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Integrated System:

Nomad X-RT consists of a robust carbon steel platform with a spring suspension system, four large all terrain pneumatic tires, four Entstort 12 volt DC high torque drive motors, troubleshooting LED's, a deep cycle battery, four ultrasonic sensors, a Raspberry Pi microcomputer, an Arduino Uno microcontroller, two 12 amp dual motor drivers, a GPS module, and a magnetometer. The ultrasonic sensors scan the area in front of and peripheral to Nomad, to assist it in navigating obstacles. The GPS module and magnetometer provide heading and waypoints for guidance, and the high torque motors allow it to traverse rough terrain. The troubleshooting LED's are located at geometrically logical points on the platform, and connected to logic circuits to identify components are not receiving proper signal.

<ROBOT DIAGRAM HERE>

Mobile Platform:

Overview:

The Nomad X-RT platform is designed for rough terrain navigation. It uses 14 gauge carbon steel for a main plate and 11 gauge carbon steel for suspension arms. Compression springs connect the ends of the suspension arms to angled ends of the main plate, providing a flexible wheel base for traversing rough terrain. Four 10 inch wheels give the platform increased height for rough terrain applications, and are arranged in a rectangular fashion where the width of the wheel base is greater than its length.

Concept:

Nomad X-RT is intended to autonomously travel long distances using GPS guidance. Since "long distances" is rather ambiguous, and there is a high likelihood that varying terrains will be encountered, it is advantageous to have a robust platform that can withstand reasonably large applied loads. Aluminum or carbon fiber would be ideal materials for constructing the platform, due to their high strength to weight ratios, however carbon steel is used as a cheaper alternative to minimize costs.

The "main plate" refers to a 14 gauge, 20 inch by 10 inch plate of carbon steel that has two 15° downward angles, measured 4 inches inward from either 10 inch long side, and angled with respect to the horizontal plane given by the middle 10 inch by 8 inch section. The main plate is built to hold Nomad X-RT's battery and electronics, and serve as a mounting point for hinge connectors for the suspension arms.

<INSERT MAIN PLATE SCHEMATIC>

"Suspension arms" refers to four 11 gauge carbon steel pieces measured $7\frac{15}{16}$ inches long, with a maximum width of $2\frac{7}{8}$ inches and a minimum width of $1\frac{3}{4}$ inches. A set of three mounting holes arrayed with equal spacing around a shaft clearance hole is positioned at one end of each arm. These holes are centered $1\frac{3}{8}$ inches from the respective end, with the three arrayed mounting holes spaced 1 inch outward from the shaft clearance hole. The clearance hole is positioned in

the center of a $1\frac{3}{8}$ inch radius, which serves as a mounting surface for a wheel drive motor. A shaft clearance hole at the opposite end of each suspension arm allows them to be connected via barrel hinge to the main plate. A 2 inch tab attached to the motor mounting surface of each arm acts as an attachment point for the respective compression spring, which connects to an angled surface of the main plate. The suspension arm and compression spring system will allow wheel base articulation as Nomad X-RT traverses rough terrain.

<INSERT SUSPENSION ARM SCHEMATIC>

Actuation:

Drive Motors:

Four 12 volt DC Entstort motors drive the wheels on Nomad X-RT. Each motor is rated at 120 pound inches, providing sufficient torque for rough terrain navigation. One motor is attached to each suspension arm, and connected directly to the wheel via a shaft with a set screw. The motors are set back from the respective mounting surfaces by a 3D printed plastic bracket. This spacing reduces bending stresses on the motor shaft by forcing the suspension arm to bear more of the load, consequently extending the life of each motor.

Torque/Loading:

The 120 pound inch motors connect to 10 inch diameter wheels, allowing for a maximum of 24 pounds of applied force per wheel. This substantial amount of torque allows Nomad X-RT to carry a payload of about 50 pounds, if desired. It also enables it to climb large inclines and some obstacles, assuming it maintains sufficient traction.

<INSERT MOTOR PICTURE>

Sensors:

Implementation:

Nomad X-RT uses four ultrasonic sensors to detect obstacles. These sensors are arrayed at various angles to cover a wide field of view, and are activated and deactivated on different intervals in order to prevent signals from interfering with each other.

Layout:

Two sensors are mounted near the middle-front of the platform, and are angled away from each other at 90°. The other two are mounted on the front corners, and are angled inward at 30°. This setup allows a large area to be viewed, without scanning so large an area that the sonar beams risk missing an obstacle until it is very close.

<INSERT ULTRASONIC SENSOR LAYOUT>

Behaviors:

Navigation:

Nomad X-RT will orient itself facing towards a GPS coordinate, and drive until it detects an obstacle. It will then its peripheral sensors to see if the edge of the obstacle is nearby. If it sees that the obstacle terminates or is far away, it will angle toward the respective direction and travel until it thinks it has cleared the obstacle or encounters another. In order to determine if it has cleared an obstacle, Nomad will increasingly angle toward the waypoint, in the direction which the obstacle was encountered. A magnetometer will be used whenever GPS signal is lost or sufficiently weak, to help Nomad X-RT keep a general bearing and continue operating. Once GPS signal is reestablished, primary navigation will switch from the magnetometer back to the GPS module.

When Nomad reaches its destination, it will switch on an indicator LED, and activate its LCD interface while it awaits for a new waypoint. If a series of waypoints is set as a specific course, Nomad will blink an indicator LED as it passes each waypoint, and hold an indicator LED on once it reaches its final destination.

<NAVIGATION BEHAVIOR CHART HERE>

Troubleshooting:

Active high indicator LED's mounted to the corners of the main plate will turn off if signal is lost or interrupted to a motor, to inform an operator that an error has occurred and signal is lost. Another indicator LED will turn on only when GPS signal is acquired. A final pair of LED's will serve as heartbeats for the Raspberry Pi and Arduino microcontrollers, to notify an operator if an error has occurred in the controllers and signals are no longer being sent properly.

<LED LAYOUT DIAGRAM HERE>

<LED BEHAVIOR CHART HERE>

Experimental Layout Results:

Platform Concept Issue and Redesign:

Nomad X-RT was originally intended to use a 6 wheel with advanced articulating suspension to navigate extremely rough terrain and climb over large obstacles. The design incorporated left and right pivot bars that connected to the forward suspension arms. The front and middle wheels were attached to these pivot bars, according to their respective side. This setup would enable Nomad X-RT to climb over large obstacles by allowing the front wheel of each side to rise upward against an obstacle, while the middle and rear wheels maintained contact with the ground or other terrain. This design utilized the same skid steer maneuvering style that is present in the final concept, which actually became the reason it could not be used.

The skid steering concept is the same maneuvering concept used in tank track steering, where one side is made to drive forward or reverse, and the other driven opposite or at a slower speed. This steering concept may be implemented very simply with motors or gearboxes, and does not require any additional steering components (linkages, steering shafts, etc.). The main restriction is that the width of the wheel base must be equal to or greater than its length. This is required to minimize the resistance caused by the outer wheels or tracks (depending on traction/propulsion method) when the vehicle attempts to rotate about its center. While rotating about the center is not the most efficient method of turning, it has significant advantages in a confined area. In order to implement skid steering in the 6 wheel Nomad X-RT concept, the wheel base width would have needed to be at least 22 inches wide. This would give Nomad a maximum width of 25 inches, a maximum length of 32 inches, and a diagonal of 38.83 inches. Such a big length would make transporting the platform a cumbersome task, and demand additional support structure/considerations for the sheet metal main plate (which would increase its weight, thereby decreasing its load capacity). This concept was discarded in favor of the simpler four wheel design, which saves monetary cost, platform and electronics weight, battery life, and construction time.

Conclusion

Documentation

Appendices