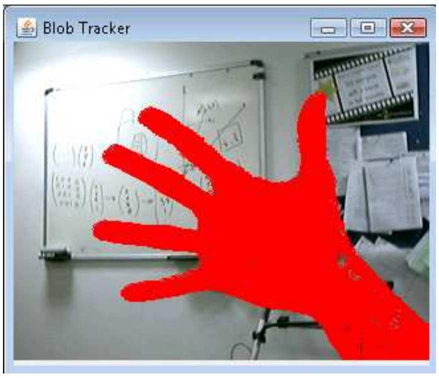
Programming Methods
Dr Robert Harle

IA NST CS and CST
Lent 2008/09
Handout 5

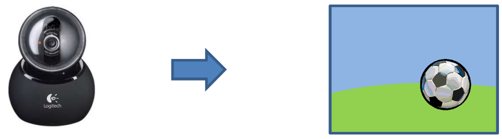
Blob Tracking

- Our goal is to build an app that detects when something enters the visual range of a webcam
- Example use: Detect when someone enters your room.



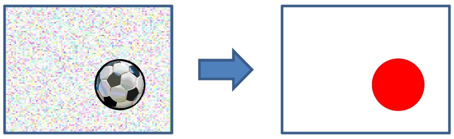
The Basic Process

- Get an image from the webcam



- Subtract some notion of ‘background’

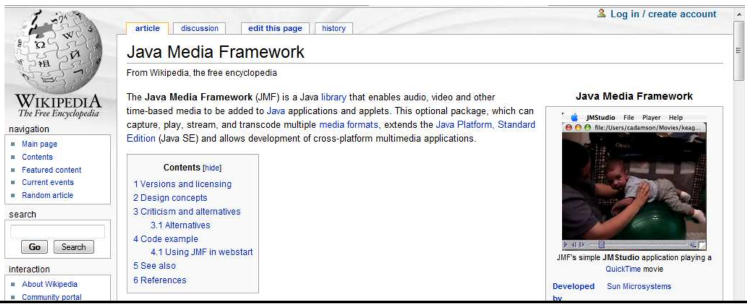
- ‘Grow’ regions of pixels to reduce noise



Getting the Image

Java Media Framework

- Java itself doesn't ship with much support for video and audio media.
- There are software libraries to get access however
- We will be using the Java Media Framework (JMF)
  - It is an 'official' Sun library
  - Gives us access to our webcam reasonably simply

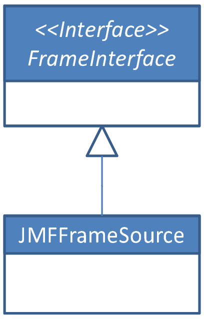


Abstraction, abstraction, abstraction...

- We don't want to be stuck with the JMF though
  - Might need a different library for a different webcam
  - Might even want to input from a video file
- Try to identify the fundamental components of something that supplies us with images (="frames")
- Abstract into an interface

```
public interface FrameInterface {
  public void open(String descriptor);
  public BufferedImage getNextFrame();
  public void close();
}
```

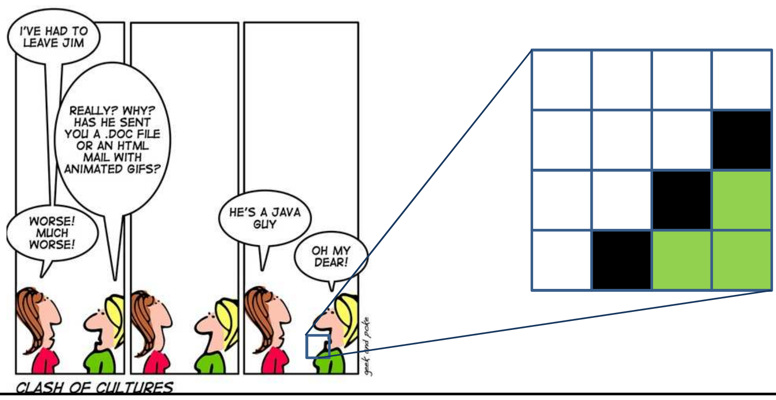
Concrete Instantiation



- The code in JMFFrameSource is not pretty because frankly the JMF is pretty awful to work with.
- You can ignore JMFFrameSource.java for this course – I refuse to teach JMF!!
- This design *encapsulates* everything about getting images from a webcam in a single class.
- The interface *decouples* the program from the JMF so you can easily substitute a better library

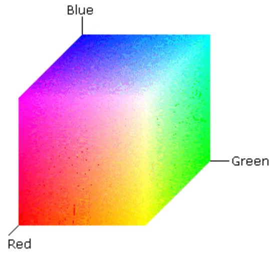
Aside: BufferedImage

- The FrameInterface returns objects of type BufferedImage
  - This is a standard class in the class library to handle images
  - The "Buffered" bit means that the image is represented by an accessible buffer – a grid of pixels



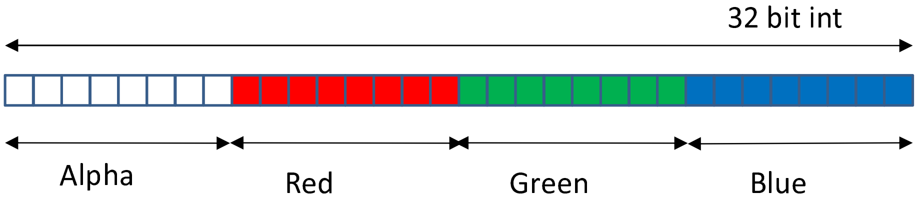
Aside: RGB Pixels

- How do you represent the colour of a single pixel?
- Actually many ways, but commonly we use RGB
  - The colour is made up from only Red, Green and Blue.
  - We use 24 bits to represent the colour
    - 8 bits red (0-255)
    - 8 bits green (0-255)
    - 8 bits blue (0-255)
  - E.g. Purple = 160-32-240 (R-G-B)
  - We can think of this as a colour space
    - Like 3D space but xyz becomes rgb



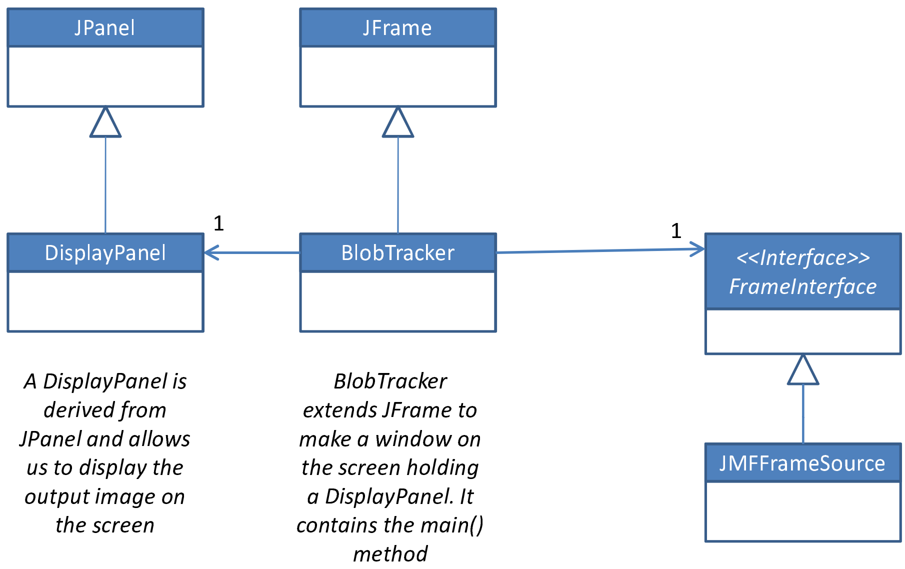
Aside: RGB Pixels

- We will need to get at individual pixels
- Buffered Image provides **getRGB(...)** methods
- Each pixel is given as an int:




```
int colour=...
int r = ((colour>>16) & 0x000000FF);
int g = ((colour>>8) & 0x000000FF);
int b = ((colour) & 0x000000FF);
```

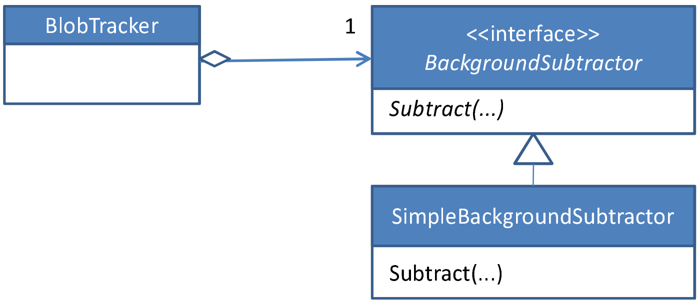
Software So Far



Subtracting the Background

Strategy Pattern

- There are lots of algorithms for background subtraction
- We should structure our software to make it easy to select between multiple algorithms
- This of course means using the **Strategy** pattern



BackgroundSubtractor Interface

```
import java.util.List;

public interface BackgroundSubtractor {
   public List<Pixel> Subtract(int[] pixels);
}
```

- We provide an array of pixels (in ARGB as discussed)
- We get back a List of Pixels representing the foreground pixels
- Class **Pixel** just stores an (x,y) pair – we'll come back to it

SimpleBackgroundSubtractor

- Remember the notion of RGB as a *space*?
- We have two readings for each pixel – the saved background reading and the latest webcam reading
- We treat them as two vectors (rb, gb, bb) and (rw, gw, gb)
  - Then we compute the Euclidian distance apart in rgb space
  - If it's greater than some threshold, we take it as different to the background
  - The threshold allows us to account for noise which is there even for a static background

Things to Note

- The background image is 'saved' using clone() the first time we get a picture

```
if (mBackground==null) {
   mBackground = pixels.clone();
   return new LinkedList<Pixel>();
}
```

- Arrays have clone() implemented by default (shallow)
  - This is an array of primitive ints so that's all we need

Things to Note

- Always think about efficiency – avoid expensive calls if you can (e.g. sqrt):

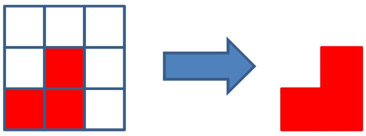
```
LinkedList<Pixel> foregroundlist = new LinkedList<Pixel>();
for (int i=0; i<pixels.length; i++) {
   int r = ((pixels[i]>>16) & 0x000000FF);
   ...
   int distsq = (r-br)*(r-br) + (b-bb)*(b-bb) + (g-bg)*(g-bg);

   if (distsq > mThreshold*mThreshold) {
      foregroundlist.add(new Pixel(i, mImageWidth));
   }
}
```

Region Growing

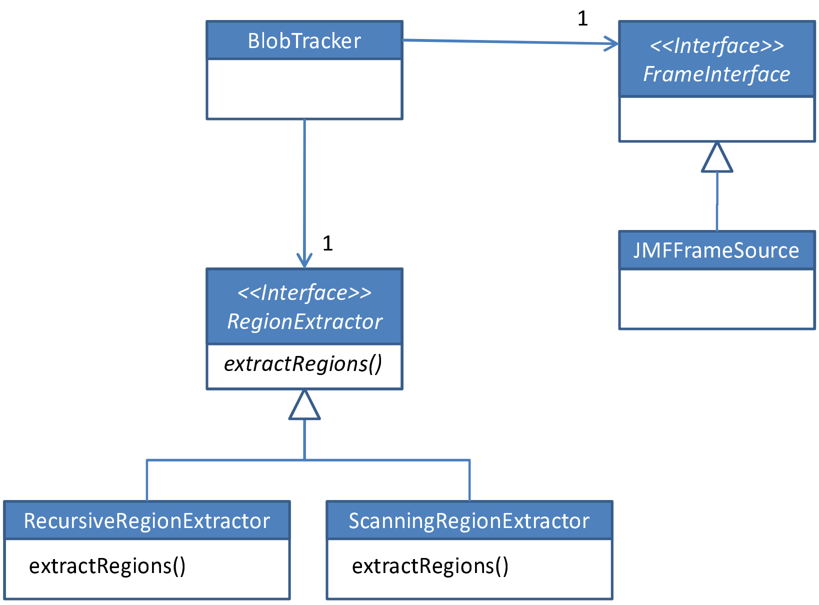
Why Bother?

- There is always so much noise that it isn't enough to just count the foreground pixels and take that as an indicator of the size of object in view
- We need to find *regions* in the image where all the adjacent pixels are marked as foreground



- So how to we go from a list of foreground pixels to lists of neighbouring, connected pixels?
- Unsurprisingly, there are lots of algorithms...

Strategy Pattern Again



RegionExtractor

```
public interface RegionExtractor {
    public List< Region > extractRegions(List<Pixel> pixels);
}
```

- We get back a List of **Region**s
- Choose a **List** because we will want ordering
  - Sort by size
  - Remove small regions (noise)
- How will the program know to sort the Regions by size?
  - We have to tell it

Region

- To sort objects, there must be a way to compare them
- Java offers us the **Comparable** interface

```
public class Region extends LinkedList<Pixel> implements
Comparable<Region>
 {
  public int compareTo(Region r) {
    if (this.size()>r.size()) return -1;
    if (this.size()<r.size()) return 1;
    return 0;
  }
}
```

Region

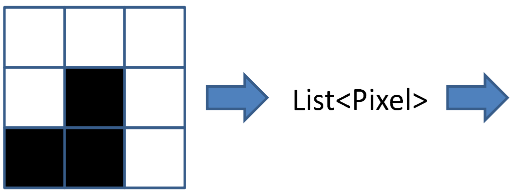
- Now we can use **Region** in structures that sort
- Either we use a structure that is always sorted (TreeSet, keys in a TreeMap, etc.)
- Or we use the static sort() method in **Collections**

```
List< Region > regionlist = mRegionExtractor.extractRegions(fgpixels);

Iterator< Region > it = regionlist.iterator();
while (it.hasNext()) {
   Region r = it.next();
   if (r.size()<10) it.remove();
}
Collections.sort(regionlist);
```

RecursiveRegionExtractor

- So how do we get **Regions** anyhow?
- Start by translating the list of foreground pixels to an array of ints because it's easier to search through
  - -1 means the cell is background
  - 0 means the cell is believed to be foreground



-1	-1	-1
-1	0	-1
0	0	-1

RecursiveRegionExtractor

- First we write a function that, given a pixel that is foreground:
  - Labels it with a region number
  - Runs *itself* on any neighbouring pixels that are foregound
  - See **extractRegion(...)**

-1	-1	-1
-1	0	-1
0	0	-1

Start on (1,1)

-1	-1	-1
-1	1	-1
0	0	-1

- Mark (1,1) with a unique region ID
- Look at the neighbours to see whether (1,1) has any foreground neighbours

-1	-1	-1
-1	1	-1
0	1	-1

- Run function on (1,2)

RecursiveRegionExtractor

- Just these three pixels need a series of recursive calls to extractRegion (recursive = calls itself)

extractRegion (Pixel: 1 1 Label 1)
extractRegion (Pixel: 1 2 Label 1)
extractRegion (Pixel: 0 2 Label 1)

- So, the bigger the region, the more function calls Java has to keep track of simultaneously
- Things can go wrong...
  - We see a StackOverflowException
  - Always a potential problem with recursive functions

ScanningRegionExtractor

- In reality we want a non-recursive algorithm
  - No StackOverflow
  - Better performance anyway
  - Much easier to debug!!
- I have implemented such an algorithm for you in ScanningRegionExtractor.java
  - It's a neat algorithm but I don't intend to go through it here
  - Can you work it out and describe it in < 150 words?

Making it all Fly...