Assignment 2 – Existing Solutions; Engineering Design Specifications

(70 points)

| **Due date:** | See CANVAS for submission deadline and instructions |
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| **Objective:** | The goal of this assignment is to study relevant existing solutions, and to further define the design problem by developing engineering design specifications which are used to quantify performance levels needed to satisfy user needs. |

1. Existing Solutions (/20 points)

***Concept 1 (/5 points)***

| What is the design concept? Describe in 1-2 sentences. (/1 point) | The Unitree Go2 Air is a quadruped design with a variety of sensors primarily for recreational use.  https://shop.unitree.com/products/unitree-go2?variant=47259197800681 |
| --- | --- |
| How is the existing design concept relevant to your design challenge? (/1 point) | The Go2 Air has many similar specs to our target design including battery life, size, and price. The use case does not match ours, and the sensors are more powerful than our current scope, but the power system and movement system are very similar to what we are working on. |
| How does the existing concept work? Provide photos or sketches to explain how this concept works. (/1 point) | The Unitree Go2 navigates by using lidar to create a map of its environment.    This robot uses a set of 12 servo motors to drive its motion.    Onboard control systems are powered by ROS1. The robot can be interfaced with wirelessly. |
| What are the pros/cons of this existing design solution? (/1 point) | Pros: Cheap for a quadruped ($1600), good maneuvering performance, long battery life  Cons: Recreational use case as opposed to research or industrial, locked down software that cannot be modified for alternate uses |
| Could you apply this existing design concept in your project? What are the limitations of applying this existing design concept to your design problem? Could it be adapted? (/1 points) | Most of this design is what inspired this project–a cheap and performant quadruped–but its primary limitation of locked down software unless you buy the edu variant–which has a less cheap price of ~$25000–prevents it from being an effective option in agriculture or research. Their tracking systems, power systems (especially battery size), and body design, however, provide a useful guide for our own robot. |

***Concept 2 (/5 points)***

| What is the design concept? Describe in 1-2 sentences. (/1 point) | https://ag.dji.com/mavic-3-m?site=ag&from=nav  The DJI Mavic 3 is an aerial drone for fast, high resolution real-time agricultural surveying. |
| --- | --- |
| How is the existing design concept relevant to your design challenge? (/1 point) | One of the desired user parameters for our robot was the ability to have surveillance capabilities. Our research into the DJI Mavic 3 is to consider its sensors and cameras to see what this robot is using to create map data and take pictures. |
| How does the existing concept work? Provide photos or sketches to explain how this concept works. (/1 point) | The drone flies in predetermined paths around the specified area preprogrammed to maintain a certain distance away from obstacles along the path    The drone viewing an area below to map the surface |
| What are the pros/cons of this existing design solution? (/1 point) | Pros: Paths around obstacles, Topographical Recreation, Multiple sensors (IR, cameras, light), 4G communication.  Cons: Low Battery Time (45 min), Far off the ground (no direct testing, complex measurement algorithms with extra error), Subject to wind and weather, Does not work well under trees or in foliage. |
| Could you apply this existing design concept in your project? What are the limitations of applying this existing design concept to your design problem? Could it be adapted? (/1 points) | Our robot could draw inspiration to how the DJI Mavic 3 navigates around obstacles, where it follows a predetermined path but senses obstacles along the way and navigates around them. This design also includes more of a stretch goal where we consider what we should be able to support in our design. In our user interviews, John Sanchez and Cody Zesiger expressed an interest in robots eventually being able to do repetitive tasks like active monitoring of crops, which this design accomplishes. By analyzing the strategies in which the DJI Mavic 3 maps the terrain and senses foliage, we may be able to replicate their detection techniques. |

***Concept 3 (/5 points)***

| What is the design concept? Describe in 1-2 sentences. (/1 point) | Boston Dynamics’ Spot is a high-end industrial robot, meant for surveying. It has modules for advanced sensor packages or manipulators to further extend its functionality.  https://bostondynamics.com/products/spot/ |
| --- | --- |
| How is the existing design concept relevant to your design challenge? (/1 point) | Spot is one of the best quadrupeds on the market. Its performance specifications are the peak of what we could hope to achieve. In particular, their system for mounting additional sensors or manipulators could provide inspiration for our design. |
| How does the existing concept work? Provide photos or sketches to explain how this concept works. (/1 point) | Spot uses 12 servo motors for movement. It has a camera array for navigation with optional lidar modules for mapping or enhanced navigation. |
| What are the pros/cons of this existing design solution? (/1 point) | Pros: Extremely capable, excellent battery life, module expansion system, autonomous charging system  Cons: Much larger than our design, extremely expensive (> $70000) |
| Could you apply this existing design concept in your project? What are the limitations of applying this existing design concept to your design problem? Could it be adapted? (/1 points) | The module system’s ability to support both manipulators and sensors provides us some guidance on the kind of connector we would want to use for our own design. We would be unable to take much inspiration from the modules themselves, however, as they are for a general purpose audience while our target is much more specific. The charging system could also be worth researching. |

***Concept 4 (/5 points)***

| What is the design concept? Describe in 1-2 sentences. (/1 point) | The design concept for this robot is performing inspections from the ground.  https://www.anybotics.com/robotics/anymal/ |
| --- | --- |
| How is the existing design concept relevant to your design challenge? (/1 point) | ANYmal is an autonomous quadruped robot designed for demanding environments. This robot is equipped with a wide variety of sensors including visual and thermal cameras, an ultrasonic microphone, a lidar scanner, etc. with the capability to carry additional, modular sensors. One of the main goals of this robot is to do inspections from the ground, which makes this robot very relevant to our design challenge. |
| How does the existing concept work? Provide photos or sketches to explain how this concept works. (/1 point) | ANYmal is designed to handle and navigate demanding environments such as this wet and bumpy terrain or stairs in the photos below using various sensors and AI-integrated control systems.      In the photo below, ANYmal is performing Inspections using its unique mobility to get low and under the objects it’s inspecting. |
| What are the pros/cons of this existing design solution? (/1 point) | Pros: its toughness, navigation skills, autonomy, unique mobility, sensors, payload capacity, battery life, and the fact that it can go into environments that might be dangerous for humans.  Cons: the complexity and the many possibilities for something to go wrong. Many quadruped robots like this today can handle extreme environments and situations, but can still fail due to unexpected factors. Additionally, this robot has a relatively short battery life of 90 minutes. |
| Could you apply this existing design concept in your project? What are the limitations of applying this existing design concept to your design problem? Could it be adapted? (/1 points) | Given enough time we would be able to implement the design concepts from the ANImal into our project. The main limitations of applying this existing design concept to your design problem are the complexity and budget. This robot is very complex, especially when it comes to its AI-integrated navigation and control systems. ANYmal is also very expensive, around $150,000, well over our budget for this project. |

***Concept 5 (/5 points)***

| What is the design concept? Describe in 1-2 sentences. (/1 point) | This design is very similar to the open dynamic project. It is an open source project which aims at creating an even smaller and cheaper option than our chosen concept.  https://github.com/Yerbert/DingoQuadruped |
| --- | --- |
| How is the existing design concept relevant to your design challenge? (/1 point) | This design is relevant because it is a quadruped robot which can be built at home using github repository and 3-D printer. |
| How does the existing concept work? Provide photos or sketches to explain how this concept works. (/1 point) | The Dingo robot is run by a Raspberry Pi running ROS1. It uses the stanford pupper and the notspot code bases. It uses servo motors as opposed to the high power UAV + encoder actuators that the open dynamic project uses.      The robot can be controlled using a PS4 gaming controller. |
| What are the pros/cons of this existing design solution? (/1 point) | Pros: Very cheap, good documentation including full bill of materials, no tether by design.  Cons: Less powerful motors, shorter legs, doesn’t run ROS2, less processing power. |
| Could you apply this existing design concept in your project? What are the limitations of applying this existing design concept to your design problem? Could it be adapted? (/1 points) | This project could accomplish most of the design goals of our project. Since our sponsor requires the robot to run ROS2, we can’t simply switch to this design. To adapt the code repositories to ROS2 is possible but not within the timeframe we have and with the skills of our team. |

1. Translate User Needs into Engineering Design Specifications (/50 points)
2. **List user needs** (/5 points)
3. Robust against weather and field conditions
   1. Temperature resistance
   2. Water tight
   3. Mud/snow navigation
4. Doesn’t get itself stuck in crops, holes, mud
   1. Ask it to do a thing, it figures out the specifics
5. Capable of avoiding crop damage
6. Relatively simple command system
7. Sufficiently long battery life or ability to pause task and charge itself, user should not have to worry about charge
8. Priced under $10k for given functionality
9. Modular Functionality – a mount for sensors or tools
   1. Outside of scope but something to leave room for on our chassis design for future projects
10. Wireless data submission system
11. **Identify engineering metrics** (/15 points)

| Metric # | Customer Needs # | Metric | Units |
| --- | --- | --- | --- |
| 1 | 6 | Cost of the robot | $ |
| 2 | 1 | Robustness and strength of the robot chassis materials | Lbs |
| 3 | 5 | Robot runtime while all motors are moving | hr |
| 4 | 2 | Response Time | ms |
| 5 | 8 | Wireless Delivery | Hz |
| 6 | 7 | Option to add modularity to the robot | #nodes |
| 7 | 1 | Accuracy of inertial measurement | mgs |
| 8 | 8 | Radio receiver range | ft |

1. **Assign Target Specification Values** (/20 points)

Assign numerical values for each of the metrics. These values should be based on information from existing concepts (i.e. benchmarking), input from technical experts, users, and project sponsors, analysis, direct testing when possible, or relevant engineering standards (see below). At this point in your project, some of them may be best guesses. But as your project progresses, the number of “guesses” should be reduced.

Below the table include a paragraph explaining your metrics and the associated value (e.g. convince the teaching team that the metrics will be a good measure of whether your design meets the required user needs).

| Metric # | Customer Needs # | Metric | Units | Value |
| --- | --- | --- | --- | --- |
| 1 | 6 | Cost of the robot | $ | <7000 |
| 2 | 1 | Robustness and strength of the robot chassis materials | Lbs | >1.5 \* weight |
| 3 | 5 | Robot runtime while all motors are moving | hr | 1-2 |
| 4 | 2 | Response Time | ms | 1-10 |
| 5 | 8 | Wireless Delivery | Hz | 1000 |
| 6 | 7 | Option to add modularity to the robot | #nodes | 2 |
| 7 | 1 | Accuracy of inertial measurement | mgs | 0.1-1 |
| 8 | 8 | Radio receiver range | ft | >1000 |

As for justification for the above targeted metrics, the project’s current budget is currently for $6000 but there is an option to go a little higher if we really need to as this is a priority for the research labs. However, if the budget goes over $7000 then we are doing something wrong as one of the big reasons for this project is to be able to do it cheaper than Unitree’s $25000 software available robot. Unitree makes their robotic quadruped for $1600 without being able to access the open software. It should be comparable in size and use similar components, but we can't get the cost as low as Unitree’s because we are unable to take advantage of economies of scale.

The robustness of the robot should be to the point where the chassis of the robot should be able to withstand 1.5 \* the weight of the robot itself. This should be enough to withstand a small fall without cracking. The robot should be able to move a decent distance to survey, take samples, or do other tasks. We were recommended by our end users to give it enough battery to go 1-2 hours without recharging.

The response time of 1-10ms was chosen to give the robot the sufficient reaction time to react and adapt to obstacles or problems. The better the inertial measurement unit the better and smoother the robot will perform. However, the better IMU will bring costs up for the robot which should be as low as possible. So an accuracy of .1-1 mgs is the most reasonable range. An end goal for the robot in future iterations is to have it be told tasks or commands remotely and then to be able to execute. That is why it should be able to give/receive commands 1000 ft away from the nearest transmitter.

1. **Identify Relevant Standards** (/10 points)

<https://compass.astm.org/document/?contentCode=ISO%7CISO%204254-1%3A2013%7Cen-US>

One standard that is applicable to our project is the ISO standard for agricultural machinery. It is used for self propelled machines of various types, which our project falls under. This standard, among other things, influences the second metric we identified. It states that the mechanical supports on the robot (in this case, the legs) should be able to support 1.5 times the target load. Other specifications in this standard we would want to consider are electrical system specifications, which suggest our electrical cables should be abrasion and fluid resistant; emergency stop system, which requires that there be some accessible emergency stop button; and automatic operation modes should include a stop function if the robot is interrupted on its path.

<https://www.fda.gov/media/107298/download>

The second standards are from the FDA and apply to machinery or tools likely to touch food crops. This will inform our design in that we need to be able to clean the robot. We don’t anticipate this changing any of our metrics.

“You must ensure that appropriate measures are taken to use equipment and tools that are of adequate design and construction to enable adequate cleaning and maintenance and prevent contamination of covered produce and food contact surfaces including, for example, appropriate storage, maintenance and cleaning of equipment, tools, instruments (including transport equipment) and building structures. (21 CFR 112.123)

Equipment and tools include those that are intended to, or likely to, contact covered produce. Examples include knives, mechanical harvesters, cooling equipment, grading belts, dump tanks, and vehicles or other equipment for transport. (21 CFR 112.121)”