Kwadropus Duster Robot

Controls

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The premise

- Octopuses live neutrally buoyant in the water—they don't really sink and they don't really rise up, they can rest in the water without moving up or down. This is similar to how an astronaut floats around in the Neutral Buoyancy Lab when they train for a space walk on the space station. When astronauts are inside the space station in micro-gravity, it is similar to being neutrally buoyant—they don't sink or rise. The air has a lot less mass so it is very difficult to move enough air to 'swim' when on the Space Station.

The Proposal:

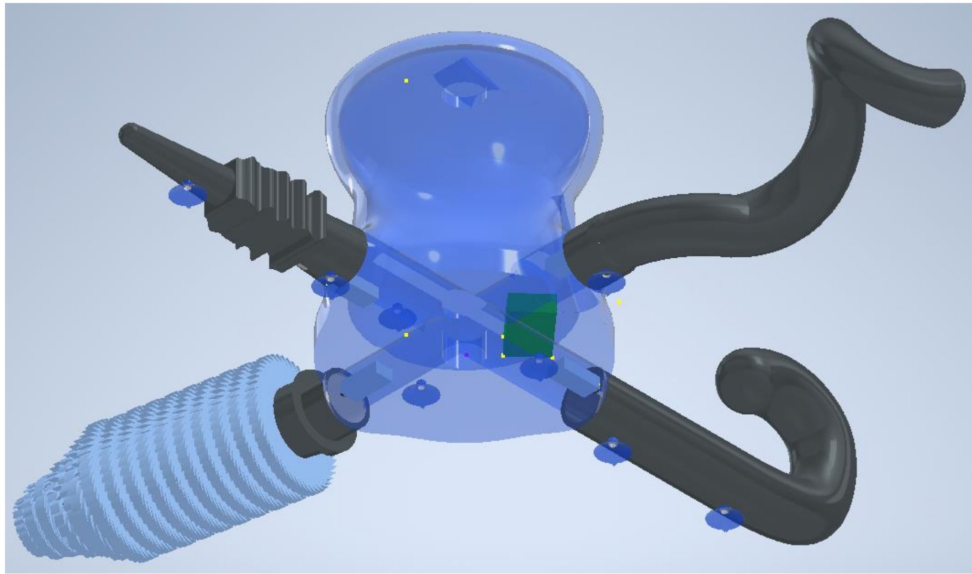
- HUNCH would like to demonstrate the feasibility of an octopus like, soft robot that can crawl around the inside of the Starlab, Axiom, Tiangong, Lunar Gateway, Orbital Reef, Haven-1 or any other Space Stations using flexible arms and suction cups on handrails and flat or curved, smooth surfaces for mobility and uses some kind of duster appendage to remove dust from the walls of the space station. The idea is that it needs to work kind of like a Roomba (but doesn't vacuum up the dirt) for a zero-g environment. An Octopus has 8 arms but HUNCH expects that our dusting robot may only need 4 arms—which makes it more of a Kwadropus. Like an octopus, each of the 3 mobility arms need to be able to act independently to find something to grasp and hold to prevent the Kwadropus from pushing away from the wall. Two suction cups per arm will need to be placed where they will have the most chance of being used. While the 4th arm, a duster arm, is cleaning, at least one of the mobility arms has to be holding the Kwadropus onto a wall or handrail either with a grasping of an object or a suction cup to a surface to keep it from being pushed away from the wall and floating aimlessly. If somehow the Kwadropus does get pushed away from the wall and handrails, the Kwadropus will use some kind of octopus like propulsion to push itself back to the wall.

A Roomba is a small, robotic room sweeper and vacuum cleaner. We are looking for a duster without the vacuum suction.

The Teams

- The **Kwadropus Robot** is divided up into **five different projects** to allow small teams to concentrate on what they are good at and increase each team's chances of success. This is how NASA or any engineering company would develop a new product. Part of each team's responsibility is to be aware of what the other team's requirements are and to stay on their own requirements so everyone continues to work for the same goal and final product.

  - Mobility Arm Team
    - Develop one robotic arm with minimal amount of rigid parts that can pull itself from one location to another using a handrail or other
    - Can rotate to grasp in multiple directions
  - Suction Cup Team
    - Develop a suction cup that can conform itself to a smooth but rounded surface and suction onto it. This could be size related—small suction cups can attach to smaller curves, big suction cups can only attach to fairly flat surfaces.
  - Propulsion Team
    - Develop a propulsion that simulates how an octopus uses a directional jet of water to move itself if it can't grab or grip the wall or handrail.
  - Duster Arm Team
    - Develop a flexible and moving dusting arm that will be able to remove and absorb dust as the robot moves around the module walls without liberating dust into the surrounding volume. (slow may be important)
  - Control Team
    - Develop a method of hive programing similar to an octopus where each arm is able to control itself autonomously—looking for a grip-- but still takes commands from the central brain to clean the room in a random fashion or if the robot is floating away from the wall



- No team should try to do a whole robot—each of these projects requires deeper thinking and prototyping. Two or more teams can put their projects together to help demonstrate how things fit together but that does not mean they will be selected together.
- Because this is the first attempt at this kind of motion, none of these have to act fast. This robot could take an hour to move a few inches. We need to see what kind of motion is possible

General ideas updated to answer several good questions

Nobody has done this before so we are exploring something new.

- As of now, we are attempting to demonstrate the technology and the techniques of how this can be done as individual parts. I'm not too worried about the size of your demonstration as long as your prototype can fit on a table top and show how it works. Once we have terrific ideas from each of the teams, then we will look at how to incorporate all of the ideas into a functional robot.
- The only team that needs to have motors at this point in the development is the control team. If you are able to show your mobility arm or duster arm works by pulling strings or use a syringe to push air in and out of it, that works for me. Later on we can see what kind of motor is needed to pull the string or pump to suck out the air. If you can activate your suction cup with a couple of strings and/or a syringe that will show the idea—motors are ok but not needed.
- This robot will eventually operate on batteries similar to a Roomba. We would aim at it being able to operate for 1 to 2 hours on its own before it has to recharge.
- Expect that the internal temperature of the space stations will be around 71 degrees F.
- It needs to be soft so that it doesn't damage hardware as it moves around. Also since we are aiming at many different space stations, soft robotics may allow for more diversity of movement in a generic environment.
- It is early to know what size the kwadropus duster will be in the end but I think we should aim for a robot that would be around 2 to 2 ½' in diameter and maybe a foot tall.

Starting points but not enough information

How does an elephant trunk work

- https://www.businessinsider.com/elephant-trunk-powerful-nose-sniff-out-bombs-2019-1

Anatomy of the tongue

- https://www.google.com/search?q=how+do+tongues+move&rlz=1C1GCEA_enUS939US939&ei=-6YhZM3SFY7DqtsP5q6lgAY&ved=0ahUKEwiNvMPxp_z9AhWOoWoFHWZXCWAQ4dUDCBA&uact=5&oq=how+do+tongues+move&gs_lcp=Cgxnd3Mtd2l6LXNlcnAQAzIFCAAQgAQyCAgAEBYQHhAPMgYIABAWEB4yCAgAEBYQHhAPMgoIABAWEB4QDxAKMggIABAWEB4QDzIGCAAQFhAeMggIABAWEB4QDzIICAAQFhAeEA86CggAEEcQ1gQQsAM6BwgAEIoFEEM6CAgAEIoFEIYDSgQIQRgAUJsIWP0XYIYbaAFwAXgAgAGHAYgBnAeSAQMwLjiYAQCgAQHIAQjAAQE&sclient=gws-wiz-serp#fpstate=ive&vld=cid:aa384407,vid:lATWhP0wJ5c

Robotic turtle—soft parts

- https://mashable.com/video/mit-robot-sea-turtle

Completely Soft Robot

- https://www.technologyreview.com/2016/12/08/155290/meet-the-worlds-first-completely-soft-robot/

Octopus soft arm

- https://onlinelibrary.wiley.com/doi/full/10.1002/aisy.201900041
- https://www.youtube.com/watch?v=8IXncY4L_nc

Chameleon inspired

- https://www.youtube.com/watch?v=trDz4Ukz_VQ

Langley Soft robotics lab

- https://www.youtube.com/watch?v=VuxnPLU_KEs
- https://www.youtube.com/watch?v=iwQRYzLZvGE

Oregami octopus—You will not be able to use magnets like this one because the changing magnetic field would damage the electrical systems in the space station, but there is some really cool thoughts here

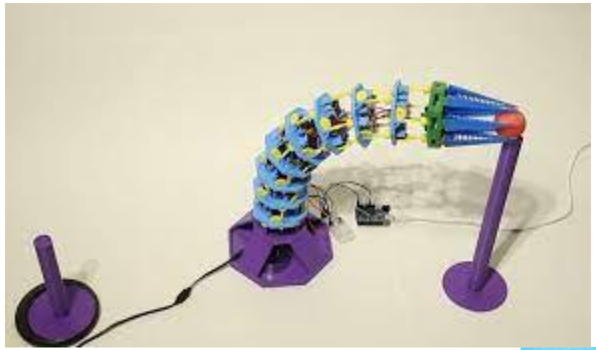
- https://techxplore.com/news/2021-08-omnidirectional-octopus-like-robot-arm-motor.html

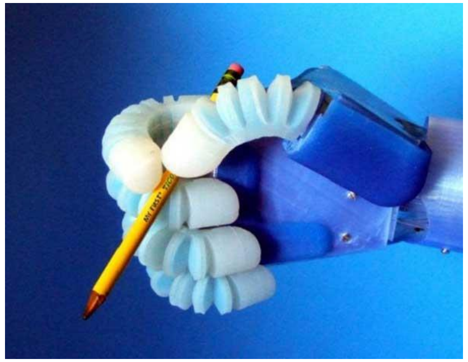
Tips for making soft robotics components

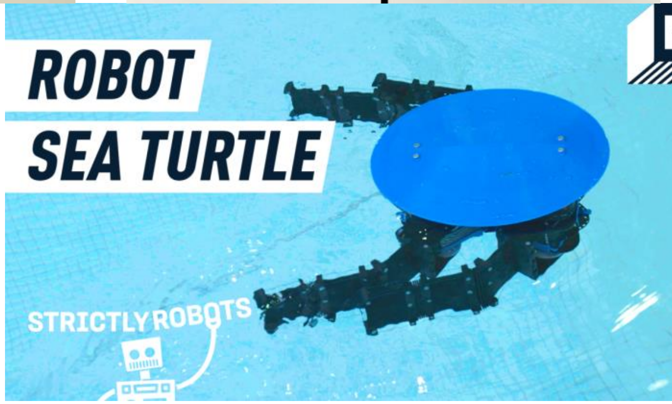
- https://www.youtube.com/watch?v=TyYW9BmMeSs
- https://www.youtube.com/watch?v=GgJt6vIbiso

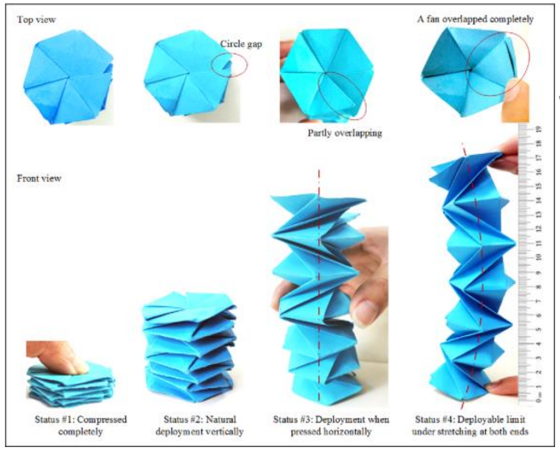
Other related ideas for soft robotics

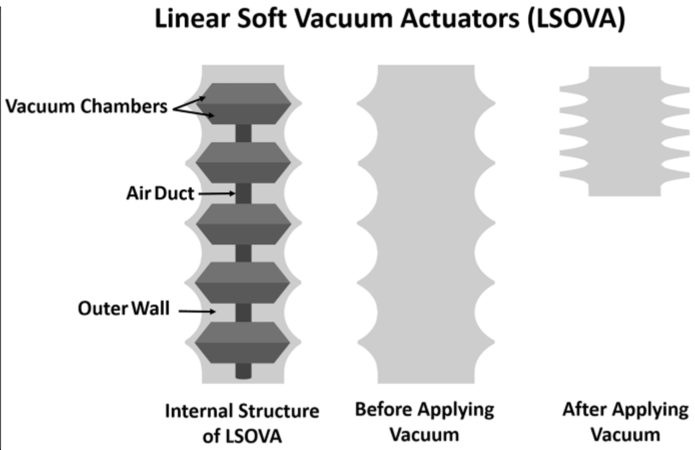
- https://www.universetoday.com/162514/engineers-design-a-robot-that-can-stick-to-crawl-along-and-sail-around-rubble-pile-asteroids/



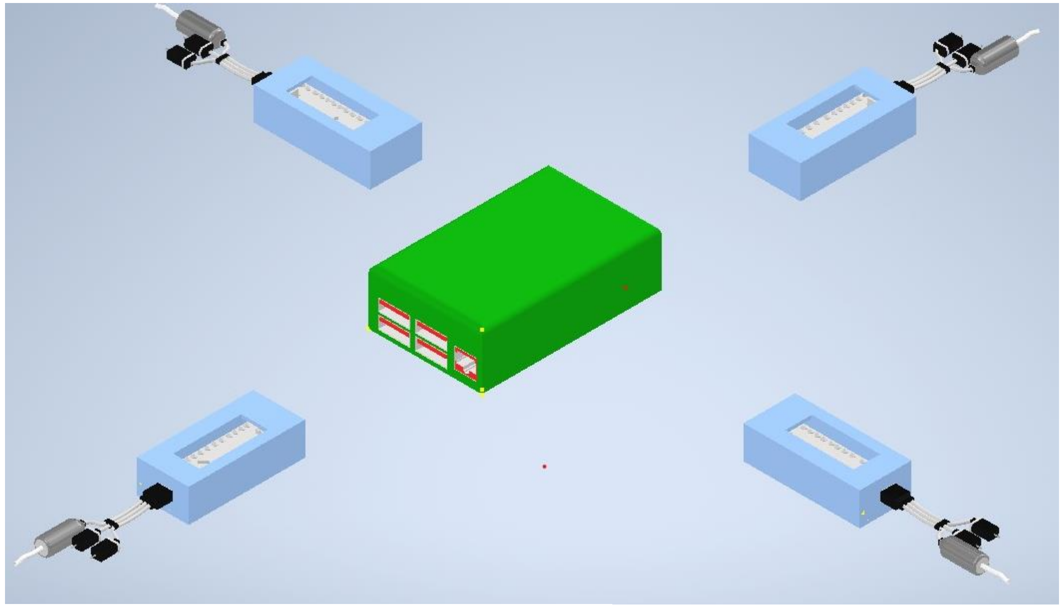




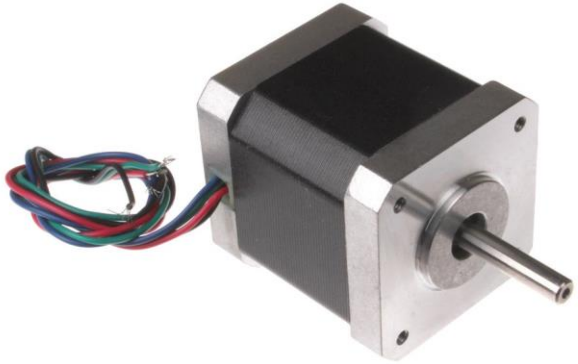


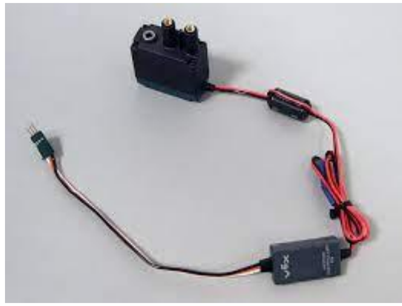


Control Team



- An octopus has 9 brains. One in each arm and one in it's mantle. This explains why an octopus arm continues to wriggle, respond to food and respond to pain for up to 5 hours after being cut off. Each octopus arm is feeling around for food independent from the other arms and from the central brain. Once the central brain makes a decision for attacking prey, escaping from a predator or other general motions, the arms react as one. Although you can find much more information on this, we should not pretend to think we understand the advantages and disadvantages of this mulit-brain. This robotic experiment may help us understand the octopus better.
- Develop the controls and software needed to drive the 3 mobility arms, the propulsion and the duster arm
- Part of the objective of this project is to explore what kind of value there may be to this kind of separation of brain functions—to simulate some of the octopus functionality. This project will use an Arduino(or similar small processor) to control 3 or more servo motors to actuate an octopus arm and two suckers. The Raspberry Pi (or similar small computer) will give commands to two other servos that will operate an air bag and a directional valve for propelling the octopus short distances with puffs of air.
- To work this project you need to be able to obtain
- This could be done with a variety of controllers-Vex, maybe even Lego robotics—the point is that primary processor needs to be able to run the duster arm, the propulsion and then let the secondary processor hunt around for a grip with the arm and suction cups.
  - Equivalent of an Arduino
  - Equivalent of a raspberry Pi 4
  - 5 servo motors or more
  - 4 micro switches that can be used as contact sensors
  - Able to program in Python or C sharp





The objective right now is not size but functionality. Show me that the secondary controller is able to independently control the arm and then take commands when the primary controller needs to give directions. Later in the development we will try to fit the needed electronics into the package that we want.

Octopus brain

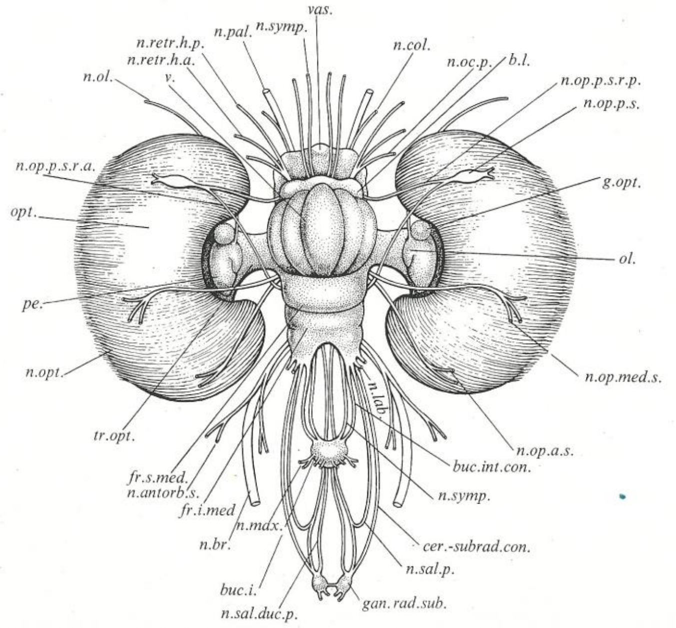
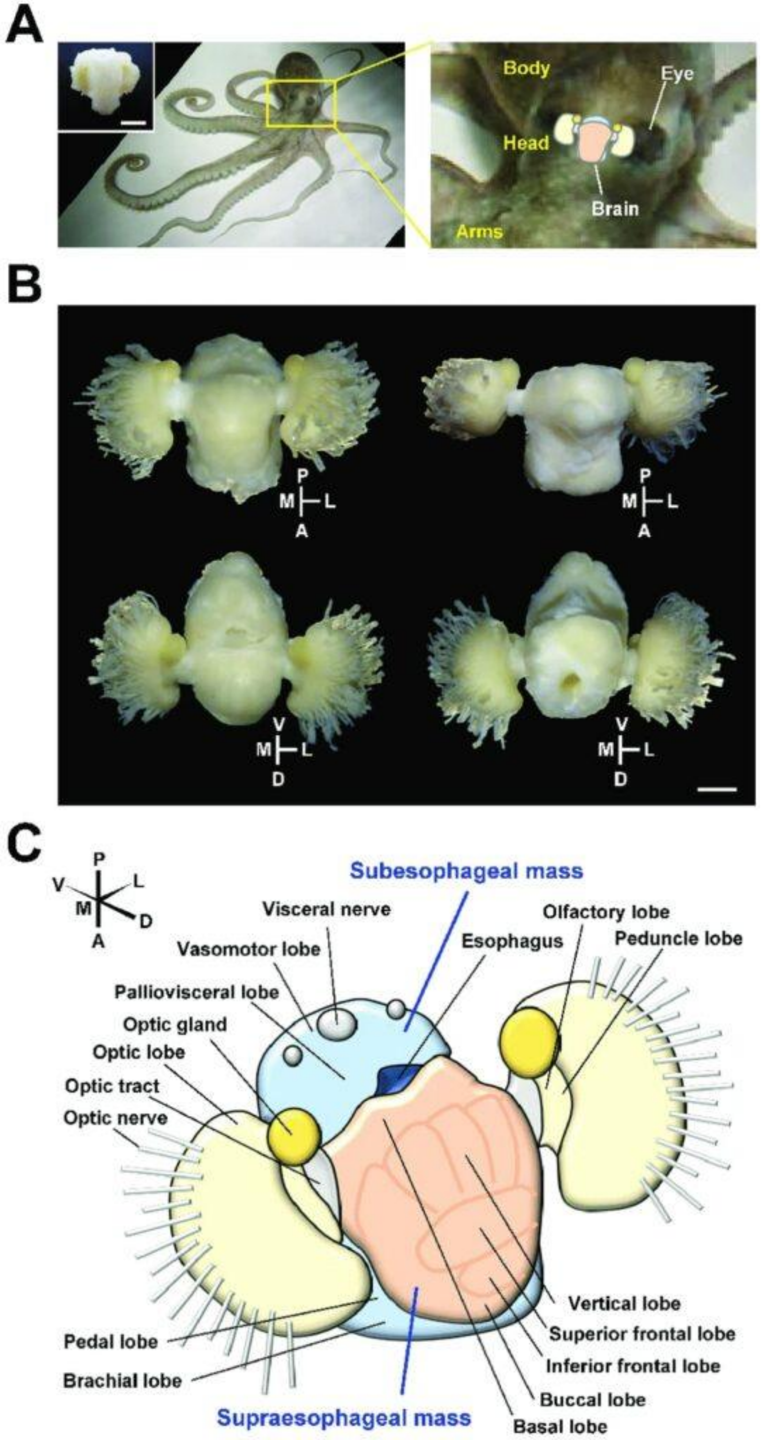
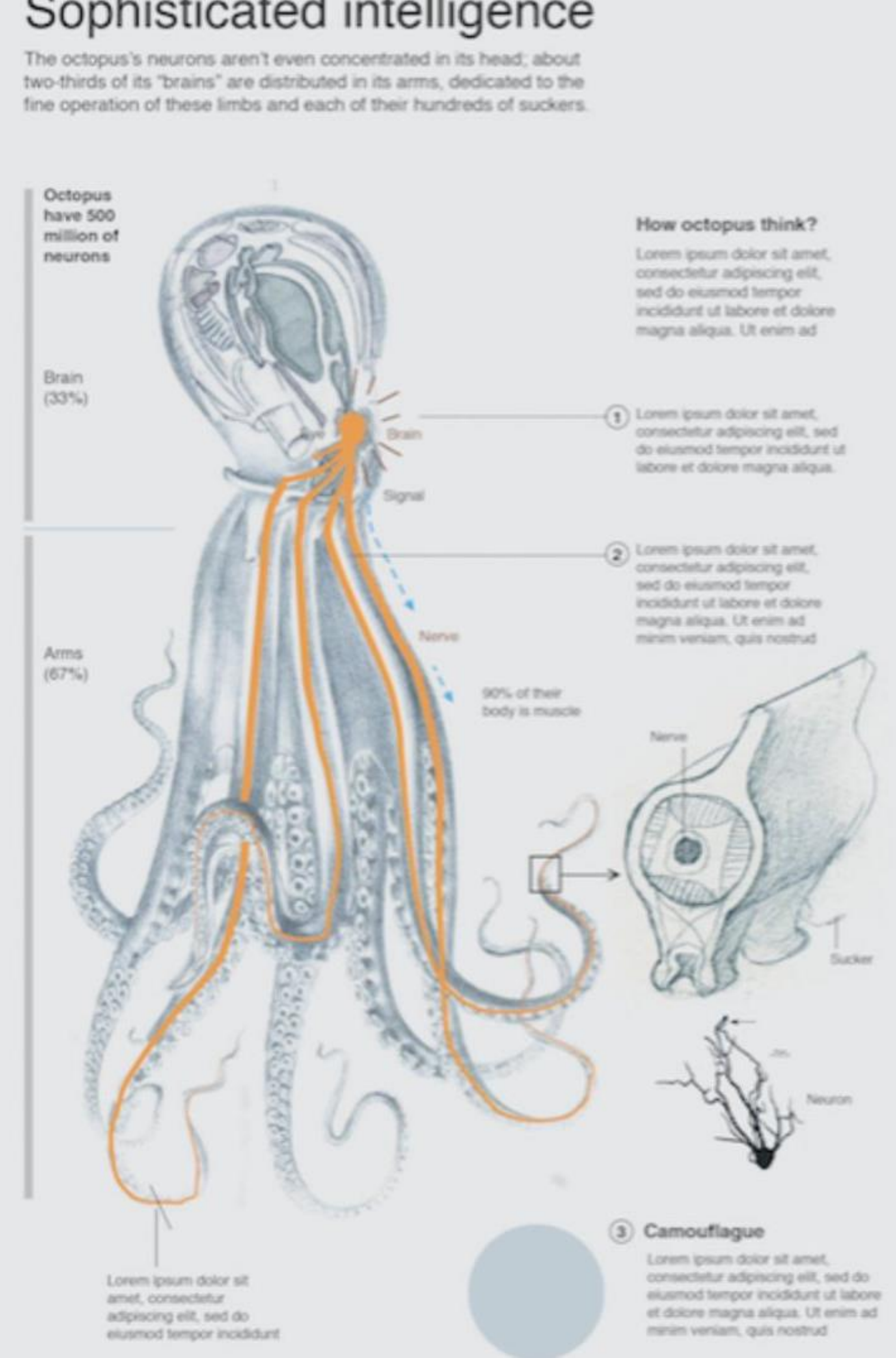


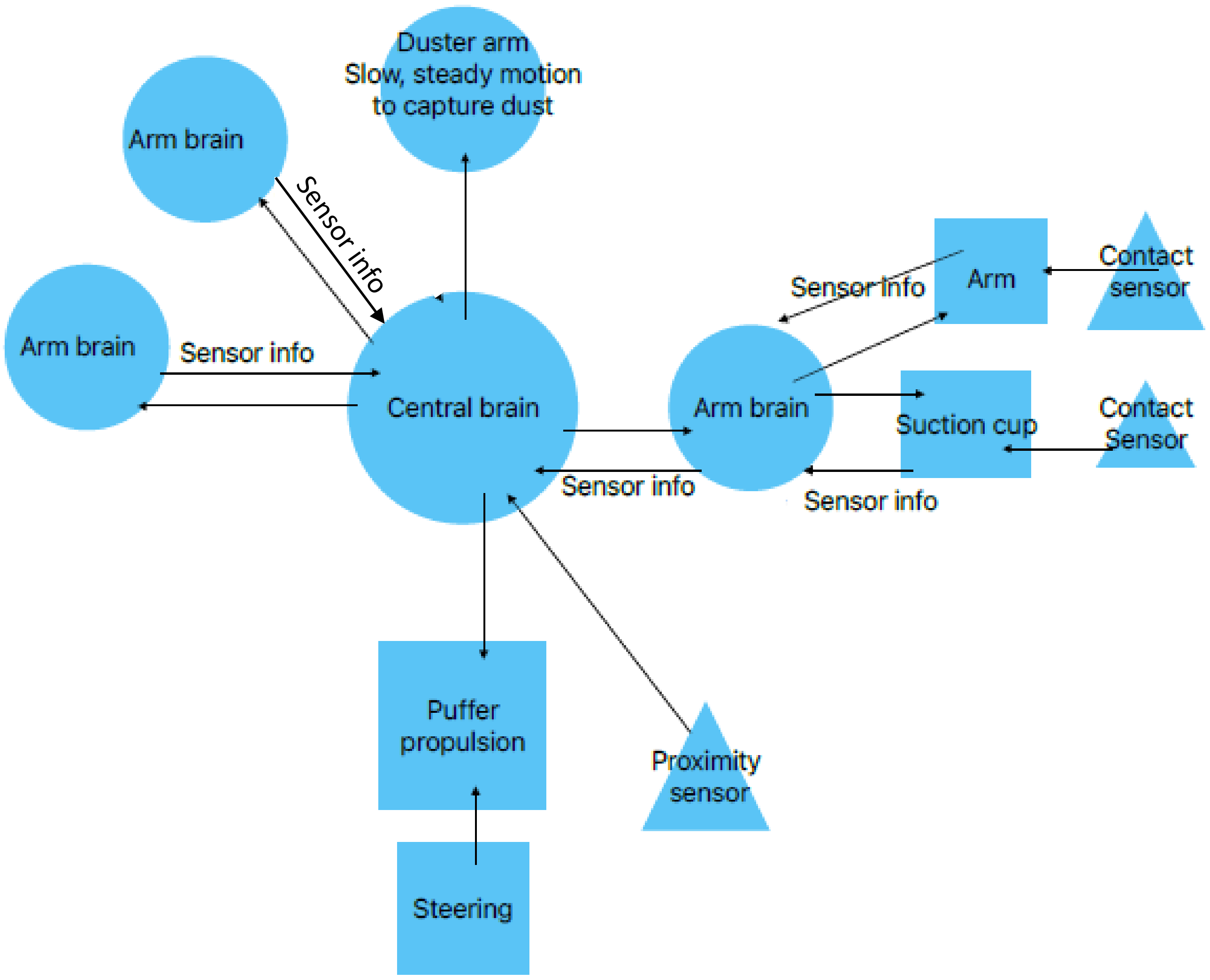
FIG. 1.6. Diagrammatic drawing of central nervous system of *Octopus* as seen from above (modified from Young 1964*b*).





Control logic

- The last team is the control team Their job is to figure out how to get all of the parts to work together. The overall design is to work similar to a Roomba by picking up dust like a dust mop and randomly move about a module and pick up dust from the walls using handrails and smooth surfaces to get around. An octopus has nine brains. Each arm has an independent brain that controls the arm. When there is a need to have all of the arms working together, the central brain takes over and determines the need for each arm. On this kwadropus each arm needs to be able to search independently for a grip on the wall so each arm will have some autonomy. However if the robot fails to grab onto a handrail or suction cup onto the surface, it will start to float away from the wall and the central brain needs to take control, get the robot back to the wall and direct the overall movement to accomplish the cleaning of the module



Coding for the arm

This is one of many types of microswitches that could be used for the contact sensor. They are usually about an inch long and are activated with very little force. The little wheel at the tip of the arm would help minimize chances of snagging.

Pretend this is a mobility arm and that functions like a party favor you blow in to extend it. There is a pump that blows air into the arm to extends it and when the air is turned off, the arm rolls up again. This is how it searches for a handrail.

There will need to be at least 3 mechanical micro switches that act a sensors. One sensor that lets the robot know that it has or has not grabbed onto a handrail. There is another sensor between the suction cups that says whether or not it has been stuck to a smooth surface. There is one more sensor that says the robot is in contact with the rack face.

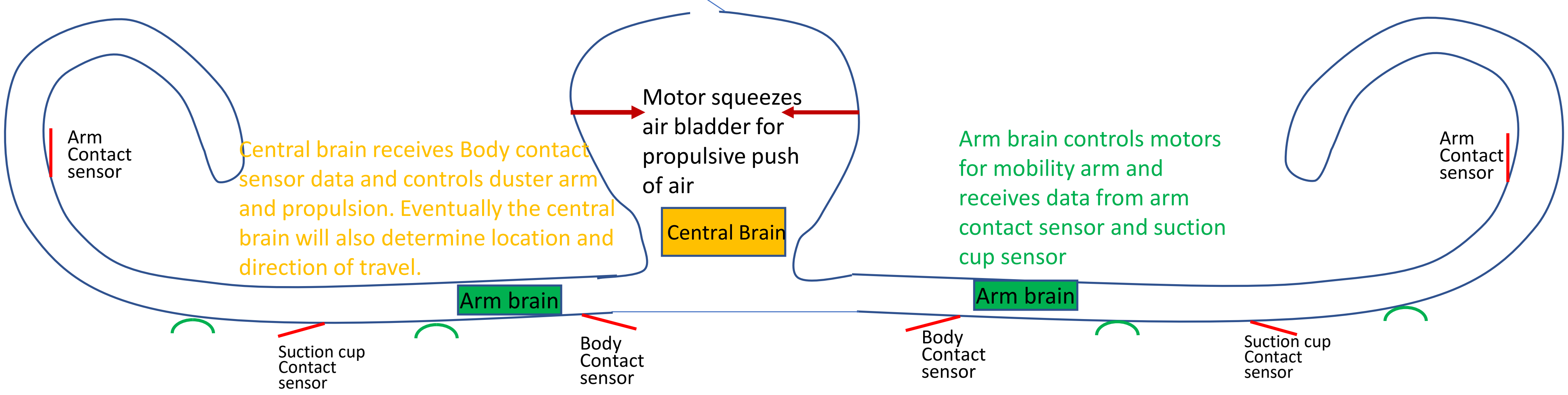
If the Arm contact sensor is depressed then the arm has grabbed onto a handrail (or other thing) and the arm can stop searching for a handle.

If the suction cup contact sensor is depressed then the suction cups have successfully attached to the rack face and the arm can stop looking for an attachment.

If the body contact sensor is **not** depressed, then the robot is floating away from the rack and the Propulsion system needs to be activated to push it back to the rack. The central brain needs to tell each of the arm brains to stop moving the arms so the kwadropus can go back to the wall. Once contact is made the arms should start looking for attachment right away.

After either the arm contact sensor or the suction cup contact sensor is depressed, the robot arm stops moving for 10 seconds so the duster can clean that area. Then the arm needs to detach and rotate its angle to search for another attachment point.

Each of the three mobility arms are doing this same thing while the duster arm is cleaning.



Some questions answered

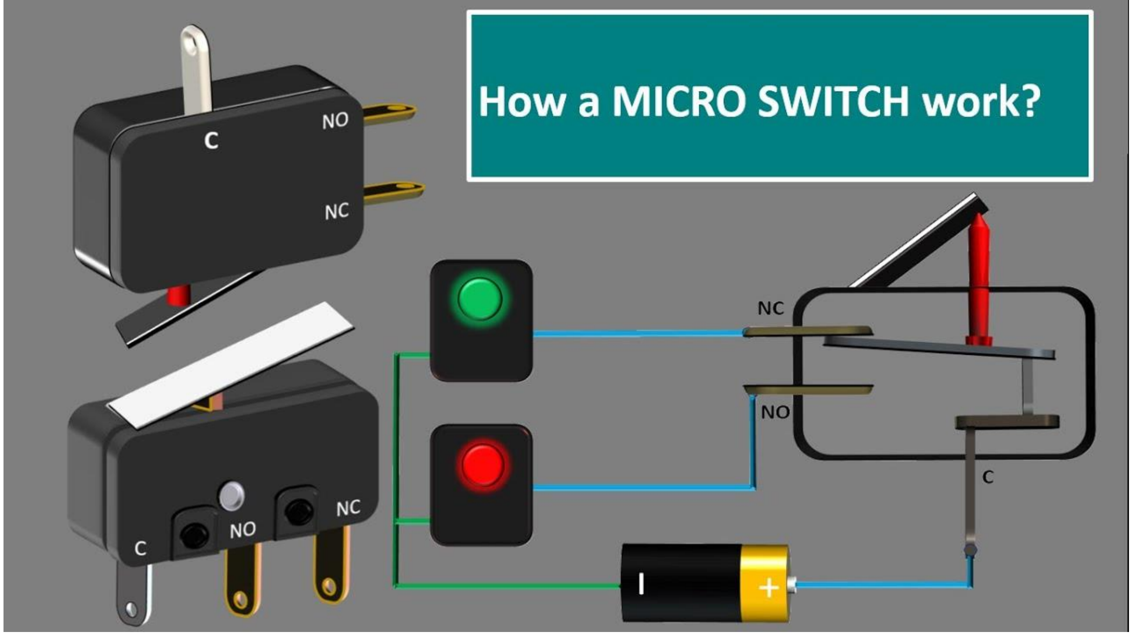
Are you looking for a distributed control system? (Logic processing located in each arm and some supervisory processor monitoring them and providing inputs when needed)
Yes. The intention is that each mobility arm is looking for a good place to grab onto so the robot is able to dust that area without being pushed away from wall. The central brain would then be in control of running the duster arm and the propulsion system if the Kwadropus starts floating away from the wall.

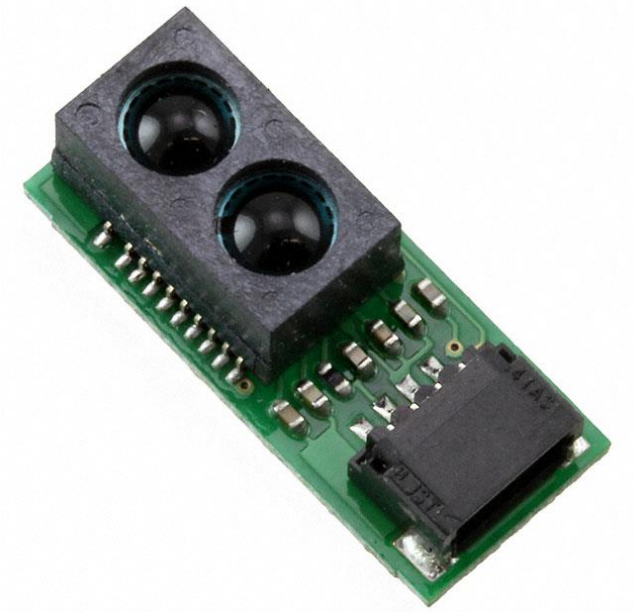
Would you like a comparison of performance between centralized control and distributed control?
I think it could be done with a centralize control but I'm more interested in distributed control because the octopus has evolved to be an intelligent, strong predator partly because of its distributed brain functions. I think there could be some valuable lessons to learn from having the arms having some of their own autonomy.

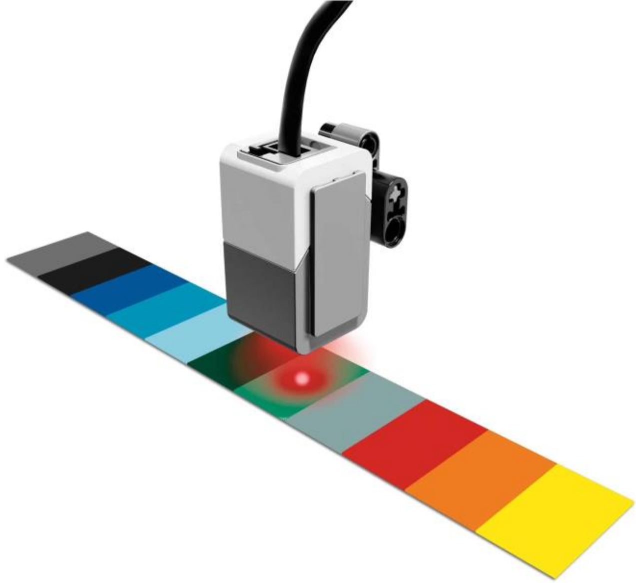
Do you care about a User Interface?
I expect that the first unit that is produced, it would need to have a user interface so that corrections can be made and we can monitor the code while operating but eventually I would like it to be as autonomous as the Roomba.

Do you care about the physical demonstration unit?
I don't care what your demonstration unit looks like. I'd like the computing systems to be minimalistic as possible to getting the job done but don't under sell your needs. I'm also hoping you can use materials your school already has for your demonstration unit so you don't have to purchase lots of equipment.

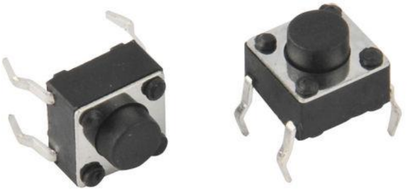
Required planning documents? Program organization and flow diagrams, Instrument Tag lists, Wiring diagrams, Pseudocode
I will be conferring with computer science teachers and programmers that can answer this better and I will get back to you on this.







Different types of color sensors from $8 to $30

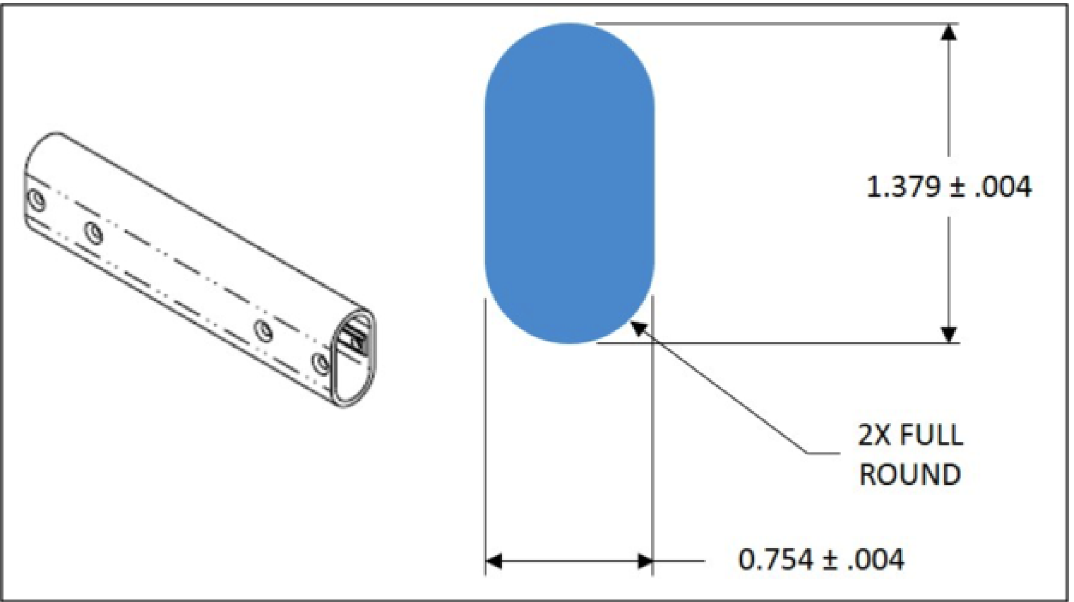


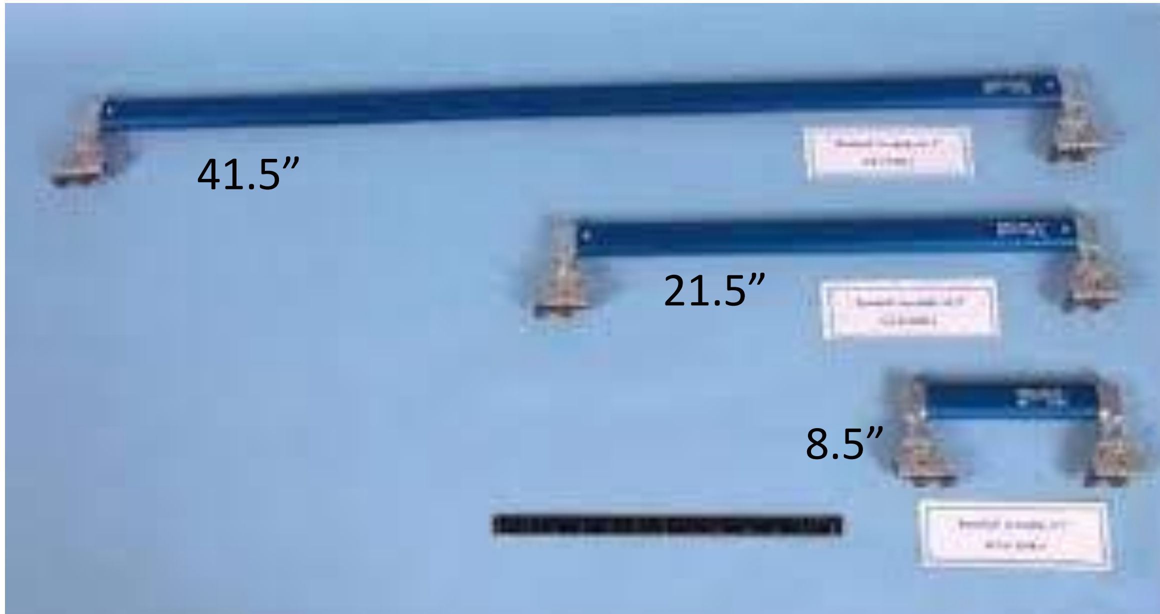
Micro switches are the easiest type of contact sensors to work with and make a great beginning. Once you get things working for something simple you can look at other options for sensors.

Ultrasonic detectors might be valuable in the future but not in the early development of the prototype

LiDAR—laser based mapping
I would not want to do this until the robot is much more advanced in the design.

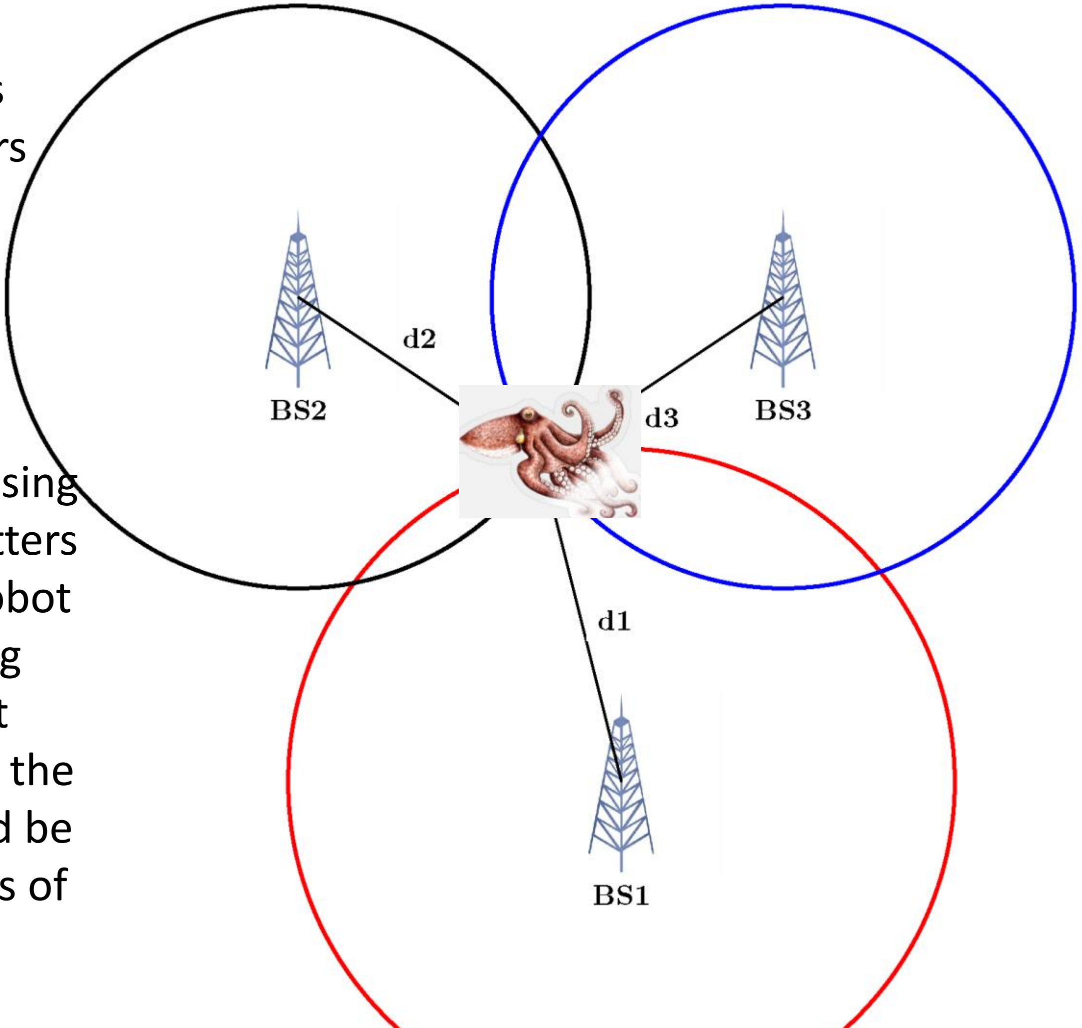
Ultrasonic and Optical distance sensors from $4 to $230


1.379 ± .004
2X FULL ROUND
0.754 ± .004


41.5”
21.5”
8.5”

Zigbee transmitters and receivers

One way the Kwadropus robot could locate where it is in a module is by using triangulation from different transmitters inside a module. It seems like the robot would need at least 3 or 4 for moving about in the volume of the room but there may be ways around that with the software and the sensors. This could be done with a variety of different types of transmitters and receivers.



Would it move randomly through a module as it cleaned or would it have a set pattern it would follow or would it be directed by the astronauts. At least part of the answer will be determined by the how the mobility arms will move it about? If it has a map of each module and the overall station, the robot may use real time information about its surroundings and objects on the wall as it cleans. All of these options will probably be available when the design matures.

Fortunately we don't need to worry about the cleaning pattern and motion yet but we should keep it in the back of our minds as the robot progresses.


Arrange teams and tools needed to optimize production.
Planning of Sprints
2
Collaborative Design Development
3
From the beginning of the process, the end users' involvement and feedback is critical.
Analysis of concepts and requirements definitions; Determine current state and your expectations.
1
Requirements Definition and Analysis of Concepts
Agile Methodology
User stories drive everything.
Create and Implement
4
Frequent development delivery through sprints. Feedback on testing & appropriate changes are imperative.
5
Review and Monitor
Ensure that you are reviewing and monitoring key metrics for success.

The future of the duster?

- It seems overkill for the duster to have 3 or 4 Arduino controllers and a Raspberry Pi. This is true—for now. We don't need lots of computing power for dusting and moving around but what kind of other tasks could a small robot be given once it is proven to be good for saving the crew time
- Part of the reason we are examining the distributed computing functions is to see if there is value in programming to what the octopus has proven over millions of years with its 9 distributed brains. They are intelligent and cunning predators that use and make tools to get what they want. Is there some kind of advantage that we can learn from having some amount of distributed thinking with a robot?
- Currently there is research to suggest that people also have some amount of distributed brain in humans. What is the purpose of this in people? What might we be gaining by having thinking components in our gut? Why not have it all located in the brain?
- A second reason we are exploring distributed computing is that we don't know how much further a duster could go. Once we get it dusting a module and a whole station, what else could it do?
- The ISS already has "SPHERES" robots that float around in the station with cameras and can watch the crew do tasks but because it doesn't attach to the handles or surfaces, it isn't able to do many tasks when it only floats around. The Kwadropus may be able to be given more tasks as it becomes more capable. Distributing some of the computing power into the mobility arms may allow for replacing an arm with a tool that has its own software. Changing out an arm would give instantaneous reprograming for the new task related to the tool. The central brain would still have similar tasks but its path or time at each location may be altered. For example:
    - Change out the duster arm and replace it with a wrench. Now the Kwadropus is moving around the station to tighten bolts (not really a task but an example)
    - Change out the duster arm for a mister so it can spritz plants.
    - If we can get the propulsion system to keep it against a panel, could it be updated to move the whole kwadropus to another module instead of 'crawling'? This would take a lot more ability with the central brain.
    - If we add a LiDAR system to the Kwadropus (on the central brain) for mapping out the inside of the station, the mobility arms would remain the same despite the extra computing and memory storage required for the LiDAR
- In short, the purpose of the distributed brain is to allow for what we don't know it can do in the future.
- A third reason is that I am asking students to do something they haven't done before—hive programming. This is not as complicated as flying 100 drones to make pretty pictures in the sky but it will give you experience that puts you and your team above others with your experience when applying to college and/or jobs.

The enteric nervous system that regulates our gut is often called the body's "second brain." Although it can't compose poetry or solve equations, this extensive network uses the same chemicals and cells as the brain to help us digest and to alert the brain when something is amiss.

Harvard Medical School
https://hms.harvard.edu › publications-archive › gut-brain

The Gut and the Brain | Harvard Medical School