Foldable Robotics

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course website:  https://faculty.washington.edu/minster/foldable_robotics_2018/
link: https://www.youtube.com/watch?v=ionC1toDJZI
what you will learn

• how to design and build your own laser-cut foldable mechanisms

• where to get parts and materials

• how to program your robot to move using a raspberry pi and off-the-shelf servos

what is not covered

• how to use our specific laser cutter (we will operate it for you)

• kinematics, dynamics, and control of foldable structures
why foldable robotics

😊 fast! cutting time is just a few minutes (vs. hours for a 3D printer)

😊 strong

😊 cheap! laser cutter is $4k–$2.5k (as of last week!), cardboard sheets ($2), sheet tape ($2)

☹ no continuous revolution

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength (kPa)</th>
<th>Density (kg/m³)</th>
<th>Strength-to-weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardboard</td>
<td>50,000</td>
<td>750</td>
<td>67</td>
</tr>
<tr>
<td>ABS plastic</td>
<td>40,000</td>
<td>1200</td>
<td>33</td>
</tr>
<tr>
<td>Steel</td>
<td>600,000</td>
<td>8000</td>
<td>75</td>
</tr>
<tr>
<td>Carbon Fiber Composite</td>
<td>1,240,000</td>
<td>1580</td>
<td>785</td>
</tr>
</tbody>
</table>
why foldable robotics

- recent advances in origami geometry
  e.g. Demaine et al, 1998: proved you can cut any shape with the correct fold & single cut

- nature is made of foldable things!
  ladybug wing folding:

- classic revolving pin joints inefficient for small <1cm mechanisms
examples
fabricating the basic element: a fold

1. Chips
2. Pin alignment
3. Bridge release
4. Pin alignment
uv laser cutting
example part
fab process

1. cut
2. bond
3. release cut
4. remove
5. fold
example part drawings

scaffold cut

hinge cuts

release cut

drawing in Inkscape
another drawing example

scaffold cut

release cut
drawing in inkscape

1. draw outline of shapes
2. draw folds & align cut
3. draw release cut

• suggestion: start with blank_drawing.svg on course website, it has useful settings for object snap and units.
designing mechanisms: ideas

link: https://www.youtube.com/watch?v=R5hGiN0Q5Qs
actuating your device with a servo and a raspberry pi
python: the all-purpose language

• run a python program
  • ctrl-c to quit

• edit a program
  • ctrl-o to save
  • ctrl-x to exit

• example program
  
  ```python
  import time
  from servo import *

  servo0(45)  # servo angle 45 deg
  time.sleep(1)  # wait 1 second
  servo0(0)
  
  mult(arg1, arg2):
  return arg1*arg2

  def mult(arg1, arg2):
  return arg1*arg2

  if test==1:
  print('hello')
  for deg in range(start, stop):
    servo0(deg)
  
  # note: python blocks are space-delimited! use four spaces to
  # indent a sub-block
  ```
more python/linux

- run python one line at a time (ctrl-d to exit)

  ```
  pi@raspberrypi:~$ python
  Python 2.7.13 (default, Jan 19 2017, 14:48:08)
  [GCC 6.3.0 20170124] on linux2
  Type "help", "copyright", "credits" or "license" for more information.
  >>> from servo import *
  >>> servo1(90)
  >>>
  ```

- list files

  ```
  pi@raspberrypi:~$ ls
  Desktop    Music     python_games slow_move.py  wiggle_servo.py
  Documents  Pictures  servo.py      Templates
  Downloads  Public    servo.pyc     Videos
  ```
reference
materials

• cardboard - “illustration board” or “mount board”, 0.04 inches thick
  • 10x15” $2 each https://www.amazon.com/Crescent-99-Illustration-Board-ply/dp/B0044SCQWO
  • 32x40” $7 each https://www.amazon.com/Crescent-Colored-Mat-Board-ply/dp/B0062TLDT0

• sheet adhesive
  • 8x11” $3 each https://www.amazon.com/dp/B00JN9FDN8
  • 6” tape roll (stronger) $40 https://www.amazon.com/dp/B00FARV8NG
laser cutter & raspberry pi

- laser cutter: glowforge basic $2.5k https://glowforge.com/tech-specs

- we will use a raspberry pi zero, total $48
  - raspberry pi zero, $10.00 https://www.sparkfun.com/products/14277
  - servo hat $9.95 https://www.sparkfun.com/products/14328
  - tall header $1.95 https://www.sparkfun.com/products/14017
  - header $0.95 https://www.sparkfun.com/products/14275
  - micro-usb cable 6 foot $4.95 https://www.sparkfun.com/products/10215
  - optional power supply $10 https://www.amazon.com/dp/B00MARDJZ4


- 5x micro servos at $2 each https://www.amazon.com/dp/B015H5AVZG
configuring raspberry pi

• (these have already been carried out for you)

• based on spark fun’s servo hat tutorial https://learn.sparkfun.com/tutorials/setting-up-the-pi-zero-wireless-pan-tilt-camera

1. solder headers onto pi and servo hat to connect them

2. with raspberry pi booted and plugged into an HDMI-capable monitor:

1. connect to U. Washington WIFI

2. update linux: run “sudo apt-get update”

3. enable I2C: run “sudo raspi-config” from a terminal and scroll to “interfacing options” ... “I2C”, select and say “yes.”

4. run “sudo nano /boot/config.txt”, scroll to the end of the file, add “enable_uart=1”, ctrl-x to save and exit.
1. plug in USB cable and open “device manager” to find which com port

2. download and run putty.exe, choose “serial” as connection type, enter in COM# and 115200

3. making sure pi has booted (~2 minutes):
   login: “pi”
   password” “raspberry”
foldable robotics
lab session assignment

course website (with slides and files): https://faculty.washington.edu/minster/foldable_robotics_2018/

1. cut and assemble a basic hinge from a provided drawing

2. perform a basic servo motion
   • to download a servo program from course website to your raspberry pi, use
     wget http://faculty.washington.edu/minster/foldable_robotics_2018/files/servo.py

3. cut and fab a more advanced design (open-ended)
   • add servo control
   • make your own design

You can take home what you make! (servos excepted)
ideas

• sarrus linkage

• wing motion using spherical 5-bar - wood2004

• crane

• robotic gripper

• muira pattern

• flower pattern

• icosahedron
Ice-breaker activity: meet your group

• be prepared to answer either (1-2 minutes per person):
  
  • if you could be any animal, what would you be and why?

  • or, if you could have an endless supply of any food, what would you
Next

walk over to Fuller Lab,
Mechanical Engineering Building Room 113
examples

https://www.youtube.com/watch?v=VxSs1kGZQqc