e-Yantra Robotics Competition

e-YRC#211-WD

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Requirements (10)

State the requirements for building the system of the theme assigned to you.

We need three basic hardware requirements to perform the task assigned in the theme. These are

1. **To build a sensor assembly to detect the weed from the plants**

   We are provided with 2 SHARP sensors and 8 IR proximity sensors. We have to make a proper arrangement of these available sensors so that we can differentiate between weed and plant without any ambiguity. All these sensors have a transmitter and a receiver. Now the range of SHARP sensor is higher and range of IR proximity sensors is smaller (below 10 cm), hence the sensor position is governed by the IR proximity sensor primarily. So we need a mechanical structure to accommodate the sensors in a proper position, at proper height from ground, at proper distance from weed, in a proper angle with respect to vertical and horizontal plane and in a proper alignment with respect to each other. And above all, this assembly has to be mounted on the FIRE BIRD-V such that the overall weight distribution remains symmetric. So we use this structure mentioned below.

2. **To build an gripper mechanism to uproot the weed**

   To make an actuator, we are provided with servo motors. We have to make a mechanical structure that serves the purpose of a gripper. In order to make a gripper, we use double four arms mechanisms with hinge joint. The part of these four arms is made of wood, fiber sheet, ply-wood as they are cheap, light in weight and mechanically rigid. We use gel-pen refill as shaft of gear and hinge joint. Two of these four arms are coupled with a plastic gear. One of those plastic gears is directly driven by a servo motor and this gear drive the other gear.

   We also have to make a mechanical structure to provide a degree of freedom to the gripper, so we have to design an arm which is mounted directly on the FIRE BIRD V. The gripper assembly is connected in the arm through the second servo motor. Now the gripper arm mechanism can move upto 180 degrees with respect to its initial position. This mechanism will help to uproot the weed and deposit in a temporary container attached with the robot.

3. **To collect the uprooted weed and deposit in the deposit zone we have to make an container**

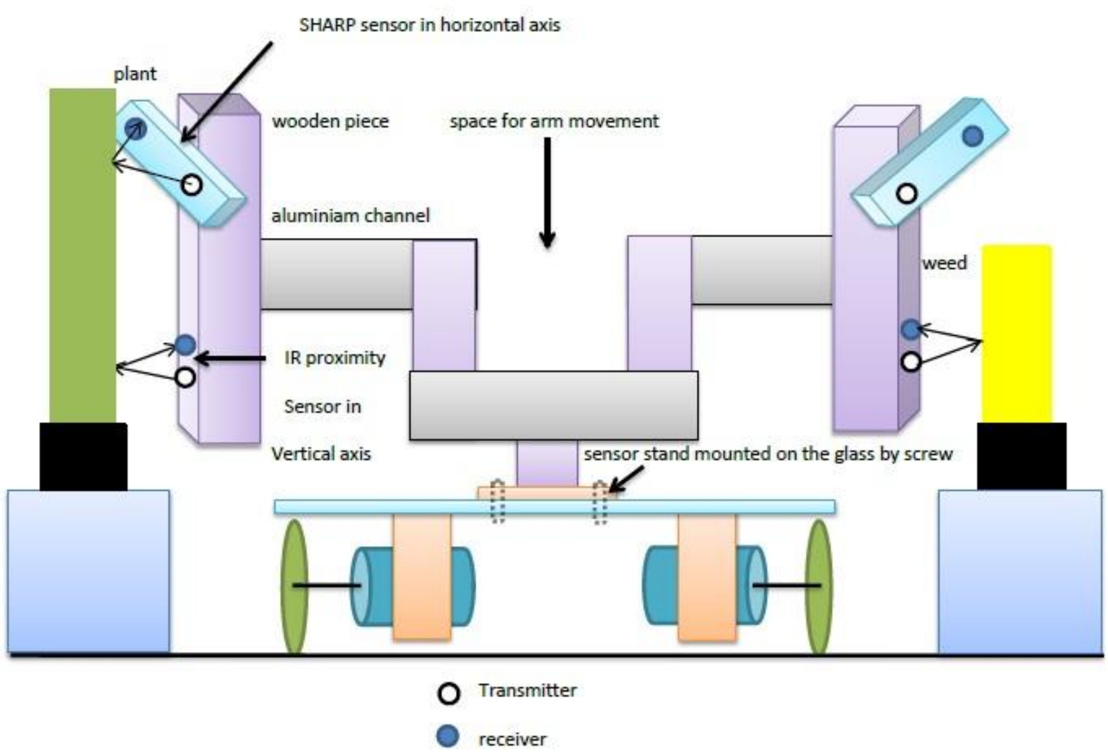
Now according to our design, arm-gripper mechanism can rotate from its zero position at back to maximum of 180 degrees to front. When it rotates back 180 degrees, it comes to the back of the robot. This is where we place our container for collecting uprooted weeds. The container has a door mechanism to drop uprooted weeds when the robot reaches a deposition zone.

Design Constraints (10)

Identify the major design constraints in the robotic system.

To successful implement the theme, we had to take into consideration a number of design constraints. They are illustrated below:-

1) For the development of the sensing mechanism, the IR proximity sensors and sharp sensors are used. Now, as the measuring range of the IR proximity sensors is small (much less than that of sharp sensors), it imposes serious constraints on the design. Considering the fact that we have to complete the task in shortest possible time, we have to scan both sides of the path simultaneously. So we make a vertical link containing an analog IR sensor at the bottom and a sharp sensor at the top. There are two such links – one on each side of the robot so that the bottom IR sensor can detect any obstacle (be it plant or weed), and the top IR sensor can detect only plant, not weed. A weed is confirmed when the bottom IR sensor goes high but the top Sharp sensor remains low. The final sensor configuration is as shown below:-



2) Number of servo motors supplied to us is two. However, based on our design, we needed an extra motor to operate the container door since the two servos supplied were being used for the actuator arm and the gripper. The degree of freedom of the actuator arm is kept only in the vertical plane for uprooting the weeds. The gripper consists of two spur gears (one being driver and the other driven) connected to mechanical wooden plates to develop the end effector. It grips only in the horizontal plane. The design of the actuator and gripper had to be kept such that the gripping plates always landed with the weed in between. For this, the initial spacing between the open gripper plates had to optimized to ensure

minimum error in weed uprooting. Regarding the container, the major constraint was to decide its inclination. Care had to be taken such that when the robot rotated towards the trough to uproot the weed, the container at the back did not collide with the opposite trough. The door mechanism of the container operated by the third servo motor had to open and close only in the vertical plane since rotation in the horizontal plane resulted in collision with ground.

3) Line following for our theme is the basic scheme of navigation of the robot. We used proportional control algorithm to change the velocity of the motors accordingly to follow the black line. Since we had to complete the task in minimum possible time, it was obvious to increase the locomotion speed of the robot. However, the analog IR sensors used have a slow response time. If robot operated too fast, the sensors did not respond accordingly. Hence, robot velocity for forward motion and corrective action had to be optimized specific to sensor responses.

4) The DC motors used for locomotion have inherent limitations. When the software command to rotate left by 90 degrees was given, it sometimes rotated by more than 90 degrees and sometimes lesser. This was probably due to varying levels of charge in the NiMH battery pack of the robot. So for rotational motion, the values provided in the algorithm had to be experimentally calibrated from time to time.

5) We faced difficulty when we tried to implement parallel operation of two servo motors as excessive loading resulted in surges and led to stalling of motors. Surge also occurred when natural movement of motors is restricted and motors tried to develop high torque to overcome the obstruction. Protecting measures in terms of software were taken by freeing servo motors when idle by providing 100 % duty cycle to them.

6) We tried to make the process of uprooting and depositing weeds faster by decreasing the delay during the process of rotation of servo motors but it had to be more than a certain value to ensure smooth operation of the motor. For example, when delay of 1 millisecond was given between rotation from one angular position to the next angular position, the motors failed to operate. When this delay was increased to 3 milliseconds, the servo motors operated smoothly.

7) The thresholds of the white line, IR and Sharp sensors varied according to illumination levels present in the arena. During daytime, there was a lot of ambient light which interfered with sensors and drastically brought down thresholds leading to unexpected responses. At night, situation was better and hence we preferred to do our trial runs at night.

Challenges (10)

Identify the key challenges faced during the development of the robotic system (hardware/software) and how each of those problems was solved.

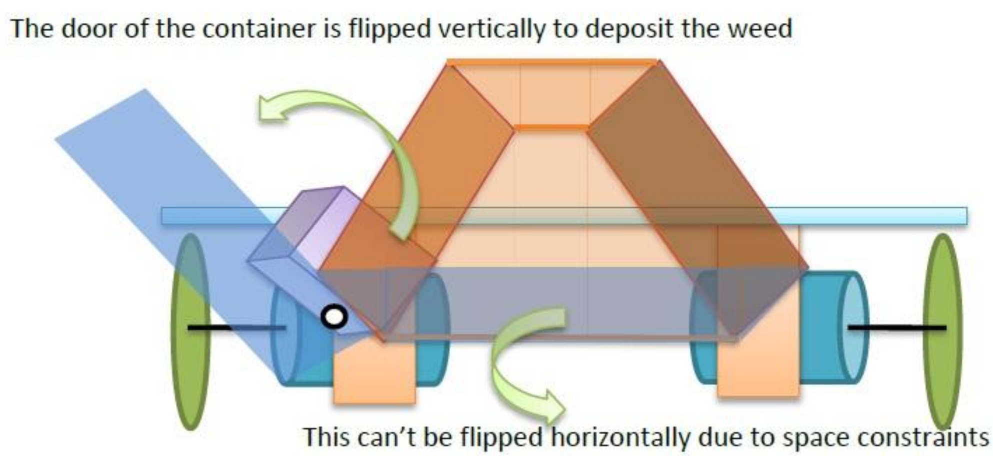
1. The analog IR proximity sensors are very delicate and have very poor sensitivity, so special care had been taken while de-soldering them from the robot PCB. We use vero-board as the alternate of PCB to accommodate these IR proximity sensors. The IR proximity sensors have maximum range of upto 10 cm, so we have to place these sensors with the help of a special structure within that range from the weed to work successfully.

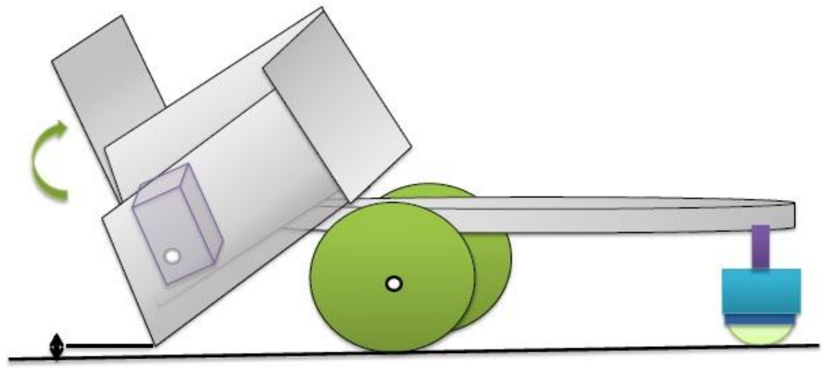
2. To solve the sensitivity problem, we decided to make an extension arm to keep the weed within the working range of IR proximity sensors. But the challenge was to design such an extension from the robot body so that it does not collide with weed or plant during navigation. So we optimized between range of sensors and safe distance from obstacle, thus selecting distance of 5 cm of the extension arm from the weed or the plant.

3. The glass cover of the FIRE BIRD V does not have much space. Since we had to mount arm-gripper assembly, sensor assembly as well as weed container in the upper surface of the glass cover, we faced a space crunch. This problem has been overcome by putting the gripper in front, the sensor assembly on the sides and weed container at back of the robot.

4. To deposit a weed in the deposition zone, the container is made inclined to make sure that when the door will open, all the uprooted weeds will fall automatically. However cases have been encountered where one or more weeds do not completely fall on the ground, i.e, while one end of the weed touches the ground, the other end still remains on the container. Such a situation hinders the normal closing of the container door and results in stall torques to the associated servo motor. To prevent such instances, the robot is moved forward by sufficient distance before the door is closed to ensure that all weeds drop completely on the ground.

5. As inclined container is needed, we also had to make sure that the container does not touch the ground while moving the robot. The door can't be opened in the horizontal axis as it collides with the ground so we design to open the door in a vertical plane. This has been illustrated below:-



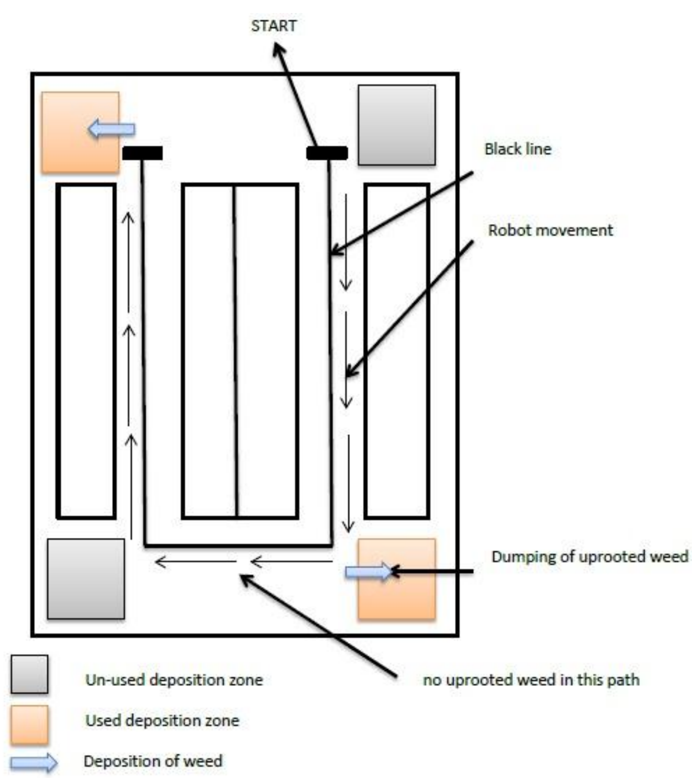


In sufficient space to flip the door horizontally

6. Another challenge that we faced regarding container is that when the robot uprooted some weeds, the container got heavy and the door, which was preliminarily connected with container through the servo motor, got loosened and consequently detached from the container. So we had to make a guide to provide some extra mechanical support so that it does not detach from the container.

7. The gripper is made of ply-wood which is smooth enough and the weed is made of wood. Problem arises when the weed gets loosened from the gripper plates due to smooth surfaces. So we use rubber coating in gripper to provide extra friction to stop it from getting loose even when uprooted at a higher speed.

8. When the robot crosses the portion of the black line between the first and second right turn junctions, no weeds or plants are supposed to be detected. However, some plant or weed near upper edges of trough 2 or 3 may get sensed by the sensors on right side of the extension arm which has to be avoided. So appropriate count of right turns undertaken is recorded by the software program and when the count is 1 (just after first right turn), the sensing mechanism is temporarily disabled.



9. Since we deposit weeds only in the 2nd and 4th deposition zones, we need to stop the robot from invoking the deposition routine when it undertakes the second right turn at the second junction near the third deposition zone. This is a software challenge and was tackled by using a boolean variable that keeps track of whether any weed has been uprooted after the previous deposition. Since the black line stretch between deposition zones 2 and 3 does not have any weed, the above boolean variable evaluates false and hence deposition zone 3 is skipped.