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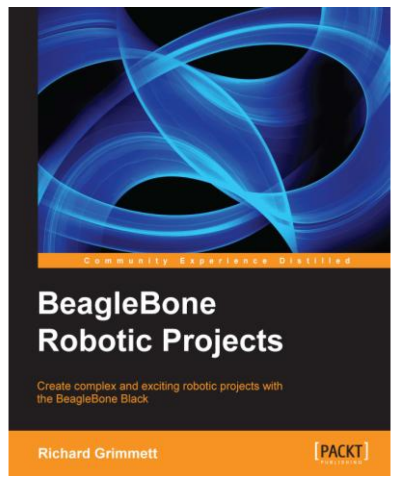
BeagleBone Robotic Projects

Richard Grimmett



Chapter No. 4

"Allowing the BeagleBone Black to See"

In this package, you will find:

A Biography of the author of the book

A preview chapter from the book, Chapter NO.4 "Allowing the BeagleBone Black to See"

A synopsis of the book's content

Information on where to buy this book

About the Author

Richard Grimmett has always been fascinated by computers and electronics from his very first programming project that used Fortran on punch cards. He has a Bachelor's and Master's degree in Electrical Engineering and a PhD in Leadership Studies. He also has 26 years of experience in the Radar and Telecommunications industries, and even has one of the original brick phones. He now teaches Computer Science and Electrical Engineering at Brigham Young University - Idaho where his office is filled with many of his robotics projects.

I would certainly like to thank my wife and family for providing me the time and wonderful, supportive environment that encourages me to take on projects such as this one. I would also like to thank my students; they always amaze and inspire me with their creativity when released from the boredom of standard educational practices.

BeagleBone Robotic Projects

We live in an amazing age. We are mostly aware of how amazing it is as we live in an age where major changes to how we live occur well within a lifetime, sometimes within a few years. Nowhere is this more evident than in the general area of technology, and the specific area of computers. Not so many years ago, certainly within the lifespan of most of the baby-boomer generation, computers were distant machines kept in the backrooms of large corporations or universities. Access to them was tightly controlled. If you wanted to program them, you punched your computer cards, fed them into the card reader, and then, after an hour or so of wait, you went to receive your computer printout. This was, I regret to reveal, part of my first experience with a computer.

These large computers were the domain of companies such as IBM, with their model 360, Digital Equipment, with the Model PDP-7, and Hewlett -Packard, with the Model 1000. These computers cost many thousands of dollars, and were rarely seen except by a privileged few, who had access to climate-controlled computer rooms.

This model fit the world just wonderfully for many years, until the advent of the personal computer. I was lucky to know someone who purchased one of the very first IBM-PCs. It had two floppies, a monochrome monitor, and was an amazing piece of equipment. Suddenly the world changed and the technology that had seemed so remote was now available on the desktop. This same technological revolution in processing power also birthed a new breed of dedicated microprocessors. These could be used for specific tasks that had previously been the realm of analog circuitry or, in many cases, human interaction with mechanical systems.

These processing solutions to specific applications are named embedded systems. They take the digital calculating capability of personal computers and shrink them even further so they can be placed in common household and industrial objects. Embedded technology has also evolved with respect to price; fortunate, for few would be willing to pay several thousand dollars for a door lock or temperature sensor. The initial embedded devices were very limited in their technology, and developing applications with them became quite a challenge. It was very common to run out of either computing horsepower or memory. Many nights were spent by the talented few shoehorning the last features into the last few bytes of memory.

The computer age has spawned an amazing array of technical advances in both the hardware and soft ware areas. Companies such as Intel and AMD have created processors with almost unfathomable computing power and more available memory that once thought possible, and both Microsoft and Apple have provided major advances in the area of soft ware functionality and usability. The personal computer has become a standard tool in most households, schools, businesses, and factories.

As the personal computer has gone, so has the embedded systems world. From what were once four bit, special purpose processors with 2000 bytes of memory, now embedded processors have emerged that rival the performance and capability of standard personal computers. One has to look no further than the cell phone for an example of significant computing capability in very small packages, and at very inexpensive prices.

This has all reached a bit of a crescendo with the introduction of small, inexpensive systems that can not only run simple, focused applications, but have the capability of powering almost any type of computing need we can create. At the same time these small but powerful systems have outgrown the small, single purpose development environments as well. They are now paired with powerful operating systems, and provide personal computer like functionality in very small packages. The overwhelming advance of tablets and smart phones has begun to take over the face of computing for many applications.

These advances have also affected the embedded area as well. Small, highly capable systems have married very inexpensive hardware with free, open source soft ware to provide a platform for almost anyone to explore the embedded world. The Arduino, the Raspberry Pi, and now the BeagleBone Black are all platforms that off er not only an affordable price point, but also an open source soft ware community that provides free capability and an easy way to interact with others to get answers to questions or exchange ideas. With these new capabilities, as we shall see later in the book, the sky is literally the limit.

This book will focus on just one of these processors, the BeagleBone Black. However, much of what is written here could be applied to other choices with some limited modifications. But this is not what you came here to learn. You came to learn how to build some very interesting, complex, amazing robotics projects. And processors such as the BeagleBone Black are impressive because they have the capability to not only make this possible, but to make it accessible to those outside of academic or research communities. In this book, we'll explore these capabilities, and build some very impressive projects.

Just a few comments on how the book is laid out. We'll start with a very basic introduction to the BeagleBone Black, and how to get the hardware and soft ware up and working. Then, we'll build some basic functionality on top of the basic system, showing you how to add sound, vision, and control.

Then we'll tackle some fairly complex capability, including GPS, audio, and some advanced sensors. Finally, we'll wrap it up by showing you how to put an entire system together with some tools that can make that a bit less complicated.

In each chapter, I'll give you some very specific instructions for how to proceed. This is a bit dangerous, and the instructions are all going to be subject to change. Hopefully you'll understand the basics of what we are trying to accomplish, so if things don't go quite to plan, you'll be able to figure out how to proceed. There is a lot of help out there, between message boards and blogs, so don't be shy.

What is critical to remember is that this is not an academic exercise. Don't just read the book, but do something with the hardware. My hope is that by the end, you'll be building the kinds of machines that will lead us all into the 22nd century. I oft en tell my students that their children will grow up as comfortable with robots as they are with computers.

So, let's begin!

What This Book Covers

Chapter 1, *Getting Started with the BeagleBone Black*, will provide instructions for initial power-up of your hardware.

Chapter 2, *Programming the BeagleBone Black*, will give you a brief tutorial so that you can be successful implementing all the amazing functionality, as many of you are new to embedded systems, Linux, Python, or perhaps even programming in general.

Chapter 3, *Providing Speech Input and Output*, will show you how to add speech recognition as well as make your robot speak.

Chapter 4, *Allowing the BeagleBone Black to See*, will show you how to add the capability for your robot to see.

Chapter 5, *Making the Unit Mobile – Controlling Wheeled Movement*, will show you how to add wheeled movement to your robot.

Chapter 6, *Making the Unit Very Mobile – Controlling Legged Movement*, shows how to build robots that have the capability to walk.

Chapter 7, *Avoiding Obstacles Using Sensors*, shows how to use sensors to avoid barriers as it hardly makes sense to have mobility if your robot is going to run into obstacles.

Chapter 8, *Going Truly Mobile – Remote Control of Your Robot*, will show how to use a remote device to control your robot.

Chapter 9, *Using a GPS Receiver to Locate Your Robot*, shows how to add a GPS device to your robot.

Chapter 10, *System Dynamics*, introduces some methods for organizing all of the capabilities so that they are available at the same ti me.

Chapter 11, *By Land, Sea, and Air*, introduces some interesting possibilities for embedded projects that can fl y, sail, or swim

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Allowing the BeagleBone Black to See

Your projects can communicate via voice; now you are going to add vision with a webcam. You'll use this functionality in lots of different applications. Fortunately, adding hardware and software for vision is both easy and inexpensive.

Mission briefing

In this chapter, you'll add a USB webcam to your system. Having the standard USB interface on your board opens a wide range of amazing possibilities. On top of that, there are several amazing open-source libraries. These offer complex capabilities that you can use in your projects without spending months coding them.

Why is it awesome?

Vision will open a set of possibilities for your project. These can range from simple motion detection to advanced capabilities such as facial recognition, object identification, and even object tracking. The robot can also use vision to detect its surroundings and avoid obstacles.

Your objectives

In this chapter we will cover:

- Connecting your USB camera to your BeagleBone Black and viewing the images
- Downloading and installing OpenCV, a full-featured vision library
- Using the vision library to detect colored objects

Downloading the example code and colored images

You can download the example code files and colored images for this Packt book you have purchased from your account at `http://www.packtpub.com`. If you purchased this book elsewhere, you can visit `http://www.packtpub.com/support` and register to have the files e-mailed directly to you.

Mission checklist

To complete this mission, you'll need a BeagleBone Black with a LAN connection and a 5V power supply. You'll need to add a USB webcam. Try to find a recently manufactured one. You may have an older webcam sitting on your project shelf, but it will probably cause problems, and the money you save will not be worth the frustration. I would stick with webcams from the major players such as Logitech or Creative Labs.

In most cases, you won't need to connect this device through a powered-USB hub; however, if you encounter problems, for example if the system does not recognize that your webcam is connected, realize that the lack of USB power could be the problem.

Connecting the USB camera to the BeagleBone Black and viewing the images

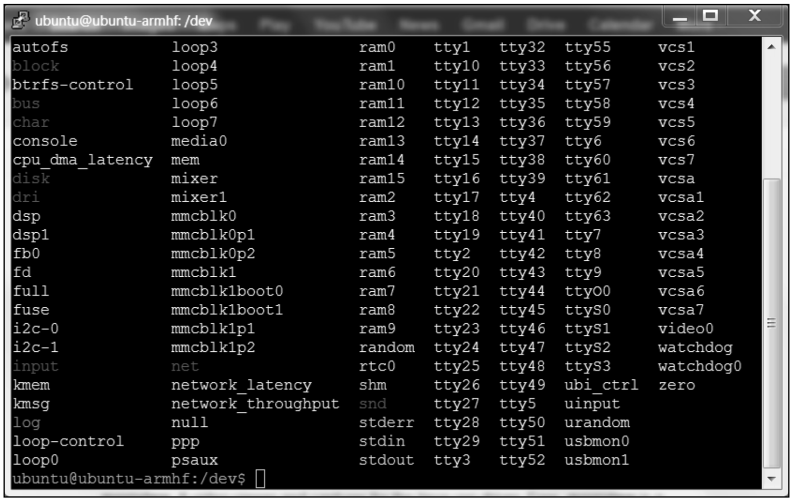
Our first step in enabling computer vision is connecting the USB camera to the USB port. I have a new Logitech HD 720 camera as my example.

Prepare for lift off

To access the USB webcam, I like to use a program called **guvcview**. Install this by typing `sudo apt-get install guvcview`.

Engage thrusters

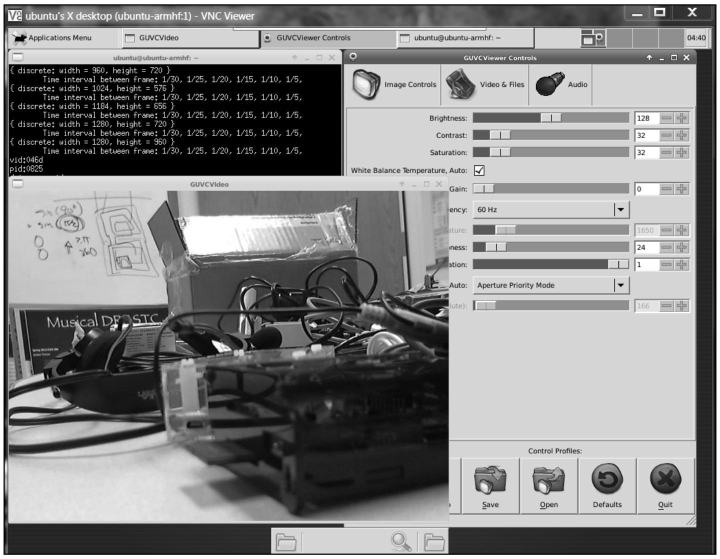
Connect your USB camera and make sure your LAN cable is plugged in. Then apply power to the BeagleBone Black. After the system is booted, you can check to see if the BeagleBone Black has found your USB camera. Go to the `/dev` directory and type `ls`. You should see the output as shown in the following screenshot:



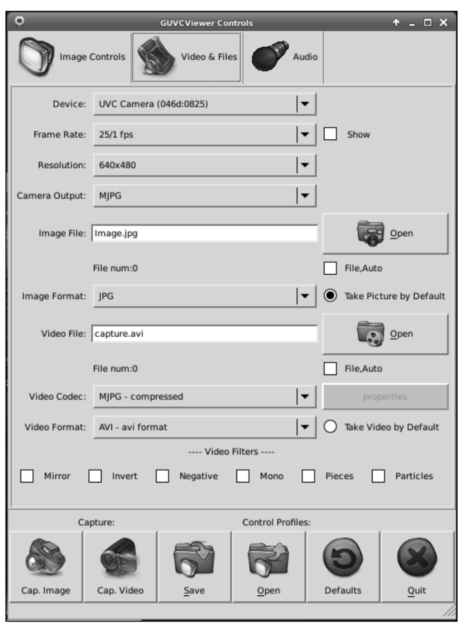
Look for the **video0** device, the webcam. If you see it, the system knows your camera is there.

Now let's use guvcview to see the output of the camera. Since this will need to output some graphics, you either need to use a monitor connected to the board as well as a keyboard and a mouse, or you can use vncserver. If you are going to use vncserver, make sure you start the server on the BeagleBone Black by typing `vncserver` via SSH. Then start up your vncviewer as described in *Chapter 1, Getting Started with the BeagleBone Black*. Open a terminal window and type `sudo guvcview`.

You should see the output as shown in the following screenshot:



The video window displays what the webcam sees, and the **GUVCViewer Controls** window controls the different characteristics of the camera. The default settings of the Logitech HD 720 work fine. However, if you get a black screen for the camera, you may need to adjust the settings. Click on the **GUVCViewer Controls** window and the **Video & Files** tab. You will see a window where you can adjust the settings for your camera.



The most important setting is the **Resolution**. If you see a black screen, adjust the resolution down; often this will resolve the issue. This window will also tell you what resolutions are supported for your camera. Also, you can display the frame rate by checking the box at the right of the **Frame Rate** setting. Be aware, however, that if you are going through vncviewer, the refresh rate will be much slower than if you're using the BeagleBone Black and a monitor directly.

Once you have the camera up and running and a desired resolution set, you can go on to download and install OpenCV.

Objective complete – mini debriefing

Your system can now "see" the outside world. Guvcview can actually capture images or video and store them as files, but OpenCV provides a full-featured set of image processing capabilities as well.

Classified intel

You can connect more than one webcam to the system. Follow the same steps, but connect to cameras via a USB hub. List the devices in the `/dev` directory. Use guvcview to see the different images. One challenge, however, is that connecting too many cameras can overwhelm the bandwidth of the USB port.

Downloading and installing OpenCV – a full-featured vision library

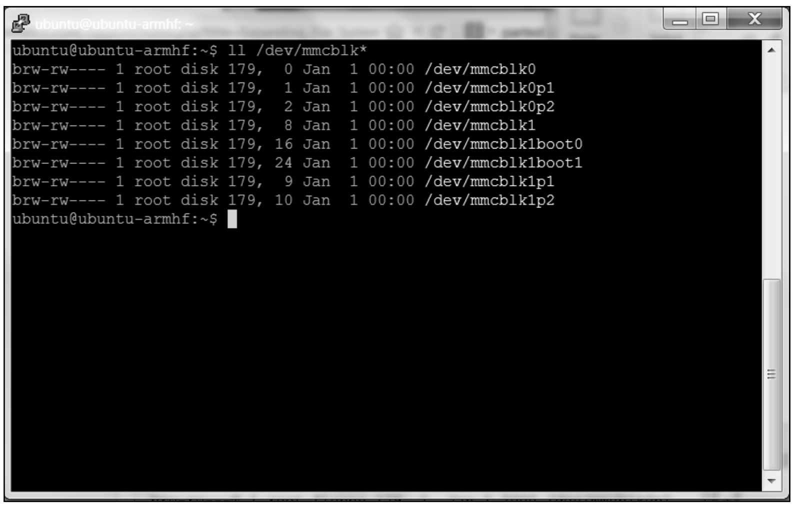
Now that you have your camera connected, you can begin to access some amazing capabilities that have been provided by the open source community. The most popular of these for computer vision is OpenCV.

Prepare for lift off

Now you need to install OpenCV, a complete vision library that provides tools for you to use to capture, process, and save your images. Before you do this, you need to expand the partition on your SD card so that you can download all the applications that you need. When you wrote the Linux operating system to your SD card, you copied a 2 GB image; so now your card thinks it is only a 2 GB card, no matter what size it really is. You need to reclaim this space.

To do this, you'll need to issue some fairly cryptic commands, but you can use the defaults, so it will be straightforward. First, open a terminal window. The card I am using is an 8 GB card, so if your card is of a different size, you might not see the exact same numbers. Fortunately you'll be using default values throughout the process, so you won't need to know anything special about your card. To begin, type `sudo su`, and then enter your password. Then follow these steps:

1. Type `ll /dev/mmcblk*` and you should see output similar to the following screenshot:



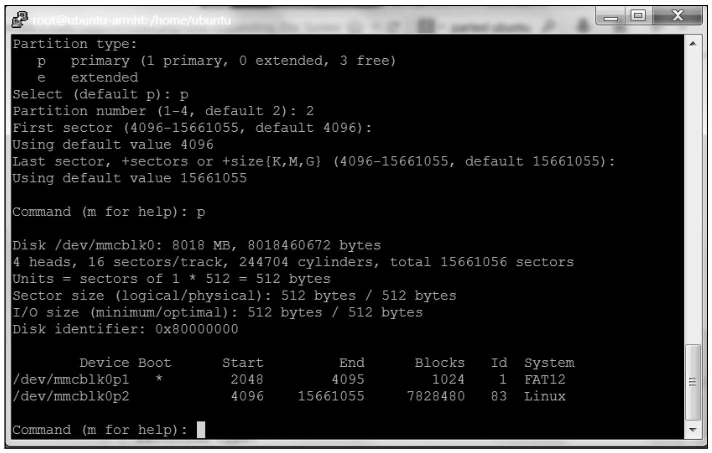
2. Now you are going to make changes to the `mmcblk0` device. Type `fdisk /dev/mmcblk0`.
3. Enter the `p` command and you should see the details of the different types of storage that you currently have available, similar to the output shown in the following screenshot:

```
root@ubuntu-armhf:/home/ubuntu# fdisk /dev/mmcblk0

Command (m for help): p

Disk /dev/mmcblk0: 8018 MB, 8018460672 bytes
4 heads, 16 sectors/track, 244704 cylinders, total 15661056 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disk identifier: 0x80000000

        Device Boot      Start         End      Blocks   Id  System
/dev/mmcblk0p1   *        2048        4095        1024    1  FAT12
/dev/mmcblk0p2            4096     3751935     1873920   83  Linux

Command (m for help):
```

4. You are going to expand the second device, `/dev/mmcblk0p2`. To do this you are going to delete the partition, then create a new partition. The information that exists on your SD card should be preserved throughout this process, however. Enter `d` at the prompt, then `2`, for partition 2. Now enter `p` again and the following screenshot will be displayed:

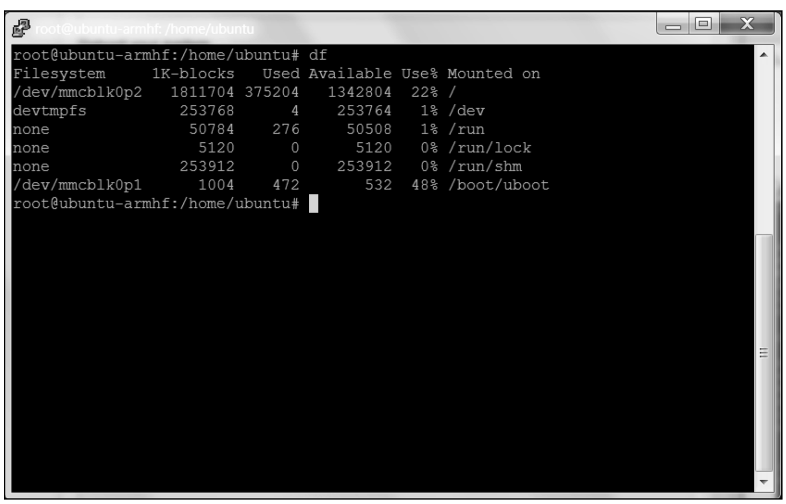
```
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disk identifier: 0x80000000

        Device Boot      Start         End      Blocks   Id  System
/dev/mmcblk0p1   *        2048        4095        1024    1  FAT12
/dev/mmcblk0p2            4096     3751935     1873920   83  Linux

Command (m for help): d
Partition number (1-4): 2

Command (m for help): p

Disk /dev/mmcblk0: 8018 MB, 8018460672 bytes
4 heads, 16 sectors/track, 244704 cylinders, total 15661056 sectors
Units = sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disk identifier: 0x80000000

        Device Boot      Start         End      Blocks   Id  System
/dev/mmcblk0p1   *        2048        4095        1024    1  FAT12

Command (m for help):
```

5. Now you will create a new partition using defaults so that the partition takes up the entire card. At the Command prompt type an `n`, then `p`, then `2` and then hit *Enter* through each choice that the programs request. Your device should now reappear, similar to the following screenshot, with a different size based on the size of your SD card:

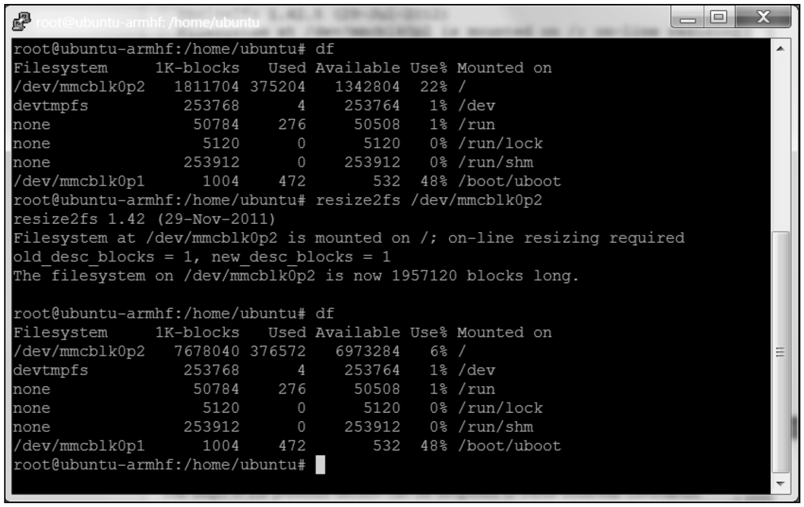


6. Notice that the second partition is now much larger than the original. Now type `w` to commit your changes. Now you need to reboot, so type `reboot`.

7. The final steps will expand the file system. After the system reboots, type `sudo su` and enter your password. Now type `df`, the command to see how much disk you have free. You should be able to see the output as shown in the following screenshot:



8. It is the `/dev/mmcblk0p2` device that you want to resize. Type `resize2fs /dev/mmcblk0p2` and then enter `df`; you should be able to see the output as shown in the following screenshot:



```
root@ubuntu-armhf:/home/ubuntu# df
Filesystem     1K-blocks   Used Available Use% Mounted on
/dev/mmcblk0p2   1811704 375204   1342804  22% /
devtmpfs          253768      4    253764   1% /dev
none               50784    276     50508   1% /run
none                5120      0      5120   0% /run/lock
none              253912      0    253912   0% /run/shm
/dev/mmcblk0p1      1004    472       532  48% /boot/uboot
root@ubuntu-armhf:/home/ubuntu# resize2fs /dev/mmcblk0p2
resize2fs 1.42 (29-Nov-2011)
Filesystem at /dev/mmcblk0p2 is mounted on /; on-line resizing required
old_desc_blocks = 1, new_desc_blocks = 1
The filesystem on /dev/mmcblk0p2 is now 1957120 blocks long.

root@ubuntu-armhf:/home/ubuntu# df
Filesystem     1K-blocks   Used Available Use% Mounted on
/dev/mmcblk0p2   7678040 376572   6973284   6% /
devtmpfs          253768      4    253764   1% /dev
none               50784    276     50508   1% /run
none                5120      0      5120   0% /run/lock
none              253912      0    253912   0% /run/shm
/dev/mmcblk0p1      1004    472       532  48% /boot/uboot
root@ubuntu-armhf:/home/ubuntu#
```

Now your device is ready to use.

Engage thrusters

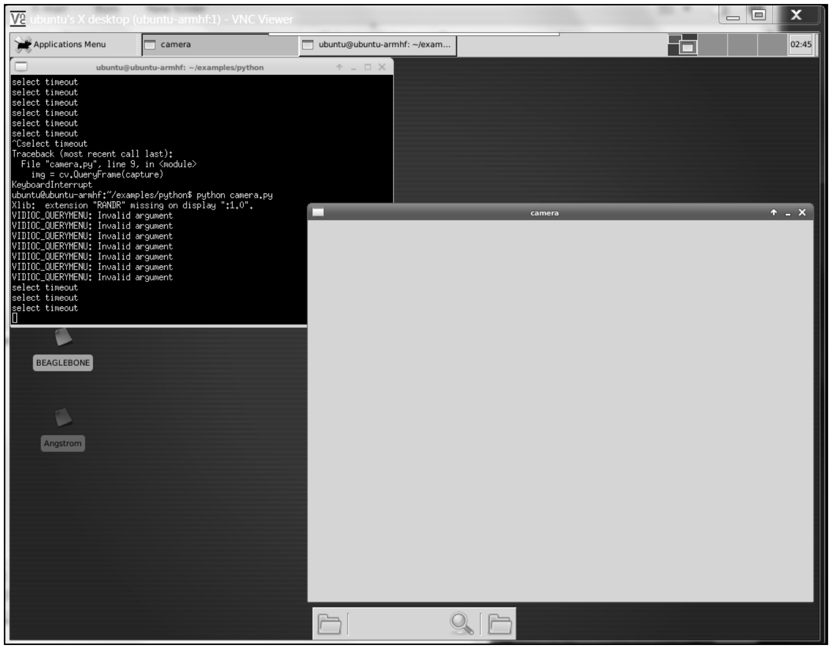
First, you'll need to download a set of libraries and OpenCV itself. There are several possible steps. I'm going to suggest the ones that I follow to install it on my systems. Once you have booted the system and opened a terminal window, type the following commands in the given order:

1. `sudo apt-get install update`: If you haven't done this in a while, it is a good idea to do this now before you start. You will be downloading a number of new software packages, so it is good to make sure everything is up to date.
2. `sudo apt-get install build-essential`: You have done this in the previous chapter, but if you skipped that part, you are going to need this package.
3. `sudo apt-get install libavformat-dev`: This library provides a way to code and decode audio and video streams.
4. `sudo apt-get install ffmpeg`: This library provides a way to transcode audio and video streams.

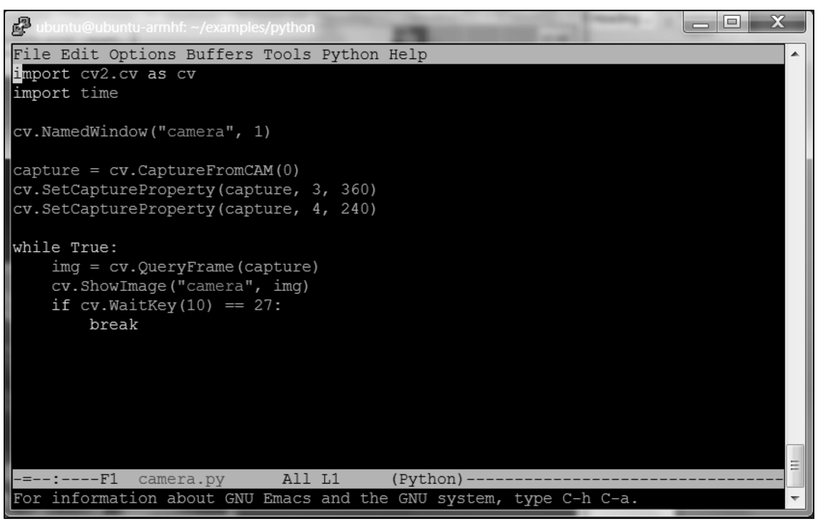
5. `sudo apt-get install libcv2.3 libcvaux2.3 libhighgui2.3`: These are the basic OpenCV libraries. Note the number. This will almost certainly change as new versions of OpenCV become available. If Version 2.3 does not work, either try Version 2.4 or google for the latest version of OpenCV.
6. `sudo apt-get install python-opencv`: This is the Python development kit for OpenCV, needed as you are going to use Python.
7. `sudo apt-get install opencv-doc`: This library provides the documentation for OpenCV, just in case you need it.
8. `sudo apt-get install libcv-dev`: This library provides the header files and static libraries to compile OpenCV.
9. `sudo apt-get install libcvaux-dev`: This library provides more development tools for compiling OpenCV.
10. `sudo apt-get install libhighgui-dev`: This is another package that provides header files and static libraries to compile OpenCV.
11. Make sure you are in your home directory, and then type `cp-r/usr/share/doc/opencv-doc/examples`: This will copy all the examples to your home directory.
12. Go to the `examples/c` directory by typing `cd ./examples/c` and type `sh build_all.sh` and you will have a set of executable files that will allow you to see if the system is working.

Now you are ready to try out the OpenCV library. I prefer to use Python when programming simple tasks, so I'll show the Python examples. If you prefer the C examples, feel free to explore. In order to use the Python examples, you'll need one more library. So type `sudo apt-get install python-numpy` as you will need this to manipulate the matrices that OpenCV uses to hold the images.

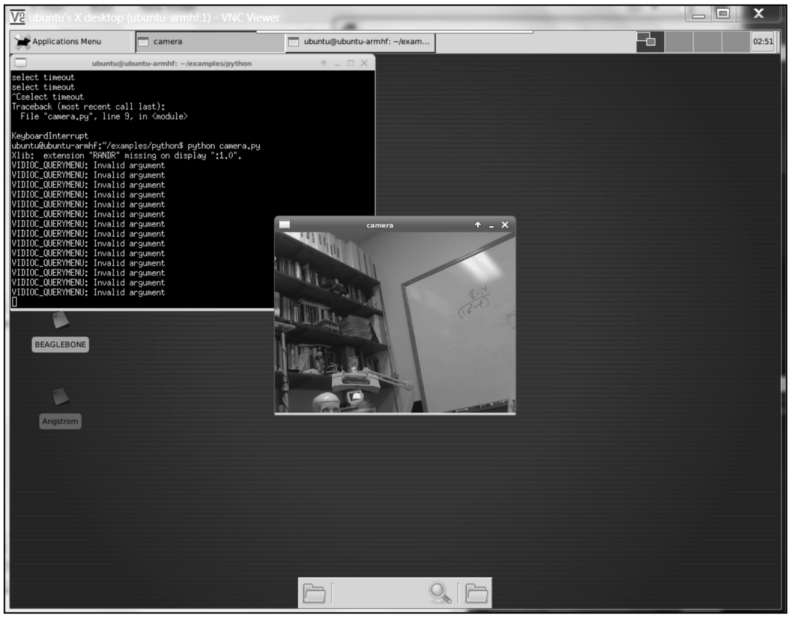
Now that you have those, you can try one of the Python examples. Change directory to the Python examples by typing `cd /home/ubuntu/examples/python`. In this directory you will find a number of useful examples, we'll only look at the most basic. It is called `camera.py`. You can try running this example; however, to do this you'll either need to have a display connected to the BeagleBone Black, or you can do this over the vncserver connection. Bring up a terminal window and type `python camera.py`. You should see output similar to the following screenshot:



In my case the camera window eventually turned black, but did not show the output from the camera. I found that I needed to change the resolution of the image to the one supported by the camera and OpenCV. To do this you edit the `camera.py` file, and add two lines as shown in the following screenshot:



These two lines change the resolution of the captured image to 360 x 240 pixels. Now run `camera.py`, and you should be able to see the output similar to the following screenshot:



Objective complete – mini debriefing

Your project can now see! You will use this capability to do a number of impressive tasks that will use this vision capability.

Classified intel

You may want to play with the resolution to find the optimum for your application. Bigger images are great—they give you more detailed view of the world—but they also take up significantly more processing power. You'll play with this more as you actually ask your system to do some real image processing. Be careful if you are going to use vnc to understand your system performance as this will significantly slow down the update rate. An image that is twice the size (width/height) will involve four times more processing.

Using the vision library to detect colored objects

Now that you have access to the OpenCV library, let's see what it can do.

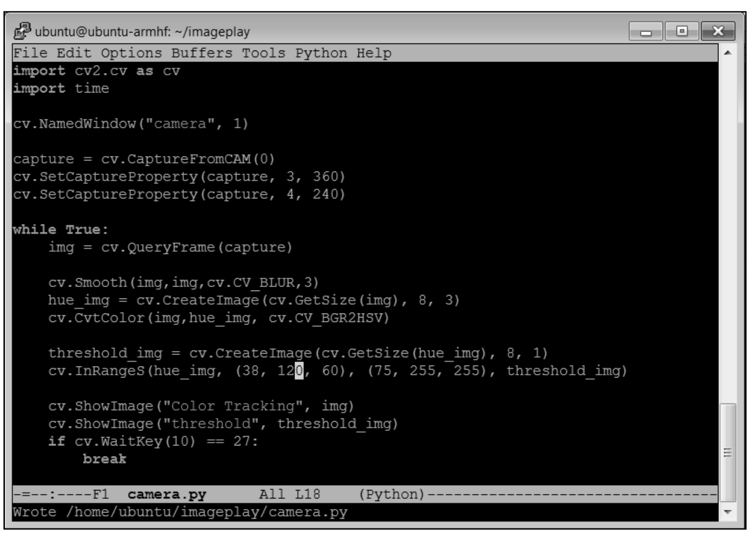
Prepare for lift off

OpenCV and your webcam can track objects. This might be useful if you are building a system that needs to track and follow a colored ball. OpenCV makes this amazingly simple by providing some high-level libraries that can help you with this task. I'm going to do this in Python, as I find it much easier to work with than C. If you feel more comfortable in C, these instructions should be fairly easy to translate. Also, performance will be better if implemented in C, so you might create the initial capability in Python, and then finalize the code in C.

Engage thrusters

If you'd like, create a directory to hold your image-based work. From your home directory, create a directory named `imageplay` by typing `mkdir imageplay`. Then change directory to `imageplay` by typing `cd imageplay`.

Once there, let's bring over your `camera.py` file as a starting point by typing `cp /home/ubuntu/examples/python/camera.py ./camera.py`. Now you are going to edit the file until it looks similar to the following screenshot:



Let's look specifically at the changes you need to make to `camera.py`. The first four lines you add are as follows:

```
#Smooth image, then convert the Hue
cv.Smooth(img,img,cv.CV_BLUR,3)
hue_img = cv.CreateImage(cv.GetSize(img), 8, 3)
cv.CvtColor(img,hue_img, cv.CV_BGR2HSV)
```

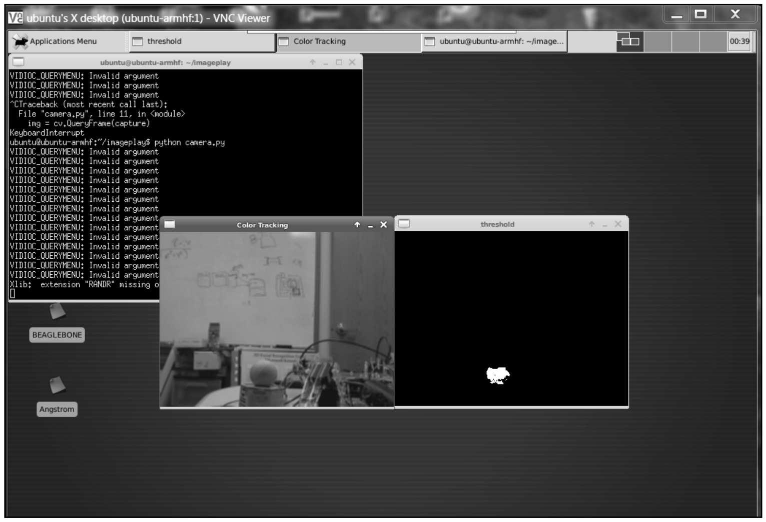
We are going to use the OpenCV library to first smooth the image, taking out any large deviations. The next two lines create a new image that stores the image in values of **HSV** (**Hue** (color), **Saturation**, and **Value**) instead of the **RGB** (**Red**, **Green**, and **Blue**) pixel values of the original image. Converting to HSV focuses your processing more on the color, as opposed to the amount of light hitting it.

Then we add the following lines of code:

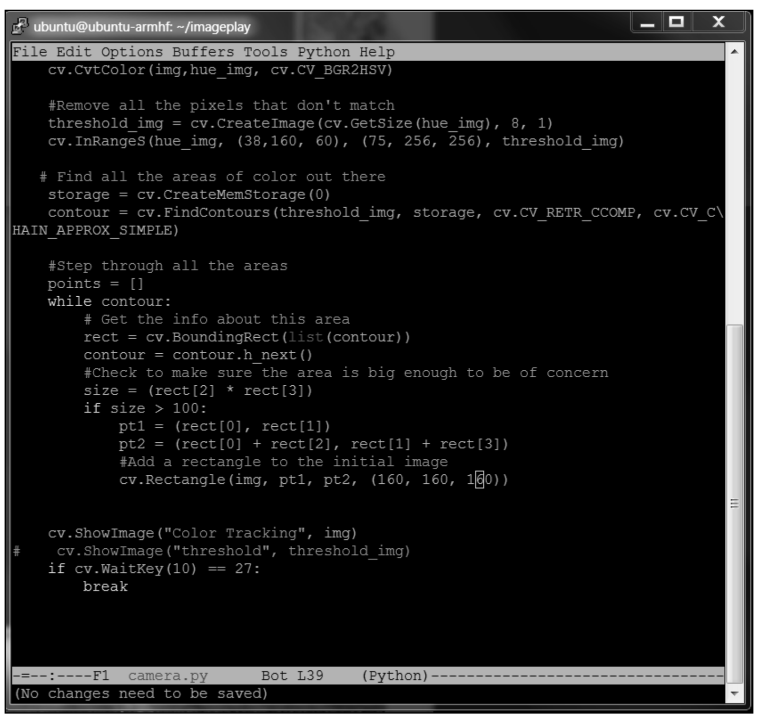
```
#Remove all the pixels that don't match
threshold_img = cv.CreateImage(cv.GetSize(hue_img), 8, 1)
cv.InRangeS(hue_img, (38,120, 60), (75, 255, 255),
            threshold_img)
```

You are going to create yet one more image, this time a black-and-white binary image that is black for any pixel which is not between two certain color values. The `(38, 120, 60)` and `(75, 255, 255)` parameters determine the color range. In this case I have a green ball, and I want to detect the color green.

Now run the program. You'll need to either have a display, keyboard, and mouse connected to the board or you can run it remotely using vnc. Run the program by typing `sudo python camera.py`. You should see a single black image, but move this window and you will expose the original image window as well. Now take your target (I used my green ball) and move it into the frame. You should see output similar to the following screenshot:



Notice the white pixels in your threshold image showing where the ball is located. You can add more OpenCV code that gives the actual location of the ball. You can actually draw a rectangle around the ball as an indicator in your original image file of the location of the ball. Edit the `camera.py` file to look like the following screenshot:



```
ubuntu@ubuntu-armhf: ~/imageplay
File Edit Options Buffers Tools Python Help
    cv.CvtColor(img,hue_img, cv.CV_BGR2HSV)

    #Remove all the pixels that don't match
    threshold_img = cv.CreateImage(cv.GetSize(hue_img), 8, 1)
    cv.InRangeS(hue_img, (38,160, 60), (75, 256, 256), threshold_img)

   # Find all the areas of color out there
    storage = cv.CreateMemStorage(0)
    contour = cv.FindContours(threshold_img, storage, cv.CV_RETR_CCOMP, cv.CV_C\
HAIN_APPROX_SIMPLE)

    #Step through all the areas
    points = []
    while contour:
        # Get the info about this area
        rect = cv.BoundingRect(list(contour))
        contour = contour.h_next()
        #Check to make sure the area is big enough to be of concern
        size = (rect[2] * rect[3])
        if size > 100:
            pt1 = (rect[0], rect[1])
            pt2 = (rect[0] + rect[2], rect[1] + rect[3])
            #Add a rectangle to the initial image
            cv.Rectangle(img, pt1, pt2, (160, 160, 160))


    cv.ShowImage("Color Tracking", img)
#    cv.ShowImage("threshold", threshold_img)
    if cv.WaitKey(10) == 27:
        break

-=--:----F1  camera.py      Bot L39    (Python)--------------------------------
(No changes need to be saved)
```

First, add these lines:

```
    # Find all the areas of color out there
      storage = cv.CreateMemStorage(0)
      contour = cv.FindContours(threshold_img, storage, cv.CV_RETR_
CCOMP, cv.CV_C\
HAIN_APPROX_SIMPLE)
```

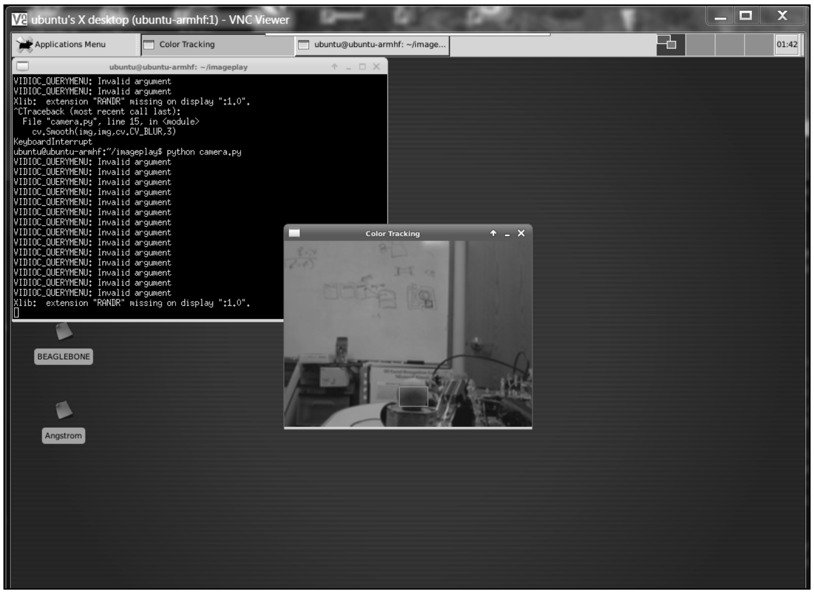
These lines find all the areas on your image that are within the threshold. There may be more than one; so you want to capture them all. Now you will add a `while` loop that will let you step through all the possible contours:

```
      #Step through all the areas
      points = []
      while contour:
```

By the way, it is important to note that if there is another larger green blob in the background, you will "find" that location. Just to keep this simple, you'll assume your green ball to be unique. The next few lines will then get the information for each of your contours. Now, you want to identify the corners. Then you can check to see if the area is big enough to be of concern. If it is, you will add a rectangle to your original image identifying where you think it is:

```
          # Get the info about this area
          rect = cv.BoundingRect(list(contour))
          contour = contour.h_next()
          #Check to make sure the area is big enough to be of
              concern
          size = (rect[2] * rect[3])
          if size > 100:
              pt1 = (rect[0], rect[1])
              pt2 = (rect[0] + rect[2], rect[1] + rect[3])
              #Add a rectangle to the initial image
              cv.Rectangle(img, pt1, pt2, (38, 160, 60))
```

Now that the code is ready, you can run it. You should see output similar to the following screenshot:



You can now track your object.

Objective complete – mini debriefing

Now that you have the code, you can modify the color or add more colors. You also have the location of your object, so later you can attempt to follow the object or manipulate it in some way.

Classified intel

OpenCV is an amazing powerful library of functions. You can do all sorts of incredible things with just a few lines of code. Another common feature you may want to add to your projects is motion detection. If you'd like to try, there are several good tutorials, try looking at:

- `http://derek.simkowiak.net/motion-tracking-with-python/`
- `http://stackoverflow.com/questions/3374828/how-do-i-track-motion-using-opencv-in-python`
- `https://www.youtube.com/watch?v=8QouvYMfmQo`
- `https://github.com/RobinDavid/Motion-detection-OpenCV`

Mission accomplished

Your projects can now speak and see! You can issue commands, and your projects can respond to changes in the physical environment sensed by the webcam. Next, you will add mobility using motors, servos, and in other ways.

Challenges

Having a webcam connected to your system provides all kinds of additional capabilities. One of the absolute neatest devices out there is Kinect for the Xbox. This device provides not only video, but depth using an infrared device. There are individuals working to make Kinect work with the BeagleBone Black. Several good libraries enable Kinect on Ubuntu.
If you'd like to try, buy a used Kinect and then go to `http://speculatrix.tumblr.com/post/23043561344/kinect-on-the-beagleboard-and-ubuntu` or `http://kinepeutics.blogspot.com/2012/04/ethernet-working-installing-kinect.html` and give it a try. Just a word of warning, this task is not for beginners.
Later we will talk about the Robot Operating System, which may make it easier.

Also, you can get 3D vision with OpenCV using two cameras. There are several good places for example code, for example in the `samples/cpp` directory that came with OpenCV there is an example `stereo_match.cpp`. Also, for more code examples, you can visit `http://code.google.com/p/opencvstereovision/source/checkout`.

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