Project Idea: Fully-Autonomous Construction Robot

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Description

As our world continues to develop, it becomes crucial that industrial processes continue to grow in efficiency. Autonomous devices capable of building various structures are crucial to this continued development of industrial society, and learning how to improve upon them is a major first step to creating the robots of tomorrow. As a result, for my project I will develop a fully autonomous construction robot that will be tasked with making a small structure out of simple materials such as popsicle sticks and/or aluminum foil. This construction robot will handle most tasks through a dedicated chip (either an STM32 microcontroller or an FPGA), though more complex tasks will be offloaded to a more capable computer over wifi. It will also be mobile, likely moving around a dedicated space using wheels attached to a chassis.

Elements:

Input(s)

Depending on the localization method I use, I will need powerful sensors to make this project work. For example, if I were to use SLAM for localization, I may want to host SLAM calculations on my PC and use a LiDAR sensor such as the following:
https://www.robotshop.com/products/benewake-tf-luna-8m-lidar-distance-sensor
For SLAM, I may also want to use a camera or multiple, an example of which I have posted below:
https://www.arducam.com/arducam-2mp-spi-camera-b0067-arduino.html
If I were to use triangulation instead, I may need multiple cameras such as that posted above to allow for stereo vision capabilities within my robot. If I were to use odometry for localization, I would likely need encoders and accelerometers to measure changes in position and acceleration of my robot. An example of an encoder I could use is posted below:
https://www.digikey.com/en/products/detail/dfrobot/SEN0230/7398886
No matter which method I use for this purpose, obtaining the data from the sensors themselves is not likely going to be too difficult, though given the volume of data from something such as a camera sensor, it is also not likely to be incredibly easy. While I haven't done this myself, there are definitely resources online that can guide me through it, so I would rank this part of the project at a difficulty level of 1.

Output(s)

The outputs generated by a robot will largely be motor-driven actions such as arm movement for manipulating structural parts and wheel movement for moving the robot around its environment. Some motors that may be useful for these tasks include the following:
https://www.banggood.com/JX-PDI-1181MG-18g-3_5KG-Metal-Gear-Digital-Core-Servo-for-WPL-RC-Car-Airplane-p-1994159.html?utm_source=googleshopping&utm_medium=cpc_organic&gmcCountry=US&utm_content=minha&utm_campaign=aceng-pmax-us-pc&currency=USD&cur_warehouse=CN&createTmp=1
I will likely want 1 or two motors in the chassis to move the robot around, which will likely need a lot of torque to move the entire weight of the robot. I will also likely need semi-high torque motors at the base of the arm, and can then get lower torque, lighter motors further up. I want the arm to have 3 DoF minimum, so I will need 3 motors for the arm and 2 or so for the chassis. I did VEX in high school, so have a general idea of how to work with motors in this capacity. While this will be more complex than motors in VEX, it shouldn't be too much more to take on, so I would give outputs a difficulty level of 1, similar to inputs.

Processing

This is where the brunt of the difficulty of the project will come in, as this involves the actual localization calculations and movement calculations of the robot, which will either be done on the STM32 NUCLEO-F446RE board which I will have on the robot, or on my PC in the case I use a more complex variant of SLAM or some equivlently complex localization algorithm. This portion of the project will also involve configuring ESP32s to send data to and from the PC and my robot, as even if I do all calculations on the board, I still want to send debugging and environmental data to my PC. This will require wifi-enabled boards on the robot, which is where my ESP-WROOM-32 may come in handy. Due to the difficulty of implementing localization and the likelihood guides for this aren't readily available online, I am assigning this a difficulty level of 3.

Physical Build

The actual construction of this robot will likely involve creating a CAD diagram of the robot and then subsequently machining the chassis and arm frames out of either wood or aluminum. In the case I use wood, I will probably laser cut the materials. If I use aluminum on the other hand, I may want to use a waterjet to machine out the parts of the robot. I have used both a laser cutter and a waterjet before, though the CADing process may take longer and require more effort. However, with some guidance this is completely doable and as a result I am assigning this category with a difficulty level of 1.

Overall, adding the difficulty levels of each section yields a total difficulty level of 6, which is a fairly acceptable difficulty and means the project's main pain points lie in achieving effective localization.

Sanity Check Questions

Answer any that are a concern:

- Does the physics work out? Can you measure or actuate the things you want to?
  - Depending on my localization algorithm used, I should be able to acquire the necessary sensors to measure and actuate the necesary parts of my robot. Small robots have been made on numerous occasions, so the physics of another one should work out. This robot will likely be smaller and lighter than most VEX robots, so it is definitely possible to build.
- If you use any motors, are they strong enough? Can you calculate the torque needed?
  - While I don't have specifics regarding the size and weight of the various parts of the robot, once I have designed it I will have the necessary weight values to determine what specific RC motors I will need to implement this project. The robot is not going to be obscenely large, meaning I will absolutely be able to find motors with sufficient torque and speed to meet the requirements of the project.
- Does your project need to be battery powered?
  - My project will be battery powered, as the robot will be disconnected from all potential power sources. Due to the many motors, boards, and sensors involved, it will also need a fairly sizable power source which may contribute greatly to weight concerns.
- If you need to purchase parts, are they inexpensive enough?
  - Many motors that may work for this are around 20 to 30 bucks, which is somewhat expensive but definitely manageable. The same applies to sensors. As for boards, I have already purchased the sufficient boards for most of this project.
- Will you be able to test your project in the classroom?
  - Yes, I can test it on an empty floor space in the classroom or on the floor in an adjacent classroom.
- Do you have access to the tools you need to build the project?
  - Invention Studio my beloved; Hive Makerspace my beloved; Aerospace Makerspace my beloved; Our classroom my beloved
- Do you have any voltages over 40V or current above 2A? If so, we should talk about safety.
  - Depending on the RC motors I use, I might have currents above 2A. It heavily depends on if I'm using brushed or brushless motors, and how powerful the motors are that I ultimately need.

Project Idea: Multi-Agent Autonomous Assembly Line

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Description

As advances in robotics continue to be made, the ability for robots to communicate with eachother to achieve a mutual goal has become ever more important in novel robotic innovations. Being able to implement a simple multi-agent system for my project will provide me with invaluable knowledge in the field of multi-agent robotics, and therefore as my second project idea I propose developing a simple assembly line consisting of a conveyor belt alongside multiple stationary arm robots controlled by a central command unit, likely consisting of an FPGA as to keep the assembly line flexible. Each arm will connect to the FPGA either through Wifi or through the ESP32 specific connection protocols as I will likely connect all the individual devices together using ESP32s.

Elements:

Input(s)

Inputs here will be similar to those used in the first project idea. LiDAR and Camera sensors can be used for proximity and vision detection to know where parts currently are and where they should be after the robot has manipulated them. Motion sensors such as encoders, gyroscope sensors, and accelerometers will likely be needed to control the movement of each arm on the assembly line. One set of sensors that will likely be needed for both projects that I forgot to mention previously are force sensors to ensure the manipulator doesn't overexert force on the objects being manipulated as to break them. An example of a force sensor is as follows:
https://www.digikey.com/en/products/detail/dfrobot/SEN0297/10136551
Overall, these sensors are fairly usable and information on how to process data from them is widely available (My special topics class, Advanced Robotic Manipulation, is teaching us how to process data in a similar way to how the data from these sensors is processed) so I am giving this section a difficulty rating of 1.

Output(s)

The outputs, similar to the previous project, will involve a lot of motor movements for the purposes of manipulation. However, in this project each robot will be stationary so there will be a lot more focus on ensuring each arm is capable of fine adjustments and movements to ensure they have sufficient manipulation capabilities. This will likely also require a lot of motors, as we may want more DoF for each arm (likely closer to 6 DoF). The goal is to mass produce some product with high accuracy and precision, so higher quality motion sensors and motor control will be necessary for

this project to be successful. As for what is being mass produced, I was thinking of making Star Wars Droids obtained from the following link:
https://www.aliexpress.us/item/3256809675035346.html?spm=a2g0o.productlist.main.1.2d864m0r4m0rfW&algo_pvid=1c4e2592-a0e1-4427-85d6-106e5367fbd6&algo_exp_id=1c4e2592-a0e1-4427-85d6-106e5367fbd6-0&pdp_ext_f=%7B%22order%22%3A%2218%22%2C%22eval%22%3A%221%22%2C%22fromPage%22%3A%22search%22%7D&pdp_npi=6%40dis%21USD%2122.52%214.26%21%21%21159.75%2130.23%21%402101ec1a17603227830601266e1baa%21120000504002654 39%21sea%21US%210%21ABX%211%210%21n_tag%3A-29910%3Bd%3Aab117a39%3Bm03_new_user%3A-29895%3BpisId%3A5000000187461913&curPageLogUid=6otdxR0Kn6gY&utparam-url=scene%3Asearch%7Cquery_from%3A%7Cx_object_id%3A1005009861350098%7C_p_origin_prod%3A
While I wont be worrying about localization for the entire robot due to it being stationary, I will still need to implement localization for the arm itself, as well as each joint within. Due to the need for precise movements to properly assemble the minifigures, this may be more difficult to implement than the first project, so I would rate this at a difficulty of 2.

Processing

Processing requirements here are similar to the first project due to the need for robotic localization. However, as the robots themselves are stationary there may be fewer variables to consider and the environment may be more predictable (though that may be canceled out by the higher DoF of the arms themselves). Due to the predictablity of this environment compared to the first project, we may be able to implement localization, controls, etc. for the robots on a dedicated chip such as an FPGA like the Digilent Basys 3 Artix-7 FPGA board or an STM32 such as the one mentioned previously. If data processing does become too complicated, however, it will be sent to my PC via ESP32s or other WIFI enabled devices. The various robots will also have to communicate with each other, which will likely be done using ESP32s to ensure a smooth production line. Similar to the first project, I still believe this to be the most complex portion of the project due to the complexity of implementing localization, robotic controls, data processing, etc. and therefore rate this at a difficulty level of 3.

Physical Build

The physical build of this project is going to require more moving parts in comparison to the first project. For example, there will be motors used for a conveyor belt alongside motors for at least 3 different manufacturing robots, and the machining of wood or aluminum for this entire system will also get somewhat complicated. Figuring out the design of the robots will also be a complicated task given they will have to be made in a way such that they can place pieces exactly where they need to be (hence the higher DoF, which in itself will also complicate the design process). While this is still doable, this higher build difficulty means I will rate it at a difficulty level of 2.

Overall, this means this project receives a total build difficulty of 8, which is 2 more than the first.

Sanity Check Questions

Answer any that are a concern:

- Does the physics work out? Can you measure or actuate the things you want to?
    - The pieces the arms will be manipulating are very light, and the assembly line can be designed in a way such that each arm fits nicely and can effectively place its respective parts where they need to be. None of the arms or similar robots used will be too heavy, meaning I will be able to source the necessary motors to make this work. I will also incorporate encoders, gyroscopes, and accelerometers that will ensure I can measure all the necessary movements to make this design work.
- If you use any motors, are they strong enough? Can you calculate the torque needed?
    - Yes, the RC motors I will be using are strong enough to handle the weight of the arms, which will likely only be a few 100 grams each given I use a lightweight material like wood or aluminum. Given these weight measurements, I will be able to calculate the torque needed and will source the proper motors accordingly.
- Can you get a power supply that is powerful enough? Is there something with high voltage or current requirements?
    - I can likely get multiple power supplies and make each robot a self-contained system, which will ensure I can get power supplies strong enough to support each individual robot. A large part of this project is creating a multi-agent system where the various robots within collaborate with each other but remain separate after all. I will likely use a 20 to 30V battery for each robot, though may need less depending on the motors I ultimately end up using for this project.
- Does your project need to be battery powered?
    - Likely, though given the system is stationary I might be able to plug it in to an outlet instead.
- Do you have any voltages over 40V or current above 2A? If so, we should talk about safety.
    - Depending on the RC motors I use in either project, I might have currents higher than 2A for similar reasons as the first project. Because of the size of the project, I may also have higher voltages though that depends on how I power each part of the project.
- If you need to purchase parts, are they inexpensive enough?
    - I can find cheaper motors and use lighter, cheaper building materials.