Introduction and Design

Mobile Robotics

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Today

- Administrivia
- Warm-up poll questions
- Defining robot requirements
- Designing the course robot
- Design your robot

Administrivia

- Mobile Robotics - Course Website

- I am administering the course in a "flipped" style so that we can use class time to build and code

- We'll have
  - Quizzes every class period
  - Exercises every week
  - You must pass all of them for an A
  - See the course website for more details

- Exercises will build on each other

Class Workflow

	Week A					Week B				
	Mon	**Tue**	**Wed**	**Thu**	**Fri**	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**
Reading	Read		Read			Read		Read		
Quiz A1		Quiz				Deadline				
Quiz A2				Quiz				Deadline		
Exercise A		Exercise		Continue		Due				Deadline
Quiz B1							Quiz			...
Quiz B2									Quiz	...
Exercise B							Exercise		Continue	...

Robotics Stack

- We'll cover most of the robotics stack
  - Low level: motor control, sensor interfacing
  - Mid level: motion profile, coordination
  - High level: AI, navigation, mapping

Communications Channel?

- Email
- Slack
- Discord
- Canvas
- Other?

Polling (Sheet)

- What robotics experience do you have (e.g., Vex, FIRST, etc.)?
- Have you taken CS 105 (or similar “low-level” course)?
- What is a robot?
- What role does artificial intelligence play in robotics?

Requirements

- What would you do if I asked you to design a robot?
- What questions should we ask (and answer) to design a robot?

Requirements Engineering

1. Requirements elicitation

2. Requirements specification

3. Verification and validation

4. Requirements management

Our Requirements

- Our robot should:
  - Automatically halt when no longer connected via wireless communication
  - Autonomously navigate around a course,
  - Avoid obstacles (static and dynamic),
  - Recognize and react to signs,

Requirements Engineering

- Functional requirements and constraints
  - How fast does the robot need to move?
  - How maneuverable does the robot need to be?
  - How small or large (footprint and mass) can the robot be?
  - Will the robot interact closely with people?
  - How costly is the robot to manufacture?
  - What is the robot’s environment?

- Nonfunctional requirements
  - How easy is it to build the robot?
  - How easy is it to fix the robot?
  - Can the robot be reused in future semesters?

Refining the Requirements

- What kind of processing speed is needed (MCU or SBC or …)?
- How much memory and storage are needed?
- What is the appropriate transmission (motors, drive system, etc.)?
- What form of internal communication is needed (I2C, SPI, UART, etc.)?
- What power and logic levels are needed?
- What battery systems (type, capacity, C-rating, voltage)?
- What form of external communication is useful (wired, BLE, Wi-Fi)?
- How much redundancy is needed?
- What are your priorities?

My Process for This Course

1. Decide on a drive system (direct drive).
2. Decide roughly on a linear robot velocity (about 50 cm/s).
3. Roughly pick a wheel diameter (about 7 cm).
4. Compute the needed motor RPMs (about 140 rpm).
5. Find motors (select 310 rpm @ 6 V, 170 mA; including encoders).

Motor Search

Walking speed	1.34 m/s (3 mph)
Wheel radius	5 cm
RPM	100 rpm
Angular velocity	10.47 rad/s
Linear velocity	0.52 m/s

Motor	Manufacturer	Cost	No Load RPM	Ratio	Voltage	No-Load Current	Stall Current	Torque oz-in	Logic	Notes
ROB-16413	Sparkfun	$ 6.88	90 @ 4.5V	48:1	3-9V	?	?	?	3.3-5V	
FIT0458	DFRobot	$ 7.40	160 @ 6V	120:1	3-7.5V	170mA	2.8A	2.78	4.5-7.5V	L-Shape
FIT0450	DFRobot	$ 7.40	160 @ 6V	120:1	3-7.5V	170mA	2.8A	2.78	4.5-7.5V	Same as above, but flat
FIT0482	DFRobot	$ 11.90	310 @ 6V	50:1	3-12v	60mA		4.8	3.3-5V	
4638	Adafruit	$ 12.50	200 @ 6V	50:1		100mA	200mA	2.78		120 RPM rated speed
DC 6V 300RPM	ASLONG	$ 8.85	300 @ 6V	30:1	3-12V				3.3-5V	SHIPPING!!!
MiniQ	DFRobot	$ 33.00	260 @ 6v	50:1			360mA	10	3.3-5V	Includes 2 motors (5.90), encoders (4.50) wheels (2.90), and mounts (3.50)

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5. Find motors (select 310 rpm @ 6 V, 170 mA; including encoders).
6. Select motor driver (select 0-11 V, 1.2 A per channel).
7. Decide on sensor modalities (inertial, distance, compass, camera).
8. Decide on communication needs (BLE and Wi-Fi).
9. Find compute devices (select ESP32-S3).
10. Design power system (1S 3.7 V battery; estimate 190 rpm).

Parts Search

Part	Source	Cost	#	Total	Note	Options	B	C	D	E	F
Chassis	Cardboard	$ -	1	$ -	Makerspace						
Caster Wheel	RobotsShop/Pololu	$ 2.29	1	$ 2.29	Could go without, but cheap	Pololu Ball Caster with 1/2" Plastic Ball					
Wheels (x2)	Cardboard	$ -	2	$ -	Makerspace						
Motor w/ Encoder (x2)	DigiKey/SparkFun	$ 6.88	2	$ 13.76	Probably want faster than 1st option	ROB-16413	FIT0458	FIT0450	4638	RM-ASMO-01B	MiniQ Motor Wheel Set with Encoder
Motor Mount (x2)	3D Print	$ -	2	$ -	Makerspace						
Motor Driver		$ 15.00	1	$ 15.00	Dual H-bridge matching motors; provide power for MCU?						
Microcontroller	Seeed Studio	$ 30.88	1	$ 30.88	Maybe the Seeed Xiao ESP32S3 Sense	Grove - Vision AI Module V2	Grove - Vision AI Module with Himax	Grove module + camera + esp32 ? Includes imu, cam, mic			
IMU	Inc		1	$ -							
Camera	Inc		1	$ -		Gravity: Huskylens					
Microphone	Inc		1	$ -							
Distance Sensor		$ 10.00	1	$ 10.00	ToF	VL53L0X Time-of-Flight Distance Sensor	Skip to the beginning of the images gallery Grove - IR Distance Interrupter v1.2				
Power Switch		$ 3.00	1	$ 3.00	Rated for all parts						
Power Fuse		$ 2.00	1	$ 2.00	Rated for all parts						
Voltage Regulator				$ -	Maybe use motor driver?						
Battery		$ 5.00	1	$ 5.00							
Battery Monitor			1	$ -	Similar to Duckiebot						
SD Card			1	$ -							
MoCap Marker			1	$ -							
USB Cable		$ 2.00	1	$ 2.00	USB-C for programming and charging?						
Charger			1	$ -	Built-in?						
OLED Display		$ 7.00		$ -							
				$ 83.93							

Finalized List

Category	Per Unit	Note	Status	Source
Robot Kit	$ 16.40	Expansion Board Base for XIAO	Delivered	Seeed Studio
Robot Kit	$ 31.38	Grove Vision AI v2 Kit (AI Module + Camera + Micro)	Delivered	Seeed Studio
Robot Kit	$ 18.62	SATEL-VL53L7CX	Delivered	Digikey
Robot Kit	$ 2.00	QMC5883L Triple Axis Compass (x10)	Delivered	Amazon
Robot Kit	$ 3.00	MPU6050 6DOF IMU (x5)	Delivered	Amazon
Robot Kit	$ 4.95	BALL CASTER WITH 3/4" PLASTIC	Delivered	Pololu
Robot Kit	$ 23.80	Gearmotor with Encoder Pair	Delivered	Digikey
Robot Kit	$ 4.95	DRV8835 DUAL MTR DRIVER CARRIER	Delivered	Pololu
Robot Kit	$ 4.80	32GB Class 10 MicroSDHC Flash Memory Card	Delivered	Amazon
Robot Kit	$ 2.25	BREADBRD DBL STRIP 70TIE-PTS	Delivered	Digikey
Robot Kit	$ 3.69	Protected 2600mAh 10A 18650 Button Top Battery	Delivered	Liion Wholesale
Robot Kit	$ 1.12	BATT CONTACT CLIP 18650 1CEL SMD	Delivered	Digikey
Robot Kit	$ 2.00	Voltage Tester	Delivered	Amazon
Robot Kit	$ 1.10	Extra-Long Break-Away 0.1" 16-pin Strip Male Header	Delivered	Amazon
Robot Kit	$ 0.82	N20 Micro Motor Mount Set	Delivered	Amazon
Robot Kit	$ 20.00	Cables, straps, brackets, connectors, fasteners, etc.	N/A	N/A
Robot Kit Total	$ 140.88			
Course Parts	$ 114.95	XRP ROBOTICS PLATFORM KIT	Delivered	Digikey
Course Parts	$ 100.00	Adeept		
Course Parts	$ 100.00	Adeept		
Course Parts	$ 515.00	Crazyflie 2.1		Crazyflie?
Course Parts	$ 34.75	XTAR VC8S Battery Charger	Delivered	Liion Wholesale
Course Parts	$ 9.99	Anker USB C to USB C Cable	Delivered	Amazon
Course Parts	$ 32.99	Anker USB C 715 (Nano 65W)	Delivered	Amazon
Course Parts	$ 8.99	M3 Black Nylon Standoff Spacer With Screws Hex Nuts	Delivered	Amazon
Course Parts	$ 9.99	M2 Black Nylon Standoff Spacer With Screws Hex Nuts	Delivered	Amazon
Course Parts	$ 7.99	Reusable Multi-Purpose Wrap Fasteners	Delivered	Amazon
Course Parts	$ 3.78	Rubber Bands Size #30	Delivered	Amazon
Course Parts	$ 6.99	Double Sided Sticky Dot	Delivered	Amazon
Course Parts	$ 28.99	6 Qt Clear Storage Box	Delivered	Amazon
Course Parts	$ 12.20	JUMPER KIT VARIOUS 26AWG 65PCS	Delivered	Digikey
Course Parts	$ 3.50	Grove - 4 pin Female Jumper to Grove	Delivered	Seeed Studio
Course Parts	$ 4.50	GROVE2DUPONT CONVERSION CABLE 20	Delivered	Digikey
Course Parts	$ 8.60	GROVE 4PIN FEMALE JUMPERS 5PACK	Delivered	Digikey
Course Parts Total	$ 1,003.21			
Other	$ 111.17	Estimated	N/A	N/A
Other	$ 200.00	Estimated	N/A	N/A
Other Total	$ 311.17			

*Missing a few late additions

Things to Check

- Power levels: voltage in Volts (V) and current in amps (A)
- Logic levels: chips need to agree on what a logic “1” is in terms of voltage
- Power reset: actuators should typically be powered after compute
- Power monitor: don’t over discharge your batteries

Prototyping

1. Define goals
2. Brainstorm designs
3. Sketch your layout (I’ve given you all “component templates”)
4. Prototype with simple materials (cardboard, sticky dots, etc.)
5. Model with CAD and fabricate
6. Make notes on what works and what doesn’t
7. Refine (back to step 5)

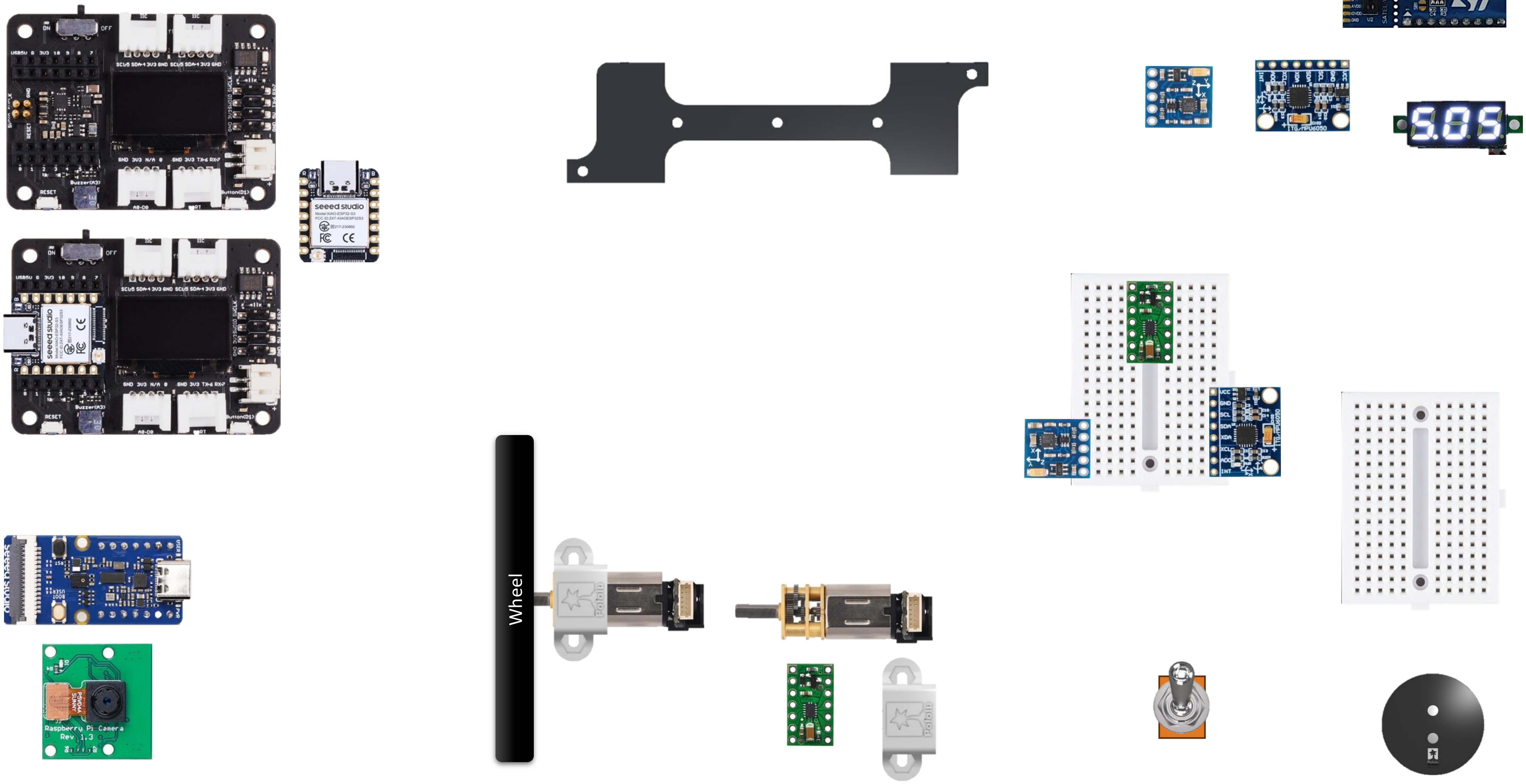
First Quiz

- Complete the first quiz on gradescope.

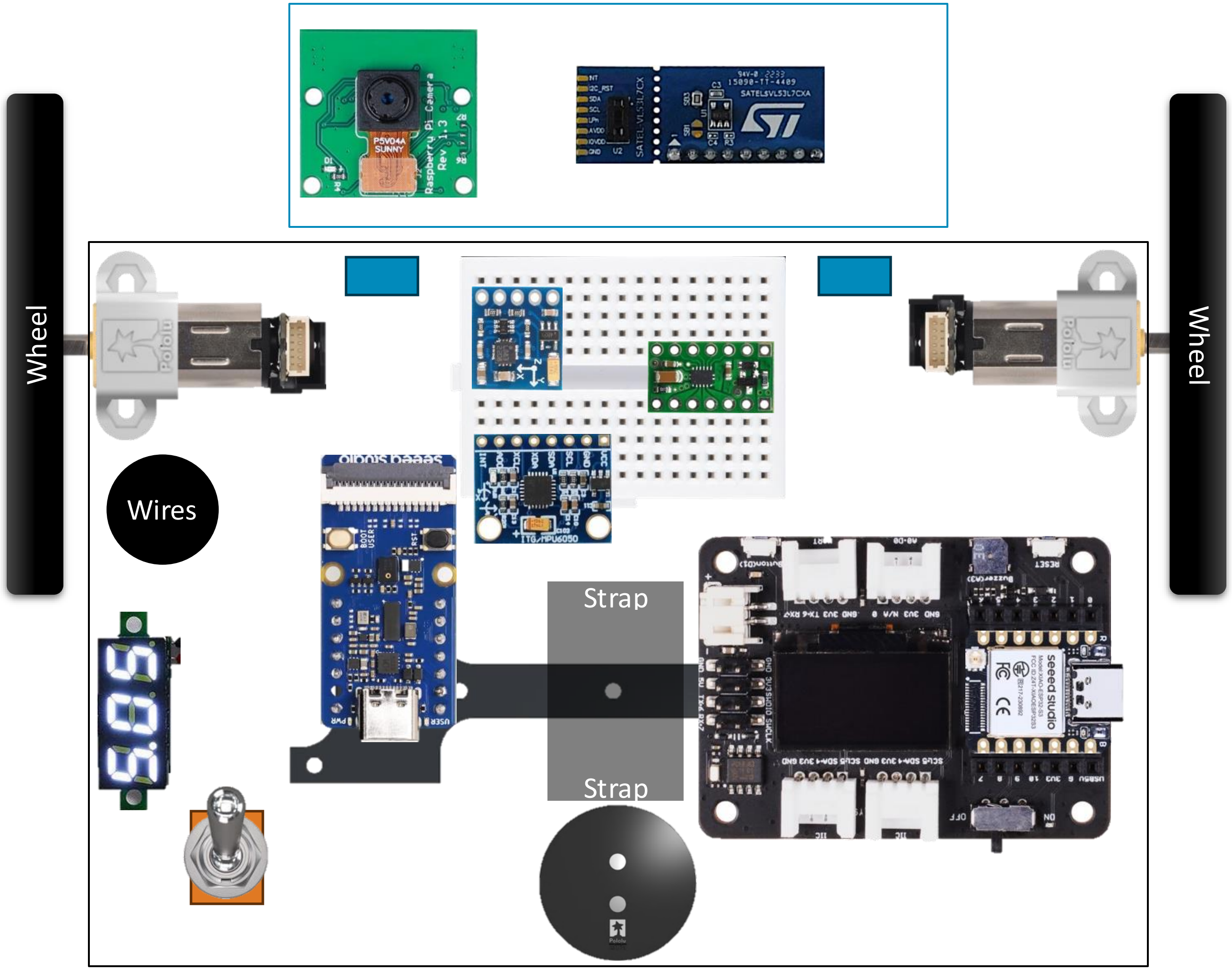
Exercise 1

- Pair-up
- Multiple pairs can work together (no more than 6)
- “Design” your robot
- You’ll start with electronics on Thursday

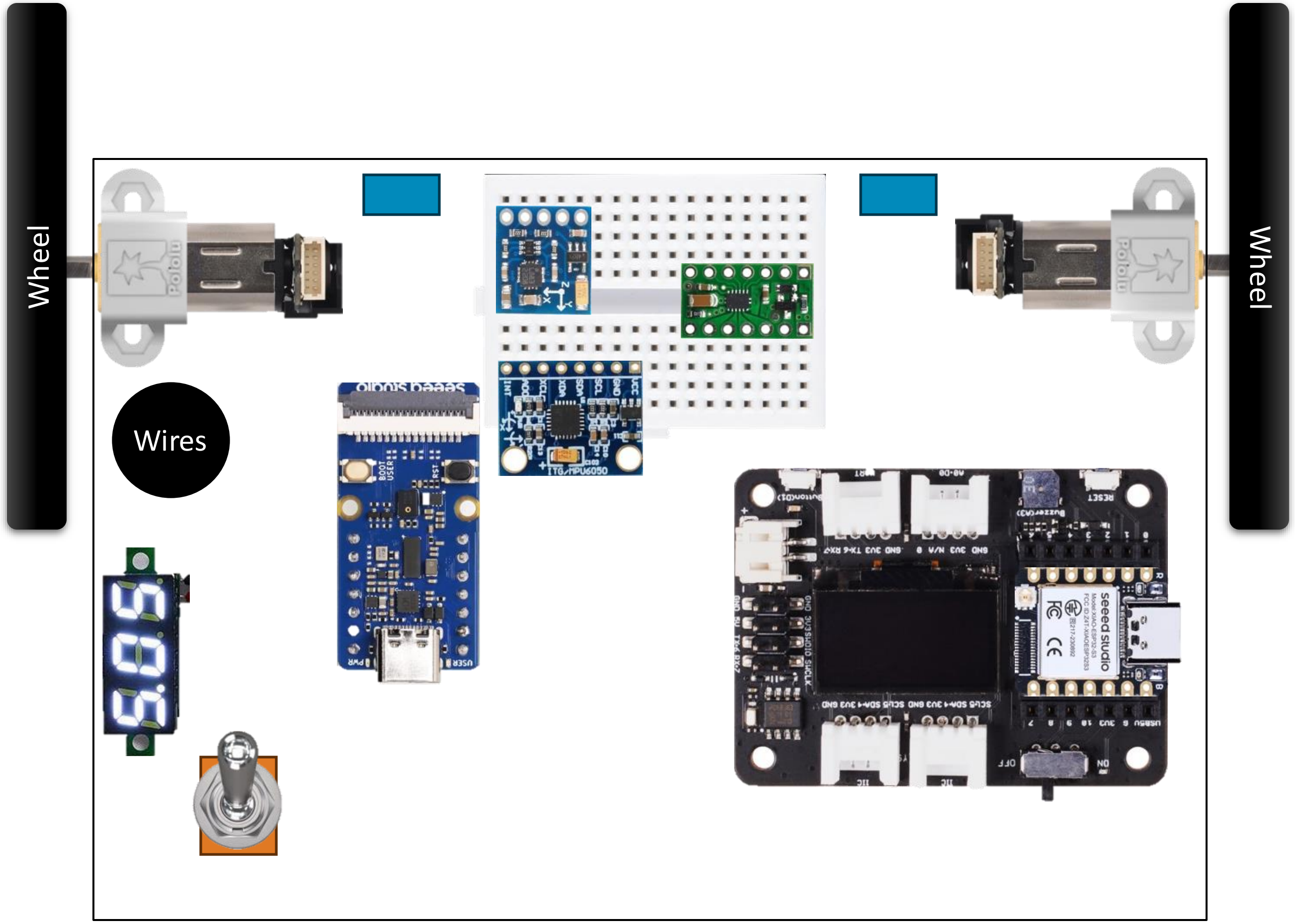
Parts (These Won't Print Correctly)



Full Layout



Top



Cross Bar


P5V04A
SUNNY
Raspberry Pi Camera
Rev 1.3


INT
I2C_RST
SDA
SCL
LPn
AVDD
IOVDD
GND
SATEL-VL53L7CX
94V-0 2233
15090-TT-4409
SATELSVL53L7CXA

Bottom