Content

Brainstorming

Each group had to think about a different environment. My group was entitled to Industry and Entertainment. But we had a lot of ideas in different environments and we wanted to show them to the other groups.

In the beginning we thought that some ideas could seem stupid, but maybe they make the group find other ideas. Then, we decided to write everything that came into our heads.

- INDUSTRY:

It is in this environment where there is the highest technology, and most likely where is easier to find new applications. Nevertheless it is not straightforward to find new ideas thinking in the whole environment. What I mean is that if it is thought in a specific factory with specific new tasks or improvements for specific machines it would be easier to find new applications, but if it is thought in general it is not straightforward to go beyond the "standard applications".

Some tasks for our robot could be:

- Weld
- Drill
- Paint
- Assemble
- Transport
- Handle materials

❖ LIBRARY:

The ceiling robot could sort the books in a library. It would be useful especially in high areas. The robot could have a barcode lector and a database.

❖ HOSPITAL:

- Guide: The robot could have a rope/wire/telescopic arm with a speech recognition device in the end of the rope/wire. It could guide the blind (or elderly people). They could say their need (dentist, ophthalmologist…), and the robot could guide them round the hospital. The device could bring a sound to alert other people. When robot comes back it should wind the wire.

Figure 1: a possible model of guide robot

- Nurse assistance: nurses often need help to move patients. Especially in hospitals, rooms are not very big. The possibility of add a robot in the floor in most cases is impossible. A robot working in the ceiling would be a good solution and most likely the only one. The ceilbot should be able to help moving patients to another bed and turning them in their bed.

- Food supplier: another useful possibility could be using the robot to provide the patient with food. The food would arrive at the room in a little lift. It would come with a special tray and the ceilbot would only have to take the tray from the lift to the bed. It could entail feeling of loneliness in the patients. Very often they need talk with someone more than medicines. Ceilbot also could provide medicines, but only if it is sure that the patient wants and can to take it.

- Surgery robot: robotic surgery is the use of robots in performing surgery. Three major advances aided by surgical robots have been remote surgery, minimally invasive surgery and unmanned surgery. Some major advantages of robotic surgery are precision, miniaturization, smaller incisions, decreased blood loss, less pain, and quicker healing time. Further advantages are articulation beyond normal manipulation and three-dimensional magnification. Using the ceiling is always a good option because it is a waste of space but, as already mentioned, in hospitals and, in this case, in operations where there are a lot of surgeons and nurses in a limited space it is a great advance if we use the ceiling.

Figure 2: Da Vinci Surgical System

- ENTERTAINMENT:

  - Cinema- Fight against piracy: the piracy is a topical subject. It is a worrying issue for the film industry. The ceiling robot could detect cameras in the cinema.
  - Cinema- Special effects: the ceilbot could sparkle, give off aromas or fog, throw confetti, etc. The robot would be programmed for each movie to do the different tasks in the right moments.
  - Humour TV shows: in today´s world there are a lot of lucrative shows full of absurd humour. The ceilbot could throw eggs, a cake, water, a colour hair spray...
  - Discos- wardrobe: the ceiling robot could take our jacket and bring it to the high areas. The area under the wardrobe is now useful. You get your ticket inserting a coin in a machine, and then you put your jacket in a hook. To retrieve your jacket, you can show your ticket in an optical sensor and it orders the robot to bring your jacket. With this tool it is not necessary a person working and there is more space in the disco.

- HOME:

  - Vacuum cleaner: there already exist different robots doing this task at ground level (Roomba), and at first it seems absurd thinking about a vacuum cleaner attached on the ceiling. But with this robot you can clean different levels, not only the ground level. It also could be useful for example if you dropped something (cereals, a flowerpot...). It could detect it and clean it.

Figure 3: Roomba

- Arm to pick up: this robot would be useful mainly for people who mustn´t bend over or crouch down frequently. If they dropped something, robot´s arm could pick up it from the floor.

❖ AIRPORT:

- Loading the luggage: it is a donkey work the task of transporting the luggage from the conveyor belt to the car which brings it to the plane. A ceilbot could help in these tasks.

❖ RESTAURANT:

- Waiter: a new concept of restaurant could be designed. The tables should be in fixed places. The waiter would be a ceiling robot. The robot with the help of a tray could take the customer the food/drink. As already commented in the case of the patients of the hospitals, in most cases we prefer humane treatment. In some cases even this is the only thing you are looking for when you go to a bar.

- Cleaning: the design of the restaurant would be similar to the previous point. The ceilbot could fulfill different tasks: cleaning the table, removing the crumbs, glasses…

❖ GARAGE:

- Entrance: the robot could have a face recognition device. People wouldn´t have to use a key or a remote control, the robot would recognize them and let them in. The use of this robot is only for private parking. One challenge would be if people who try coming in are not the usual tenant (a friend, family).

❖ BANK:

- Security camera: the robot could follow the thief recording him. It should be able to distinguish the face and try to record his face. It should be small enough that thief doesn´t see it. It could advance in a thin rail inside the ceiling. Big problem: how can the camera differentiate between a thief and a normal client?

❖ ANYWHERE:

In this section different robots which can be used in many places will be shown.

- Fire extinguisher: a ceilbot which is interacting with smoke detectors could localize the fire´s source and extinguish the flame. This robot is the main goal of this studio, and then it will be detailed in next sections.

- <u>Burning building</u>: the robot could localize people inside the building and/or help them to go out.
- <u>Changing lamps:</u> there are a lot of high buildings where is not easy reach the ceiling. The robot could change the lamps instead of us. One of the main challenges is that there are a lot of kinds of lamps.

After the study of the possibilities, finally we decided to work in the fire extinguisher. From here on all the sections are referred to this robot.

Fire Robot

Our robot is Fire-fighter robot, so its task is a monitoring of the room and a detection of the fire. For this function it uses commercial available smoke sensors in the room. The robot is waiting in its base position for the signal from smoke detectors. In this base position it is connected to electric plug, so it can charge its batteries. When the signal from smoke sensors appears, at first the robot notifies with sound beep signal people in the room. In this time the person who is in the room can cancel the procedure of the robot with the pressing of the stop-button. Robot makes a picture of the room with a camera and sends it to the fire station. And then the robot is moving to the fire source. Robot has a first approach about the position of the fire in the room from smoke sensors. For better localization it uses smoke and heat sensors on its arm. The arm can move up and down, so the robot can estimate the best position for the use of the extinguisher. It also can turn. After coming to the fire it uses the extinguisher and tries to stop the fire. And then it is returning to the base station.

Challenges

The target of this chapter is to identify the main challenges that we face in the building of the robot.

- NAVIGATION: how it will be the motion of the robot on the ceiling avoiding lamps, walls, projector, etc. The robot must be able to both navigate without any human assistance.
- SENSING: the robot needs some way to determine the position of the fire, the walls, etc.
- FIRE FIGHTING - ARM: the fire must be extinguished. The ceilbot must have a tool for extinguishing the flame.
- REMOTE CONTROL: It also must be able to be controlled by human.
- TAKING PICTURES
- SOUND SIGNAL-STOP BUTTON
- SENDING INFORMATION TO FIRE STATION: fire brigade must know that there exists a fire. They will go to the building to check the situation. They will be able to control the ceilbot and to take pictures if it is necessary.

We will discuss these ideas in more detail later on.

Possibilities of motion

This section is devoted to describe some options of how it could be the navigation of the robot over the ceiling.

- VACUUM: the idea was to build a shelf in a corner where the robot would wait for the signal of the smoke sensors. In this shelf, the robot would be charging its batteries and it would not need to be sucking at all times to remain on the ceiling. But in the motion, it requires a lot of energy .And a big problem with this ceilbot could be an energy failure. If energy is over, the robot will fall down causing damages everything will be under it. Another problem would be that it makes too much noise. But it could be a possibility for our robot.
    - Example: http://www.youtube.com/watch?v=aXm6kKCNJ5g

- PERMANENT MAGNET: using permanent magnets it would not be necessary as much energy as last case. The problem would be that it would have to build a suitable ceiling where the robot could remain with permanent magnets. An energy failure also can be dangerous in these robots. With regard to the fire robot, this ceiling could be a problem. If the fire heats the ceiling too much, it could damage the contact between the robot and the ceiling and it would heat the robot.
    - Example: http://www.youtube.com/watch?v=fVs_a-PKjws

- RAIL: another possibility would be to add rails to the ceiling. With the rails the navigation is limited. The robot´s arm is designed with only two degrees of freedom (vertical and turn), then the motion of the ceilbot over the ceiling must be able to reach anywhere. These obstacles made us rule out this option.

- BEAMS: the group appointed to work in Sports Hall showed us the possibility of attached the ceilbot with beams. We thought that also it would be a good option for our robot. This option requires building a beam´s system, but it is simpler than building a new ceiling for the magnet-robot. With beams, we only need small engines to make the robot move, and the weight of the ceilbot is supported by the beams. Finally we chose this option.

Structure of the robot

- MOVING BEAMS: for moving we use the beams system, so we can move rectangular in the room.

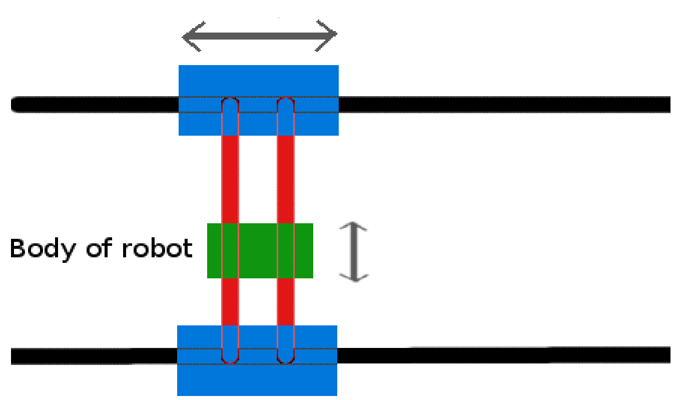


Figure 4: beams system

- FRAME OF THE ROBOT: inside, there will be one engine to move the robot along the beams. The engine will be connected to an axis. The same system as a car. One more to move the pulley which makes the arm go up and down and one more to makes the arm turn.
- FIRE ESTINGUISER SYSTEM:
  - The <u>bottle</u> is placed on the body of robot and the arm works as a pipe.
  - A <u>valve</u> is in charge of making the bottle open/close.
- ARM: it is showed in the figure 5. A cable is tied to the smallest cylinder. The engine connected to the pulley makes it up and down. The gravity does the rest.
- RECHARGING: the robot will have a battery which will be charged in the rest position.

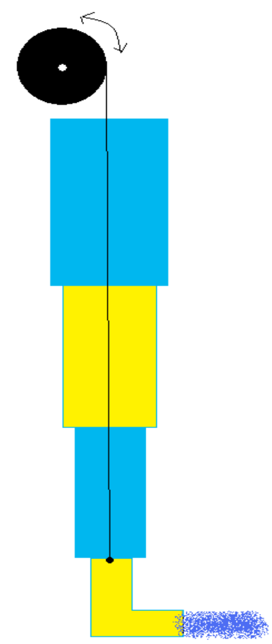


Figure 5: arm

- ENGINES: most of them have already mentioned. It is only necessary now talking about the other two engines which are inside the blue boxes (see figure 4)
- SENSORS: there are not often changes in the ceiling. Then, our robot will have programmed the map of the ceiling not being necessary sensors to avoid lamps, projectors, walls or anything.
  - <u>Smoke sensors in room:</u> these sensors are permanently on the ceiling and they are used for the basic localization of the fire. The count of sensors depends on the size of the room. More sensors are better for better localization and the key point is the earlier detection of fire. Our robot can put out only small fire and when the fire appears, it's necessary to react as fast as possible. They are connected by wires with the ceilbot when it is plugged in the rest position. The robot would be programmed to know which sensor is sending the signal. With this, the ceilbot has a first approach about where is the flame, and it will go fast in the right direction.

- Heat and smoke sensor: these two sensors are placed on the arm, and they are used for the accurate localization of the flame. The heat sensor is used almost for the estimating of the high of the source of the flame. It's necessary to estimate the source of the flame very accurate, because our extinguisher bottle is small and with bad estimation we cannot be so successful.
- Infrared sensor: in the vertical movement of the arm, it can find obstacles. This sensor will make the robot stop where the arm can reach the source of the flame.
- Camera: camera is used for making pictures of the room and then it is used for remote-control .Fire brigade can see through the camera and display on their device.

❖ POWER SYSTEM:

First of all, we need to know where we need energy. In response to the Figure 4, we have two linear movements. According to the picture, the horizontal movement is carried out by the robot and the two red beams, then the biggest energy will be required in this movement. The vertical movement only has to overcome the weight of the robot.

These were the movements of the robot; we have now to consider the motion of the arm.

The arm has to movements: up-down and turn. It already explained how we got the vertical movement in the arm using a pulley. What we need then is an engine which moves this pulley. This engine must be able to turn in both directions to make possible the up and down movement. When the arm is going down, both the gravity and the pressure of the extinguisher will help to the motion, decreasing the energy required. For turning the arm, it will be necessary the use of another motor. The energy needed here it will be limited.

- Possibilities of power systems:

  We are going to talk about four different ways to feed the robot: pneumatic, hydraulics, electrifying the beams and using batteries.

  - ✓ Pneumatic: This technology uses compressed air as way of transmission of the energy needed to move and make work mechanisms. The air is an elastic material and then, on applying a force, it is compressed. It keeps this compression and it will return the energy accumulated when it could expand, according with the ideal gases law.

    Some of the advantages are:

    - The air is easily collected and is abundant.

- The air does not have explosive properties, and then there is not risk of sparks.
- The actuators can work in easily adjustable and reasonable high velocities.
- The work with air does not damage the circuit components because of water hammers.
- Overloads do not cause dangerous situations or damage permanently the equipments.
- Changes in the temperature do not affect significantly.
- Clean energy.
- Immediate changes of direction.

The main disadvantages are:

- In big circuits, there are significant energy losses.
- It requires of special installations to recoup the air previously used.
- Pressures which it usually works with do not enable apply great forces.
- High levels of noise generated by the download of air to the atmosphere.

✓ Hydraulics: The hydraulics is the area of the physics and the engineering which is in charge of the study of the mechanical properties of the fluids. All this depends on the forces which intervene with the mass (force) and its drive.

Some advantages of these systems are:

- It enables to work with high levels of forces or torques.
- The oil used in the system is easily recoverable.
- Working velocity easily adjustable.
- Compact installations.
- Simple protection against overloads.
- Swift changes of direction.

The disadvantages are:

- The fluid is more expensive.

- Losses of load.
- Technical personal for maintenance.
- Fluid very sensible to the contamination.

The movements carry out by the robot have too long span (~30 meters). It is not a good idea using pneumatics or hydraulics. One possible option will be using pneumatic pistons moved thank induction. These systems have cylinders without piston rods. Inside these cylinders there is a magnet with ring shape. In the part outside of the cylinder there is a slide which also has a magnet. With these systems it can be reached longer strokes than conventional systems, but our system has still too long span for these.

Another issue to deem, for the particularity of our environment, is the temperature. In hydraulics, to get an optimum working life of both the oil and the hydraulic system, it recommends a maximum working temperature of 65°C. For nylon tubes used in pneumatic the maximum temperature gets on for 90°C; and polyethylene-based tubes the maximum temperature is close to 80°C. The group GIDAI, Department of Transports and Projects Technology of the University of Cantabria (Spain), estimated the temperature of two different environments exposed to fire. The first one was an industrial establishment constituted by an independent building with gable roof. The dimensions were 18x50 meters and 10 meters tall in the highest point. It considered that the establishment was used to manufacture and store paint. The second environment studied was an enclosure of an office´s building. In this case, the volume and the height are much smaller than the previous enclosure. The office studied has a surface of 84 square meters and 2,5 meters tall. It is obvious that our robot could be everywhere. According to the dimensions, our environment could look like the first one. Thing is that the maximum temperatures estimated were approximately 180°C in the factory and 800°C in the office. We try to prove that these temperatures are far from the ones which can be resisted by pneumatic or hydraulic systems.

✓ Electric power

The electric power will be the main source energy of our robot. Electricity is necessary for the moving, for the sensors, for the control, for the communication, without enough energy robots can't complete its mission. We have more different opportunities, basic dividing is the battery system and the system, which is still connected to electricity. Every type has some advantages and disadvantages.

- Permanent connection to electricity

- Battery

The mean advantage of permanent system is, that it's still connected to electricity and we don't need recharging and we have no problems with the capacity limits of energy from batteries. But there is a problem, when the building is without connection to the electricity during the fire, this situation is very often. Other disadvantage is resistance of the long wires.

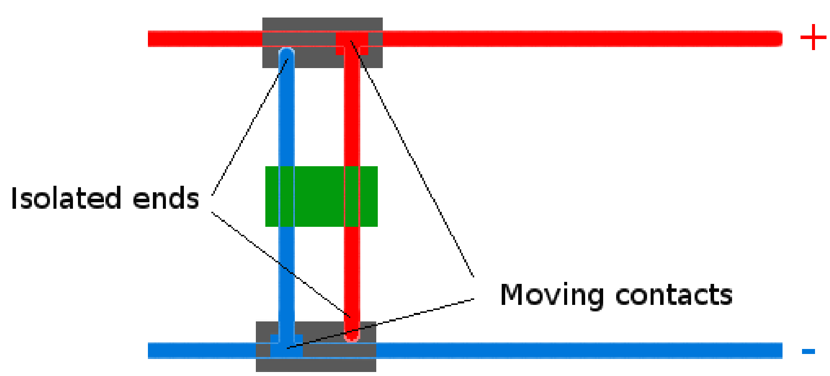


Figure 6: Example of distribution electricity

The biggest advantage of battery system is, that it's working without connection to the electricity. But it's necessary to monitor capacity of the battery and then recharge the battery. And it's necessary to estimate, if we will use only one central battery on the body of robot, or more batteries, one for the robot and 2 batteries for the each motor, which moves with the robot on the beams.

When we use only one battery, we have more possibilities how to connect parts of the robot. First possibility is in the figure 1, the beams work as wire. The second is to use special tracks on beam, figure 2(the same principle can be used for the communication, only to add some track). In both ways it's necessary to use special contacts to connect to the electricity.

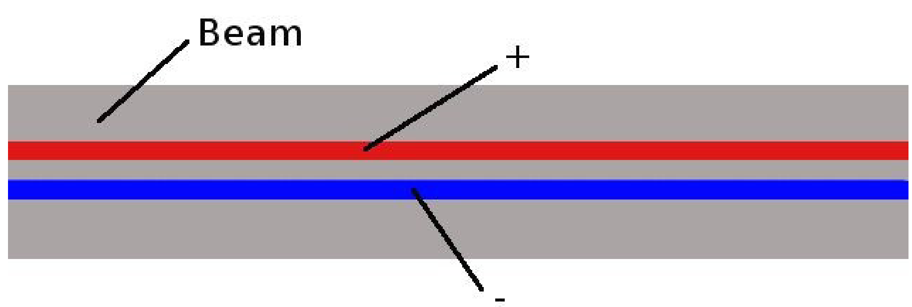


Figure 7: Tracks for the electricity

When we use battery, we need the recharging, in the figure 3 is an example of a socket and a plug for the recharging, this socket is with communication plug too.

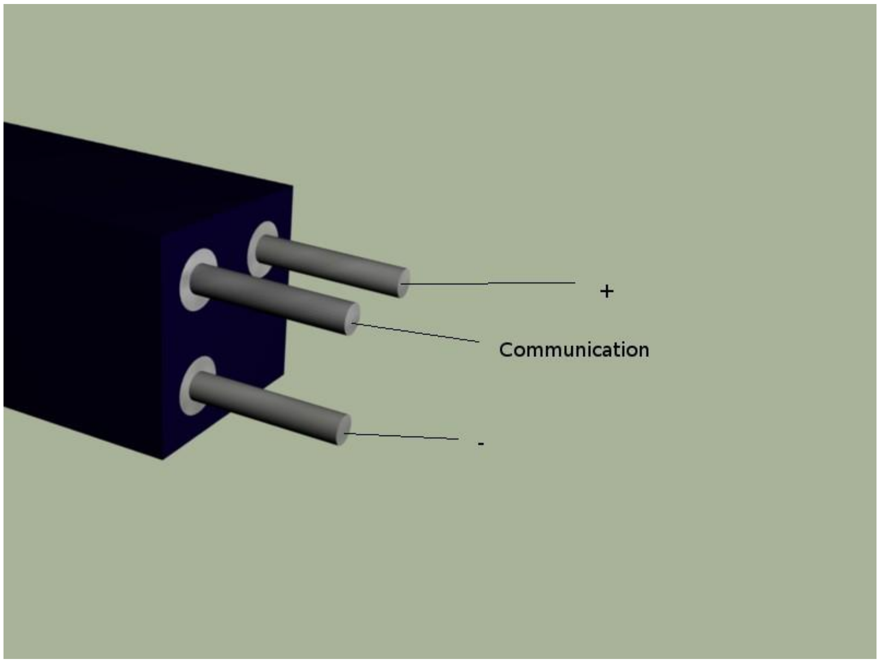


Figure 8: example of electric plug

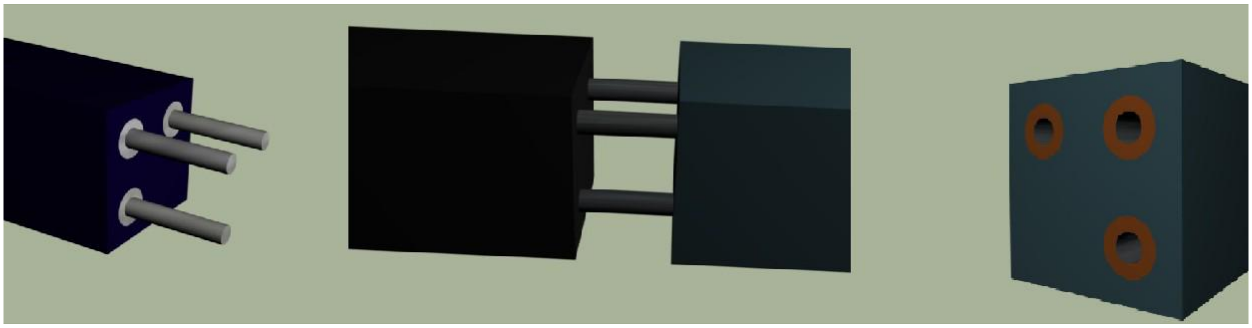


Figure 9: plug end socket

Capacity of Battery

Here is simple calculation for the capacity, it's very simplified:
For weight 100kg, then the force is: Fg=1000N.
F = ksi * Fg ~= Fg (in real application ksi <1(rotation coef.))
Power P = F*v, v=1 ms-1, P = 1kW
Energy W = P*t, t = 120, W = 120 kWs
For voltage U=12V the capacity is around 3Ah.
And now here are some examples of batteries:
Battery in car has typical capacity 40 -60Ah,
motorbike from 3Ah, the voltage is 12V, so

this batteries are possible to use.
Then other example are Li-Ion batteries(for example in laptops), these batteries have maximal capacity around 7-8Ah and the voltage form 10 -25V.

Figure 10: Lead-acid battery

Figure 11: laptop batteries

Special example is a military Li-on battery, it has voltage 26 V and capacity 14.0Ah(http://www.saftbatteries.com/MarketSegments/Defence/tabid/153/Language/en-US/tabid/353/TypeControl/Produit/ProduitId/97/Default.aspx)
Next types of batteries are accumulators for drill machines, the voltage is 9 - 14 V and capacity is from 1Ah (example: Bosch NiMH 14,4V; 3Ah).

Figure 12: Accumulator for drill machine - Bosch NiMH 14,4V; 3Ah

- ❖ BEEP DEVICE: this device is a sound generator which is used for informing people in the room, that there is a fire in the room and they can cancel this alarm and stop the robot with a switch.
- ❖ COMMUNICATION DEVICE (mobile – sending MMS)
  - The robot´s task is putting out the fire in the room, but it's a big deal only for a robot. So it is necessary the fire brigade comes to the place, although the robot has been successful extinguishing the flame. It is necessary an inspection from the fire brigade or other people after the fire. On the other hand our robot cannot be successful with the fire and it maybe needs the help from fire fighters. So we need inform them. And the best way is the mobile communication, because the wires in the room can be destroyed by a fire, so we cannot use this wire communication. And the mobile communication is everywhere available and of course the microcontroller with GSM module is available too.

Materials

In this chapter it shows the possible materials to use in the building of the system robot-beams.

For the study of the different possibilities in the construction of the beams, we did a spreadsheet using Microsoft Office Excel 2007. This helped us to get some findings.

- <u>First study</u>

According to the design shown in the Figure 23, we had to estimate the maximum deflection both in the beams placed on the left and the right(longitudinal beams:"LB"), and the beams where the robot is supported(transversal beams:"TB").

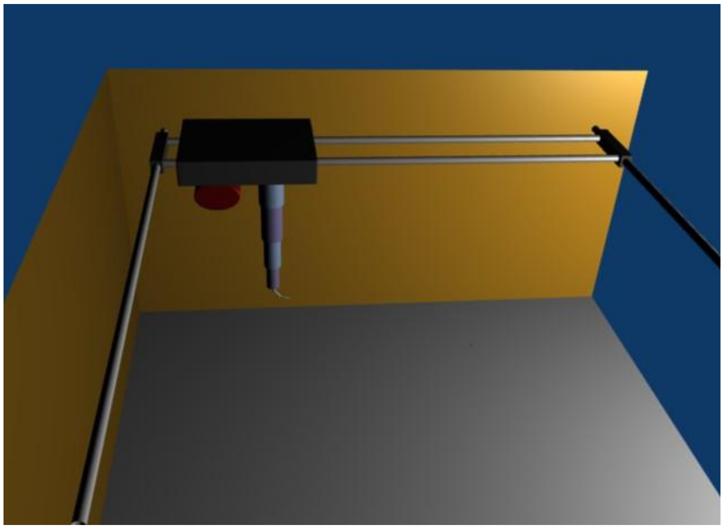


Figure 11: first system beams-robot

The first we had to do was considering how the LB could be attached. These beams had to support the weight of the TB, the robot and their own weight.

It occurred to us some basics solutions:

- Putting supports in the extremes of the beams attached to the walls.
- Putting supports in the extremes of the beams attached to the ceiling.
- Putting supports in the extremes of the beams attached to four columns in the corners of the room.
- Putting several supports attached to the ceiling.
- Putting several supports attached to several columns.

We showed some of these ideas in the meeting obtaining many and interesting suggestions. We realized that we were using too much material and the torques was big. We were using solid beams, so we could try with hollow beams. And we were putting perfect fixed joints, and this was the reason because we had big torques. We could change these joints for simple joints.

With these new considerations we designed the final prototype.

- <u>Second study</u>

Moreover of these two changes, fixed supports for simple supports and solid beams for hollow beams, another important change was done. The robot was not too heavy, so it was enough if we changed the two transversal beams for only one. The weight of the beams were exactly which affected to a greater extent.

To calculate the deflection in the beam, we used the Mohr Theorems:

- 1st Mohr Theorem:

$$\theta_B - \theta_A = \int_{x_A}^{x_B} \frac{M_f(x)}{EI_f}\, dx$$

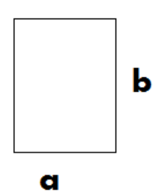
- 2nd Mohr Theorem:

$$\Delta_{B|A} = -\int_{x_A}^{x_B} \frac{M_f(x)}{EI_f}(x - x_A)\, dx$$

And we also need the formulas of the second moment of inertia for the different sections of the beam:

- Rectangular (Solid):

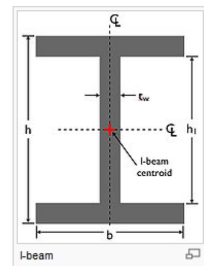
$$\boldsymbol{I = \frac{1}{12}ab^3}$$



- Cylindrical (Solid):

$$I = \frac{1}{64}\pi d^4$$ Being "d" the diameter of the beam.

- I-Beam:

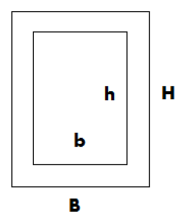


$$I = \frac{bh^3 - 2\frac{b - tw}{2}h1^3}{12}$$

(Note: the position of the beam would be which appear in the picture)

- Rectangular (Hollow):

$$I = \frac{BH^3 - bh^3}{12}$$



- Cylindrical (Hollow):

$$I = \frac{\pi}{64}(D^4 - d^4)$$ Being "D" and "d" the external and internal diameters respectively.

We chose similar dimensions for the different beams:

- Rectangular (Solid):
  - a = 10 cm
  - b = 15 cm
  - I = 2.81E-05 m^4

- Cylindrical (Solid):
    - D = 15 cm
    - I = 2.48E-05 m^4
- I-Beam:
    - b = 10 cm
    - h = 15 cm
    - h_1 = 10 cm
    - t_w = 2 cm
    - I = 2.15E-05 m^4
- Rectangular (Hollow):
    - B = 10 cm
    - b = 8 cm
    - H = 15 cm
    - h = 10 cm
    - I = 2.15E-05 m^4
- Cylindrical (Hollow):
    - D = 15 cm
    - d = 11 cm
    - I = 1.76E-05 m^4

We estimated a weight for the robot of 25 kg, considering that the bottle chosen weighed approximately 13 kg.

The length of the beam corresponds with the width of the room, it deemed 30 meters.

The characteristics of the materials chosen were:

	Steel	Aluminum	Carbon Fiber
Young Modulus (N/m^2)	2.00E+11	7.00E+10	5.31E+11
Density (kg/m^3)	7850	2700	1740

All these characteristics are only indicatives. The materials will change their properties depending on the alloys for example. Or the carbon fiber will have a different Young Modulus depending on the way to weave the fibers. Not talking about the dimensions of the room of course. But all the changes produced by these variations will be easily calculated using the spreadsheet that we have created.

The table of the Figure 12 shows next characteristics for three different materials and five different shapes for the beam:

- Mass of the beam for different materials and sections.
- Forces supported in the extremes.
- Maximum deflection of the beam.

	RECTANGULAR (SOLID)	CYLINDRICAL (SOLID)	I-BEAM	RECTANGULAR (HOLLOW)	CYLINDRICAL (HOLLOW)
m(Steel)(kg)	3532.5	4159.51875	1648.5	1648.5	1922.622
m(Alum)(kg)	1215	1430.6625	567	567	661.284
m(CF)(kg)	783	921.9825	365.4	365.4	426.1608
Steel:					
R1(N)	17787.5	20922.59375	8367.5	8367.5	9738.11
R2(N)	17787.5	20922.59375	8367.5	8367.5	9738.11
V(mm)	2.23E+00	2.97E+00	1.38E+00	1.38E+00	1.95E+00
Aluminum:					
R1(N)	6200	7278.3125	2960	2960	3431.42
R2(N)	6200	7278.3125	2960	2960	3431.42
V(mm)	2.24E+00	2.97E+00	1.42E+00	1.42E+00	1.99E+00
Carbon Fiber:					
R1(N)	4040	4734.9125	1952	1952	2255.804
R2(N)	4040	4734.9125	1952	1952	2255.804
V(mm)	1.94E-01	2.56E-01	1.25E-01	1.25E-01	1.75E-01

Figure 12: masses, reactions and deflection for different materials and different sections

It has deemed that the robot is placed in the middle of the beam because it is in this position where it created the maximum forces, and then the maximum deflection.

As we see, any deflections exceed 3 mm. This is reasonable against a span of 30 meters. It could be even greater.

So the issues to consider would be the weight which is able to support the walls and the prices of the materials.

The solid beams (rectangular and cylindrical) would be totally rule out according to the amount of material that they need, and the forces that it entails. They are which produced greater deflection owing to the high weight they have.

Take a look at the columns of the I-Beam and the hollow rectangular beam. They have exactly the same characteristics for the dimensions chosen. Both use less material, produce less forces and have less deflection than the cylindrical beam. So any of them would be a good choice.

The last step would be choosing a material. We see a big different between the weight of the beams made of steel and the other two materials. But the price of the carbon fiber is significantly higher than the other materials. We should know the weight which the walls are able to support and the current price of the materials in the wished shape in the moment we went to build the robot.

Another possible solution could be making the beams of wood. It does not seem good idea thinking about the robot will be used to extinguish a fire, but with special fireproof isolation some kinds of wood could resist more than some metals without losing its mechanical properties.

Other option would be using some kind of lattice. These types of structures are frequency used for long spans.

Figure 13: different kinds of lattices

To make the arm, we need different properties from the materials. The arm is not going to be subjected to big forces. It has to be as lighter as possible, but strong enough to resist the pressure of the extinguisher. It also has to be heat-resistant. It is going to be the part of the robot which is going to stay nearest to the flame. The aluminum has a low melting point (660ºC), but it could be enough in most cases.

The frame of the robot could likewise be made with aluminum. It could be reinforced with some thermal isolation. It is important to protect the devices inside the frame as well as the bottle of extinguisher.

In the Figure 14 we can see the new model. We observe that the robot now moves along only one beam. This picture shows a rectangular beam, but it can be of many different shapes as commented before. Another observation is how the beam is attached on the wall. It is now not necessary longitudinal beams, it can take advantage of a projection on the wall. The projection could contain bearings for example. And it must let the beam a slight rotation to avoid big torques. The bottle of extinguisher is now not visible because it is inside the frame of the robot.

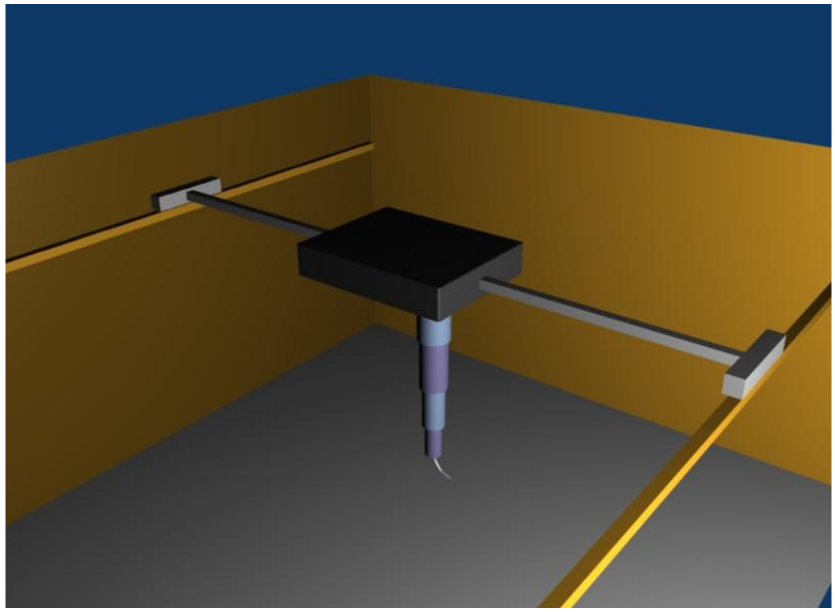


Figure 14: possible model with rectangular beam

User interface

The robot will have in its memory a map of the room, and then it needs some device for loading data to the memory. The user interface should be simple and fast. For people in the room it will be only a stop button. When the robot senses a fire in the room, it will immediately report fire brigade. This communication will be through mobile services, probably through GSM. This message will be a picture and other data (info about robot, address, tenant...). Fire brigade will have a special control device. They will see photos from robot on the screen and they will move the robot taking the pictures they want. The communication between robot and the remote control device will be based on Bluetooth.

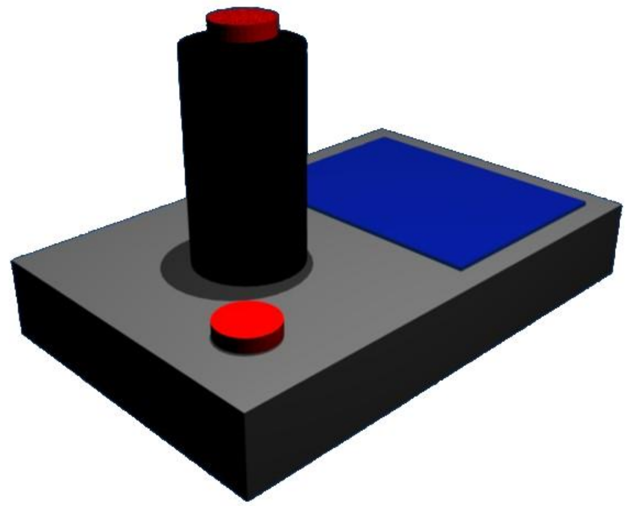


Figure 15: joystick for remote control

Safety

Any project must consider the safety subject as a prime issue. Asimov stated in his tale "Runaround" in 1942:

- "A robot may not injure a human being or, through inaction, allow a human being to come to harm."
- "A robot must obey any orders given to it by human beings, except where such orders would conflict with the First Law."
- "A robot must protect its own existence as long as such protection does not conflict with the First or Second Law."

In response to these laws, we can differentiate three main issues to consider in this section: people, robot and environment.

- **PEOPLE:**

People are in first place. Mainly, our robot is thought to help when nobody is in the cinema. Because, allegedly, if there is someone in the place, he can take an extinguisher from the wall and call the fire brigade informing about the facts. But it can also help people to extinguish the fire. Then, we have to think about the robot interacting with people.

It is not a normal situation. The cinema will probably be crowded and the exits could be blocked. Trapped people would start to feel panic with all that it entails.

One thing to consider is the possibility that our robot collides with people in its motion to reach the flame. The frame of the robot will be on the ceiling being impossible to collide with anyone. The problem would appear when the arm went down. In this point, we have two possibilities. The robot can move over the ceiling and get longer its arm when it will be just above the flame; or the fastest solution, the arm could go down simultaneity with the body motion. If we considered the possibility that nobody were in the cinema, then probably the best option would be the second one; but we are now talking about safety for people, and then we have to consider the possibility of people, for example, running along the corridors. For this goal, the arm would have some motion detector. Thanks this sensor robot could avoid people in its path to the flame.

In the selection of extinguishers, it must always be considered the possible risks for the healthy. Generally the manufactures put visible warning labels about extinguishers which could contain toxic or breakdown steams. Sometimes, nevertheless, the danger is not in the extinguisher but in the place where is going to be used. This problem can be fight placing warning signs, having long-range devices, installing special ventilation or providing artificial respiration to the employers of the zone.

All water-based extinguishers only can be used for Class A fires, apart from the AFFF models, which are used in Class B fires. If water-foam models are used in Class B fires, blazes can be produced, fire can be spread or operators can be damaged. If water-based models are used over electrical equipments or in the proximities, the jet of water can transmit an electric shock to the operator.

Although CO_2 is not toxic by itself, it is not breathable when it is used in amounts bigger enough to extinguish a fire. If a CO_2 extinguisher is used in an area without enough ventilation, it dilutes the oxygen and anyone who stay in the area can lose consciousness and even die because lack of oxygen. Anyway, a dense cloud of CO_2 can cause the disorientation of people. Another problem is the temperature of the CO_2 inside the bottle (≈-76ºC). A directly stream would cause the death of a human.

Dry chemical models are not considered toxic, but they can irritate if they are breathed for prolonged periods. The most irritant product is the monoamonic phosphate, and after this the potassium-based agents. The least irritant is the sodium bicarbonate. If it downloads dry chemical extinguishers in a closed area, they can reduce visibility and cause disorientation.

Dry chemical agents do not conduct electricity. They can also block, if they are downloaded in the proximities, the filters of the fitting-out or air cleaning systems. The polyvalent chemical agents (based on monoamonic phosphate) have acid nature and if they are mixed with water, even in a small amount, they will corrode some metals, unless it was clean quickly.

The initial download of the agent of an extinguisher has a considerable strength; if it is thrown in short distance against a small fire of liquid or flammable fat, it can give rise to a considerable spread before reach to control it.

The extinguishers which contain Halon have only a slight toxicity in normal conditions. Nevertheless, products from its breakdown can be dangerous. When these extinguishers were used in areas without ventilation (small rooms, wardrobes and other closed places), it must avoid to breath the vapors or gases produced by thermal breakdown.

It must stress that practically all fires emanate toxic products of breakdown and some ignited materials generate high toxicity gases. Until the fire has been extinguished and the area has been completely aired, it is important staying out of the zone, or using artificial breath devices.

In our environment, a cinema, the fire would appear in ordinary combustibles (textile, wood), fires of Class A. For these reasons finally we chose a water extinguisher.

Figure 16: label about uses of water extinguisher

Another question to consider is that our robot is attached on the ceiling. This new solution is precisely to make useful the space under the robot, and then we have to be sure that all parts and devices in the robot are completely fixed, being impossible that they fall down injuring people or the environment.

- **ROBOT:**

According to the third law of Asimov, we have also to consider the safety of our robot.

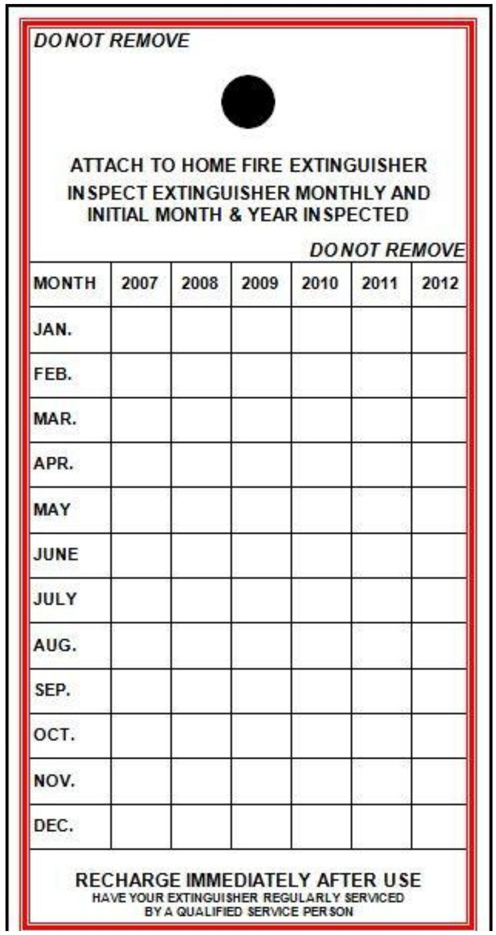
The robot must move along the beams deeming the different levels of the seats in the cinema and without colliding with anything. It will have to avoid obstacles like lamps, loudspeakers, etc in its motion. The beams will be previously placed considering all kinds of obstacles both on the walls and on the ceiling. The different heights will be programmed in the microcontroller and stored in the memory. The robot will be able to know the distance from its position to the floor (the seats) with only one coordinate.

As mentioned before, all parts of the robot will have to be attached to the robot with high accuracy and considering all the accelerations or forces that could appear.

Another issue to deem in our specific environment would be the high temperatures that can appear in a situation with a fire. We have to protect the robot against this enemy. The frame of the robot, the arm and the beams will be built with some metal. Then, they will be able to resist during a long time before lose their mechanical properties. It will not be the same with the devices inside the robot (microcontroller, memory, batteries) or with the bottle of extinguisher. For example the plastic parts will not be able to resist temperatures above ~80ºC. The working temperature for batteries is from -40ºC to 70ºC, and it is approximately the same for the rest of electrical devices. For conventional extinguishers the working temperature is from -20ºC to 60ºC.

At first, our system should be needed never. Then, it is going to be without being used for a long time. The robot has to be ready when it was required. It is very important an accuracy and frequent maintenance, both of electrical devices and the bottle of extinguisher. It is also a prime subject the fact that batteries go flat with high temperatures. This has to be considered in the moment of the choice.

Figure 17: tasks for monthly maintenance of an extinguisher



DO NOT REMOVE

ATTACH TO HOME FIRE EXTINGUISHER
INSPECT EXTINGUISHER MONTHLY AND
INITIAL MONTH & YEAR INSPECTED

DO NOT REMOVE

MONTH	2007	2008	2009	2010	2011	2012
JAN.						
FEB.						
MAR.						
APR.						
MAY						
JUNE						
JULY						
AUG.						
SEP.						
OCT.						
NOV.						
DEC.						

RECHARGE IMMEDIATELY AFTER USE
HAVE YOUR EXTINGUISHER REGULARLY SERVICED
BY A QUALIFIED SERVICE PERSON

Figure 18: example of inspection tag

- **ENVIRONMENT**

It has already been mentioned indirectly the things to deem to protect the environment.

For example, it commented that the robot must not collide with anything on the walls or the ceiling. This problem would be resolved placing the beams so the robot, in its motion, did not come up against anything. The same would be applied to the arm.

Of course it is also necessary to fixed with accuracy all the parts of the robot to avoid them fall down breaking seats or anything.

Other possible uses

Our robot is designed only for one task. But other use of our robot can be monitoring of room and moving in the room, so it can be use like alarm in the room and it can record the burglars. The other ideas of different tasks are: pouring insecticide or pesticide in flowerpots or feeding small pets, like birds, turtles or fishes during a long time. These tasks mean removing the bottle of extinguisher and adding a tank with other liquid or with food. Other idea can be to add some manipulator for moving objects, but it is big change in our concept, it means improve/change the whole arm.