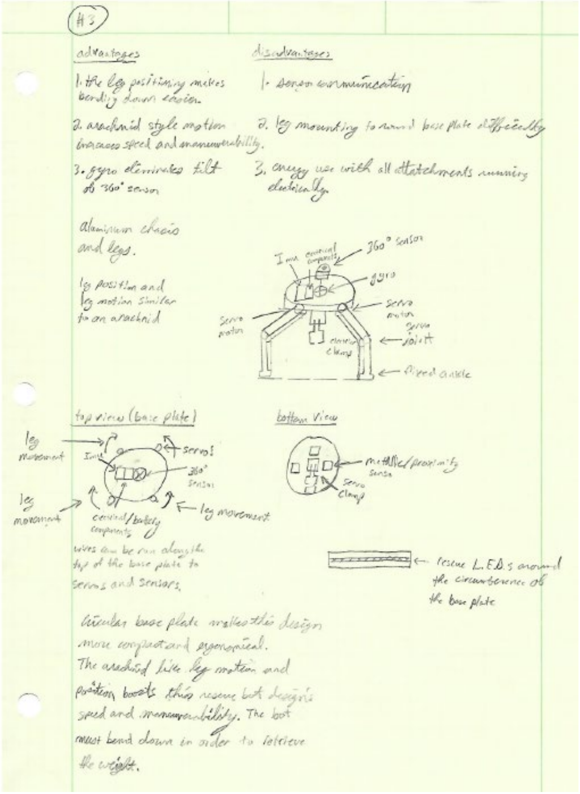
Concept Design Part of the design process when alternative design concepts are generated and selected for further development

- Common Characteristics of design concepts
  1. Work by some physical principle
  2. Physical principles act on a surface or object
  3. Imply relative motion of surfaces or an object
  4. Imply general material types

Design Fundamentals

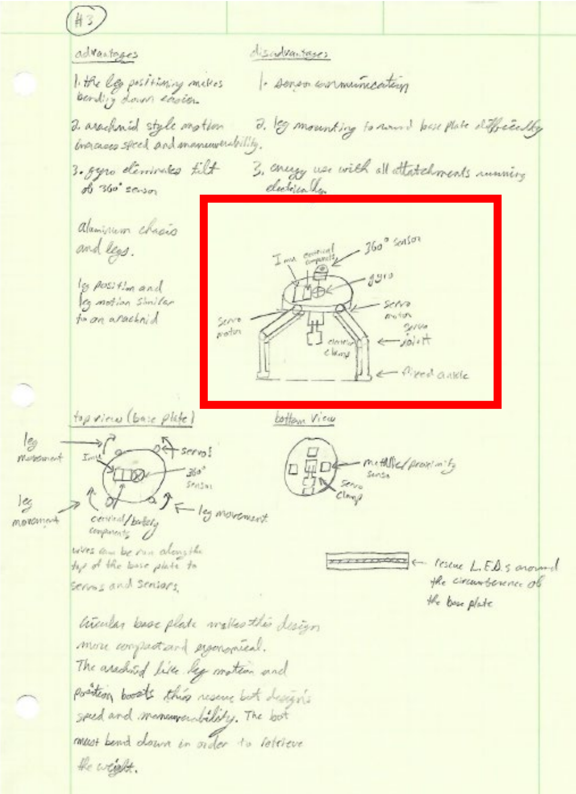
<u>Concept Design</u> Part of the design process when alternative design concepts are generated and selected for further development

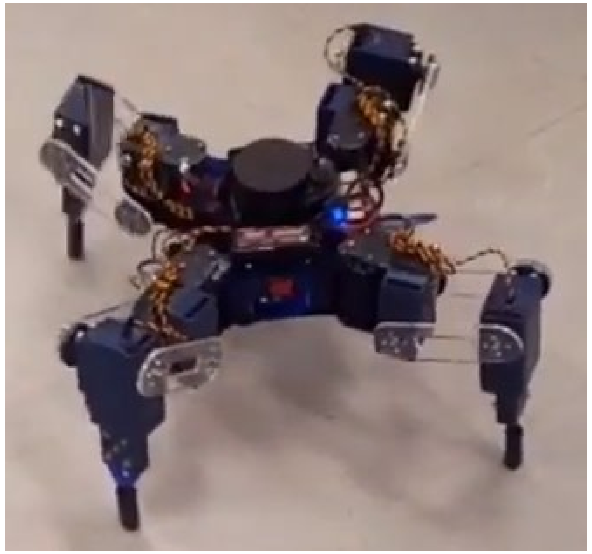
- Design Sketches (suggest 10 per person)
  1. Working geometry
  2. Physical principle
  3. Material
  4. Motion of device
  5. 3 disadvantages
  6. 3 advantages
  7. constraints



Design Fundamentals

Design sketches are NOT just about drawing random lines on a piece of paper





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Design Fundamentals

Concept Design Part of the design process when alternative design concepts are generated and selected for further development

Weighted Rating Method – teams can rate different designs or parts of the design with specific criteria

- Method is subjective but helps spark discussion
- Method helps identify key areas of weakness in a design

Design Fundamentals

Concept Design

Criteria	Importance Weights	Gear Rating	Gear Weighted Rating	Chain Rating	Chain Weighted Rating
High efficiency	35	4	(.35)*4 = 1.4	3	(.35)*3=1.05
High reliability	15	2	(.15)*2 = 0.3	4	(.15)*4 = 0.6
Low maintenance	25	3	(.25)*3 = .75	3	(.25)*3 = .75
Low cost	25	3	(.25)*3=.75	2	(.25)*2 = .5
Total	100	N/A	3.2	N/A	2.9

Rating	Value
Unsatisfactory	0
Just Tolerable	1
Adequate	2
Good	3
Very Good	4

Design Fundamentals

<u>Concept Design</u> Try going through this process with your team

		Design 1		Design 2	
Criteria	**Importance Weights**	**Rating**	**Weighted Rating**	**Rating**	**Weighted Rating**
?	?	?	?	?	?
?	?	?	?	?	?
?	?	?	?	?	?
?	?	?	?	?	?
?	?	?	?	?	?

<u>Rating</u>	<u>Value</u>
Unsatisfactory	0
Just Tolerable	1
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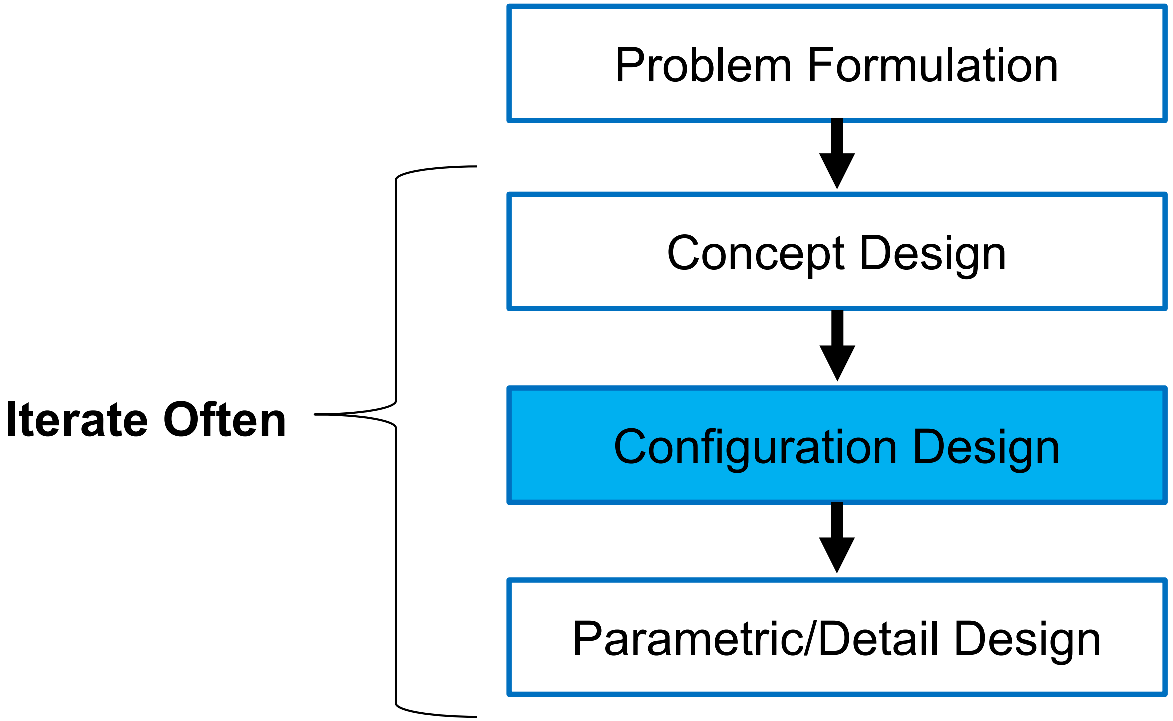
Good	3
Very Good	4

Design Fundamentals

Concept Design

THE CONCEPT DEISGN STAGE IS CRITICAL. TEAMS THAT TAKE THIS SERIOUSLY HAVE TREMENDOUS SUCCESS. THOSE THAT DO NOT OFTEN STRUGGLE.

Design Fundamentals



Design Fundamentals

Configuration Design Part of the design stage in which the number and type of parts or geometric features are determined. The list of design variables is also determined.

Common questions to be answered in this stage:

1. what types of actuators?
2. How many actuators?
3. How many links?
4. How many joints?

Design Fundamentals

<u>Configuration Design</u> Part of the design stage in which the number and type of parts or geometric features are determined. The list of design variables is also determined.

<u>Design For Function</u>: Designing a product with the customer in mind. It should work according to the customer's expectations (or better), and it should be easy to maintain and last a long time

1. Are the parts strong enough?
2. Too flexible?
3. Will they buckle?
4. Do they use too much energy?

Design Fundamentals

<u>Configuration Design</u> Part of the design stage in which the number and type of parts or geometric features are determined. The list of design variables is also determined.

<u>Design For Assembly</u>: The name that is used to describe a set of ways that aim to reduce the cost of part handling, insertion, and fastening

1. Minimize part count
2. Modular assembly
3. Use standard parts
4. Design parts with self-locating features

Design Fundamentals

<u>**Configuration Design**</u> Part of the design stage in which the number and type of parts or geometric features are determined. The list of design variables is also determined.

<u>Design For Manufacture</u>: The set of practices that aim to improve the fabrication of individual parts

1. Is the manufacturing process costly?
2. Are the tolerances too tight?
3. Is the raw material available in standard form

(sheets, rolls, bars, etc.)

Design Fundamentals

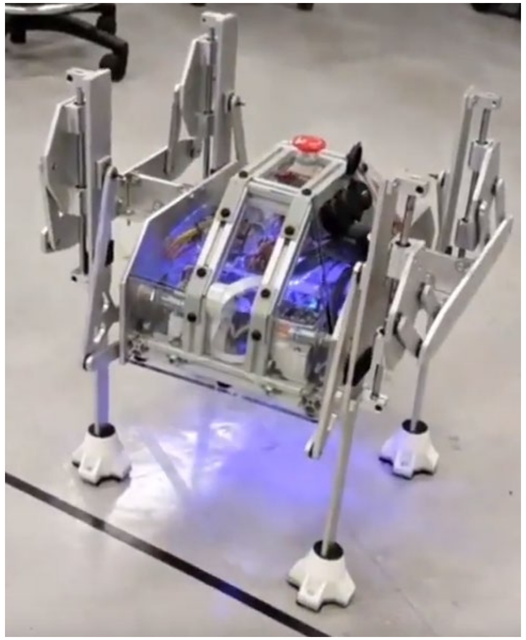
Configuration Design Part of the design stage in which the number and type of parts or geometric features are determined. The list of design variables is also determined.

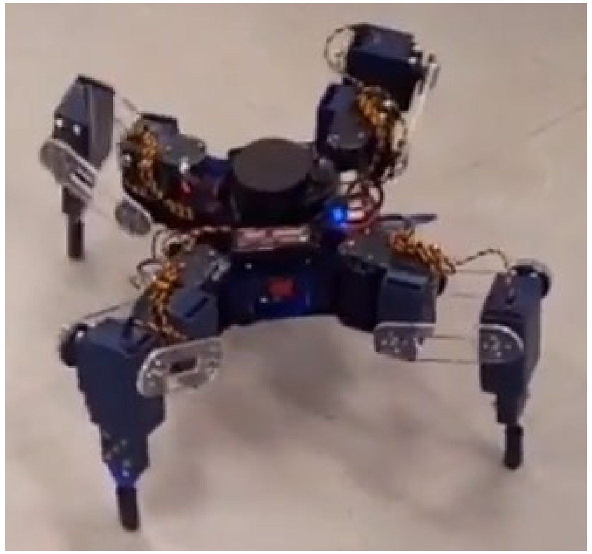
Design For Safety: The set of design practices aimed at reducing the risk of harm or injury to those involved with the product

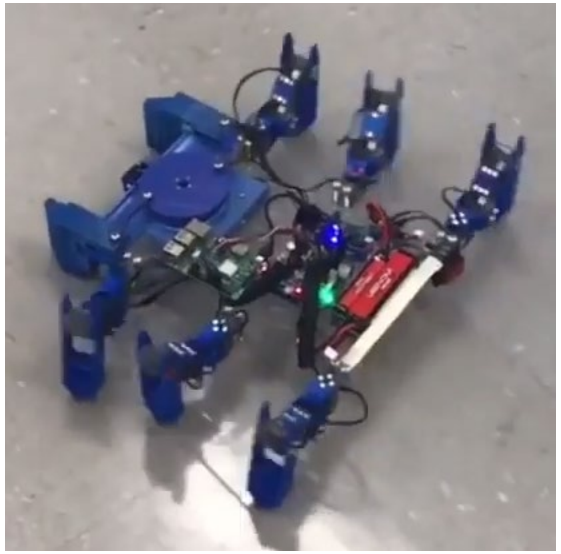
1. What safety measures are in place?
2. Is there an emergency stop or other way to shut down power?
3. Are sharp corners removed?
4. Etc.

Design Fundamentals

What are the positives and negatives of each design?

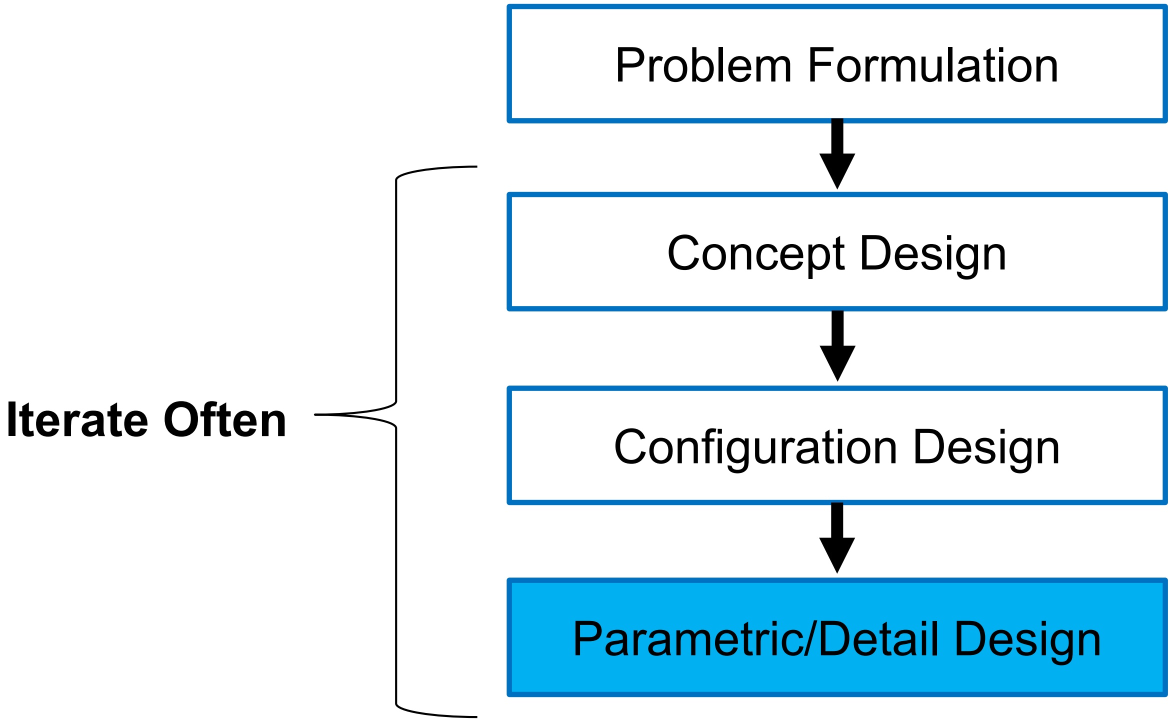






*These robots were developed by seniors at Middle Tennessee State University.

Design Fundamentals



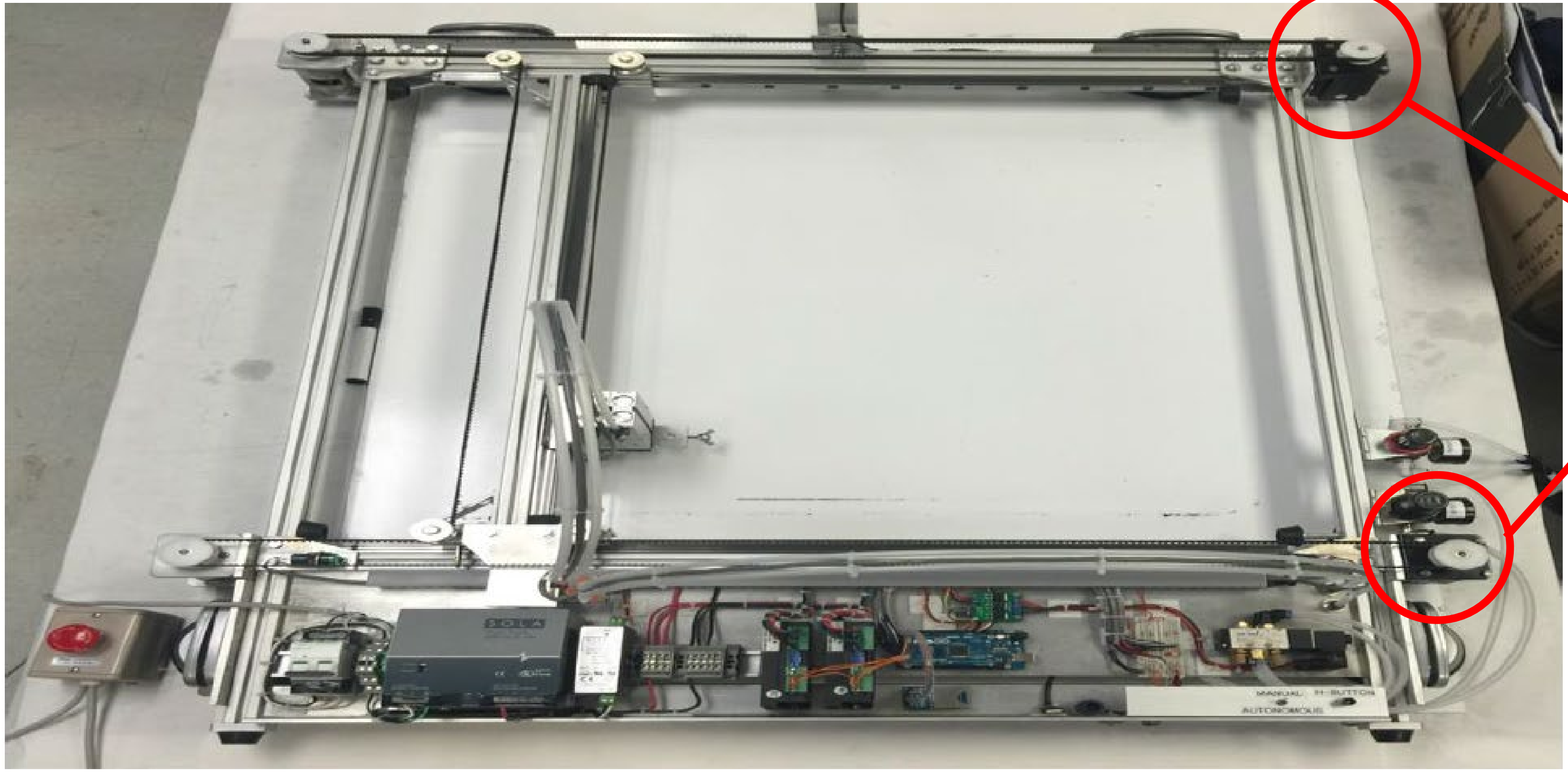
Design Fundamentals

Parametric/Detail Design Part of the design stage in which the system is optimized, and calculation/analysis/testing is completed.

Common questions to be answered in this stage:

1. What mathematical analysis needs to be completed to solve for the design variables?
2. How do I choose exact lengths/dimensions?
3. How can we optimize the system?

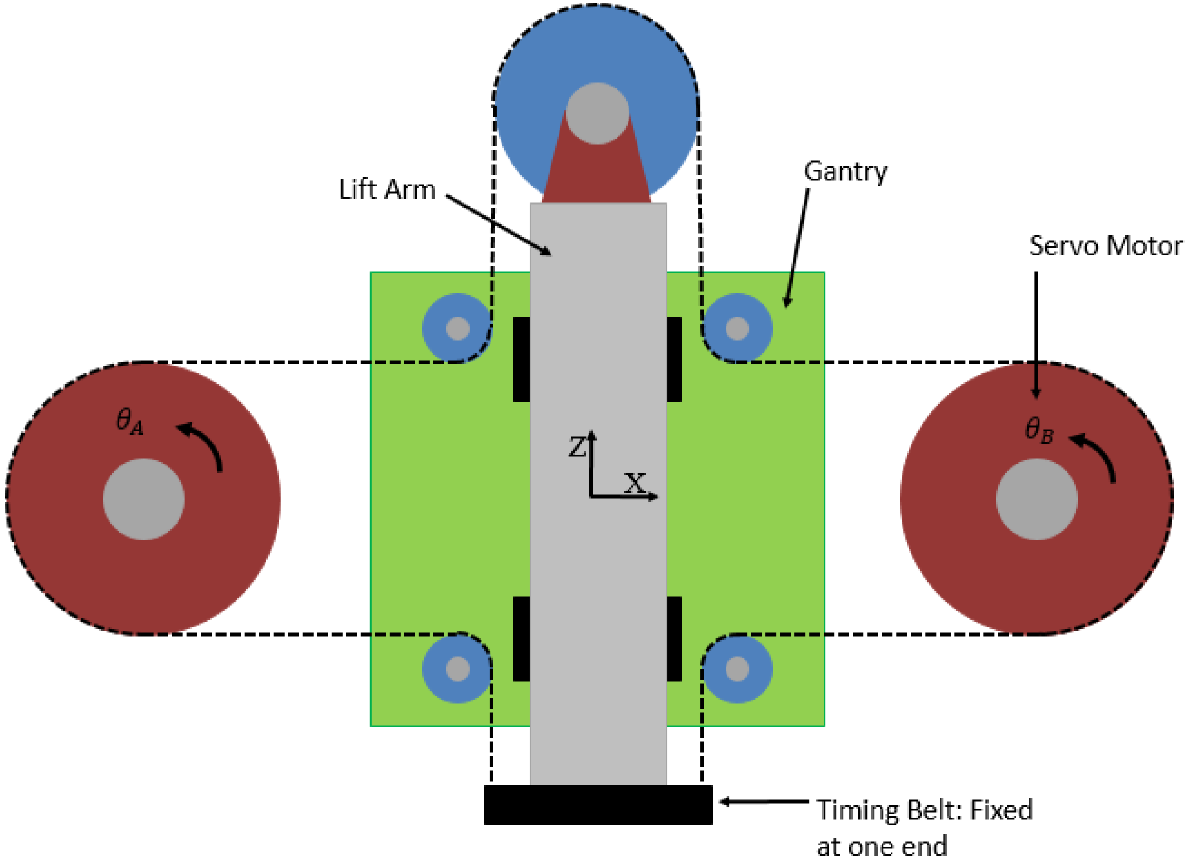
Design Fundamentals



Motors

Design Fundamentals

EX. Simulate a control system for the whiteboard robot



Design Fundamentals

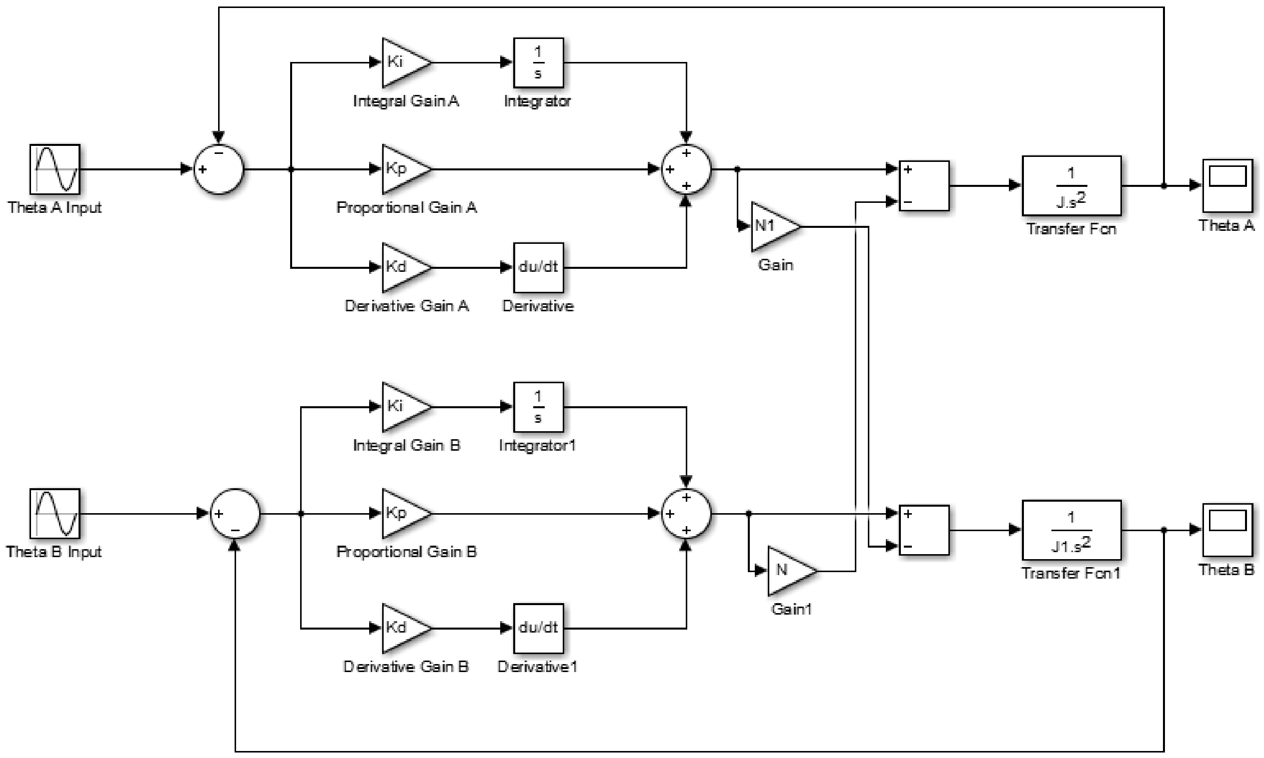
EX. We can start with deriving the equations of motion

$$\tau_A = \left[\frac{r^2}{4}(m_1 + 2m_2) + I_A\right]\ddot{\theta}_A + \left[m_1\frac{r^2}{4}\right]\ddot{\theta}_B$$

$$\tau_B = \left[\frac{r^2}{4}(m_1 + 2m_2) + I_B\right]\ddot{\theta}_B + \left[m_1\frac{r^2}{4}\right]\ddot{\theta}_A$$

Design Fundamentals

EX. Skipping a bunch of steps, we can get to a Simulink simulation which will allow us to get an accurate torque curve for each motor!



Design Fundamentals

How can you relate what you have learned in your courses to your project?

Design Fundamentals

Finally…

Prototype, Prototype, and Prototype!