

Unsupervised thresholding

- Idea: find threshold T that minimizes *within-class variance* of both foreground and background (same as k-means)

$$\sigma_{within}^2(T) = \frac{N_{Fgrnd}(T)}{N} \sigma_{Fgrnd}^2(T) + \frac{N_{Bgrnd}(T)}{N} \sigma_{Bgrnd}^2(T)$$

- Equivalently, maximize *between-class variance*

$$\begin{aligned}\sigma_{between}^2(T) &= \sigma^2 - \sigma_{within}^2(T) \\ &= \left(\frac{1}{N} \sum_{x,y} f^2[x,y] - \mu^2 \right) - \frac{N_{Fgrnd}}{N} \left(\frac{1}{N_{Fgrnd}} \sum_{x,y \in Fgrnd} f^2[x,y] - \mu_{Fgrnd}^2 \right) - \frac{N_{Bgrnd}}{N} \left(\frac{1}{N_{Bgrnd}} \sum_{x,y \in Bgrnd} f^2[x,y] - \mu_{Bgrnd}^2 \right) \\ &= -\mu^2 + \frac{N_{Fgrnd}}{N} \mu_{Fgrnd}^2 + \frac{N_{Bgrnd}}{N} \mu_{Bgrnd}^2 = \frac{N_{Fgrnd}}{N} (\mu_{Fgrnd} - \mu)^2 + \frac{N_{Bgrnd}}{N} (\mu_{Bgrnd} - \mu)^2 \\ &= \frac{N_{Fgrnd}(T) \cdot N_{Bgrnd}(T)}{N^2} (\mu_{Fgrnd}(T) - \mu_{Bgrnd}(T))^2\end{aligned}$$

[Otsu, 1979]

Unsupervised thresholding (cont.)

- Algorithm: Search for threshold T to maximize

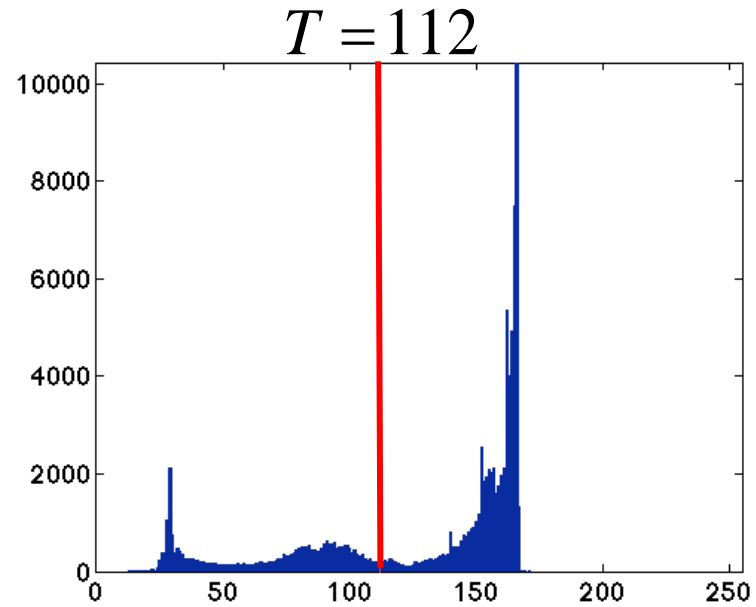
$$\sigma_{between}^2(T) = \frac{N_{Fgrnd}(T) \cdot N_{Bgrnd}(T)}{N^2} (\mu_{Fgrnd}(T) - \mu_{Bgrnd}(T))^2$$

- Useful recursion for sweeping T across histogram:

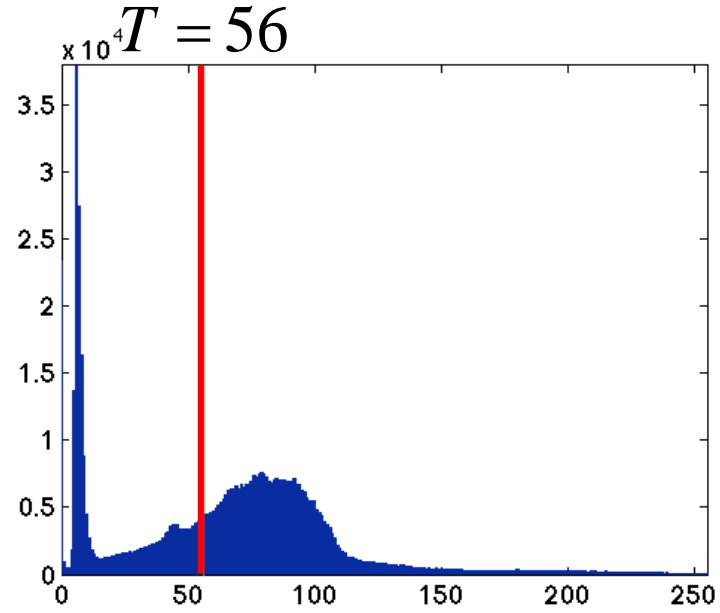
$$\begin{aligned} N_{Fgrnd}(T+1) &= N_{Fgrnd}(T) + n_T \\ N_{Bgrnd}(T+1) &= N_{Bgrnd}(T) - n_T \\ \mu_{Fgrnd}(T+1) &= \frac{\mu_{Fgrnd}(T) N_{Fgrnd}(T) + n_T T}{N_{Fgrnd}(T+1)} \\ \mu_{Bgrnd}(T+1) &= \frac{\mu_{Bgrnd}(T) N_{Bgrnd}(T) - n_T T}{N_{Bgrnd}(T+1)} \end{aligned}$$

[Otsu, 1979]

Unsupervised thresholding (cont.)



Unsupervised thresholding (cont.)



Unsupervised thresholding (cont.)

The Stanford Daily

Tuesday, September 18, 2012 ♦ 13



SIMON WARREN/The 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.

Stephan Taylor: It all starts and ends with Stanford's workhorse. Taylor was everything you could ask for and more against USC. He provided the big plays with a game-tying touchdown on the ground, another score through the air and the consistent ground-and-pound to wear down the Trojans at the end. His 213 total yards of offense to go with a pair of TDs had fans on both sides forgetting

about Andrew Luck. **Josh Mauro:** The backup defensive end saw most of his action at nose tackle in the second half, where he completely took over the ball game. Mauro dominated USC backup center Cyrus Hobbs all half to provide the key pressure up the middle from the defensive line that kept Matt Barkley rattled. The rest of the D-line played great in support, but Mauro went above and beyond the call of duty to help Stanford's defense completely shut down USC for the Pac-12 title.

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 eliminator, the road to Miami 2013 is not walk in the park. The toughest challenges remaining on the schedule are games at Notre Dame, Oregon and UCLA, all of whom 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. Door Number One leads 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 win 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 beat down 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 to third-and-10 on, Nunes was good enough to win a championship. USC's defense is nowhere near a pushover, so Jordan Williamson's 0-3 kicking night 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 bowls excited, so grabbing an at-large selection to the BCS won't be easy. Still, as Stanford showed in

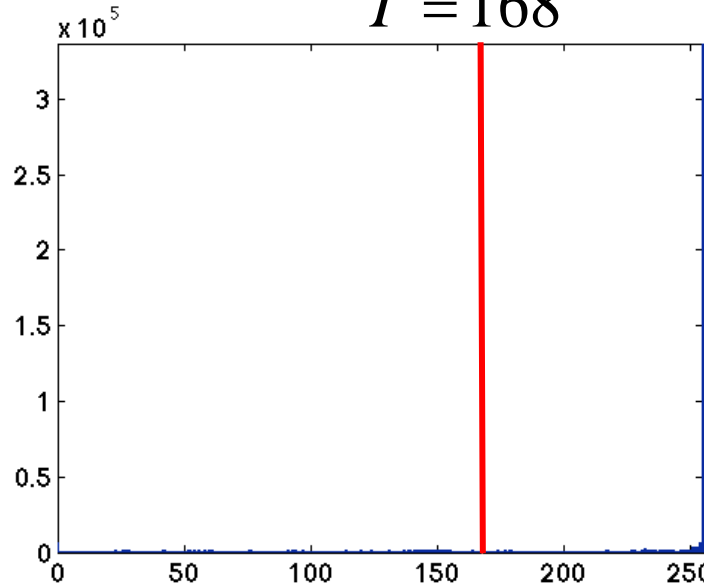
the last two seasons, beating everyone on the schedule except for Oregon is probably good enough to warrant a top-four BCS ranking and an automatic bid to a BCS game.

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 Card 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 in now. No Toby Gerhart, no Jim Harbaugh and no Andrew Luck; just Josh Nunes, Stephan Taylor, a rabid 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 crazy to think about.

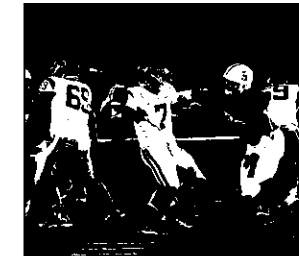
Contact Sam Fisher at safisher@stanford.edu.

$T = 168$



The Stanford Daily

Tuesday, September 18, 2012 ♦ 13



SIMON WARREN/The 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.

Stephan Taylor: It all starts and ends with Stanford's workhorse. Taylor was everything you could ask for and more against USC. He provided the big plays with a game-tying touchdown on the ground, another score through the air and the consistent ground-and-pound to wear down the Trojans at the end. His 213 total yards of offense to go with a pair of TDs had fans on both sides forgetting

about Andrew Luck. **Josh Mauro:** The backup defensive end saw most of his action at nose tackle in the second half, where he completely took over the ball game. Mauro dominated USC backup center Cyrus Hobbs all half to provide the key pressure up the middle from the defensive line that kept Matt Barkley rattled. The rest of the D-line played great in support, but Mauro went above and beyond the call of duty to help Stanford's defense completely shut down USC for the Pac-12 title.

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 eliminator, the road to Miami 2013 is not walk in the park. The toughest challenges remaining on the schedule are games at Notre Dame, Oregon and UCLA, all of whom 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. Door Number One leads 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 win 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 beat down 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 to third-and-10 on, Nunes was good enough to win a championship. USC's defense is nowhere near a pushover, so Jordan Williamson's 0-3 kicking night 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 bowls excited, 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 Card 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 in now. No Toby Gerhart, no Jim Harbaugh and no Andrew Luck; just Josh Nunes, Stephan Taylor, a rabid 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 crazy to think about.

Contact Sam Fisher at safisher@stanford.edu.



Unsupervised thresholding (cont.)

