Capstone Design Studio

Common Studio Session for Week #4

Date 09/12/2022

REMINDERS/ANNOUNCEMENTS

- ALL Links and Slides are posted here: http://mecapstone.gatech.edu/students

- All of you should be in a Studio section AND Lab section (specific to your team's primary advisor) on CANVAS.

- Common MS Teams Support Network: https://mecapstone.gatech.edu/support

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CONSULTING SUPPORT

Kinsey Herrin
Thursdays 12:30-1:30
GTMI 357, open to appointments by email

Jacob Blevins
Wednesdays 12-2 pm
Invention Studio Front Desk

Jacob Tompkins
Wednesdays 1-3 pm
MRDC Design Commons, open to appointments

Terrence Pleasant (TA) : Wednesdays 12-1:30 pm, message on Teams, through email or on canvas

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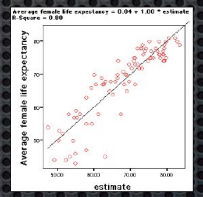
Recap: Prior Art Search, Market Research and Marketing

Market research is used to determine idea viability and create marketing plans

- What?
  - Verify need for product
  - Determine market size: How big is my idea?
  - Choose target customer: Where do we focus first?
  - Understand target customer
- How?
  - Primary
    - Methods: Surveys, Focus groups
    - Risks: Question & facilitator bias
  - Secondary
    - Methods: Reports and studies
    - Risks: Report or study bias



Mr. David Moeller,
CSO, Sectigo
GT BSME 2002

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Product Failure Stories

- Why do you think so many new products fail?

Don’t abandon loyal customers based on a narrow focus group study

Don’t offer with what you can make/sell, sell what the customer needs

Don’t assume customer’s willingness to pay!

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How to conduct Market Research?

- Primary
  - Methods: Surveys, Focus groups, observation, interviews
  - Risks: Question & facilitator bias
  - Outcome: Customer pains, needs and wants

- Secondary
  - Methods: Internet, Reports and studies
  - Risks: Report or study bias
  - Outcome: Market size, customer habits, practices, etc.

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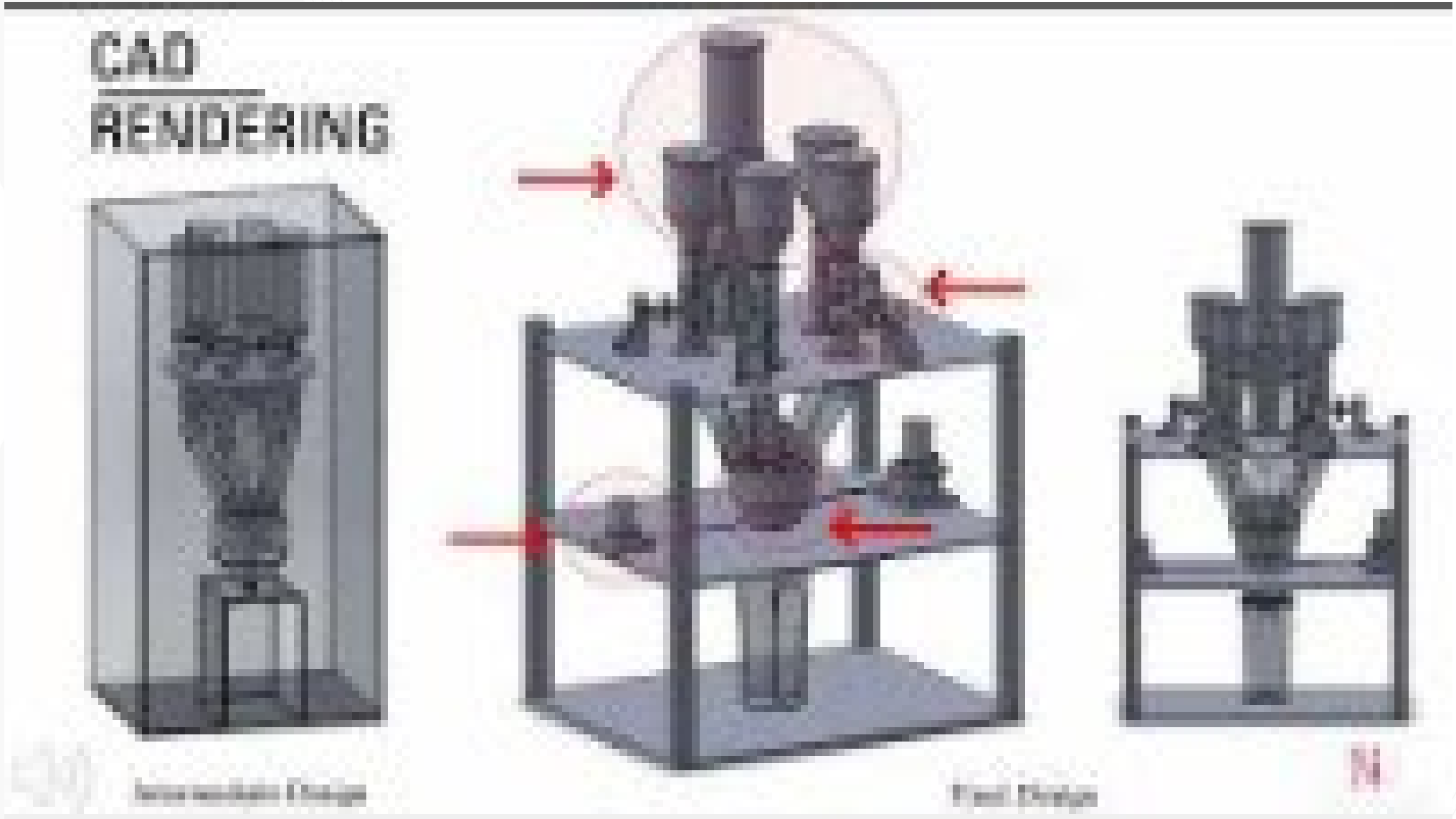
Past Project Example - 1



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Past Project Example - 1

Smart Dispensing Mechanism for Nutritional Supplements
NutriVend

Abdullah Algrafi, Woosik Chung, Varisa Gumpangkum, Samuel Orr, Marla Pinckney, Mario Reid, Parris Skiouris

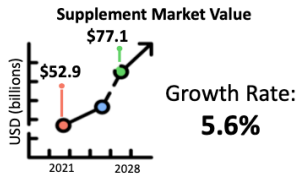
Georgia Tech College of Engineering
George W. Woodruff School of Mechanical Engineering

Background

Optimal supplementation is needed to achieve and maintain fitness goals.

Problems

- Many supplements
- Not enough knowledge
- High initial cost



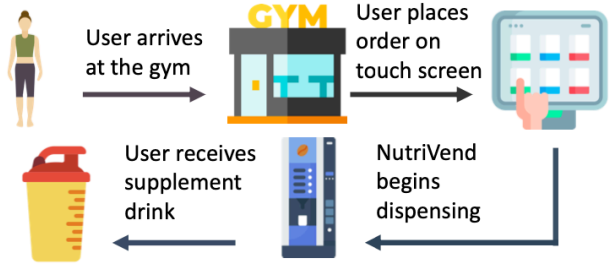
Growth Rate: **5.6%**

Value Proposition

Proprietary mobile app → Personalized supplements → Max Performance Recovery

Mobile application takes in user data and creates a personalized supplement formula. The NutriVend machine dispenses the formula upon user request.

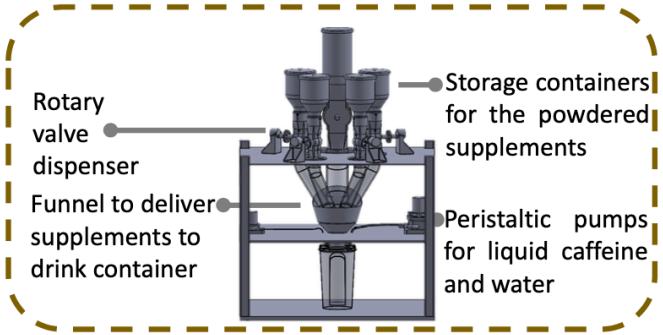
Product Overview



Customer Needs:

- Variety of supplements & flavors
- Supplement recommend-ation
- Quick and easy to use

Features

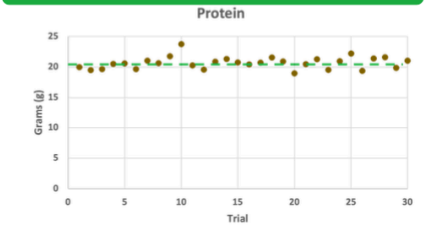


Arduino to control motors, pumps, IR sensors.

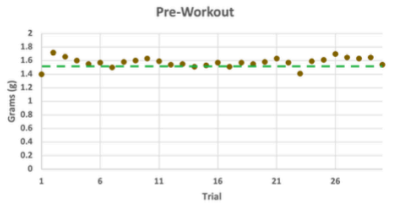
Web app to order drinks on iPad.

Mobile app to save drink orders.

Results



The large rotary valve dispensed an average of 20.683g of protein powder.



The small rotary valve dispensed an average of 1.576g of pre-workout.

Future Considerations

Final Product: The NutriVend will hold 100 supplements and flavors total. The dispensing mechanism will have increased accuracy and the machine will be programmed for custom drinks. A mobile app will allow customers to save drink orders.

Increased Accuracy | **More Variety** | **New Features**

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Past Project Example - 2

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Past Project Example - 2

THE SQUIRCLES

Automatic Hinge Screw Insertion

Shahar Ben-Dor, Braeden Dickson, Celina Huang, Derrick Mu, Nathan Wang

Georgia Tech · ROPER CORPORATION

BACKGROUND

Roper Corporation, a subsidiary of GE, manufactures kitchen appliances, including ovens. Their oven doors have hinges that are secured by 6 screws.

DESIGN PROBLEM

Roper's oven door hinge screws are inserted manually, which leads to high cycle times, inefficient use of labor, and wasted material.

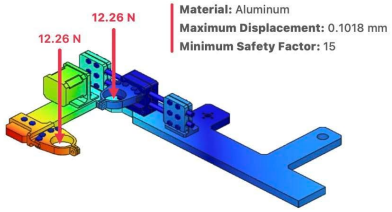
DESIGN GOAL

CYCLE TIME	OPERATORS	CONTROL
≤ 20 SECONDS	1	AUTOMATED

MARKET RESEARCH

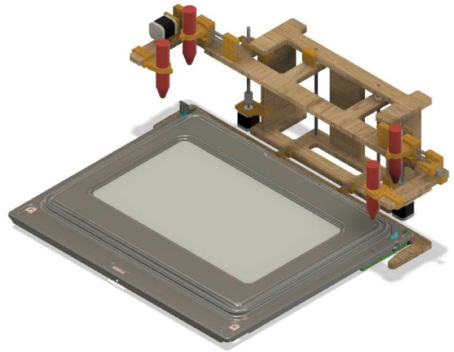
A fully automated system can insert screws 10x faster than a human. In 2021, industrial users ordered 37% more robots compared to 2020.

FINITE ELEMENT ANALYSIS



FINAL DESIGN

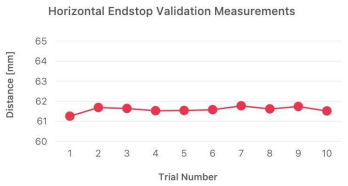
- Four automatic screwdrivers
- Stepper motors to raise and lower platform
- Belt drive to reposition screwdrivers
- LEDs to indicate the progress of the automatic system



VALIDATION

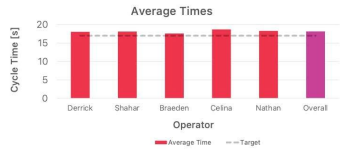
POSITION

Average standard deviation across all positioning tests was 100x smaller than diameter of screwhead

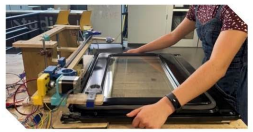


CYCLE TIME

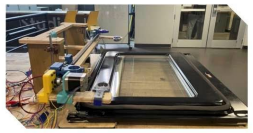
Average total cycle across a variety of users was ~1.5 seconds over the target



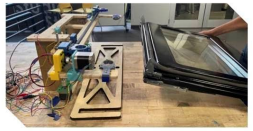
SYSTEM OPERATION



Operator places door and presses button



Automatic system inserts all 6 screws



Operator removes assembled door

IMPACT

3 Operators	→	1 Operator
31 Seconds	→	20 Seconds
Cost Savings	→	$80,000 / year

FUTURE WORK

- Operate device in a true factory setting
- Test cycle time with experienced operators
- Fabricate aluminum prototype
- Integrate with automatic screwdriver blow-feed system

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Past Project Example – 3

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Past Project Example – 3

Delta Aircraft Parking Project

Alex Tanner, Alyson Riben, Andrea Preacher, Bruce Bowers, Jasmine Hornbeck, Victoria Chee

CHOCK IT LIKE IT'S HOT

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Advisor | Dr. Jianxin Jiao

DELTA

Sponsors | John Mathis and Mitchell Rife

Background

Chocking: The act of placing an object in front of a plane's tires to prevent movement.

Design Problem

Problem: Delta Aircraft are being **mistakenly** left **without** their **wheels chocked** or chocks are being **improperly set.**

Main Objective: Determine a way to **ensure** the aircraft meets **compliance** by being **chocked properly** every time.

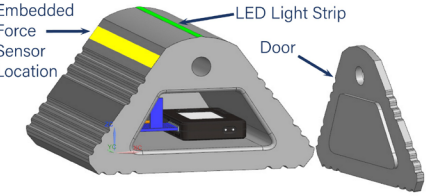
Design Goals

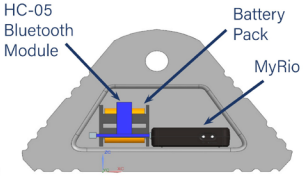
- Weight Under 30 lbs
- Notification Time Under 20 sec
- Withstand Force Applied to Chock

Market Research

75% of surveyees who were affiliated with chocking think an **automated system** would **improve compliance.**

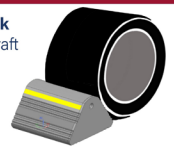
Final Chock Design



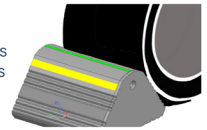


Chock Notification System

1 **Place Chock** against aircraft tire.



2 The LED Light Strip will **light up green** to indicate to the grounds crew that the aircraft is **properly chocked.**



3 The lights on the **user interface** located on an iPad will then **light up green.** After 10 seconds, a **message pops up** to notify Pilot and Jet Bridge Workers that the aircraft is **properly chocked.**

Comparison

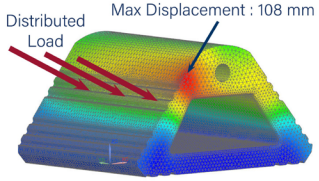
Current Chock

- Rubber **triangle**
- **Verbal** or **hand signal** communication used when plane is chocked
- Does **not ensure compliance**
- **Different length** chocks for **different planes**

New Chock

- Rubber **trapezoid** with **storage capacity** and **round top** to reduce human error
- **Bluetooth** communication used when chocked
- **Ensures** and **tracks** compliance using **notification system**

Finite Element Analysis



Max Stress : 24 MPa

Observation: Maximum displacement is localized on the corner as a result of storage space.

Impact

- Avoids up to **$6 Million** in **maintenance costs** due to the **decrease** in wear rate on brake pads and rotors.
- **Ensures** and **tracks** chocking compliance **100%** of the time.
- **Eliminates** the chance for **chocking procedures** to be the cause of **delays** for **future departures.**

Final Specs

25 lbs Final Weight

10 sec Total Notification Time

Bluetooth Capability

Compatible with **100%** of the tires in Delta's fleet

Future Work

- Create a more in depth **communication system** to **connect all chocks** for each gate.
- Implement **smaller electronics** in order to reduce storage capacity to meet **structural specifications.**
- Integrate with **preexisting** Delta **software.**

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Prior Art Search – What?

- **Any** evidence that your invention is already known
- An existing product is the most obvious form of prior art
- Many inventions never become products, yet there may be evidence of them somewhere.
- ***Competing Art***
  - *Other solutions to similar problems*

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Prior Art Search – Why?

- How novel is your idea?
- Leverage existing ideas, technologies
- Benefit from known successes and failures
- Know your competitors
- Avoid Patent Infringement

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Prior Art Search – How?

- Choose Sources
  - Online Databases: http://www.uspto.gov; https://patents.google.com/
  - Journals and Conference Proceedings
  - Trade Journals
  - YouTube Videos
  - Amazon, eBay, etc.

- Define your scope
  - Date range, countries

- Ask the right question
  - Keywords
  - Search citations and competitors

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Presenting your Prior Art Search

2. **Existing Products, Prior Art and Applicable Patents** (portions may be an Appendix)

   Provide information on current competitive products/procedures

   a. Document and discuss any competitive designs already on the market, or in research and development (should include at minimum 6 references of 4 different types)
      a. What are the commercial applications of the technology?
      b. How does underlying technology work?
   b. Perform a patent search and identify related concepts.
   c. Discuss how these designs are related or different from your intended design

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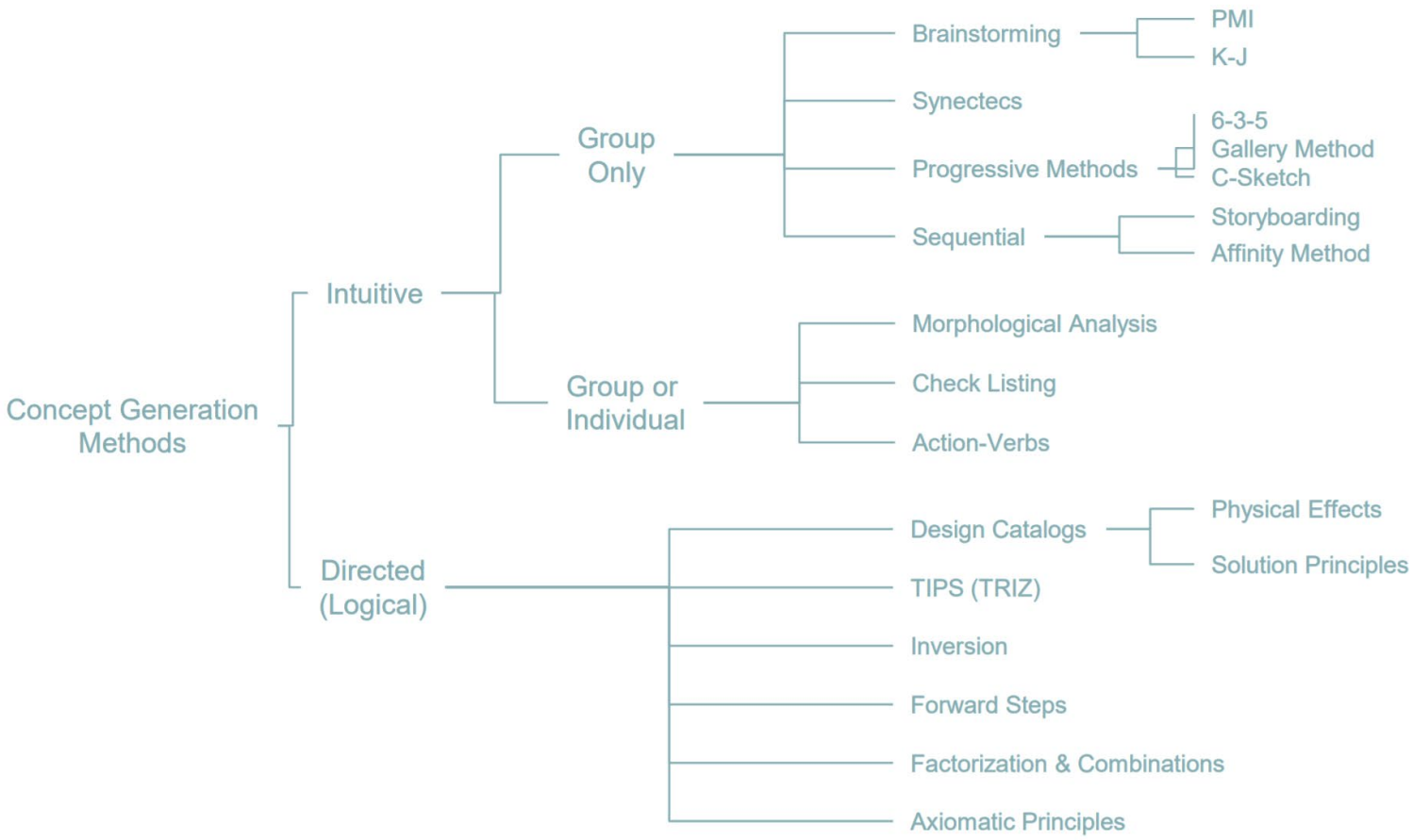
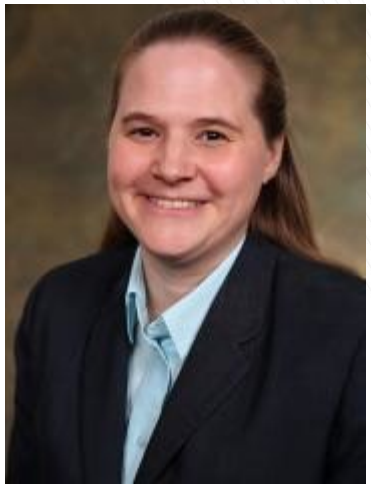
Recap: Ideation & Concept Generation

Overview of Methods



Redrawn from figure 10.3, Product Design



Dr. Julie Linsey
Associate Professor
G.W.W. School of Mechanical Engineering

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Key Takeaways

1. Generate more ideas
2. “Rules” of ideation
3. Idea Generation CHECKLIST

- Relevance to Design Report
  - Function Tree
  - Morphological Matrix
  - Concept generation
  - Concept Selection and Justification

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How to Ideate?

- First Principles approach
- Apply ideas from one domain to another

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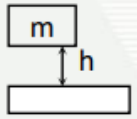
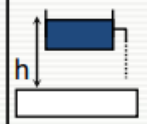
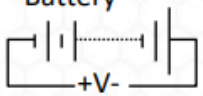
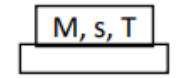
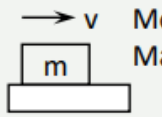
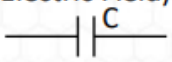
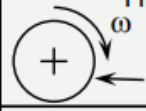
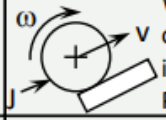
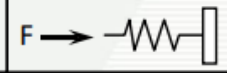
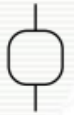
Generate more ideas *with functional decomposition and morphological matrices*

- Identify individual functions and sub-functions
- Functions are a Verb+Noun combination (example: loosen/tighten screws, measure force)
- Stay solution agnostic
- Consider WHY and WHAT, not HOW

Type of Energy / Working Principle	Mechanical	Hydraulic	Electrical	Thermal
1	 Pot. Energy	 Liquid Res. Pot. E.	Battery 	Mass 
2	 Moving Mass	Flowing Liquid	Capacitor (Electric Field) 	Heated Liquid
3	 Flywheel			Superheated Steam
4	 Wheel on incline Plane			
5	Spring 	Other Springs Comp. Gas		
6		 Hydraulic reservoir e.g, Piston		

Different working principles to satisfy the function "store energy" by varying the type of energy.

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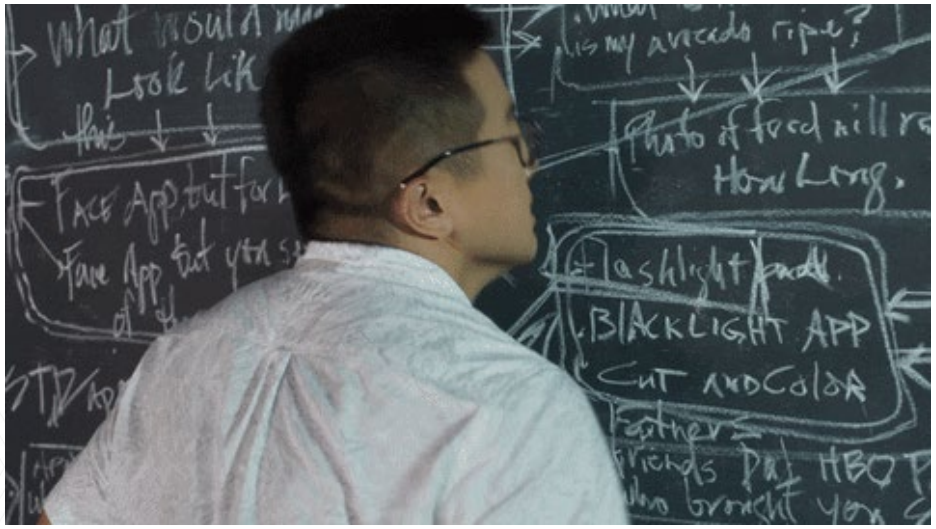
Rules of Ideation



Stupidity/absurdity is part of the creative process

DO MORE

SPEAK UP

WRITE DOWN

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Idea Generation Checklist

- SCAMPER - Substitute, Combine, Adapt, Magnify or minify, Put to other uses, Eliminate or elaborate, Rearrange or reverse
- CREATIVITY - Combine, Reverse, Enlarge, Adapt, Tinier, Instead of, Viewpoint change, In other words, To other uses, Yes!
- Analogies
  - Existing products or bio-inspired design

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Relevance to Design Report

6. Design Concept Ideation

In this section, the concept ideas you generated are to be discussed. Feel free to use an appendix to include additional concepts and details.

a. Discuss and list the functions that the design needs to fulfill
b. Identify and describe different concepts for fulfilling each function. Use ideation techniques covered in lecture.
c. Present and discuss a morphological (matrix) chart with these different concepts/possible solutions for each (sub)function
d. Introduce and discuss the different integrated concepts you derived from the set of possible functional solutions

7. Preliminary Concept Selection and Justification

a. Discuss the selection process used to identify the promising concept(s) to be designed further. Use a decision-matrix type approach, evaluation matrices, etc.
b. Perform an initial evaluation of the (selected) concept(s)' feasibility with respect to the design specifications. If possible, perform quantitative analyses to confirm feasibility.
c. Discuss potential risks and countermeasures that you foresee at this point

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Past Project Example – 4

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Past Project Example – Original Function Tree

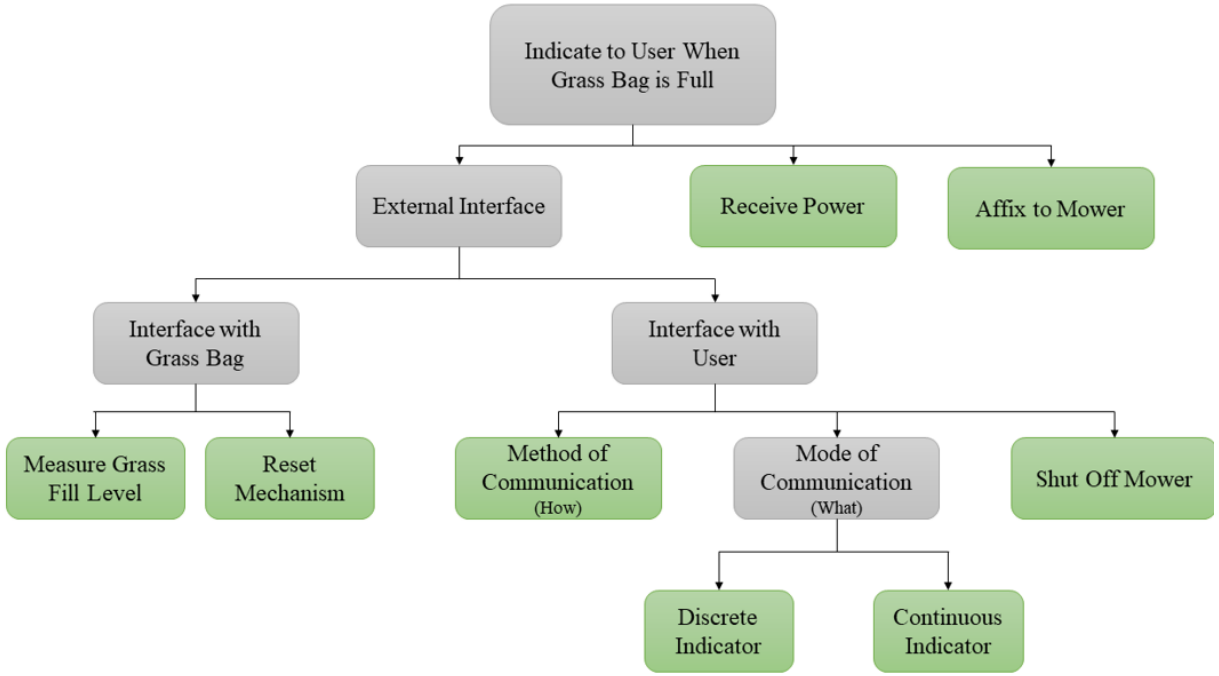

Figure 16. Function Tree for Mower Grass Bag Fill Sensor Project

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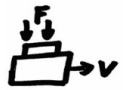
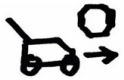
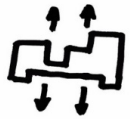
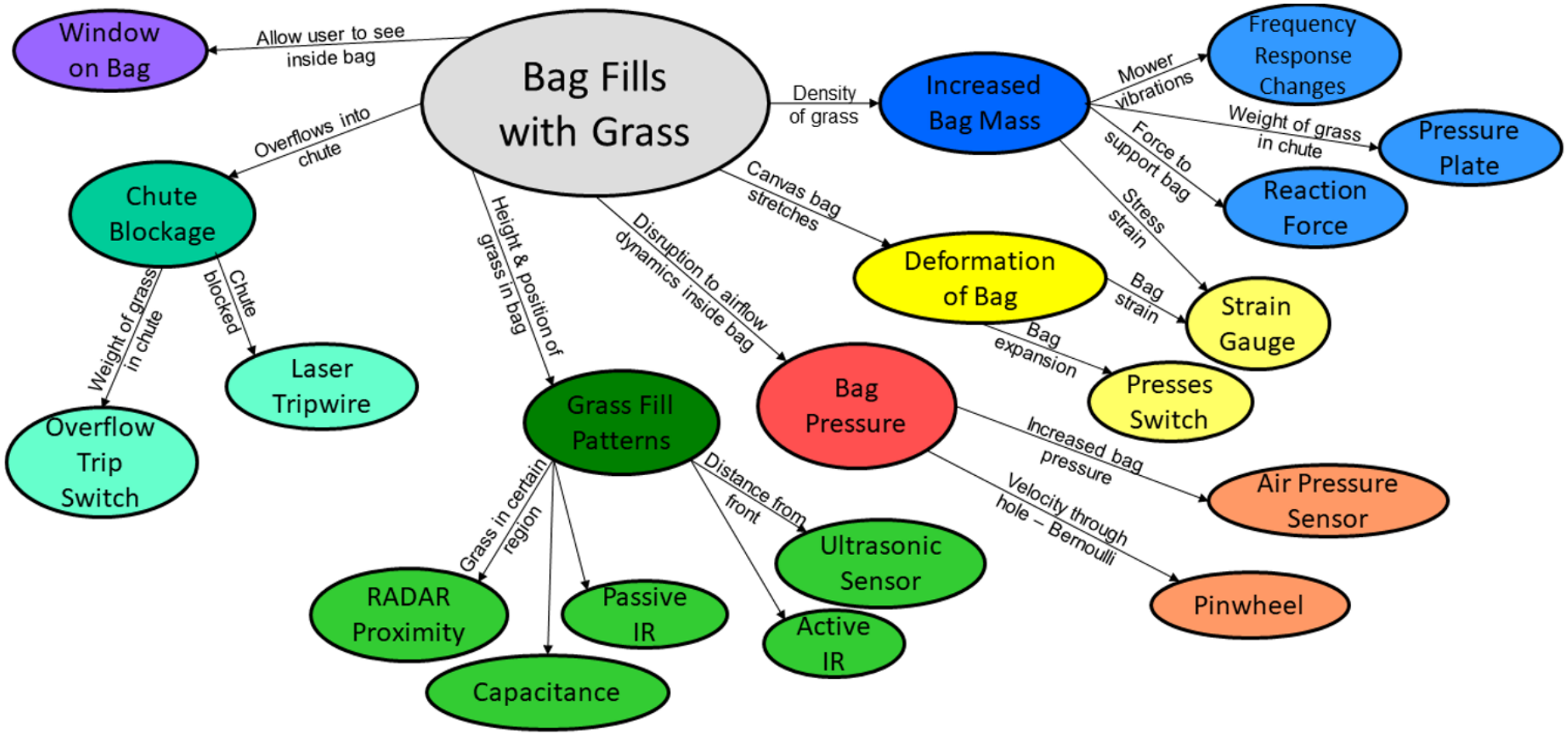
Past Project Example

POTENTIAL DESIGN SOLUTIONS											
	1	2	3	4	5	6	7	8	9	10	11
Measure Fill Level (C) if continuous measure-ment possible)	Capacitive Proximity (C)	Force Trans-ducer. (C) 	Motor Power Draw (C)	Radar (C)	Bag Strain Gauge (C)	Mechanical Lever (C)	Air Pressure Sensor (C)	Membrane Limit Switch	Electrical Conductivity	Air Flow Force Lever	Particulate Sensor (C)
	Spinning Pin-wheel	Visual Cues	Active IR (C)	Passive IR	Laser Tripwire	Capacitive Array (C)	Window (C)	Resonant Freq of Bag (C)	Ultrasonic Distance (C)		
Reset Mechanism	Spring Lever	Manual Lever	Retract Pop Out	Reset Button	Reset Visual marker	Power Cycle	Detect under limit	Remove bag motion	Hall effect switch		
Communi-cation Method	Buzzer (Auditory)	LED Indicator (Visual)	Vibrate Handle (Haptic)	Olfactory	Electric Shock	Raise a Marker (Visual)	Increase wheel resistance	Stop Auto Propel 	Illuminated Text	Pop button on handle	
Shut Off Mower	Don't	Mechanical Brake	Cut motor power	Force up bail bar							
Mode: Continuous Indicator	Dial Gauge	Bar Meter	Increasing Frequency	LCD Panel	Fluid level gauge	Numerical readout	Marker Position	Rotational Velocity			
Mode: Discrete Indicator	Constant Indication	One-Time Indication	Pulsing Indication								
Affix to Mower	Build into inj. molded parts 	Screw into plastic body	Screw into bolt/standoff	Clamp	String (sewn to bag)	Velcro to bag	Snap fit	Permanent Adhesive	Welding	Rivet	Channel Insert

Past Project Example – Mind Map



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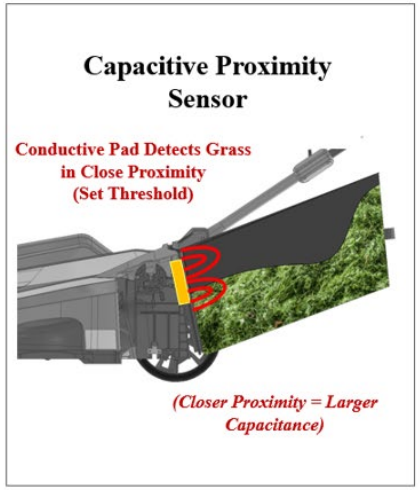
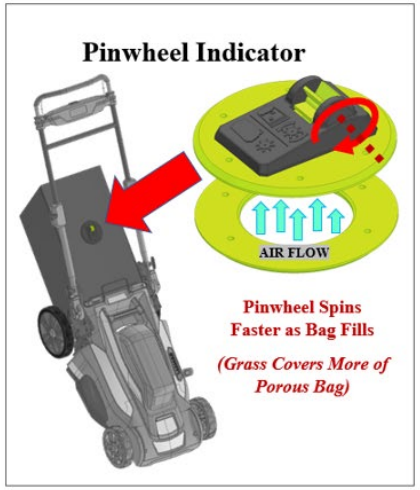
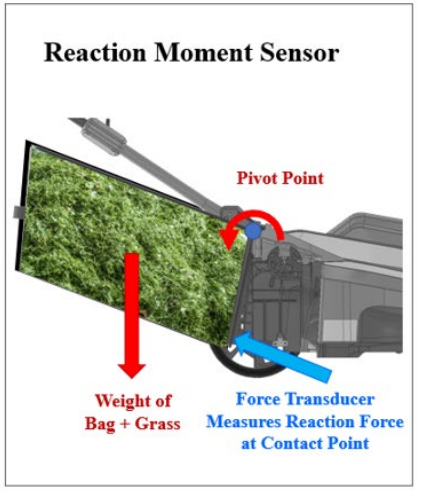
Past Project Example – Evaluation Matrix

	WEIGHTS (1-5)	Capacitance Sensor	Pinwheel Sensor Mounted to Bag	Reaction Moment Sensor
IPXX Rating	4	5	4	4
Structural Robusticity	3	5	5	4
Non-Invasiveness	4	4	3	4
Size	2	4	4	3
Standards Compliance	5	5	3	5
Accuracy Potential	4	4	4	5
Precision Variance	5	4	5	1
Disturbance Rejection	4	4	5	4
Power Consumption	3	4	4	4
Service Life	2	5	4	5
Low Maintenance	3	5	4	4
Training Time	3	5	3	5
Indicate-Clog Time	3	5	2	5
Bag Removal	3	5	5	5
Cost	5	3	5	3
Degrees of Separation	4	4	3	2
Continuous / Discrete	2	4	4	4
TOTALS	295	257	234	226
% REQ. SATISFIED		87%	79%	77%







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Past Project Example – Final Outcomes

Georgia Tech School of Electrical and Computer Engineering
Georgia Tech George W. Woodruff School of Mechanical Engineering

Capacitive Mower Grass Bag Fill Sensor

Alex Field, Phillip Holloway, Samuel Kiley, Maxwell Koerner, Joshua Shafran, Eli Tiemann
Advisor: Kenneth Cunefare, PhD • Sponsor Representative: Fahad Vora

TTI GRASS GURUS

DESIGN SCOPE

Motivation

- Walk-behind mowers currently do not employ fill sensing mechanisms
- Adds quality-of-life improvement to mower experience

Solution

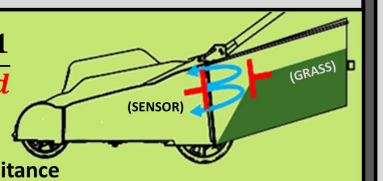
- The capacitive sensor determines when the grass bag on a walk-behind mower is full.
- An accompanying indicator signals this information to the user.

NOTABLE FEATURES

- Fully Integrated System
- Programmable Sensitivity
- Cost Below $12 Per Unit
- Low Current Draw (25 mA)
- Intuitive Operation

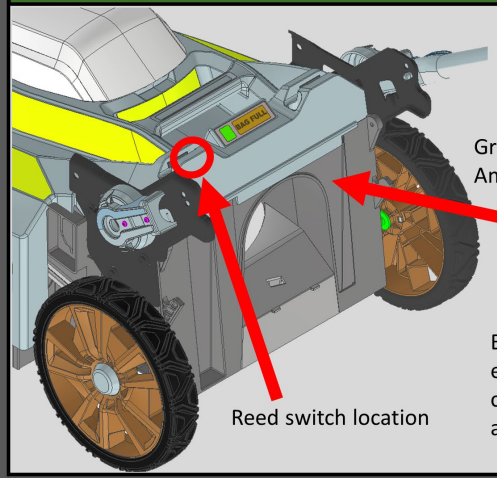
CAPACITANCE THEORY

$$C \propto \frac{1}{d}$$



C = Capacitance
d = Distance between sensor pad and grass
As grass clippings approach sensor, measured capacitance increases.

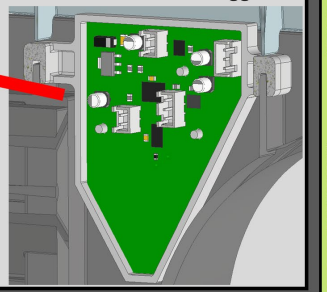
MECHANICAL DESIGN



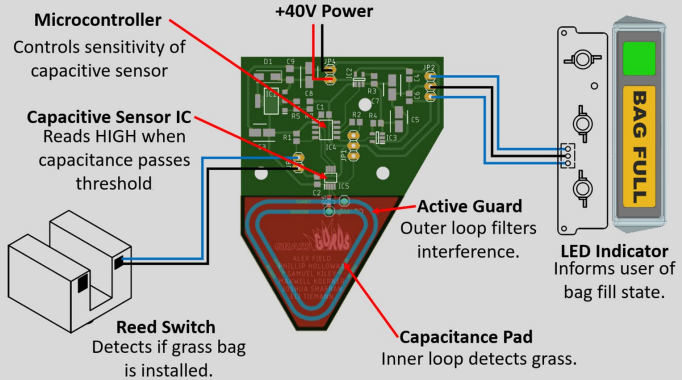
Green status light informs user that sensor is operational
Amber "Bag Full" indicator flashes when sensor triggers.

Reed switch location

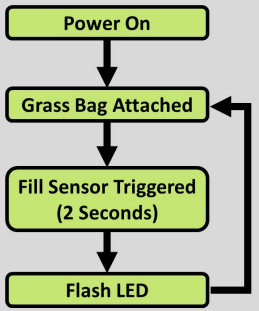
Enclosure fits around existing ribs in mower chassis. IP55 rating is achieved after potting.



ELECTRICAL DESIGN



Control Flow



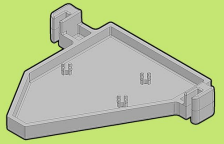
TESTING AND VALIDATION

- Highlighted region triggers at 85% fill
- Pad area influences sensing distance
- Triangular pad maximizes area

Prototype sensor reliably triggers when the bag is on the verge of clogging

FUTURE WORK

- Research into using snap fits on the enclosure
- Turn sensor off when mower not in use
- Dynamically adjust sensitivity on inclines



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ADDITIONAL REFERENCES

- ME2110 Lecture Materials
  - Functions and Solutions, Design Concept Generation
    - SLIDES | VIDEO
  - Design Concept Evaluation
    - SLIDES | VIDEO

- The shape of ideation: https://youtu.be/BErt2qRmoFQ
- Visual tools for ideation: https://youtu.be/ByjKT9IUkjA

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Ideation & Concept Generation

- What are the functions that the design needs to satisfy? (Functional decomposition)
- How can those functions be accomplished (means)? (morph charts)
- What are your integrated concepts/initial design alternatives, and how do they map to these functions and means?
- How will you weigh customer desires vs. specific functional performance?
- How are your concepts informed by and influenced by prior art?

- What formal selection processes will you use to identify the promising concept(s) to be further explored?
- What feasibility analyses may be necessary for your concepts?

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Industrial Design & Human Factors

Prof. Wayne Li
Professor of the Practice of Design and Engineering
School of Industrial Design

- How do human factors impact your design problem?
- How will you explore human factors issues in your design process?
- What are the human interaction-points with your design problem? (from manufacture through to disposal)

- What Industrial Design considerations impact your design?
- How does visual hierarchy and language impact your design?
- How does branding factor into your design problem?

You may contact **Prof. Wayne Li** via email if you need more guidance on how you would apply this topic of Industrial Design to your project: wayne.li@design.gatech.edu

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