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Ceilbot in home environment

1. Possible tasks

The project started with brainstorming possible tasks in home environment. The tasks were divided into two sections, services and cleaning. Most of the services section tasks could be done with only the elephant's trunk manipulator or another similar solution. However, most of the cleaning tasks require additional modules for getting satisfactory results.

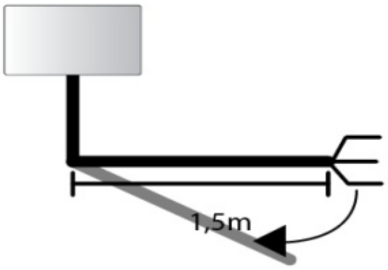
The first and most important service task for home environment robot is recognizing and moving objects. It includes bringing the user items that he wants that could be for example remote control, drinks and phone. The robot could also assist on meals by serving the table and afterwards putting the dishes into the dishwasher. Is needed, the robot could also empty the washer and put the dishes into closets. The manipulator could also be used for feeding animals, watering flowers and chancing the light pulps. Though, light pulps might be difficult to change with only a basic gripper manipulator. The robot could also do security tasks like monitoring house and alarming the police if intruders are detected.

Picture 1: Concept image.

There are many cleaning tasks in home and no-one really likes to do any of them. At the moment, there are no automatic products that could do multiple cleaning tasks, and the ceilbot could be a solution to this problem. The main cleaning tasks that the ceilbot could do in homes are arranging the house by taking dirty clothes into a hamper, arranging predetermined objet, vacuum cleaning, wiping dust from all surfaces and washing windows. For example, vacuum cleaning would definitely need another module in to the robot so the robot solution could be modular. In the modular robot solution the robot could take only needed parts to the task zones. The window cleaning task would definitely need water and this water could also be used to quell fires. In Home fires the most important moments are the first minutes so automatic solution could be the best way to save a house.

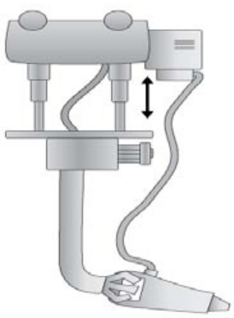
2. Required properties

There are many properties that are either useful or necessary for completing previously mentioned tasks. First, the robot manipulator must be very light and agile. Light manipulator is easier and faster to control when motor power is limited and lightness leaves also more room for payload. Agility is important because the manipulator must be able to avoid object and go around them, because the robot can't always get to right in front of the object with direct line of sight. The robot should also be able to reach all the places in the house including different rooms and all heights. Reaching all heights could cause stability problems to the manipulator, because rooms are quite high and torque can become quite large when reaching from long distances. The thought was that the minimum weight that the robot should be able to hold in position with stretched manipulator is 2 kg.



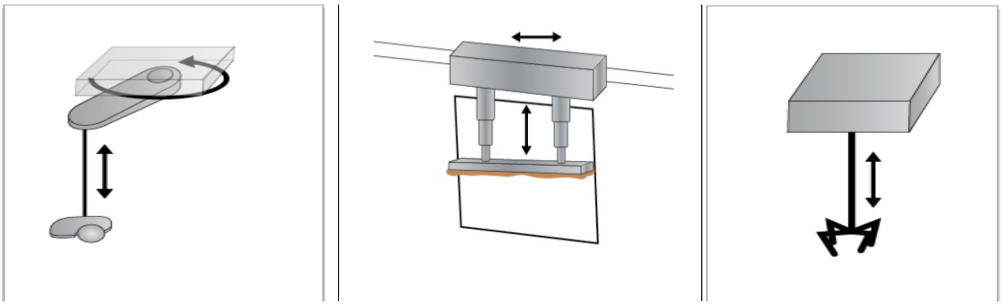
Picture 2: Torque challenge.

A solution for this torque problem could be telescopic extensions for the manipulator which makes it possible to get closer to the heights that are required and so making the manipulator shorter and more stabile.



Picture 3: Sketch of ceilbot including the telescopic solution.

In this phase there was also consideration for simple solutions, but they were dismissed for their lack adaptability.



Pictures 4, 5 and 6: Vacuum cleaner, window washer and crane.

3. User interface

The robot should have a wireless system installed so it may be accessed from computer for updates and instructions. Computers may also be used to relay information from for example web-based applications. The Robot should also be programmable for all users so the applications should be very simple. The best main interface for the robot would probably be voice control. When there is already wireless system installed it is easy to add notes for voice control to all the rooms so even if the robot is not in the same room it can hear commands. There should always be some redundancy so a remote control with a joystick could also be used to operate the robot and the manipulator. the Robot should also be able to interact while performing tasks so for example when facing multiple choices it could ask from the user what to do and the user could respond by voice control or by pointing to the right solution. The wireless system could also use some standard so it could be integrated with other home automation systems.

4. Sensors

The robot should be able to detect and recognize object so it needs sensors. Sensors weight quite much so the most convenient place for installation would be the body but that also causes problems for visibility to the manipulator and so also controlling of the manipulator. Sensors are also quite expensive, but the minimum requirement won’t be covered with less than laser scanners and camera. These sensors could also be used together to make 3 dimensional maps of rooms.

The camera main uses would be in the area of identification. The camera should be able to identify some preprogrammed objects and identification stickers. The identification stickers could be used to mark object that are not preprogrammed or are in use for a short while only. Color identification should also be implemented so user could use commands like: “bring me the red blouse”. Camera could also be used to identify where user points so the robot could get direction of the object.

The main uses of laser-scanner would be position finding and helping the gripper. Laser can be used for finding the exact position of the robot if the rooms are mapped by simply comparing reading from the scanner and the room’s shapes. It would be useful to install the laser on the manipulator because it would have better synchronization and visibility for gripper actions, but weight could become an issue. Position could also be handled with optical scans from the rails, which would have predetermined patterns. Another optional technology for implementation could be RFID. With

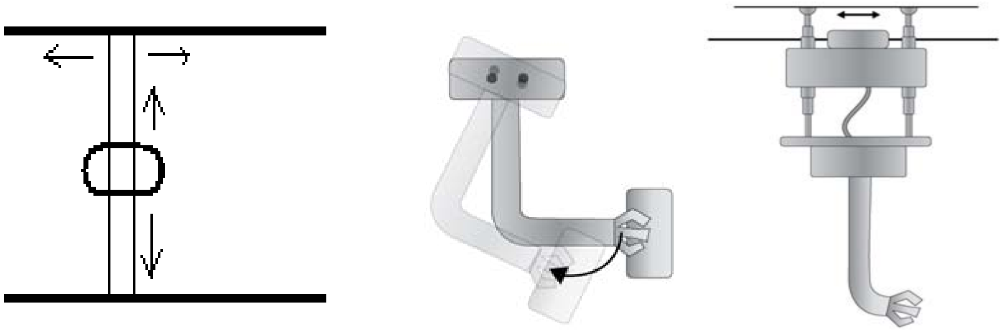
RFID technology objects could be tagged and it would be easier for the robot to find those objects. In the future when the RFID has become more common, it could have more uses, because for example food products could be tagged already on stores.

5. Safety issues

If the robot is to work and interact with humans, it must be safe. The greatest safety threat comes from collisions and squeezing so they must be avoided. Methods for avoiding could be camera and laser recognition and route planning. TTY has already made studies that cameras can be used to detect humans. When humans are detected the robot could make safety zones around them and act accordingly. Laser could mainly be used for adaptive mapping of objects and also recognizing blockades. Route planning could be used as a preventive measure. When humans are in the work area the robot would choose route that most likely won't have humans or dangerous crossings.
When collisions do happen it is important to minimize damage. The basic methods are force-feedback recognition and a good safety protocol. Force-feedback would be essential in recognizing collision, because it is the only way of doing it in real-time. Jamming recognition should also be used for driving motors, so if the robots position won't change when driving it knows it might have collided. Safety protocol is essential because the robot can't just go offline in collision. The robot should be able to actively make safe decisions in collisions and so actively defuse possibly dangerous situations. The robots are also the safer the lighter, because lighter robots don't have as much momentum, and they don't need as powerful actuators.
Safety should also be included when thinking wireless protocol. Wireless protocol should be redundant and reliable which makes protocol designed for wireless automation prime candidates. The gripper of the robot must also be secure, so the robot won't stop anything heavy on people or other objects. Safety should also have its own thread in the program that could use for example some already available danger assessment model.

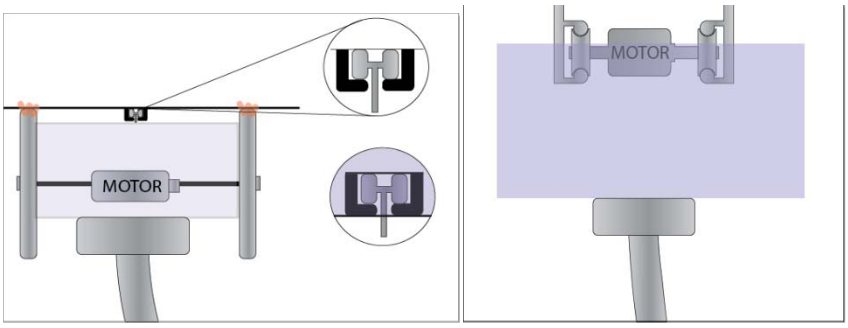
6. Attachment to the ceiling

First there were two possibilities, robot hanging by wires which would be attached to the walls by railings and robot hanging from a rail on the ceiling. The wire solution was dismissed for home environments because it couldn't change rooms and it would have stability problems. The stability problem would have a solution but it would further complicate the system.



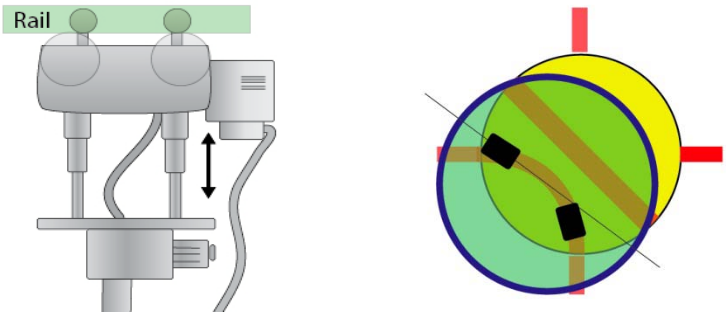
Pictures 7, 8 and 9: Wire solution, stability issue and solution to it.

The railing solution was selected because it didn’t have these issues. The only advantage that the other solution would have had was speed. There is still issue of how the robot would move on the railings. The possibilities are drawing wheels on rails and drawing wheels touching the ceiling. The advantage on the first solution would be that there is plenty of friction, because the robots mass lies on them. The disadvantage is that it would make attachment to the railing more complicated, because they are also used for power. The wheels that touch the roof should still be there even if the drawing wheels are on the rails, because they would make robot more stabile. There were also considerations for stabilizing rails, but they would most likely be too large and unesthetic. The rails could also be implemented two ways, on the ceiling and inside the ceiling. Rails on the ceiling would be easier and would fit to more houses, but rails inside the ceiling would be more durable and esthetic.



Pictures 10 and 11: Drawing wheels on ceiling, different rail solutions and stabilizing rails.

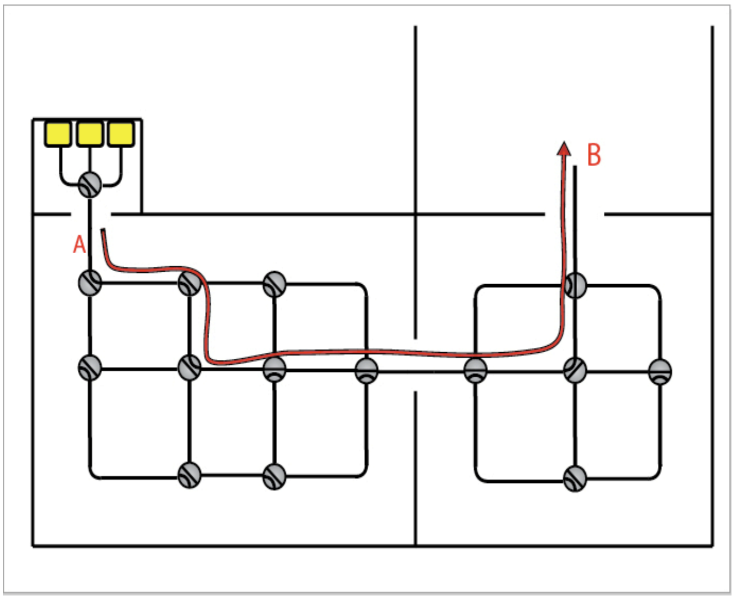
The number of wheels also causes some considerations. If the robot would use two driving wheels, it would be more stable and safer, but it would also have problems with tight corners. Advantages of one driving wheel include also that the supporting structure can be made simpler.



Pictures 12 and 13: Two driving wheels and tight corner.

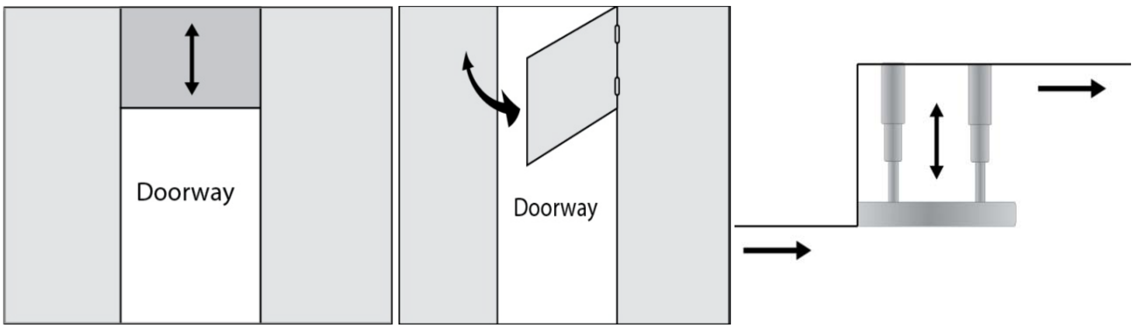
7. Railing structure

The basic railing structure would consist of three different parts, straight, corner and turntable. With the use of these parts, extensive net that covers the whole house, can be made. The turn tables should have wireless access so they could be turned to right positions for preplanned routes.



Picture 14: Railing example. Yellows are module platforms.

With the railway solution there is also issue with the doorway passes and level changes. The doorway arches should be made passable for the robot and there are three possible solutions, rising arch, turning arch and whole in the arch. The Rising arch would be hardest to build, but it would fastest and most stylish. The turning arch would be cheapest, because the robot could operate it with its manipulator, and whole in the wall would be in between the two of them. The solution for the level changes could be lifts, though they are expensive, complex and slow.



Pictures 15, 16 and 17: Rising arch, turning doorway and lift.

8. Trunk

The trunk is the robots manipulator, which resembles elephant's trunk. To perform mentioned tasks the trunk should be able to bare medium loads, which causes large torques to the upper trunk. The trunk should also have accurate control and be as light as possible.

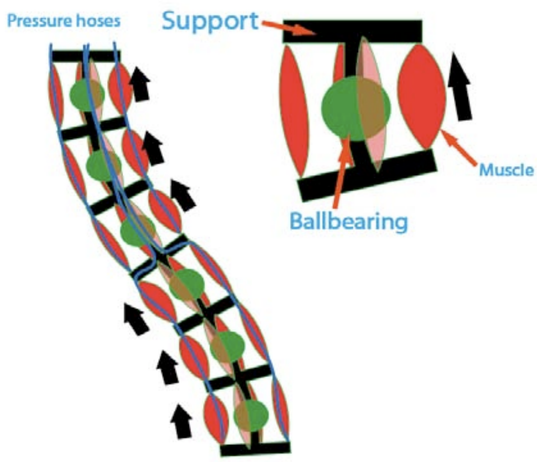
8.1 Electric trunk

Servo operated trunk could be build by using tendons that are pulled with the servos. The tendons would run in the spine to their actuation part where they would be in the surface of the trunk. When a tendon in the surface is pulled, it makes the trunk bend. Electric trunk is the easiest to build and control, but the trunk will need a motor for each tendon that can be operated. So, if the manipulator must be able to form complex shapes, the amount of motors needed grows fast and becomes a weight problem. For electric motors the loads that the ttrunk should be able to handle are also out of reach if weight limits are considered.

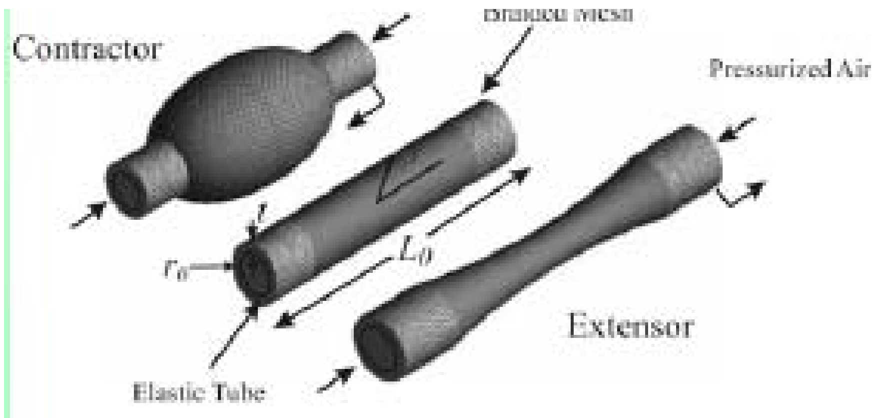
Picture 17: Electric trunk.

8.2 Pneumatic trunk

Pneumatic trunk could be build using pneumatic muscles as actuators. When pneumatic muscles are pressurized they contract and become shorter. So, similar to the cables the muscles would be in the outer layer. The main difference is that the muscles could be operated with single compressor and a digital valve system, and that means fewer parts, less weight and as much actuated muscles as needed. The muscles are also capable of delivering large forces, when enough pressure is being applied. The upper parts of the trunk should be wider and longer than the lower. The width increases directly the amount of torque that the muscles cause. Also, longer muscles can deliver larger forces. The lower parts of the trunk must be designed to be in harmony with the upper and to carry weight they don't need as much torque as the upper ones, so the lower parts must be smaller and lighter. The lower part needs also more accuracy for manipulation tasks which supports the idea of smaller and fewer muscles. If pneumatic muscles are used, the compressor could also be used to actuate cylinders for lowering the robot. The size of the cylinders needed is proportional to the weight of the robot and the pressure of the compressor.



Pictures 18 and 19: Pneumatic trunk.

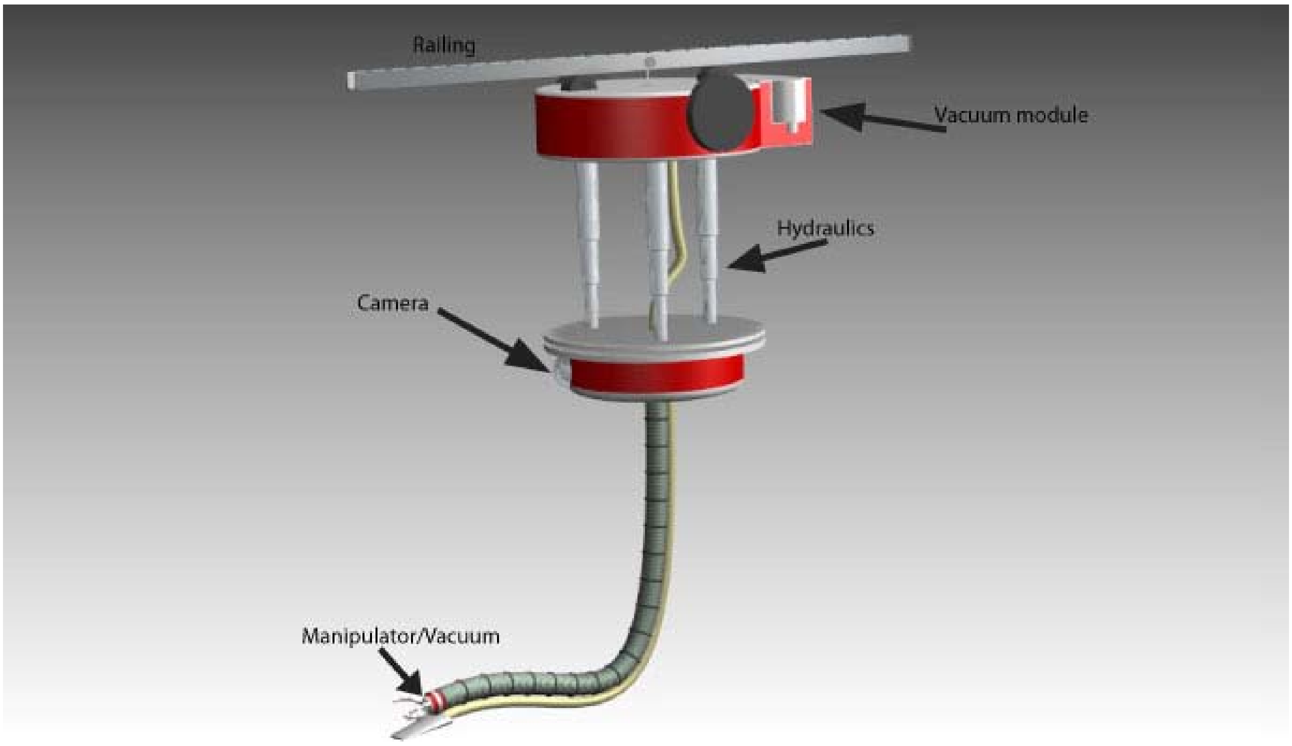


Picture 20: Pneumatic muscle.

9. Weight estimation

Weight is an important part of the robot design. Lighter robots are cheaper, safer and smaller. Mainly the manipulator must be made as light as possible, because then it can handle more payloads. The weight of the final product is hard to estimate, because everything depends on the manipulator's weight. If the manipulator is heavier the robot will need bigger compressor bigger muscles and bigger cylinders when the body will also become bigger. Estimation as follows:

- Compressor 5 – 8 kg
- Valves 2 kg
- Motor 1 kg
- Body 5 kg
- Arm 5 - 8 kg
- Telescopes 3 kg
- Total ~30 kg



Picture 17: Robot with the vacuum-module attached.