

Image Segmentation

What is Image Segmentation?

- We can divide or partition the image into various parts called segments
- It's not a great idea to process the entire image at the same time as there will be regions in the image which do not contain any information
- By dividing the image into segments, we can make use of the important segments for processing the image
- Image segmentation creates a pixel-wise mask for each object in the image
 - This technique gives us a granular understanding of the object(s) in the image

Different types of image segmentation



Image 1

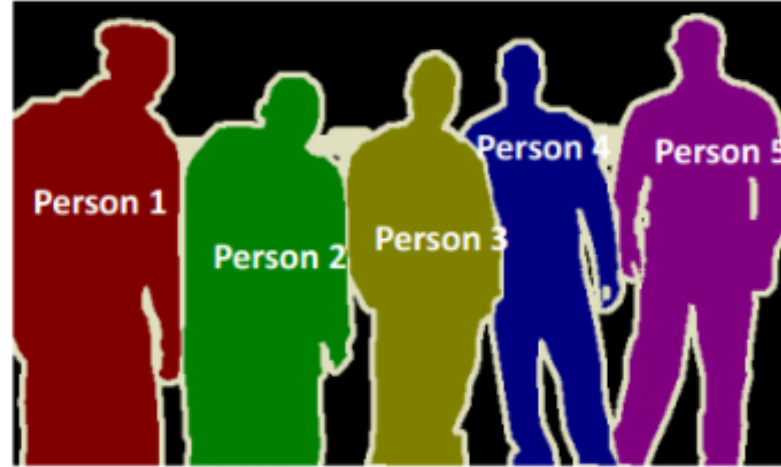


Image 2

- Image 1: Semantic segmentation
 - Every pixel belongs to a particular class (either background or person)
- Image 2: Instance segmentation
 - Different objects of the same class have different colors (Person 1 as red, Person 2 as green, background as black, etc.)

Threshold segmentation

- One simple way to segment different objects could be to use their pixel values
 - The pixel values will be different for the objects and the image's background if there's a sharp contrast between them.
- **Threshold segmentation:** the pixel values falling below or above the threshold can be classified accordingly (as an object or the background)

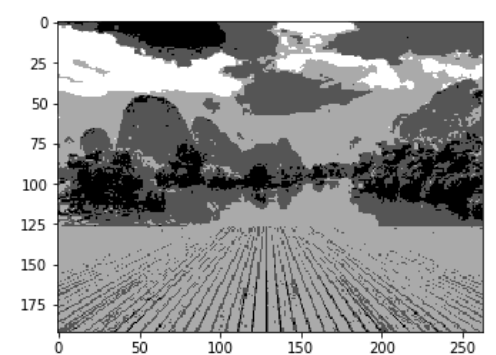
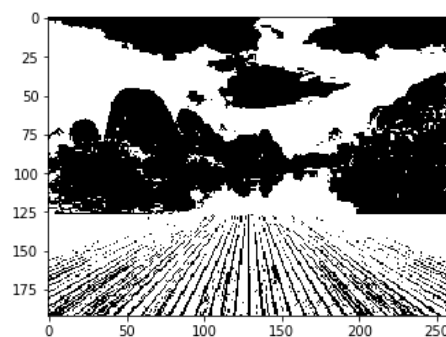
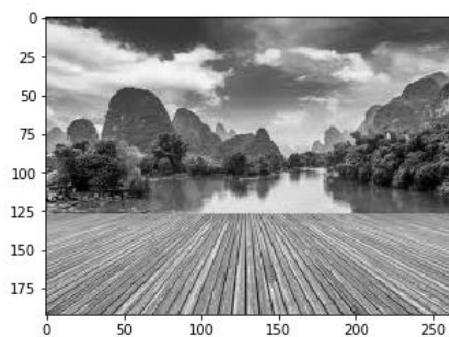
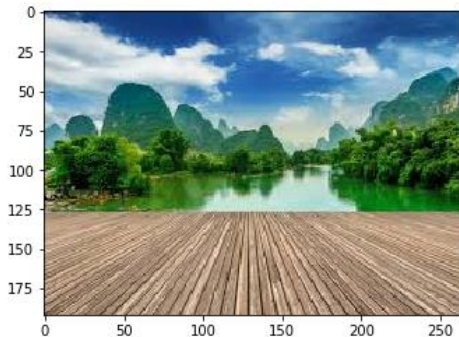
Threshold segmentation

- Global threshold: If we want to divide the image into two regions (object and background), we define a single threshold value
- Local threshold: If we have multiple objects along with the background, we must define multiple thresholds

There are four different segments in the above image.
We can set different threshold values and check how the segments are made.

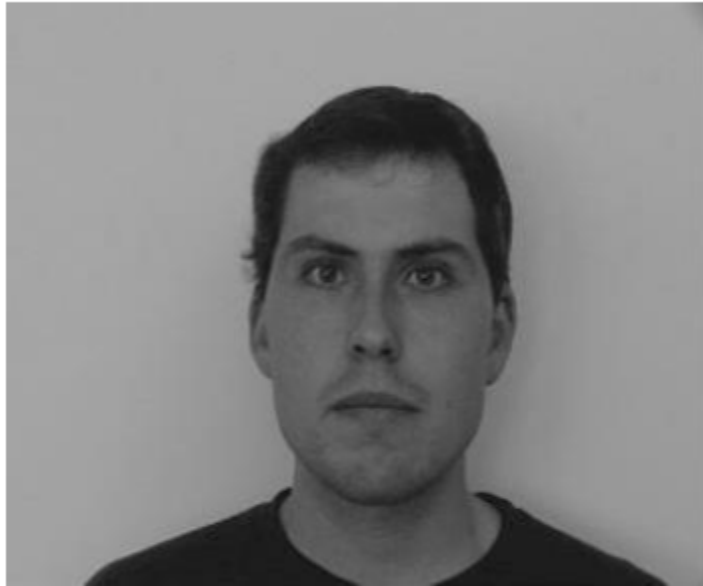
(192, 263, 3)

<matplotlib.image.AxesImage at 0x7fc845de2048>

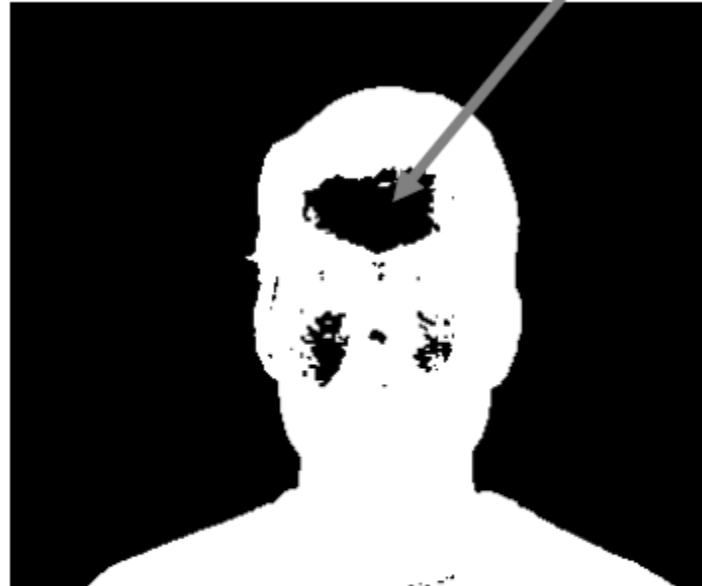


Gray-level thresholding

How can holes be filled?



Original image
Peter $f[x,y]$

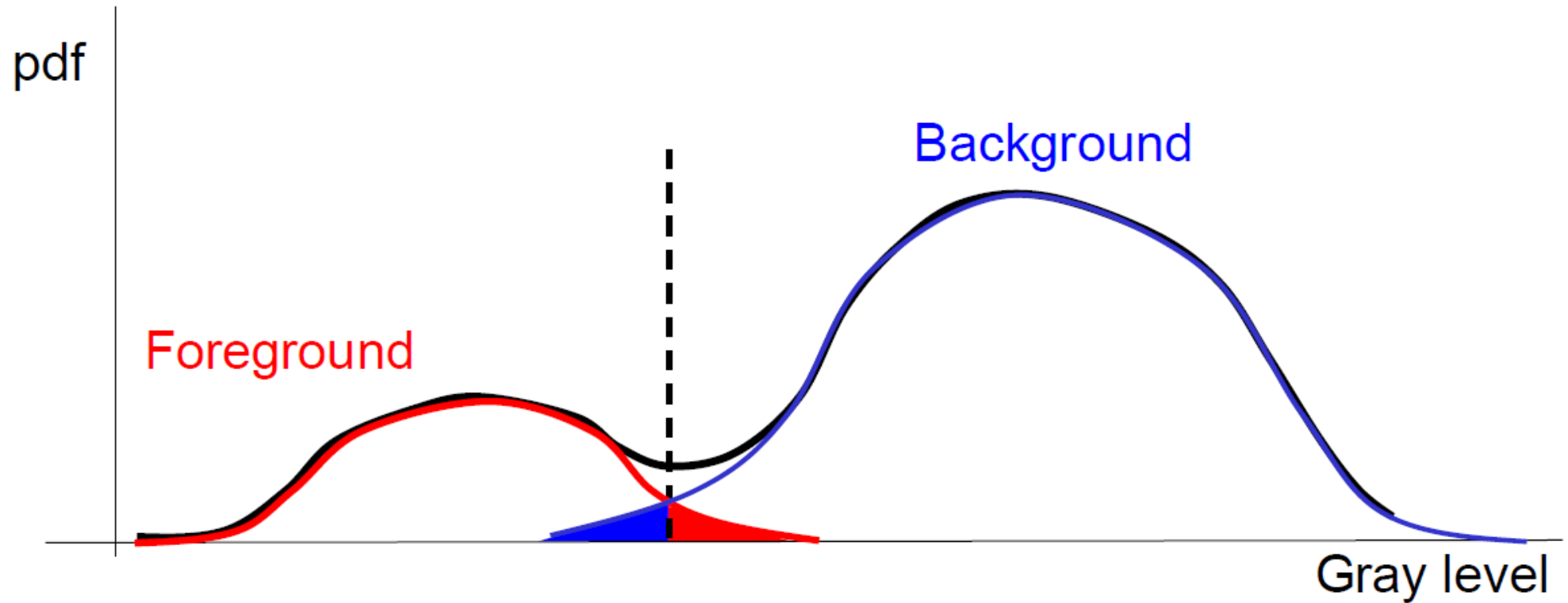


Thresholded
Peter $m[x,y]$



$f[x,y] \cdot m[x,y]$

How to choose the threshold?



Otsu's Thresholding Method

- Based on a very simple idea: Find the threshold that minimizes the weighted within-class variance
- This turns out to be the same as maximizing the between-class variance
- Operates directly on the gray level histogram [e.g. 256 numbers, $P(i)$], so it's fast (once the histogram is computed)

Otsu: Assumptions

- Histogram (and the image) are bimodal.
- No use of spatial coherence, nor any other notion of object structure.
- Assumes stationary statistics, but can be modified to be locally adaptive
- Assumes uniform illumination (implicitly), so the bimodal brightness behavior arises from object appearance differences only

The *weighted within-class variance* is:

$$\sigma_w^2(t) = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

Where the class probabilities are estimated as:

$$q_1(t) = \sum_{i=1}^t P(i) \qquad q_2(t) = \sum_{i=t+1}^I P(i)$$

And the class means are given by:

$$\mu_1(t) = \sum_{i=1}^t \frac{iP(i)}{q_1(t)} \qquad \mu_2(t) = \sum_{i=t+1}^I \frac{iP(i)}{q_2(t)}$$

Finally, the individual class variances are:

$$\sigma_1^2(t) = \sum_{i=1}^t [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)}$$

$$\sigma_2^2(t) = \sum_{i=t+1}^I [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

Now, we could actually stop here. All we need to do is just run through the full range of t values $[1,256]$ and pick the value that minimizes $\sigma_w^2(t)$.

But the relationship between the within-class and between-class variances can be exploited to generate a recursion relation that permits a much faster calculation.

Between/Within/Total Variance

- The basic idea is that the total variance does not depend on threshold (obviously)
- For any given threshold, the total variance is the sum of the within-class variances (weighted) and the *between class variance*, which is the sum of weighted squared distances between the class means and the grand mean

After some algebra, we can express the total variance as...

$$\sigma^2 = \underbrace{\sigma_w^2(t)}_{\text{Within-class, from before}} + \underbrace{q_1(t)[1 - q_1(t)][\mu_1(t) - \mu_2(t)]^2}_{\text{Between-class, } \sigma_B^2(t)}$$

Since the total is constant and independent of t , the effect of changing the threshold is merely to move the contributions of the two terms back and forth.

So, minimizing the within-class variance is the same as maximizing the between-class variance.

The nice thing about this is that we can compute the quantities in $\sigma_B^2(t)$ *recursively* as we run through the range of t values.

Finally...

$$\textit{Initialization...} \quad q_1(1) = P(1); \mu_1(0) = 0$$

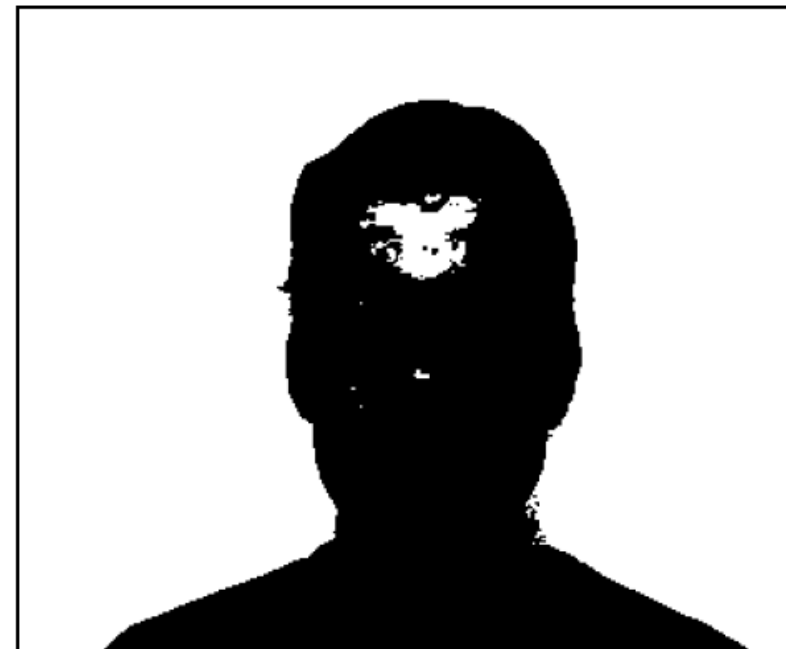
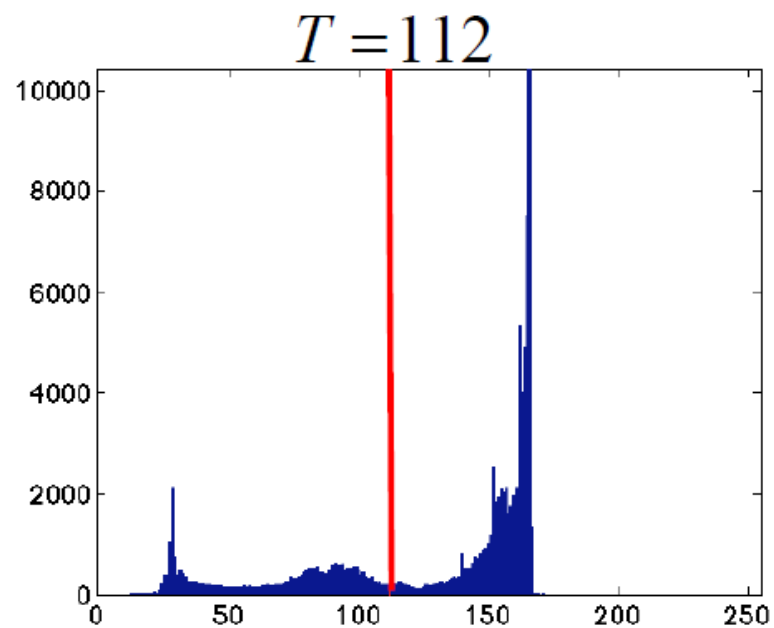
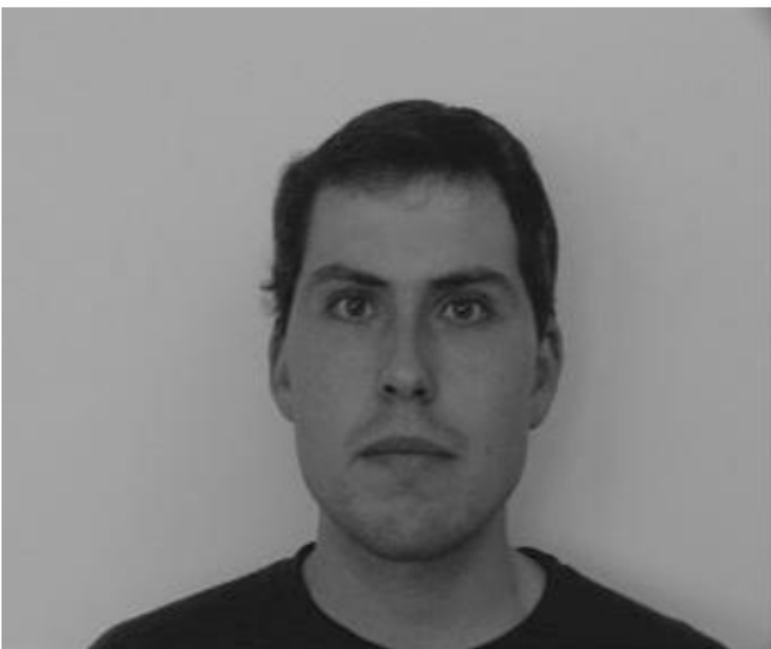
Recursion...

$$q_1(t+1) = q_1(t) + P(t+1)$$

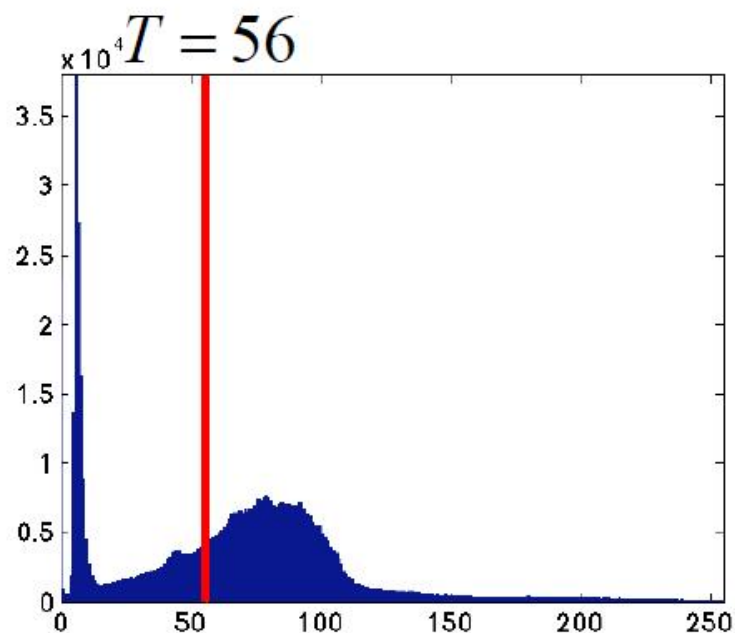
$$\mu_1(t+1) = \frac{q_1(t)\mu_1(t) + (t+1)P(t+1)}{q_1(t+1)}$$

$$\mu_2(t+1) = \frac{\mu - q_1(t+1)\mu_1(t+1)}{1 - q_1(t+1)}$$

Unsupervised thresholding (cont.)



Unsupervised thresholding (cont.)



Unsupervised thresholding (cont.)

The Stanford Daily

Tuesday, September 18, 2012 ♦ 13



SAM FISH/STANFORD DAILY

Stanford defensive lineman Josh Mauro put the pressure on USC's Matt Barkley. Mauro was relentless in the second half as Stanford's defense completely shut down Barkley and his touted wide receivers.

Handing out the USC game balls

By SAM FISHER
FOOTBALL EDITOR

about Andrew Luck

Stephen Taylor: It all starts and ends with Stanford's workhorse Taylor. He was everything you could ask for and more against USC. He provided the big plays with a game-opening interception on the ground, another score through the air and the consistent ground-and-pound to wear down the Trojans at the end. His 233 total yards of offense to go with a pair of TDs had fans on both sides forgetting

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Please see **AWARDS**, page 15

FOOTBALL

The winding road ahead

By SAM FISHER
FOOTBALL EDITOR

Andrew Luck may be gone, but with Saturday night's win over USC, the Stanford Cardinal put itself in position to achieve beyond the path paved by number 12. You heard right, though there's plenty of work left to do, this 2012 Stanford team showed that it is capable of playing at a national championship level.

Though Stanford survived one of its toughest tests in the gauntlet that is the BCS National Championship, elimination, the road to Miami 2013 is no walk in the park. The toughest challenges remaining on the schedule are games at Notre Dame, Oregon and UCLA, all of which are currently ranked in the top 20. The next two games, at Washington and then at home against Arizona, are no pushovers, either. And as Stanford has showed top-ranked opponents in years past, any team on the Cardinal's schedule has the potential for a magical upset.

From Stanford's current vantage point, there are three paths the rest of the season could take. Does Number One lead to the Promised Land, a berth in the BCS National Championship Game. In all likelihood, because Stanford is not named Alabama or LSU, the Cardinal will have to wait out to earn a trip to South Beach, including wins at No. 3 Oregon and a potential rematch against USC for the Pac-12 title.

For Stanford to even think about returning to the site of its 2011 Orange Bowl head-on of Virginia Tech, Josh Nunes will have to build off his fourth-quarter success against USC to play at a higher level consistently from the 12-yard scramble on third-and-10 on. Nunes was good enough to win a championship. USC's defense is nowhere near a pushover, so Jordan Williamson's 6-3 kicking right is also a major concern. With the way the Stanford defense played against USC over the last 41 minutes Saturday night, a national championship isn't completely out of the question, but it's still not the most likely ending to 2012.

Waiting behind Door Number Two for Stanford is a trip to a BCS bowl for the third straight season. Stanford has a bit more wiggle room to get back to the BCS, thanks to a strong strength of schedule. However, the path is anything but straightforward. One thing we do know is that if Stanford can win the Pac-12, the Rose Bowl becomes the worst-case scenario. To get there, Stanford almost certainly has to win at Oregon on Nov. 17, one of the toughest tasks in all of college football.

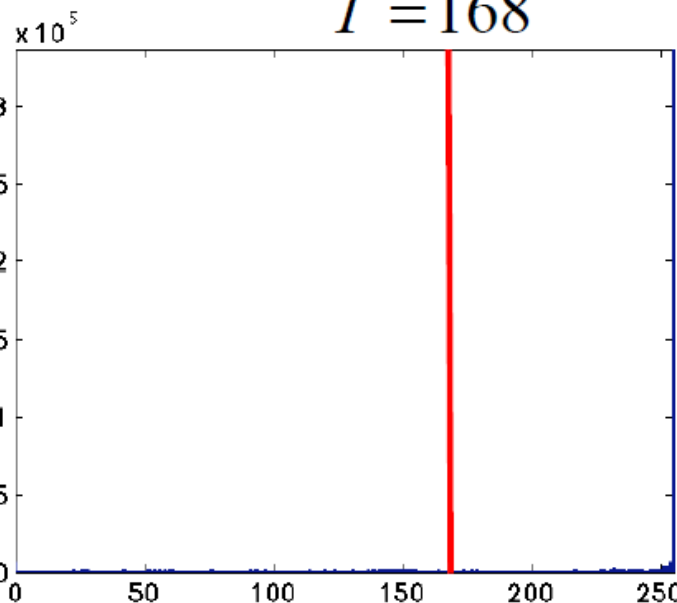
If Stanford can't beat the Ducks, a BCS bowl remains a legitimate possibility. Stanford is still struggling to shake the reputation of not having a big enough fan base to get benefit created, so grabbing an at-large selection to the BCS won't be easy. Still, as Stanford showed in

the last two seasons, beating everyone on the schedule except for Oregon is probably good enough to warrant a top-four BCS ranking and an automatic bid to a BCS game.

Door Number Three is the disappointment, the setback, the wasted opportunity. Stanford put itself in a remarkable position with its win over the second-ranked Trojans. However, if the Cardinal regresses to San Jose State game form at any point, it is primed to be upset a few times. It might not even take that bad of a performance, as Stanford has five teams left on its schedule in the AP Top 25, including road games at No. 3 Oregon, No. 11 Notre Dame and No. 19 UCLA. If Stanford loses more than two games, it will in all likelihood end up in a second-tier bowl game for the first time since the 2009 season, when Stanford lost a close game to Oklahoma in the Sun Bowl.

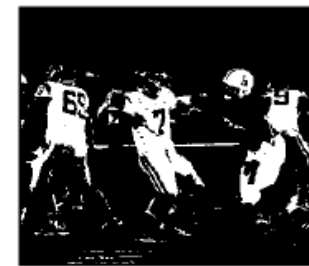
There is obviously tremendous uncertainty as to where the rest of the season leads, but it's truly remarkable for Stanford to be in the position it is now. No Toby Gerhart, no Jim Harbaugh and no Andrew Luck; just Josh Nunes, Stephen Taylor, a solid defense and a whole bunch of guys showing a lot of heart. The superstar names might be gone, but the talent left behind is rising to the top, making Door Number One not so scary to think about.

Contact Sam Fisher at sfisher@stanford.edu



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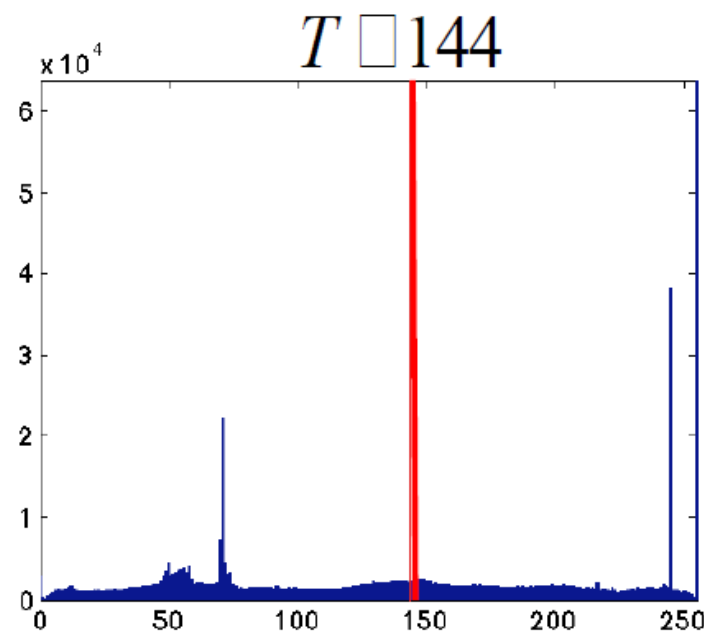
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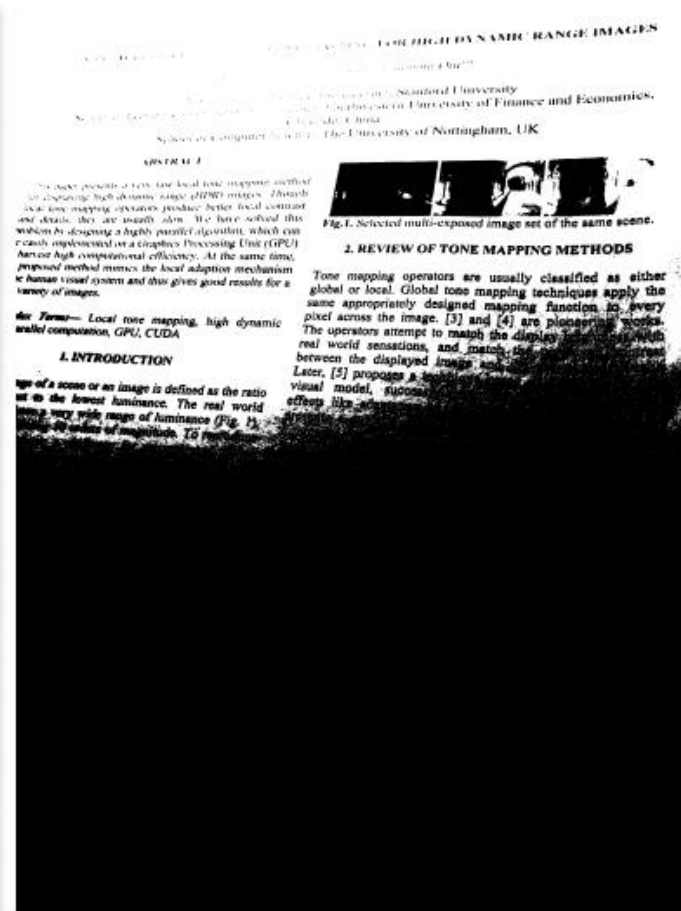
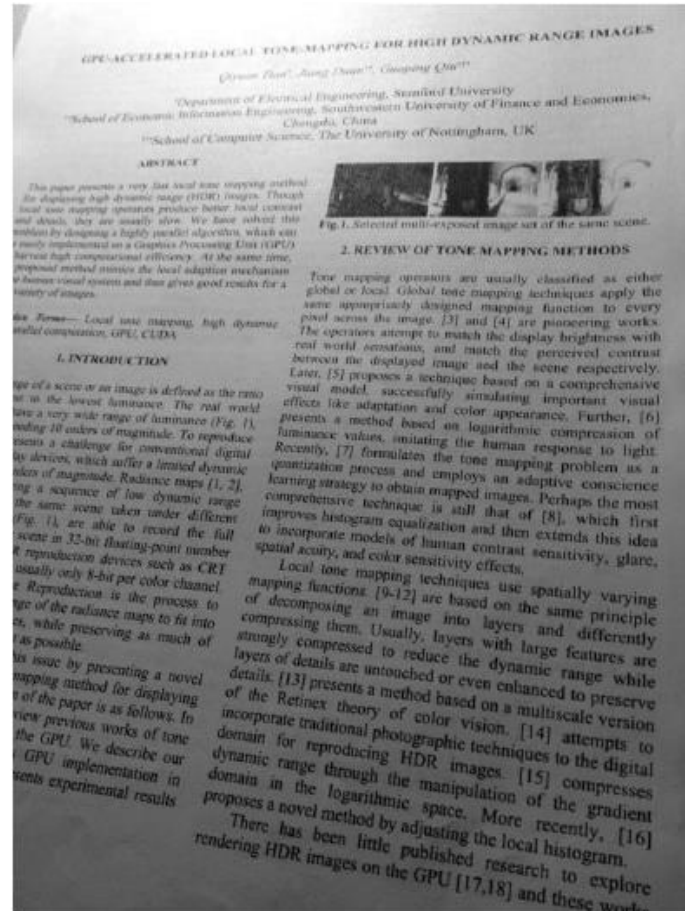
Contact Sam Fisher at sfisher@stanford.edu

Unsupervised thresholding (cont.)



Sometimes, a global threshold does not work

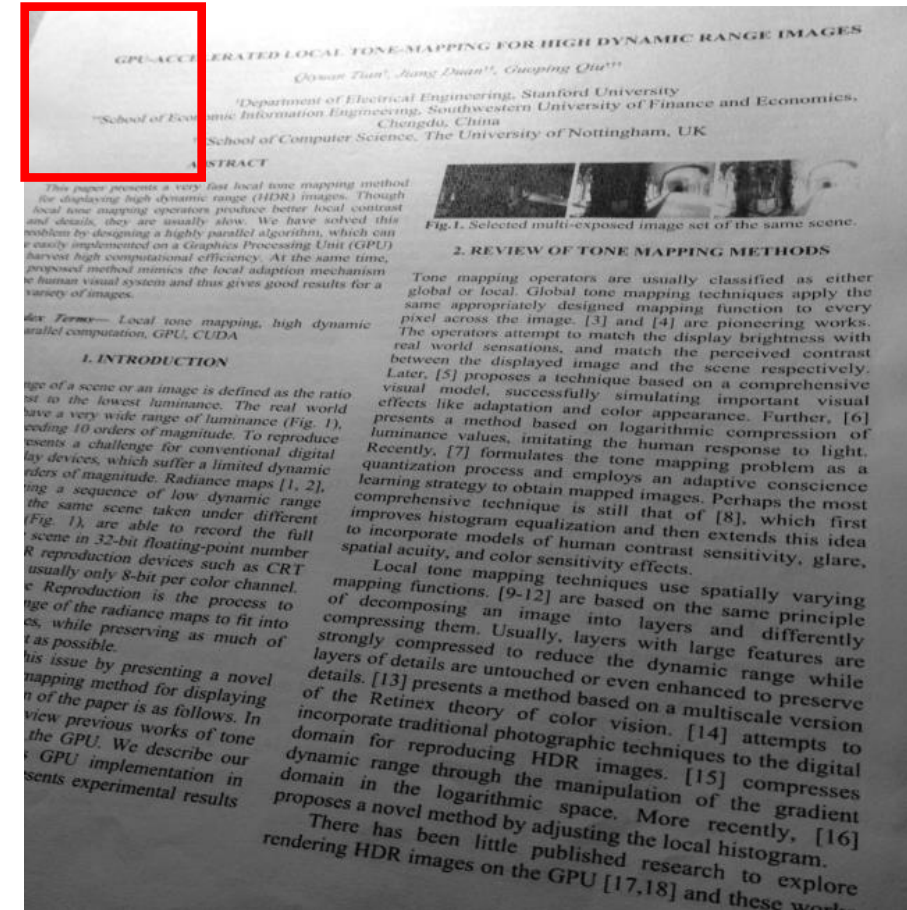
Original image



Thresholded with
Otsu's Method

Locally adaptive thresholding

- Slide a window over the image
- For each window position, decide whether to perform thresholding
 - Thresholding should not be performed in uniform areas
 - Use variance or other suitable criterion
- Non-uniform areas: apply Otsu's method (based on local histogram)
- Uniform areas: classify the entire area as foreground or background based on mean value



Locally adaptive thresholding (example)

