Case Study

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Introduction:

Considering a problem where a mobilized robot that has a single 6-dof arm, a camera for vision, sensors to detect obstacles and collisions, 4 smooth-bearing tires for movement, which loses traction on rough surface, such as wood chipping, and remnants of harsh weather, camera that is not accurate, where the robot tends to end several inches from it's intended mark, collides into objects that are not in the view of the camera. I am trying to solve these issues suggesting new features or improvements on existing systems.

Methodology:

1.0 Focusing on how the Robot can handle multiple types of surfaces.

- **Why Selecting Smooth-Bearing Tires for Movements?**
  - Low Friction
  - Silent Operation
  - Maneuverability
  - Simple Maintenance
  - Cost
- **Considered Tires.**
  - All-Terrain Rubber Tires (Non-Pneumatic)
  - Tracked System (Treads)
  - Lugged Pneumatic Tires (with Rubber Spikes)

1. **All-Terrain Rubber Tires (Non-Pneumatic)**
   a. Good for outdoor, have a durable rubber with deep treads for grip, low maintenance (no air pressure), moderate shock absorption.
   b. Traction might not be good for very loose surfaces.
   c. Can cost up to $15-$60 per wheel.
2. **Tracked System (Treads)**
   a. Have a good traction and stability.

b. Even weight distribution, will be good for supporting the robotic arm while lifting.
c. Can be complex, because of it might need tensioners, more motors or gearboxes.
d. Tires will be heavy, high-power consumption
e. Can cost up to $100-$100 per side
f. Won't be productive and lose of time when the robot tries to have a U-turn or a side turn as the tracks are not flexible.

3. **Lugged Pneumatic Tires (With Rubber Spikes)**
    a. Aggressive treads or Spikes bite into soft terrain.
    b. Might not be good for concrete, tiles and indoor types of floors (assuming the robot might be needed for indoors).
    c. Not generally good for icy surfaces, can slide instead of gripping.
    d. Won't generate enough friction to prevent skidding because of the spikes.
    e. Can cost between $15-$50 per wheel.

- **Selected Tire.**
    - **Foam-Filled Pneumatic Look Tires (Non-Pneumatic)**
        - Shock Absorption: Better, because foam acts like air, providing some cushion
        - Traction: Better, especially with aggressive tread
        - Puncture Resistance: Excellent as it doesn't have air but only foam inside.
        - Durability: High
        - Comfort for Arm: Better shock absorption where it can protect arm.
        - Can cost around $32-$150+
        - Can be costly, but can withhold a lot, and can withstand most of the surfaces.

While this is more expensive than smooth-bearing or standard rubber tires, foam-filled tires are low-maintenance, durable, and resilient to punctures, which saves time and repair cost in the long run.

2.0 Focusing on how we can improve the vision for greater accuracy.

- **Analyzing.**
  - Why does the robot need Camera, is it only for detecting the localization or can it be used for detecting objects for the arm to pick?
  - If it is also for detecting objects other than only localization, why is the camera mounted on the base?
- **Finding Solution:**
  - For the problem improving vision for accuracy for navigation, first we can mount the camera to an elevated mast. This can reduce occlusion and can give a better perspective.
  - We can consider the type of camera, like Standard RGB Camera, Stereo Camera, Depth Camera, but the price increases per type, for instance \$10-\$100, \$150-\$700, \$150-\$600. Also, this will cost more as we might need 4 cameras for each side.
  - Just for finding the accuracy of inches from the intended mark, it won't be productive to get a camera type that cost more, as the robot already uses sensors to detect obstacles and collisions.
  - The sensors can be:
    - LiDAR
    - IR
    - Stereo Cameras/Depth Cameras
    - Etc.….
  - Using these sensors, we can get the information and can identify the location of where the robot is and confirm if the robot is on it's intended location.
  - Because it mentioned intended mark, if that's a regular, or more often place the robot visits, we can use a QR, and projective geometry/data from the sensors (LiDAR based SLAM, Visual SLAM, etc..) to understand how far away the robot is from the intended mark.
  - Calibrate the camera, as it is important and can play a big part.

I chose the less expensive approach, because just to find only the distance of inches, we can approach by various of other options/technologies by saving money.

3.0 Focusing on how we can improve the collision.

- **Why is it colliding even after the robot have sensors for detecting collision and obstacles?**
  - Sensors are not well-placed?
  - Sensor Data isn't integrated properly (Software Issue)?
  - Poor Reaction Time/Delay?
  - Thresholds are too loose?
  - The Robot Ignores Loose/Dynamic object?
- **Solutions:**
  - Sensors might be too high, too narrow or too directional. Re-evaluation of sensor position is needed.
  - Needs to ensure coverage at multiple heights and angles, especially near the base where the robot is most likely to hit things.
  - Not be reading the data in real-time, so should program to read it real-time.
  - If there is a delay between obstacle detection and robot motion adjustment, the robot may still bump into things, so we need to ensure a control loop is running in a faster Hz.
  - Implement environment tracking or map updating.
  - Combine with vision, LiDAR or other sensors together to detect dynamic changes.
  - Needs to run diagnostics
  - Replace or reconfigure faulty units
  - Apply machine learning based obstacle recognition for uncertain or cluttered environments.

Short Answers (Detailed Explained above):

1. I believe improving the design of the original machine would be good, as there are only technical, misplacing of sensors has been understood or assumed but a fault of the original robot's design has not been found, other than some removeable parts from the design.
2. Can use Foam-Filled Pneumatic Look Tires, as it has more advantages when working on rough surfaces, and on uneven grounds. Also, it has good life and low maintenance.

3. Vision accuracy can be improved by calibrating the camera, fetching other sensors data and making sure where the robot is currently present and where it needs to go.
4. Because it is colliding on loose objects, which can be a new object that appeared after mapping or a falling real-time, the sensors need to be checked frequently, get real-time data, have camera on base as that is where the collisions can happen often.
5. I chose to improve the existing design, and I took this path because it feels more cost effective, productive, have life more than the older model. As I have thought about the entire robot system and how can behave for each part that we are adding it to the robot and how it can take and how advantages will it be for the robot. For instance, took Foam-Filled Pneumatic Look Tires, where it can absorb more shock, comfort for arm as it moves, as the arm might have sensitive parts. I considered why the older model is designed in such a way and what considerations may have led to that design choice and what I can offer in the new design that will have the advantages of the older model but with more advantages.