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Intelligent Machines Design Lab EEL-5666

SkyRiser

First Formal Written Report

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Abstract

The goal of this project is to bring the time and cost saving advantages of mobile platforms to the construction site. The design calls for a mobile platform capable of locating the studs on a construction site and securing the sheetrock using anchor screws. To accomplish this task, the platform will need to be capable of: tracking along walls, raising itself to a number of vertical heights, avoiding obstacles, and drilling into the wall. For ease of control, the motion will be achieved using two motors mounted along a central axis. The wheels will be housed inside the platform to make wall following behaviors easier. The vertical lift will be accomplished using scissor lifts, lead screws or a combination on methods. Linear motion required to pull the lift closed and apply pressure to the drill will be provided through the use of rack and pinion assemblies. The robot will use a capacitance stud sensor to detect density differentials in the wall, and a motion detector to determine the location of nearby site workers. A combination of infrared and bump sensors will be employed towards the end of achieving wall following and obstacle avoidance behaviors. The value of a robot capable of meeting the goals laid out in this report would be substantial, allowing onsite construction projects, like the forty-eight currently in progress on campus, to be completed at considerable savings to cost and time.

Introduction

Computer numerically controlled (CNC) machining and stationary robotic arms have rapidly become staples of the construction and manufacturing industry. However autonomous tools have yet to become prevalent in this field limiting the ability of robotic agents to assist in on site assembly. The idea I have for my robotic platform is an autonomous construction stage. The specific goal of the design is to support building construction crews by anchoring wall paneling in place. The robot would be able to locate a stud and raise itself to sequentially drill a number of support screws into the wall.

Integrated System

The core processing power of my robot is the Atmel AVR MAVRIC-IIB, assembled and tested, Pin Headers, at a speed of 14.7456 MHz. The microcontroller will control all of the behaviors that my robot will emulate. The robot will also have an LCD screen to display important status updates, and operational warnings.

Mobile Platform

The mechanical design needs to allow for easy navigation throughout the environment and provide the capability to follow walls along the perimeter of rooms. For this reason I believe that a two wheel platform would be the best choice. The issue with this design will be the support and pressure needed to get the screw into the wall. Additionally, the design will need a mechanical means of lifting itself to provide a vertical line of support screws in the wall. One possible plan is that upon arriving at the designated location the robot will lift itself off the ground on extending legs. This rig could be extended and retracted to specific distances to provide an accurate height positioning system. Importantly the legs would offer a significant stability advantage over the two wheels used for motion. This should allow the drill sufficient leverage to force the screws into the wall. Lowering the legs to lift the body allows me to firmly secure the drill and screw feeding system in place on the assembly without having to worry about individually raising and lowering these components. A second possibility is the use of a scissor lift to raise the platform, which still allows me to firmly secure the drill assembly in place. However, as this plan would still leave the wheels as the only frictional points in contact with the ground, additional means of support will probably be needed. One simple solution either alone or in the addition of a lowered break or brace, is simply to have the wheel axis perpendicular to the motion of the drill going into the wall. This provides increased resistance to the reaction force of the wall pushing against the assembly. Another benefit of this wheel positioning is that after a stud is located during wall tracking the robot will not need to turn to drill the screws into the wall. To further assist in the wall following behavior so crucial to this robots successful operation, the wheels will be placed just inside the robots frame so that a smooth surface buts up against the wall.

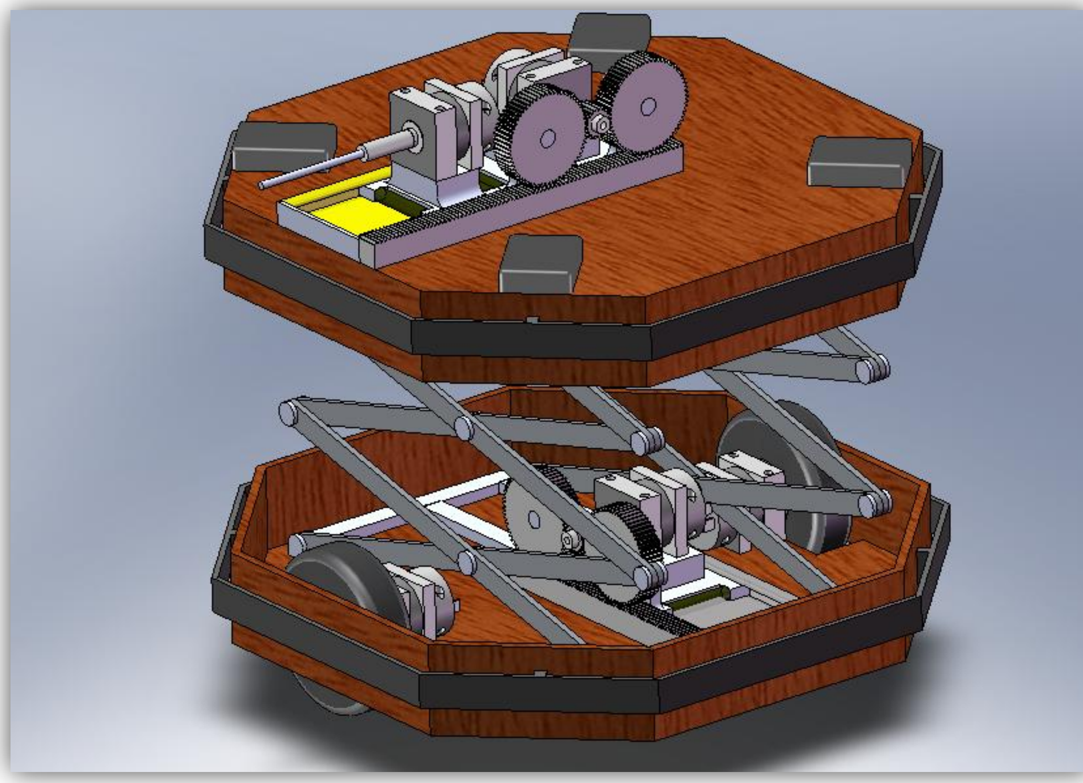

Figure 2.1 : SolidWorks Design Concept

Actuation

This design will require four specific types of actuation in order to complete its outlined objectives. First in order to achieve its wall following and generally mobility functions it will need a powered drive system. In order to simplify the programming of its motion, I have selected a two wheel system with the motors mounted along a central axis. This setup allows to robot to turn in place and eliminates the need for a dual differential drive train assembly.

Secondly the robot will need vertical lift in order to reach varying heights along the wall. At this time I am considering two types of lifting mechanisms and the final decision will be based on the tested success of each design. One option is to raise and lower the robot along lead screws positioned around the platform. While enough lead screws would create a sturdy setup, the draw backs of this design would be that speed would be severely limited. Another option would be the use of a scissor lift. This design would have the advantage of speed but perhaps create an unstable platform at the top. A possible solution to this problem, and one that will require further testing, is to mount three scissor lifts in varying formation or four in the shape of a square. The mechanical feasibility of these designs will also need to be tested. In order to accomplish this testing rapidly I plan to use a combination of smaller scale prototypes and SolidWorks finite element analysis software.

The design also requires linear motion, for both the drilling force into the wall and the pulling force necessary to raise the scissor lift. To achieve this motion I plan on using a rack and pinion assembly. This will effectively transfer the rotational motion of the selected electric motors into linear movement.

Finally, in order to actually drill the screws into the wall I will need a motor situated on one of the rack and pinion assemblies to provide rotation motion. This rotation does not have to be accurate per rotation, but the motor will need to have enough torque to not be stopped by the friction of the wood against the screw. To determine if the motor will have enough force I plan on comparing it to the torque provided by low end commercially available drills.

Sensors

One of the first tasks for this robot upon being introduced into an environment will be to find a wall so it can begin tracking and looking for studs. Additionally, while it's traveling around the room it will need to be able to avoid workers and other people in the area. To distinguish between walls and people I plan to use a motion/ heat sensor to detect and avoid people in the immediate area. This is particularly important because autonomously operating power tools in the vicinity of other people, even at low speeds, has a degree of risk involved.

I plan to use a combination of Infrared and bump sensors to detect the immediate surroundings for the use of obstacle avoidance and wall tracking. Bump sensors will also be employed as limit switches at the extreme ends of the rack and pinion assemblies. When the limit switch is triggered, the power to the pinion will be cut, halting further progress. Switches could also be employed at intervals along the rack and pinion assembly to let the microcontroller know when the scissor lift has reached specific heights, and therefore when to begin the drilling subroutine.

Particularly important and possibly functioning as my special sensor will be the stud finder. There are two types of stud finders to choose from using either capacitance or radar [1]. The first method uses an internal capacitor plate to detect changes in the dielectric constant of the wall as the finder moves over the surface of the wall [2]. The second method uses a small radar device to show exactly where the edge of the stud is behind the sheetrock [2]. I believe I can use one of the commercially available stud finders from a home improvement store by adapting it to work with the Atmel microcontroller. For this application the stud finder which uses a capacitance plate to detect density differentials would appear to be the best option. This is because this sensor locates the center of the stud, right where I would want to drill, as opposed to the edge which would require additional calculations for correct positioning.

Behaviors

The behaviors of this robot will be grouped into the two statuses of its operation. That is to say that it will behave in a certain way when the lift is retracted and it is moving around a room, and follow a separate set of rules once the lift is extended. While the lift is retracted, the robot functions as a mobile unit. Using the IR and bump sensors it will perform obstacle avoidance routines and move around the room searching for a wall to follow. If the motion detector detects people in this mode, it will be simply ignored as more basic obstacle avoidance parameters will be adhered to. Once in place along a wall it will have to turn to ensure that it is following along in the correct direction to keep both the drill and stud sensor aimed at the wall. During this wall following behavior, the stud sensor will be scanning the wall to determine the location of the studs.

If a stud is detected the robots second set of behaviors are activated. Now if the motion detector locates a person within the immediate vicinity the robots operation will be temporarily halted to prevent possible injury. The platform will then be raised to a number of predetermined heights, pausing at each level to activate the drill and linear slide in order to anchor the sheetrock into the stud. As mentioned in the discussion of sensors, these pre-determined eight levels could be determined by the placement of switches along the linear slide that closes the scissor lift. Upon attaching the screw at the highest level, the platform will collapse once more and resume its wall following behavior looking for another stud.

Experimental Layouts and Results

Prototyping experiments as well as finite element analysis will need to be conducted to determine the effectiveness of the scissor lift as opposed to lead screw designs. Specifically in regards to the arrangement of these devices with respect to one another.

Conclusion

The real value of a robot capable of meeting the goals laid out in this report would be substantial. Onsite construction projects, like the forty-eight currently in progress on campus, could be completed at considerable savings to cost and time.

References

[1] R. Berendsohn, 7 New Stud Finders Let You See Through Walls, Popular Mechanics, July 2004.

[2] How Stud Finders Work, www.howstuffworks.com, 2006.

Appendix