

6.869 Advances in Computer Vision

Spring 2010, A. Torralba

Problem set 1

Due date: Wednesday, Feb 17, 2010

You need to submit a report with brief descriptions of what you did. The most important part is to insert the pictures that you took, as well as Matlab plots. You can also include some pieces of your Matlab code.

The goal of this problem set is to become familiar with Matlab and with some of the basic concepts from geometry.

Before starting the problem set, read the full document.

You can do parts 1 and 2 of the problem set in groups of 2 – 4 people. Each person should submit a separate report. Write in the report the names of the people you collaborated with. You can include the same images.

1 - Building a digital camera obscura

1.1 Build the camera obscura

The first part of this project consists in building your own “camera obscura“, or pinhole camera. A camera obscura is a dark chamber with a single hole in one extreme that lets light in. The light gets projected into the opposite wall forming an image. In order to capture the projected image we will use a digital camera. One of the problems with pinhole cameras is that the amount of light that enters the device is very small. Therefore, we will need to use long exposure time to capture images with enough contrast. Many digital cameras with a manual mode allow setting the exposure time. I used a Canon G11 for the pictures I took.

Let's first start building the device (I took this instructions from [1]):

- Take a box (I used a card box with 11x9x15inches).
- Make a hole in the center of one of the faces. The hole has to be small (a diameter of 5 millimeters).
- Make a second hole so that you can fit the lens of the camera inside.
- Cover the inside walls with black paper to reduce inter-reflections.
- Cover the inside wall facing the pinhole with white paper. The white paper will be the screen in which the image will be projected. The digital camera will be used to take pictures of the image that gets projected into the white paper.

Here there are some pictures of my construction:



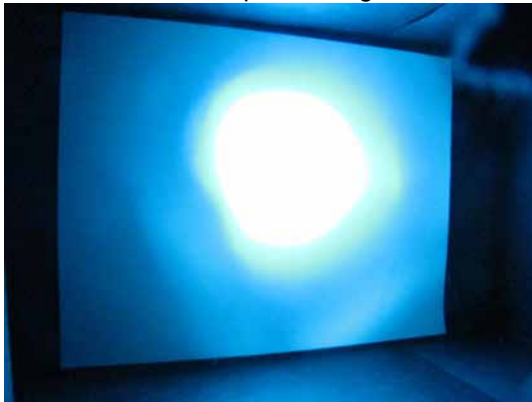
In my construction, the distance between the pinhole and the white wall is 11 inches. The big hole visible in the pictures is the hole I used to insert the digital camera. The pinhole is a very small hole in the center and it is hard to see in these pictures. It is important that the camera fits tightly so that no light enters via that aperture. Make sure that light enters only via the small hole in the center of the box. You can find more practical details about how to build the device in [1] as well as some comments about the geometry of the device.

Once you have built your camera obscura, take some pictures of your construction to put on the report and we will share them with the rest of the class.

1.2 Take some pictures with the camera

For this you will need a digital camera for which you can set the exposure time. I used an exposure time of 15 seconds and setting the camera to maximum sensibility (I use a Cannon G11).

Here there are a couple of images taken with my set up:



Left) This is a picture of a bright light source. This picture makes the white screen on the back of the wall appear clearly. *Right)* A picture on a cloudy day.

If the images appear too blurry, you can increase the sharpness by reducing the size of the hole. But then you will need to increase the exposure time.

You need to take pictures under bright light (sunny day outdoors). But you can play first by shining a light at the hole. If you see nothing, then there might be something wrong with the camera settings.

Here there are a couple of images I have taken during a sunny day:



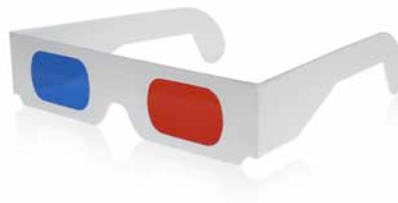
Think about the geometry of the construction to understand why the pictures appear slightly deformed.

2. Anaglyph camera obscura

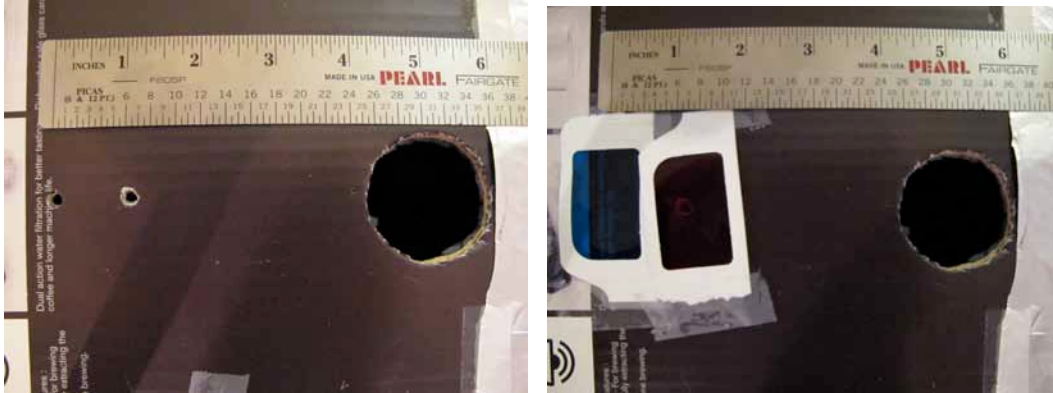
One interesting aspect of this device is that you can build different types of cameras by playing with the shape of the pinhole. So, let's make a new kind of camera obscura. In particular, we can build a camera that produces anaglyph images in a single shot by making two pinholes instead of just one.

There are several ways of taking stereo pictures and viewing them. The most common mechanism is that two pictures are taken independently (with two cameras) and then they are combined to form anaglyph images, or viewed with special devices (e.g., LCD shutter glasses, polarized 3d glasses, stereoscopes,...) that show each image from the stereo pair to each of the two eyes. Anaglyph images are a particular method to produce 3D images. Anaglyph images are formed by superimposing a pair of stereo images into two different color channels. They provide a 3D effect when viewed with color glasses.

We will transform the camera obscura into an *anaglyph camera obscura* by making two holes and placing different color filters on each hole. This will produce an image that will be the superposition of two images taken from slightly different viewpoints. Each image will have a different color. Then, to see the 3D image we can look at the picture by placing the same color filters in front of our eyes. In order to do this, I used color glasses with blue and red filters:



I used one of the glasses to get the filters and I placed them in front of the two holes. Here are two pictures of the two holes (left) and the filters positioned in front of each hole (right):



Suggestions: For this to work you will have to experiment with the distance between the two holes. I tried two distances: 3 inches and 1.5 inches. I found easier to see the 3D for the 1.5 inches images. Try to take good quality images. Once you would have placed the color filters on each hole, you will need longer exposure times in order to get the same image quality than before. If the images are too blurry, it will be hard to perceive 3D. Also, as you increase the distance between the pinholes, you will increase the range of distances that will provide 3D information. However, the images will be farther apart which makes the 3D perception harder. If the images are too far apart, the visual system will not be able to fuse them and you will not see a 3D image when looking with the color glasses. You can also try viewing the images by changing the image size.

The next image shows one of the anaglyph images I took:



----- Do the rest of the problem set individually -----

3 – Image correction

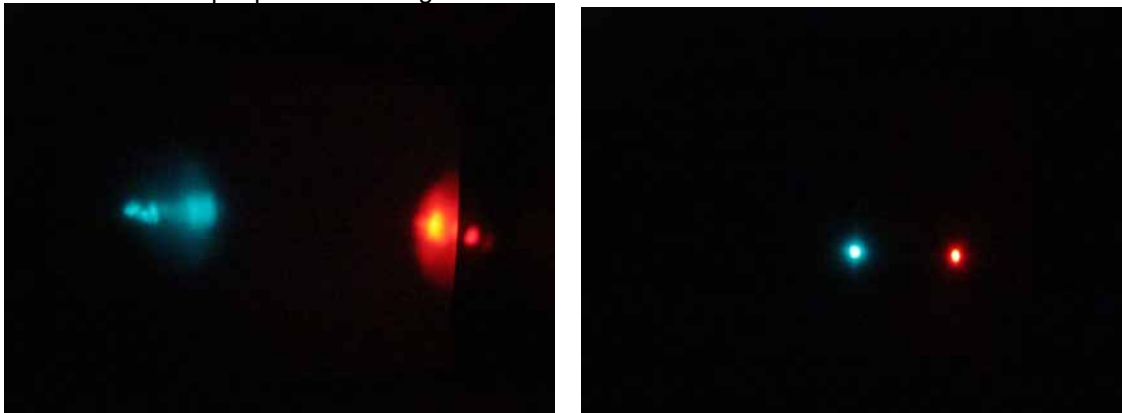
The images taken by the digital camera have geometric distortion due to the fact that the pictures are taken at an angle respect to the white screen. You can correct that geometric distortion by warping the image so that the boundaries become rectangular. To warp images, you can use the matlab function *interp2* or *griddata*.

If your images are noisy, you can play with different filtering techniques such as *medfilt2*.

4 – Anaglyph camera obscura: A device to measure distances to objects

We can all measure distances to an object by using a ruler. However, using a ruler is an intrusive procedure, as it requires physically placing one extreme of the ruler touching the object. Some objects do not like to be constantly approached by rulers. Stereovision provides a way of measuring distances between the camera and other objects in the world remotely, without touching them.

Here are two example pictures of a light taken at two different distances:



As you can see, a single light produces two spots in the picture. This is due to the fact that the light enters the camera obscura through two pinholes instead of one. Each spot has a different color because I placed two colored filters on each pinhole to form the anaglyph image. The interesting property is that the distance between the two spots (d) changes with respect to the distance (Z) between the camera and the light. Therefore, we could measure the distance (Z) to the light by just measuring d and if we had a perfect model of the geometry of the camera. We will do this in the next part:

3.1 Find the relation between the separation of the lights and distance.

Place the light at various known distances from the pinhole and take a set of pictures.

You can decompose the anaglyph image into the images projected by each pinhole by visualizing the red and blue channels separately:

```
img = imread('yourfilename.jpg');  
figure  
imshow([img(:,1); img(:,3)])
```

You can use the command *ginput* to measure corresponding points between the two images.

Plot the relationship between Z and d .

You should think about the geometry of the camera in order to derive an analytical expression that relates the distance between the two spots in the picture with the distance of the light respect to the camera and the parameters of the camera (distance to the back wall, separation between the two holes, etc.). Check that your predictions fit the experimental data.

3.2 A manual stereo algorithm

In this part, the goal is to apply manually a stereo reconstruction algorithm. The goal is: given two images, to recover the full 3D structure of the image (we will only produce a coarse approximation to it). Automatic algorithms for measuring depths from stereo can be challenging. However, we will do it manually by following the next steps:

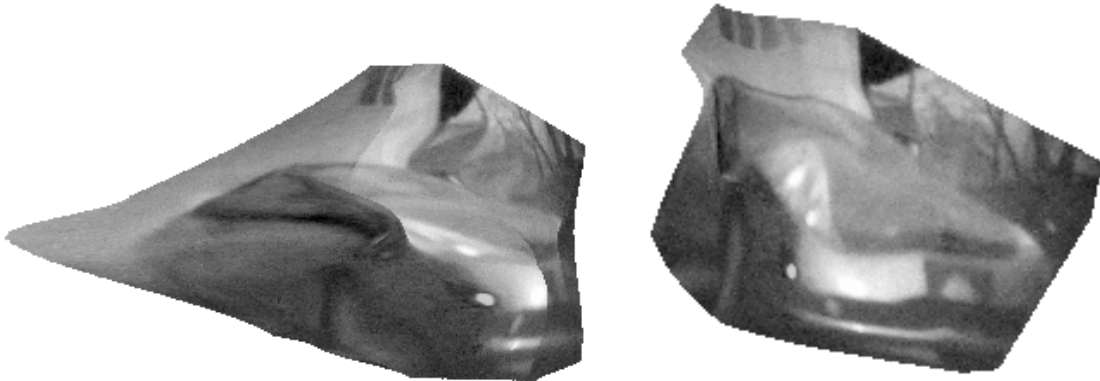
- Take a picture with the anaglyph camera. Try to take a picture in which there are many clear elements that can be easily identified in the image. Also, select a scene with enough depth differences (with some elements very close to the camera and others far away).
- Use matlab to select a number of matching points between the two color channels of the anaglyph image manually.
- Use the function from the previous section that relates the horizontal distance between matching points to recover the distance between the camera and the selected points.
- Now you will need to interpolate the distance in order to create a continuous image of depths. You can use the function *griddata*.

Here is one example showing the red and blue channels of the stereo picture:



I used the top image as the reference image. Then, I computed depth at a set of selected points on the top image.

Once you have a depth map (the value of the distance at each pixel in the image), you can do different things like trying to rotate the image in 3D. Here are two different viewpoints of the car:



References:

[1] Digital pinhole camera,
http://www.foundphotography.com/PhotoThoughts/archives/2005/04/pinhole_camera.html