# Ocean Plastic Sensor

by **Hector Hatrick** on June 30, 2014

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## Intro: Ocean Plastic Sensor

Since 1940 we've been producing and disposing more and more plastic in the ocean. In 2013 alone we estimate to have produced about 300 millions of tons of plastic - the same weight of all humanity (flesh and bones) in plastic, only in one year. Plastic is toxic. Plastic ingestion can lead to the development of infections, cancer or even death. Plastic floats for hundreds of miles, far away from those who produced it. Plastic may change our lives in a very bad way if we don't take action now.

**What is the problem we are trying to address?**
We are trying to sense plastic in the ocean. What do we mean by "sense" :

- Localise (where at what moment - timestamp)
- Qualify (what)
- Quantify (how much of it)

The oceans are huge, we know plastic is out there, but it would make it a lot more easier to clean if we know where it is. Until recently we thought we would find ten to a hundred millions of tons of plastic at the ocean surface. A recent study suggests that plastic floating at the surface of the ocean accounts only accounts for 34,000 tons maximum.

Where is 99% of the rest of the plastic we thought we would find?

- A/ Does fishs / turtles / birds eat it? Digest part of it? Poop it?
- B/ Does it sink at the bottom of the ocean?
- C/ Does it breaks down so small, it releases all it's chemistry?
- D/ Does it reaches the beach?

Today, we don't know in what proportions and where plastic is, which is concerning. For instance, if a big part of plastic was consumed by marine animals in that kind of quantity, it would have devastating consequences on the food chain we are part of. It might explain partly why we have already killed 90% of the ocean large fishes since 1950 and corroborate the theory that by 2048 all large fish in the ocean would be gone.

**How do we sense plastic in the ocean today? What do we propose to investigate?**
As of today (2014 July) we take big ships out, extend a long arm at the end of which there is a fine net (manta trawler) to capture plastic bits. Plastic pollution research with nets has been very slow, dangerous and time-consuming because all this plastic has been sorted by hand under a dissection microscope.

In this instructables we investigate the possibility of developing an optical sensor, so instead of "collecting stuff" (plastic but also plankton) with a net, we collect the "image of stuff" and convert it immediately into "data" (Timestamp, localise, qualify, quantify). Marine biologists have been doing this technology for decades for plankton using LOPCs (Laser Optical Particle Counter).

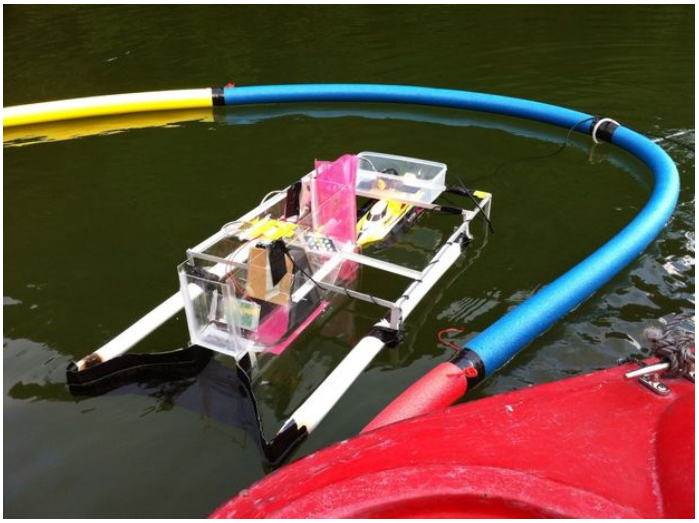
**How are we doing it?**
We're hacking a radio-controlled sailing robot to carry a webcam that video records water and plastic particles flowing though it. The plastic is then collected with a net attached to the end of the contraption so we compare what we estimate from video feed VS what we actually physically collect - so we can establish how accurate our system is (tolerance). The current prototype is very rough but confirms that it is possible remotely operate a compact platform to capture video of plastic particles.

We are working on :

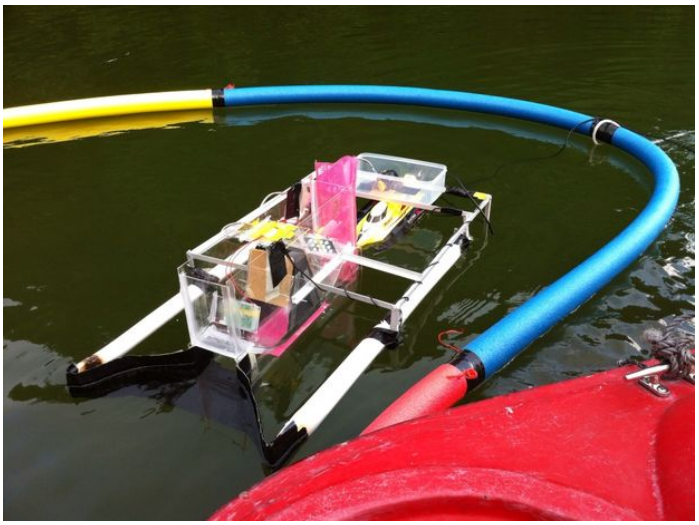
- improving the sensor (watertightness, optical quality, size, energy usage)
- improving the transport of the sensor (power boat, perhaps wind-powered)
- process video, isolate moving bits
- use laser diode that help us distinguish plastic from plankton
- develop an on-board software to process the data (on the Banana Pi)
- communicate the data online in real-time

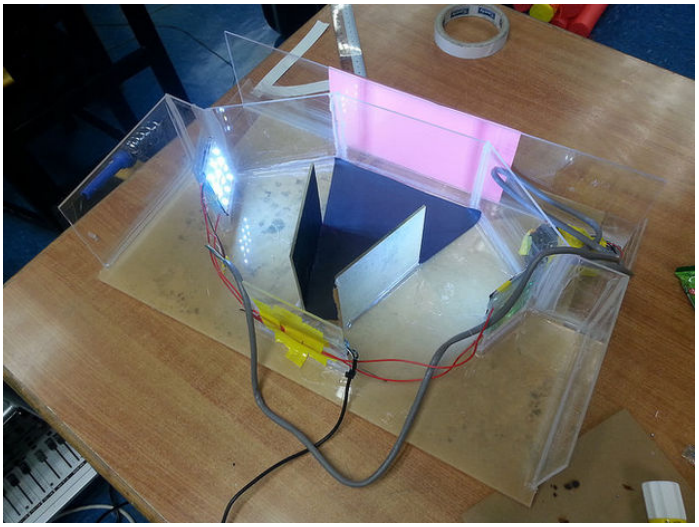
**Who are we?**
This instructables was made by students of the Hong Kong Harbour School : Brandon Wong, Riccardo Ricci, Aiyana Campbell, Lara Bevan, Matteo Griffiths, Hector Soekarno, Alexander Paul, Max Wilson, Andreas Zhang, and Akasha Campbell guided by Johnson Stanley, Cesar Harada and our principal Christine Greenberg. The parents also helped a great deal and deserve a lot of credits. Thanks to Edward Fung (Hong Kong), Taivo Lints (Estonia). Original research proposal by Cesar Harada here.

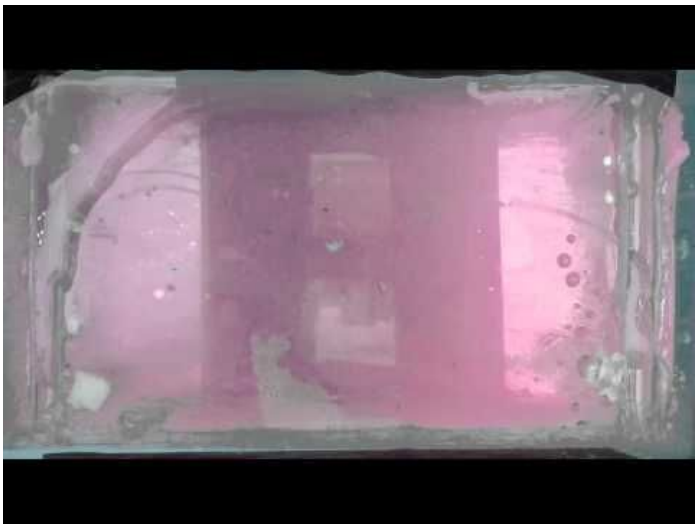
Top image of dead whale credit : http://www.pelagosinstitute.gr

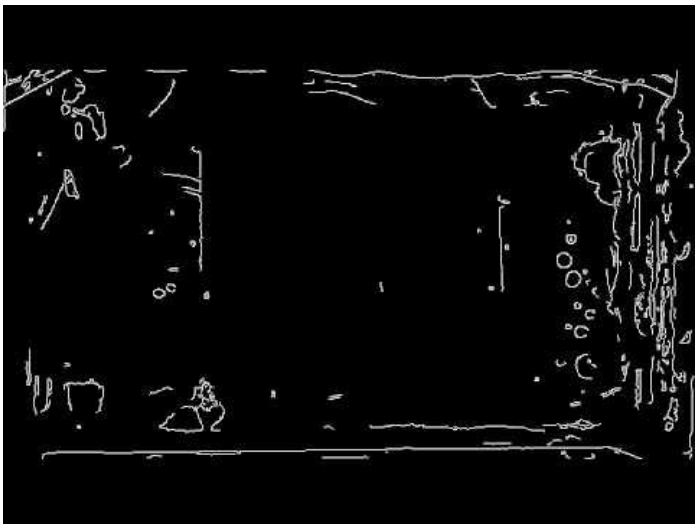


Scientists discover a dead sperm whale and conduct an autopsy to find the cause of death
facebook.com/OccupyEducated
Inside the whale's unusually bloated stomach, they find 100 plastic bags





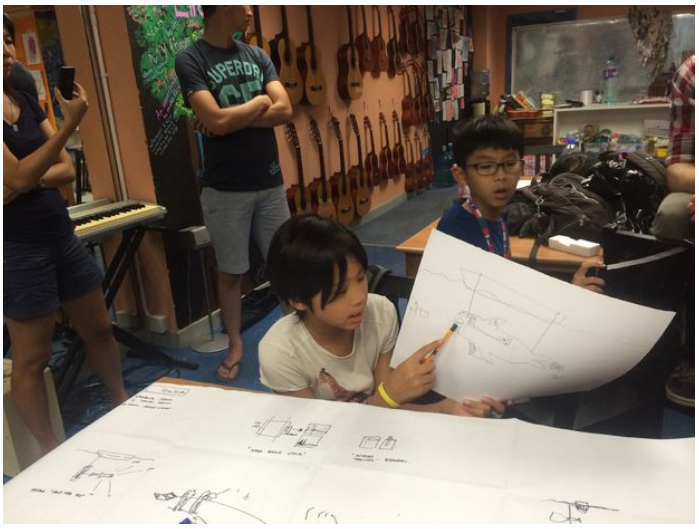


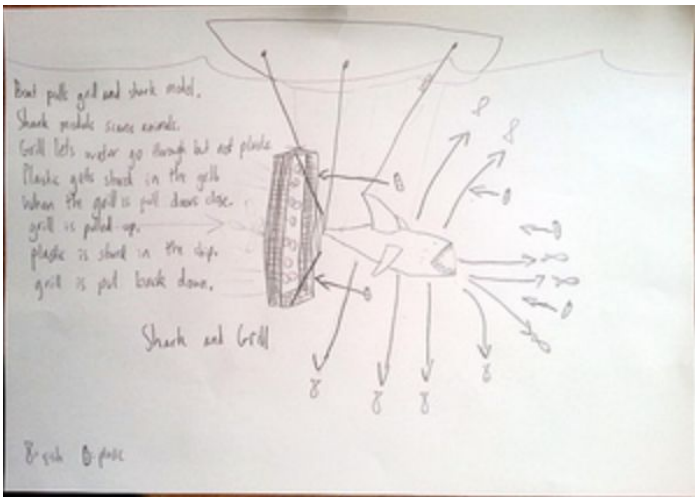


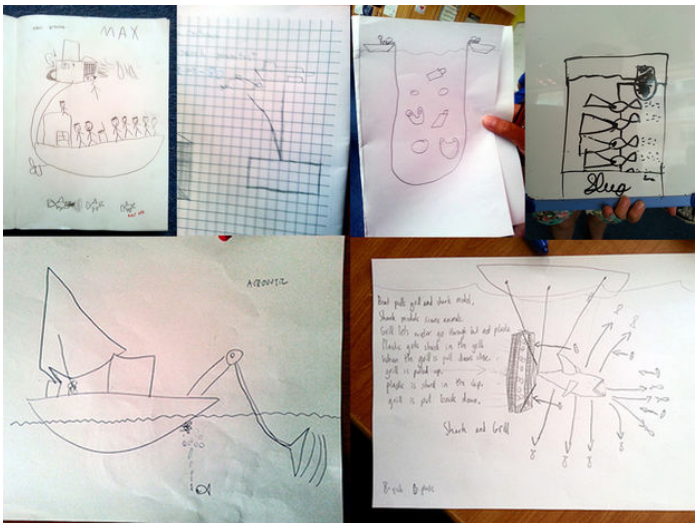
## Step 1: Brainstorming

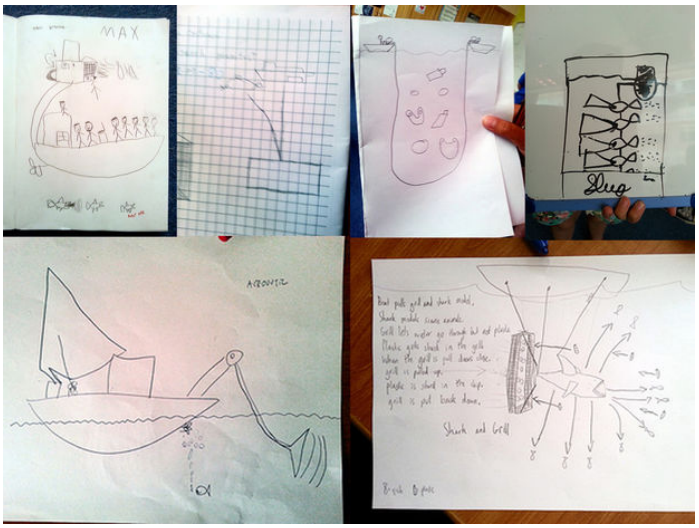
The students came up with many creative ideas of how we could measure plastic in the ocean.

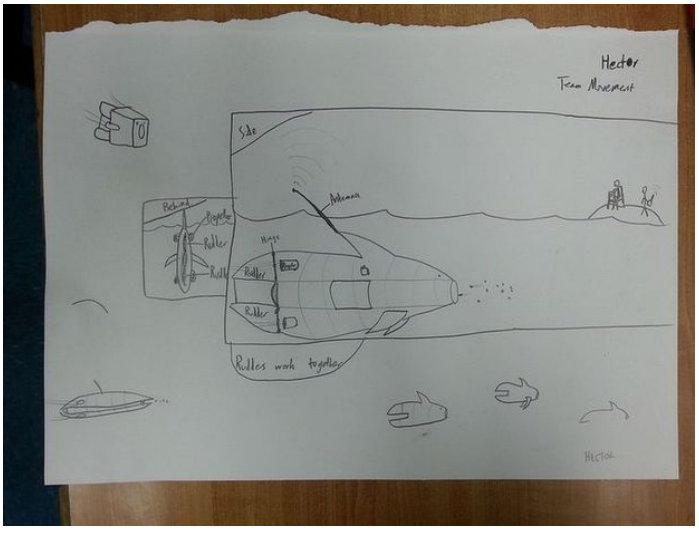
Hector had a shark to scare away the fish and plankton so that they are not recorded. Riccardo had a "Killing box" to kill everything that collects inside the box. After that, he will collect the plastic that is left inside. Other designs include robot fish consuming the plastic, a net that looks like a tube closed off at one end to collect anything solid, and one idea included plastic "adhesives" attached to a steel block to stick to plastic and thus making it easier to collect. For more inspiration and designs from other members of the team, click here.

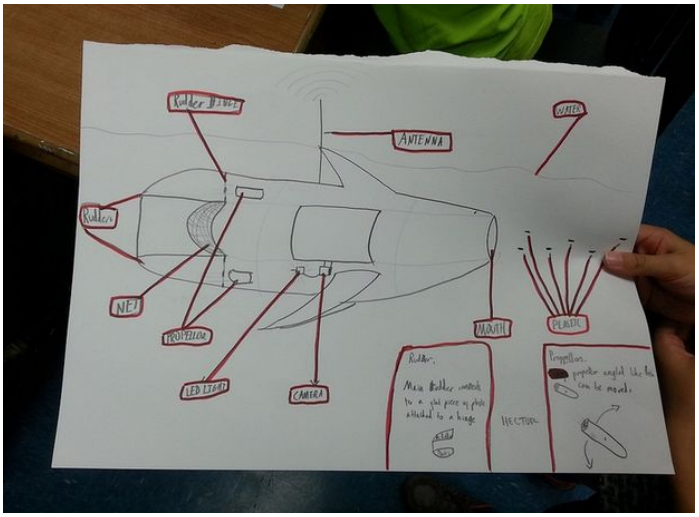






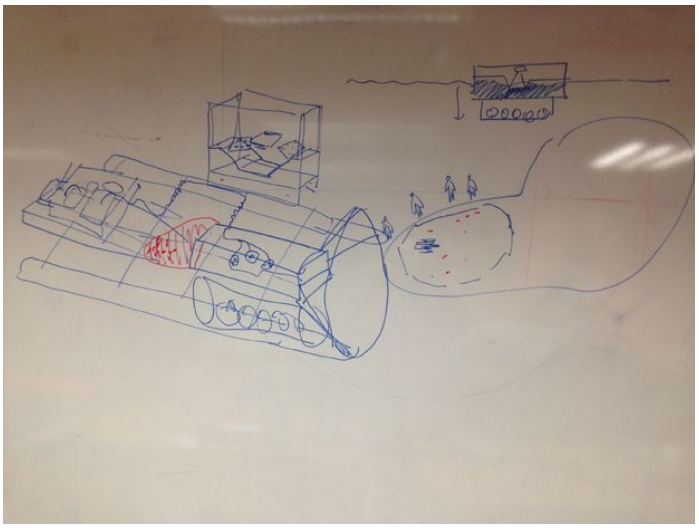

## Step 2: Merging ideas into one

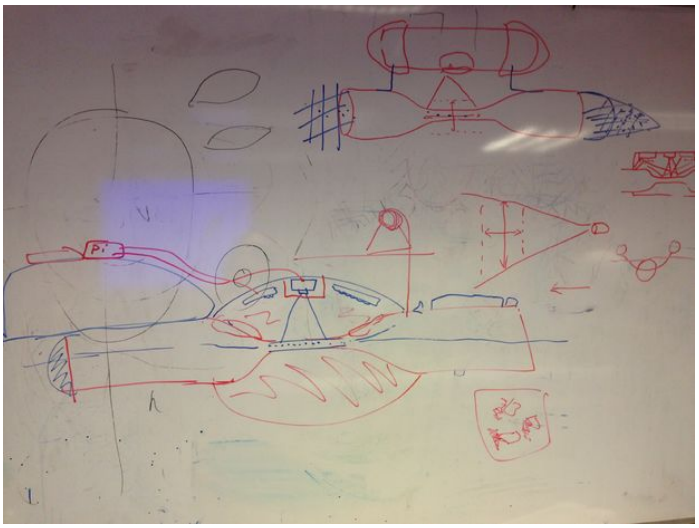
We did not know whose idea to choose, so we tried to combin all of them into one idea. This was no easy task as our ideas were incredibly different. Eventually, our mentor Cesar proposed an idea. The design would be a transparent acrylic tube would have water should pass through a narrow window so it could be recorded with a customised webcam. Two lights would shine on both sides of window allowing the camera to 'see' more clearly.

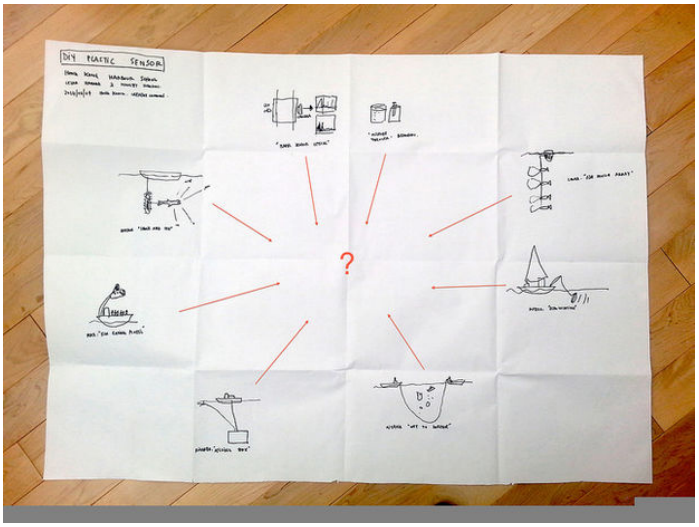
The webcam would be connected to an on-board Raspberry Pi that will record and process the video.

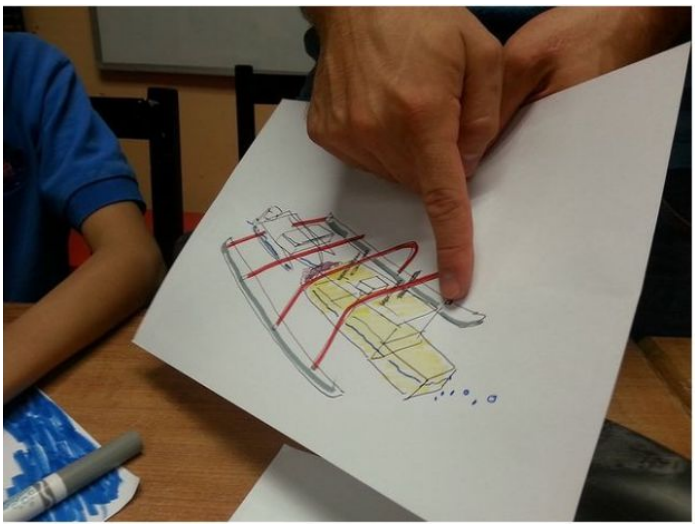
A radio-controlled power boat would propel the sensing contraption through the water.

The contraption would be held together by a large aluminium frame, 2 lateral floats (PVC tubes) would stabilise the craft and maintain the video water channel at the appropriate depth.





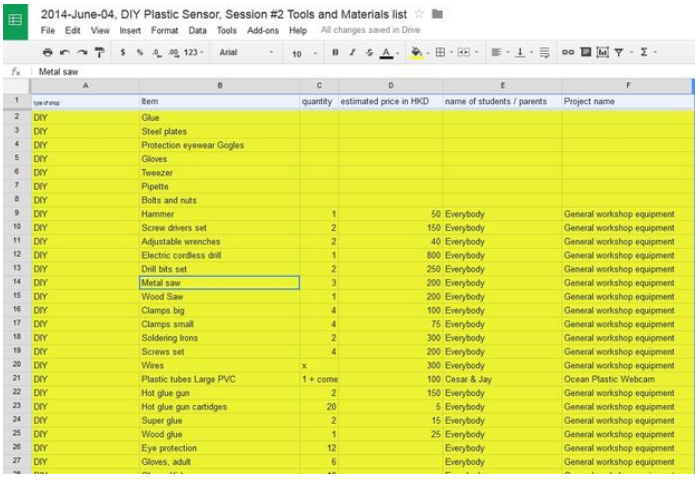


## Step 3: Buying tools and materials

Once we had come up with the design we went to buy our tools and materials in Sham Shui Po (Hong Kong).

For easy reference, please refer to our shopping list here.

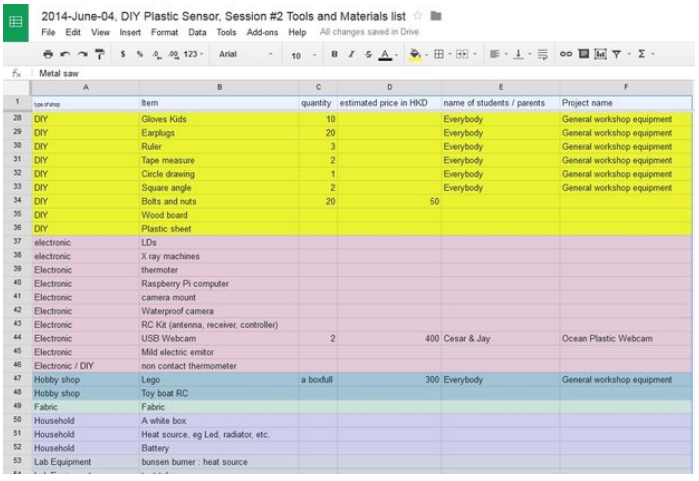


2014-June-04, DIY Plastic Sensor, Session #2 Tools and Materials list

File Edit View Insert Format Data Tools Add-ons Help All changes saved in Drive

Metal saw

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | type of shop | Item | quantity | estimated price in HKD | name of students / parents | Project name |
| 2 | DIY | Glue | | | | |
| 3 | DIY | Steel plates | | | | |
| 4 | DIY | Protection eyewear Gogles | | | | |
| 5 | DIY | Gloves | | | | |
| 6 | DIY | Tweezer | | | | |
| 7 | DIY | Pipette | | | | |
| 8 | DIY | Bolts and nuts | | | | |
| 9 | DIY | Hammer | 1 | 50 | Everybody | General workshop equipment |
| 10 | DIY | Screw drivers set | 2 | 150 | Everybody | General workshop equipment |
| 11 | DIY | Adjustable wrenches | 2 | 40 | Everybody | General workshop equipment |
| 12 | DIY | Electric cordless drill | 1 | 800 | Everybody | General workshop equipment |
| 13 | DIY | Drill bits set | 2 | 250 | Everybody | General workshop equipment |
| 14 | DIY | Metal saw | 3 | 200 | Everybody | General workshop equipment |
| 15 | DIY | Wood Saw | 1 | 200 | Everybody | General workshop equipment |
| 16 | DIY | Clamps big | 4 | 100 | Everybody | General workshop equipment |
| 17 | DIY | Clamps small | 4 | 75 | Everybody | General workshop equipment |
| 18 | DIY | Soldering Irons | 2 | 300 | Everybody | General workshop equipment |
| 19 | DIY | Screws set | 4 | 200 | Everybody | General workshop equipment |
| 20 | DIY | Wires | x | 300 | Everybody | General workshop equipment |
| 21 | DIY | Plastic tubes Large PVC | 1 + come | 100 | Cesar & Jay | Ocean Plastic Webcam |
| 22 | DIY | Hot glue gun | 2 | 150 | Everybody | General workshop equipment |
| 23 | DIY | Hot glue gun cartidges | 20 | 5 | Everybody | General workshop equipment |
| 24 | DIY | Super glue | 2 | 15 | Everybody | General workshop equipment |
| 25 | DIY | Wood glue | 1 | 25 | Everybody | General workshop equipment |
| 26 | DIY | Eye protection | 12 | | Everybody | General workshop equipment |
| 27 | DIY | Gloves, adult | 6 | | Everybody | General workshop equipment |



2014-June-04, DIY Plastic Sensor, Session #2 Tools and Materials list

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Metal saw

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | type of shop | Item | quantity | estimated price in HKD | name of students / parents | Project name |
| 28 | DIY | Gloves Kids | 10 | | Everybody | General workshop equipment |
| 29 | DIY | Earplugs | 20 | | Everybody | General workshop equipment |
| 30 | DIY | Ruler | 3 | | Everybody | General workshop equipment |
| 31 | DIY | Tape measure | 2 | | Everybody | General workshop equipment |
| 32 | DIY | Circle drawing | 1 | | Everybody | General workshop equipment |
| 33 | DIY | Square angle | 2 | | Everybody | General workshop equipment |
| 34 | DIY | Bolts and nuts | 20 | 50 | | |
| 35 | DIY | Wood board | | | | |
| 36 | DIY | Plastic sheet | | | | |
| 37 | electronic | LDs | | | | |
| 38 | electronic | X ray machines | | | | |
| 39 | Electronic | thermoter | | | | |
| 40 | Electronic | Raspberry Pi computer | | | | |
| 41 | Electronic | camera mount | | | | |
| 42 | Electronic | Waterproof camera | | | | |
| 43 | Electronic | RC Kit (antenna, receiver, controller) | | | | |
| 44 | Electronic | USB Webcam | 2 | 400 | Cesar & Jay | Ocean Plastic Webcam |
| 45 | Electronic | Mild electric emitor | | | | |
| 46 | Electronic / DIY | non contact thermometer | | | | |
| 47 | Hobby shop | Lego | a boxfull | 300 | Everybody | General workshop equipment |
| 48 | Hobby shop | Toy boat RC | | | | |
| 49 | Fabric | Fabric | | | | |
| 50 | Household | A white box | | | | |
| 51 | Household | Heat source, eg Led, radiator, etc. | | | | |
| 52 | Household | Battery | | | | |
| 53 | Lab Equipment | bunsen burner : heat source | | | | |

### File Downloads

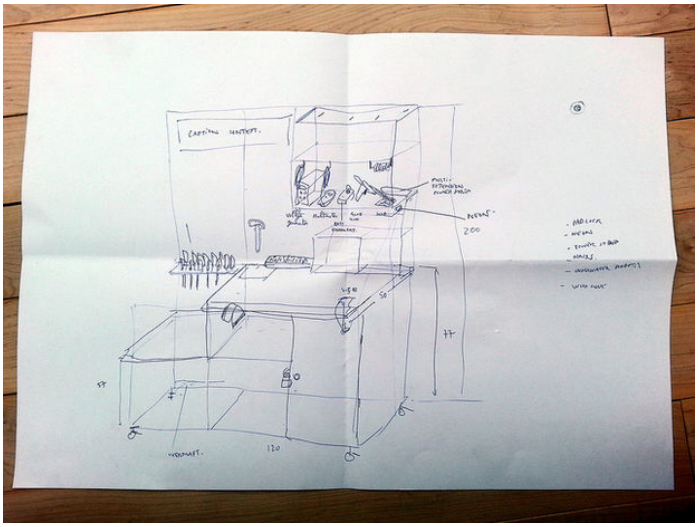
**Workbook1.xlsx** (37 KB)

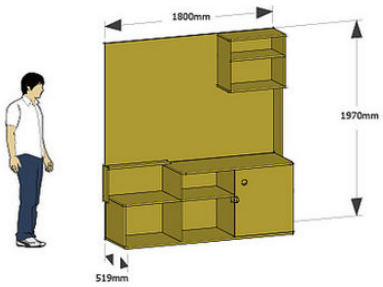
http://www.instructables.com/id/Remote-Controlled-Optical-Plastic-Sensor/

[NOTE: When saving, if you see .tmp as the file ext, rename it to 'Workbook1.xlsx']

## Step 4: A workbench for short and tall kids

Now we had everything we needed except a place to build. We built a workbench with 17mm thick plywood that could fit all our tools and materials, accomodate kids tall and short. We placed the dangerous tools high, the less dangerous tools lower. We used 3 large plywood boards (4 x 8 ft) and the bench is on 6 lockable wheels.





## Step 5: Hacking a radio controlled boat

Now we could build the actual thing. We split into 3 teams :

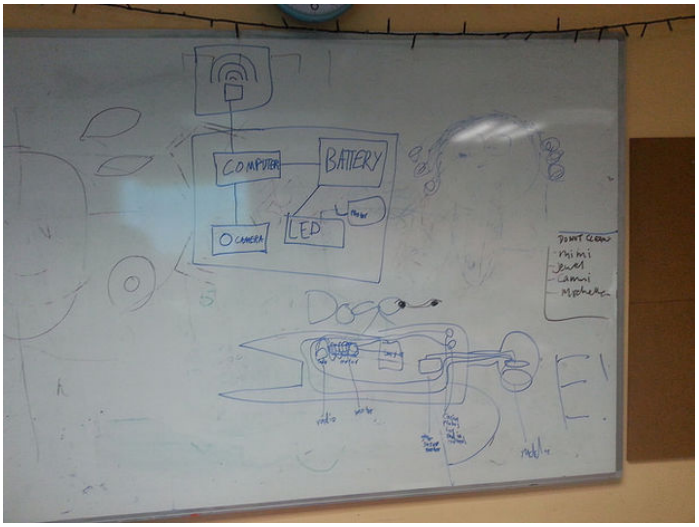
1. **Mechanical and radio team** - that would take care of the boat, the frame construction, the general build
2. **Electronics team** - that would hack the webcam, build the acrylic window, water channel, exchangeable coloured backdrop
3. **Environment team** - that would build the plastic barrier so we do not contaminate the environment, prepare plastic samples, invent a testing procedure

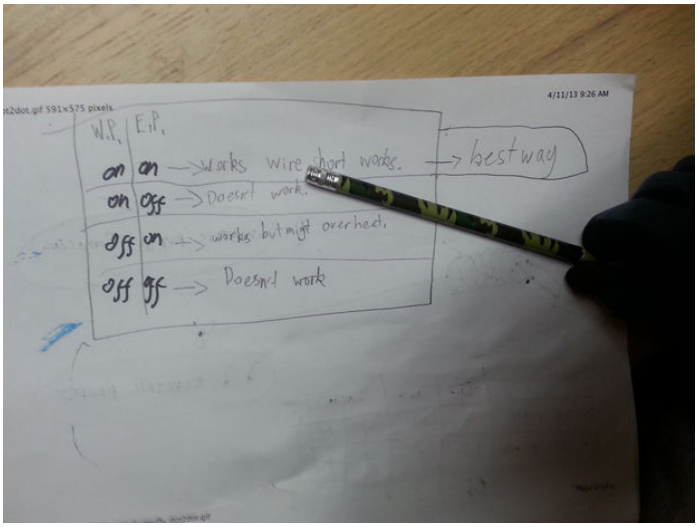
The parents also helped in the build, input ideas, work hands on, helped us with logistics buying parts, transportation, food.

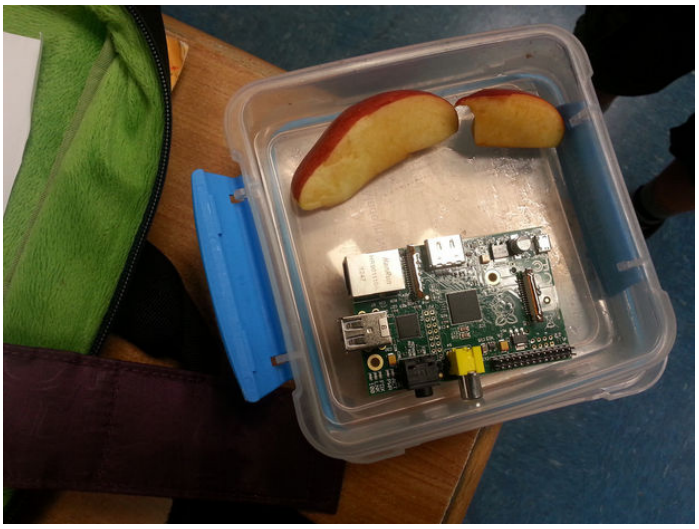
We hacked a little radio-controlled power boat. First, we had to test the safety system of the boat. If the electric water switch has disconnected from the water, the boat should stop functioning. The function of the boat is to propel the machine through the water.

We attached a lunchbox on top of the cabin (Screw + hot glue) so it would hold the Raspberry Pi, the mobile phone external battery, the USB cable that connects the Pi to the webcam.

We than built an aluminium frame with L profiles, all pop-riveted.



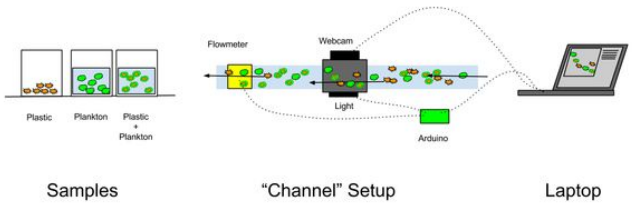



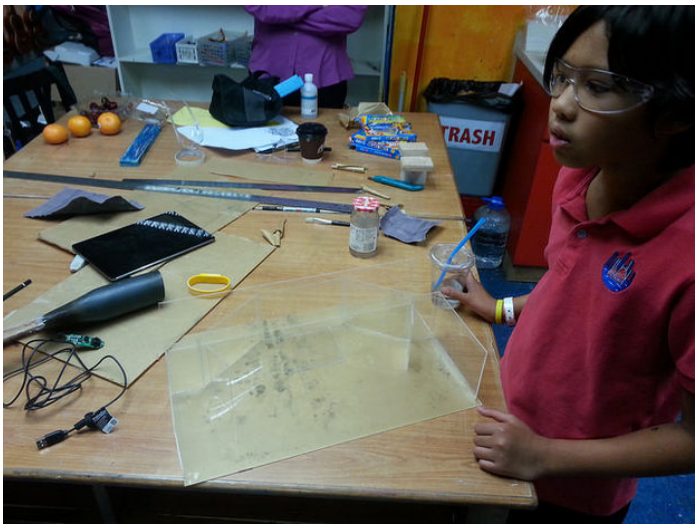


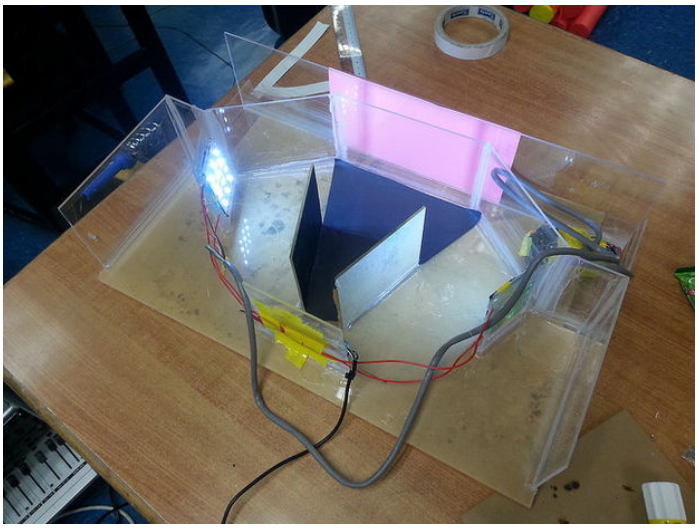
## Step 6: Hacking a webcam and LED desk lamp

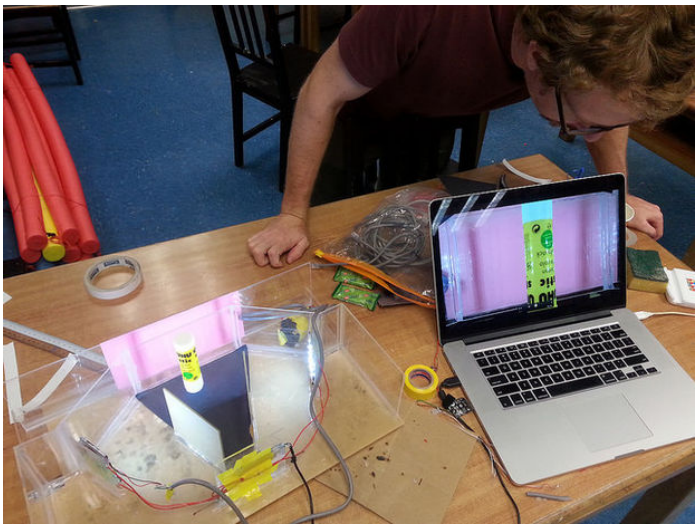
After painstakingly constructing the first design (one whole day!), we realized there were a few problems apart from the leak in the channel which could have been easily siliconed. In the original design, we were to somehow fix the camera in the big PVC tube sliding the channel directly under. The problem was when we installed the web camera, we find that while focusing the camera, it had to be further away from the channel than the tube allowed in order to get a clear visual. So we had to ditch this design and evolve to a new one to take into account LED lighting and camera distance.

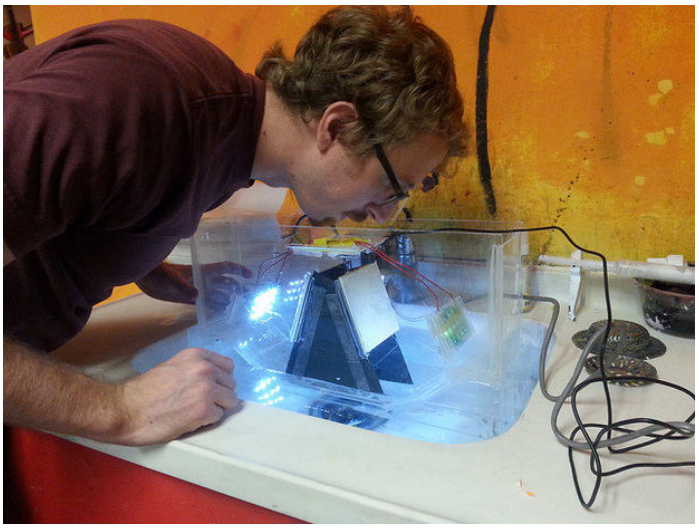
For the new design, we first measured the distance needed between the camera and the channel which was 8cm. We decided to build the channel out of perspex because it's easily to cut into shape, can be glued together easily and is transparent. We also added a net at the back of the channel in order to count the plastic caught and compare against the plastic sensed by the machine. Since the sensor is enclosed, it will restrict a good amount of light, impairing the camera's ability to capture images of the plastic flowing through the slit. To counter this problem, we added lights to lighten up the situation.




TRASH



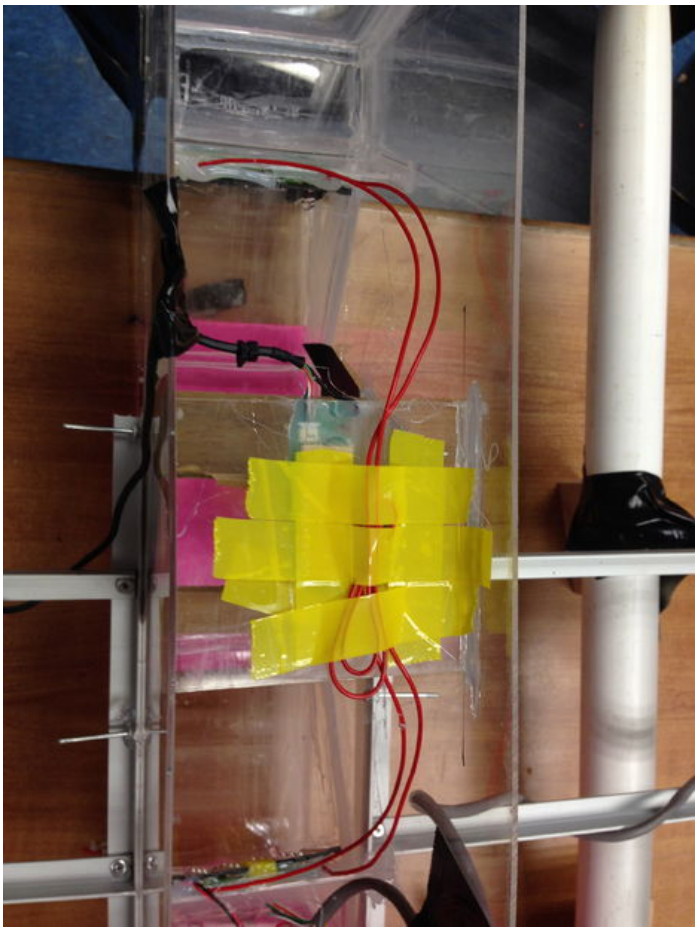


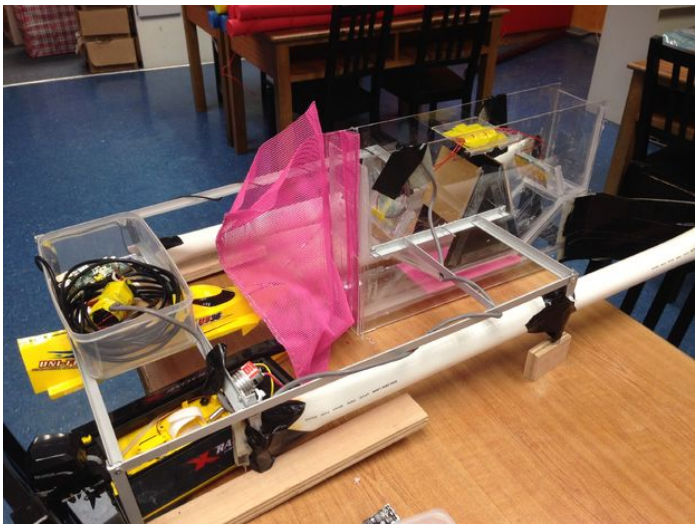


## Step 7: Combining the sensor (webcam) with the motor drive (RC boat)

We built 2 long white PVC tubes that we finished with a heat gun.

Now that we had the boat, the frame, the PVC tubes and the sensor, we assembled it together.





## Step 8: Grinding plastic debris

We looked at the plastic scientists collect in the middle of the ocean : most of the time very small fragments of plastic.

We did not have such small fragments so we put in the mixer plastic Jo Wilson collected on Lamma Island beach. Lara and Aiyana used different types of plastics. They used Vita bottles, sponges, bottle caps and other plastic bits. It takes a lot of work to get it very small in the workshop as Lara and Aiyana found out. They used a blender to cut up all the plastic into very small bits and then chopped it up even smaller by hand with scissors. They weighed the plastic.

We than filtered it and washed it until it was perfectly clean.

## Step 9: Creating the environment for testing the machine

In order to test the machine, we had to create an environment in which to test it. We used foam noodles to keep the plastic in a confined space.

## Step 10: Testing our ocean plastic sensor

**At the lake**

We deployed our floating barrier... And got our mobile plastic sensor out on the water. The plastic debris was then released and in a few seconds scattered all over the buoy contained area ... We started the engine to move the boat around...

But what very unfortunately happened was that all of a sudden, an army of little TURTLES arrived and started EATING THE PLASTIC !!! We had to immediately stop the experiment. Note also that the floating barrier area was actually really too small and our boat that had limited manoeuvrability got stuck quite easily in the barrier.

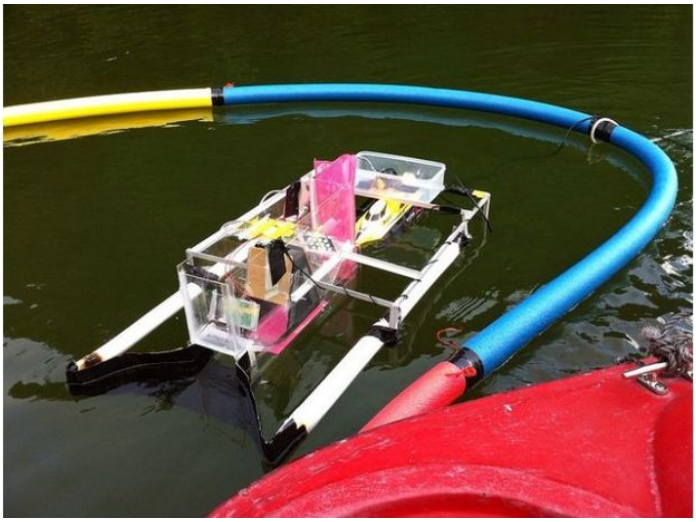
**In the big swimming pool**

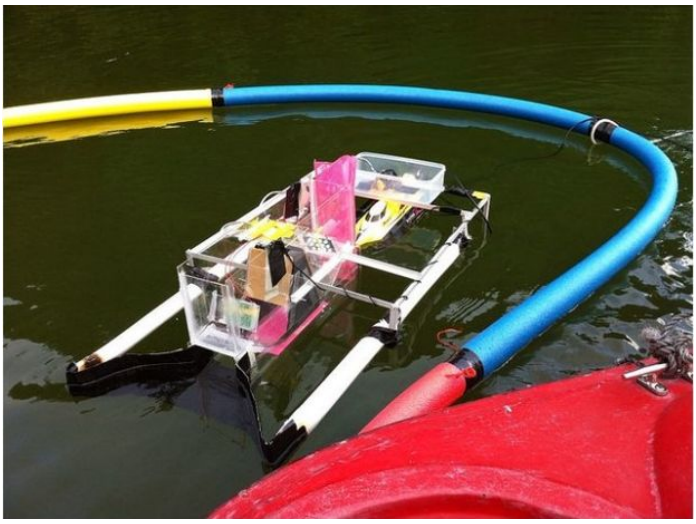
We could not give up, and Carolyn kindly offered to use the swimming pool of the residency. This time, we tested the navigation capacity of the boat and the video feedback with great success.

**In the baby swimming pool**

We repeated the experiment and released the plastic debris in the baby pool, tightly contained with handheld floating barriers. We captured video of water and plastic passing though the video channel.

http://youtu.be/lhFqjVvKHQ4





## Step 11: Analyzing the data

What would be the best way to analyze data?

Edward Fung tried different things on OpenCV :

**The goal of the experiments**

1. see if I can just use any one of the channels in HSV color space to find the plastic.
2. see if Canny edge detector yields a reasonable good result from this footage

**Procedure**

- Install opencv
- Read the video.
- For each frame img:
- Convert img to HSV and grayscale image
- Run Canny edge detector
- save the result into video for record
- Evaluate with human eyes // The most scientific part... (o:

**Tools**

1. Opencv 2.4 (python binding)
2. Canny edge detector with parameters (50, 100)
3. ffmpeg

**The result videos**

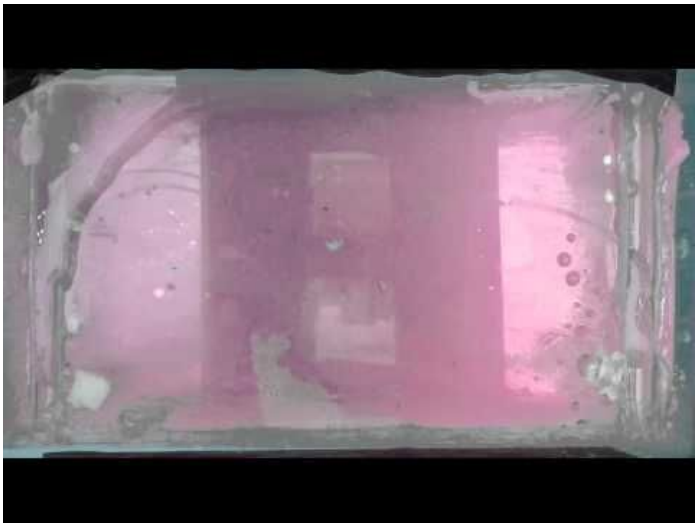
http://youtu.be/lhFqjVvKHQ4

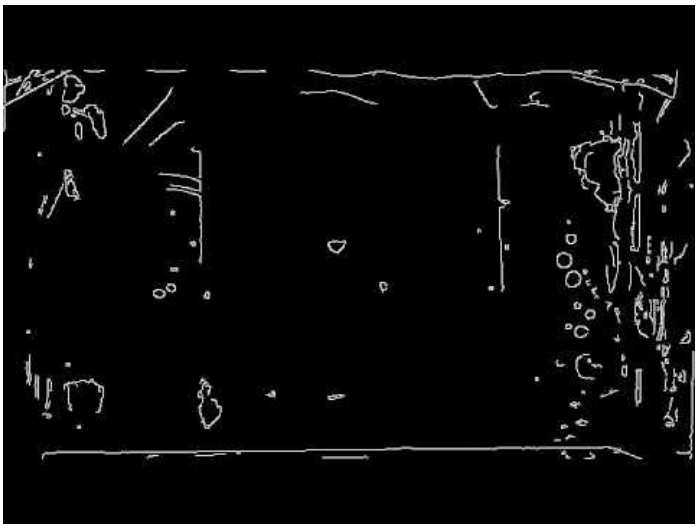
The original file is here : http://protei.org/download/20140619plastic_sensing.mp4

http://youtu.be/g2V3ppbpikw

http://youtu.be/SUMKZEpwD9w

All videos are here: http://wiki.scoutbots.com/home/research/ocean-plastic-debris-optical-sensor/20140628-treatment-of-the-video-with-opencv





## Step 12: What and How can we improve?

We had a lot of great feedback how to improve our plastic sensor. Some are in the comments at the bottom on this wiki page. We're going to use not white (day) light, but go for Laser diodes.

Brandon suggests : http://www.idec.com/sgen/technology_solution/our_core_tech/plastic_sensing.html

“We succeeded in developing technology that is capable of sensing plastics using an InGaAsP semiconductor laser diode (LD).It was discovered that upon measuring light absorption spectra in plastics, in the wavelength range of 300 to 3000 nm, the peak values were always observed at or near 1700 nm, regardless of plastic types. This discovery opened the possibility for simple optical sensing of plastics with the use of a LD in this wavelength range. Observation of unique light absorption characteristics within the near infra-red spectrum of each different plastic type has led us to develop the world’s first technology capable of detecting different types of plastics with the use of a LD (with three different wavelengths).”

Working on the mobile robotic plastic sensor gave us some inspiration to develop other machines to sense plastic.

**Optical Plastic sensor (the one we are building now)**

- some of it floats on the top of water
- Too small for nets degradation to chemical level

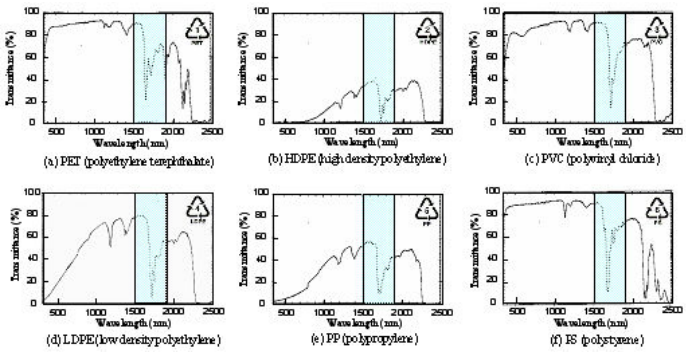
**Vibration tank, collect plastic on the surface of a sandy beach, bottom of the sea)**

- plastic is at the bottom : go down and scrape the bottom and find plastic

**Biological experiment (to understand how much animals eat plastic)**

- fish eats it, and poop it Fish digest it

We are looking for your feedback to improve our plastic sensor. This is just the beginning of a great adventure with Open Technologies for the Oceans



## Related Instructables

**Smart home automation webserver on OpenWRT router WR703N interfaced to Arduino, compared to Raspberry Pi and Ubuntu** (Photos) by janisalnis

**Making an autonomous boat using a Raspberry Pi (WiP)** by SilverJimny

**Raspberry Pi xbmc IR Sensor and Remote** (video) by misperry

**Turning your Raspberry PI Into a Media Center Extender** (video) by misperry

**Wireless Multi-Channel Voice-Controlled Electrical Outlets with Raspberry Pi** by Ben Finio

**Raspberry Pi remote webcam** by sat481

## Comments

**8 comments** **Add Comment**

**cesar harada** says: Jul 6, 2014. 5:26 AM **REPLY**

Hi Guys, how do you feel about it now? Good enough? It better be because tomorrow it will be presented at the Chinese University! Who presents which part? Well done to all !

**Bevan-Shiraz** says: Jul 4, 2014. 8:45 PM **REPLY**

I have included my ideas and have done some editing. I have also added some pictures and changed the order of the steps.Thanks!

**bwzx** says: Jul 3, 2014. 9:33 AM **REPLY**

I have included all of my ideas in this document. Thanks!

**AiyanaCampbell** says: Jul 3, 2014. 2:23 AM **REPLY**

Hi Hector, good job! I added some steps and pictures. But I need more pictures. Maybe Cesar has them? I cannot figure out how to add between your steps so instead, I just listed them down as 8 and 9. They should really go between steps 5 and 6.

**cesar harada** says: Jun 30, 2014. 11:33 AM **REPLY**

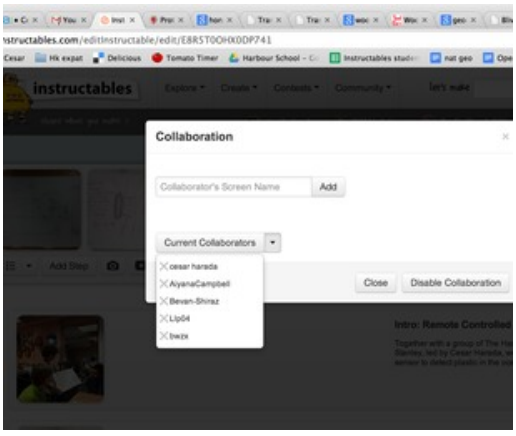
WOW !!! You went faster than the whole team! This is so cool! Look, do you want to invite all of us on your instructables as a "collaboration" so we can improve all on top of what you have already done / or do you prefer that we make another collective instructables separated from this one? You did a great job. I love how precise and clear are your drawings.

**Hector Hatrick** says: Jul 1, 2014. 6:21 PM **REPLY**

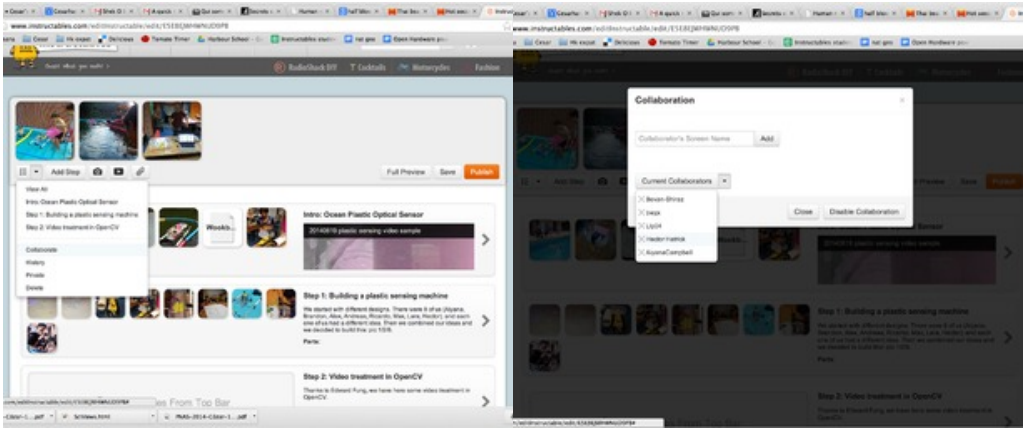
OK. I think I have finally managed to include collaborators. Hope it works.

**cesar harada** says: Jul 1, 2014. 7:08 PM **REPLY**

hey, I checked, yes, it worked !
Attached the screen capture, I can see everybody :)



**cesar harada** says: Jul 1, 2014. 10:26 AM **REPLY**

Dear Hector, You did a great job at explaining the project, but I believe we can make it even better all together with the team :) Would you be kind to invite us all to collaborate? The other team mates registered so far are :
- Brandon : bwzx
- Aiyana : AiyanaCampbell
- Lara : Bevan-Shiraz
- Cesar : cesar+harada

Please invite them as explained in the photos.
Can you add us all to collaborate please, so we can expand your wonderful work?