Introductory Manufacturing Process Course based on an Educational Mobil Inverted Pendulum (MIP) Robot

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Background Information
TIGs Supported Project

‘Development of a Project-Based Introductory Manufacturing Process Course’ supported by the PACE center

- have students to experience a complete product development cycle
- demonstrate common concepts, tools, methods, and equipment used in manufacturing industry
- stimulate students’ interest in the manufacturing field and thus to other courses covering advanced topics
- Involve anyone interested in product design & development
Rational

Engineering Technologists with applied manufacturing knowledge and skills are in high demand in Houston area

- utilize computer aided design (CAD) software to develop 3D models and engineering drawings
- conduct simulation and modeling to analyze performance of components
- apply manufacturing processes to fabricate a prototype to verify functionality, safety, and reliability
Degree Programs at SHSU

- B.S. in Design and Development
- B.S. in Mechanical Engineering Technology plan to be launched in Fall 2020
  - Mechanical Design
  - Mechatronics
  - Manufacturing
Start with a Question
How Pencils Are Made?
How Pencils Are Made?

- How the cedar wood board is made?
- How the glue is made?
- How the paint is made?
- How the eraser and aluminum ferrule are made?
- How the graphite lead core is made?
NOT A SINGLE INDIVIDUAL ON EARTH KNOWS HOW PENCILS ARE MADE!
Fundamental Concepts
Design & Prototyping?

**Design**: the creation of a plan or convention for the construction of an object, system or measurable human interaction

**Prototyping**: the process to create a sample, a model, or an early release of a product. It is built to test a concept, process, or to act as a subject to be learned from
Successful Design

• **Quality**: functions satisfy needs, robust, reliable,
• **Time**: return on investment, technology, competition,
• **Development cost**: investment into product design, prototyping, and finalizing
• **Flexibility**: future expansion/upgrade
• **Manufacturing**: quantity, equipment, tools, labor
GoPro & Iridium

Founded in 2002 with $1.18B revenue in 2017

Defaulted on $1.5B after spending $5B in 1999
Design

A series of methodical steps to create functional product or processes involving

• *Decision making*: mechanism, control, material, manufacturing, maintenance, service

• *Iterative*: prototype, test, modification
Inter-disciplinary

- Physics
- Chemistry
- Mechanical Engineering
- Civil Engineering
- Electrical Engineering
- Nano-Technology
Prototyping

A series of manufacturing / fabrication steps to create functional product or processes involving:

• **Decision making:** process, material, equipment, tool

• **Iterative:** prototype, test, modification
3D Printing
Casting
Machining
Plastic Processing
Other Methods

From Powders to Net shape

- Binder
- Feedstock
- Metal powder
- Molded part
- Sintering shrinkage 20%
- Sintered part
Challenges

• Designed & unexpected working conditions
• Systems integrated with various functional modules
• Interactions between modules
• Manufacturing
• Maintenance and repair
• Environmental consideration
• Cost
Failure

Fail of Tacoma Bridge

Fail of FIU Bridge
How Big a Problem?

United States Consumer Product Safety Commission
Problem to Solution Approach
Mobile Inverted Pendulum (MIP) Robot

MIP robot as the platform to discuss design & prototyping methods include:

• Part design using Inventor
• Assembly design using Inventor
• 3D printing
• CNC & manual machining
• Sand casting
• Plastic injection molding
Educational MIP (EduMIP)

Beaglebone Black with Robotics Cape & WIFI

Beaglebone Blue
Beaglebone Black & Robotic Cape
Beaglebone Blue

- 3-axis gyroscope
- 3-axis accelerometer
- 3-axis compass
- Barometer
EduMIP Components

- Drive train with two wheels
- Beaglebone Black
- Robotics Cape
- 12V 1A DC Power adapter
- Battery
- Mini USB cable
- JST ZH/SH Pigtails
- Hardware
- Motor speed encoder
- Top skids left & right
- Lower front bumper
- Battery retainer
- Lower bulkhead
- Barrel jack plug
Assemble the MIP
Disassemble the Drivetrain

- Use a P1 Philips screwdriver to remove the 8 screws (red dot shown) holding the drive train assembly
- Remove top cove and then the two motors
- Keep the top and screws in a safe place
Power Supply to Motors

- Solder the 2-pin JST ZH pigtails to the motors in the orientation shown.
- Pig tails come stripped, tined, and cut to length.
- Ensure that the red wire is connected to the ‘+’ terminals on the motors.
Reassemble the Drivetrain

• Put the motors and cover top back
• Put the 8 screws removed back
• Arrange the wires as shown
• Reassemble the drivetrain by tightening the 8 screws
• Be careful! Don’t pinch or trap the wires
Attach the Bulkhead

• Connect two 4-pin JST SH cables to the two encoders
• Place the bulkhead on top of the drivetrain with all cables holding under it
• Align the two mounting holes on the bulkhead to the bosses protruding on the top of the drivetrain
• Secure it with two 4-40X3/8” machine screws
Attach the Beaglebone Blue

• Align the two mounting holes on the Beaglebone Blue to the two holes on the sloped surface of the bulkhead

• **STOP! What problem do you notice?**

• The picture shows a Beaglebone Black
How to Solve the Problem?

*Modify the bulkhead design and build another prototype!*
Inventor Start Page
Projects
New Model
Inventor User Interface
Example
Extrude to Create the Third Cube
Start a New Engineering Drawing
SAVE YOUR FILES
Summary

• Start a new file: file type and unit system
• 2D sketch on selected drawing plane (orientation of plane)
• Extrude to create 3D feature

Any other way to do it?

YES!
Redesigned Buckhead
Other Tools

- Work Features: Plane, Axis, Point, and UCS
- Revolve
- Sweep
- Loft
- Fillet and Chamfer
- Emboss
- Rib
- Pattern
- Mirror
3D Printing & Final Assembly
Makerbot Replicator+
Fused Deposition Modeling (FDM)
FDM Filament Materials

- **Polylactide Acid (PLA)** biodegradable
- **Acrylonitrile Butadiene Styrene (ABS)**

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<th>Specifics</th>
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<td>Fumes</td>
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<tr>
<td>Price</td>
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Print
Final Assembly
Assembly the updated Buck Head
Attach the BeagleBone Blue
Connect Power & Encoder Cables
Prepare Battery & Retainer
Assemble the Top Skid & Battery Retainer
The EduMiP
Connect to the Beaglebone Blue

• Power on the Beaglebone Blue by connecting the battery to it
• Wait ~20 seconds for the Beaglebone Blue to power up
• Check available WiFi connection to find the one for your board (it is named as ‘BeagleBone –****’, where the ‘****’ are combination of four letters and numbers. The actual **** is on top of the Octavo processor) and then connect to it (if the system is asking for password, it it ‘BeagleBone’ by default
Run the Robot

- Open a browser and go to ‘192.168.7.2’ (192.168.6.2 for Mac)
Run the Cloud9

- Scroll to ‘Cloud9 IDE’ to start the programming environment
- Type ‘/usr/bin/rc_balance’ at the command to start the robot
Balancing the Robot!
More Challenges
Wheel Redesign

Redesign wheel to accept Pololu 60 X 8mm tire and the drive shaft coupler
Prototype the Wheel using CNC
Prototype the Wheel using Injection Molding
Tools

This bearing block orientation is not possible for WS-10-40 and WS-10-80.
Research on tools, methods, and equipment required to logically solve a practical problem

-- Fred Pirkle
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<td>This course addresses problem solving skills</td>
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<td>I wish more courses can be designed to incorporate project(s) and delivered in similar learning-by-doing style</td>
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<td>This course stimulate my interest to study related areas in other courses</td>
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<td>This course illustrated the process of product design and prototype using different manufacturing methods</td>
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<td>The EduMip robot is a good selection for the course</td>
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ALL THE TECHNIQUES WE COVERED WERE VERY INTERESTING. I HAD A GREAT TIME LEARNING THEM. I WOULD LIKE TO LEARN HOW TO USE ALL THE MACHINES AVAIL. I WOULD HAVE ENJOYED A LITTLE EXPERIENCE IN PROGRAMMING THE ROBOT TO PERFORM DIFFERENT FUNCTIONS.

More robot with different design. Like a car design.

I feel that techniques on how to draw areas of certain part that are repeated to use the mirror tool or others would have been helpful to know.

More lazer hands on & CNC Programming

Learning a bit about all of the different programers (AutoCAD, Inventor, Creo). Work more in the shop and using laser print, CNC, and 3D printer.
This was a very engaging course and I only wish it lasted longer. I do believe that experience w/ Inventor & AutoCAD should be a pre-req. I enjoyed the team-based aspect of this course. I also enjoyed the work pace of this course. However, I would have really enjoyed using all the machines available. Dr. Ma is the best instructor for this course.

I really enjoyed getting to experience so many different techniques and machines that I've never been exposed to. The course was a lot of fun & didn't always feel like work. My problem solving skills have also greatly improved. Overall, I loved the course, it's one of the most fun+hands on surveys I've had at SHSU.

I would have liked more time to be creative with my designs but most of my time was spent trying to learn the program Inventor. I also would have liked an actual preview of each machine available.
I really enjoyed the course. All of the material and processes covered in the class were very interesting.

Supply & demand section for how quick you can produce a product compared to demand of a product. From scratch pad to store self.

This course was fun and exciting. Seeing what you have learned being applied is very reassuring and gives me the confidence to go and make things and design in industry.

The structure of this class' work is very well thought out, but I only wish the class was longer.

The course was extremely interesting and I loved all of the hands on work.
Suggestions

Good program. Well done job. AA Dr. Ma.

Enjoyed the course.

Suggestions: The course should be offered in a normal fall and spring semester.

I believe I took in a lot more information because we actually designed and printed which is a process that happens in the real world. I learn more by doing and working on projects. I think it would be helpful if lecture were quick and short to the point so that we have more time to work. I feel that if I had more time to work on designs I could be more creative since I am struggling with new programs I never worked with most of the time.
Suggestions

I think in a regular semester much more can be achieved. Dr. Ma designed this mini-course very well. I have had regular semesters that did not have the structure set up like this course. This course should be mandatory for all design and development students. Improving a product (robot) was great hands-on experience. I think that the semester project should consist of a team design or Individual design using Inventor, then 3D print all parts and put product all together and present it (something like Shark Tank tv show). Students definitely need Inventor as a pre-reg and marketing or consumer-science class would possibly help also. Adding a supply demand section in this class during reg semester would be useful also.

This course was excellent and presented well by Dr. Ma. I am a student that is already in the manufacturing industry and Dr. Ma explained difficult and understood material well. The course kept me engaged and excited. The Design & Development program could use more courses like this one that Dr. Ma has given.

I truly enjoyed all of the hands-on work we did. This would be an excellent freshman introductory class. It gave me the opportunity to learn more about what goes into the design process. I liked the daily assignments due and that the course gave you an opportunity to solve problems.
Future Work
Laser Processing
Future Manufacturing Courses

- Work Methods and Measurement
- Machine Tool Technology
- CAM/Robotics
- CNC/CIM
- Material Joining Technology
- Heat Treatment and Foundry
- Six Sigma and Lean Manufacturing
- Industrial Control Systems

NSF Education and Human Resources (EHR) Program
Questions?