Introduction to Image Forensics

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ECE 278A

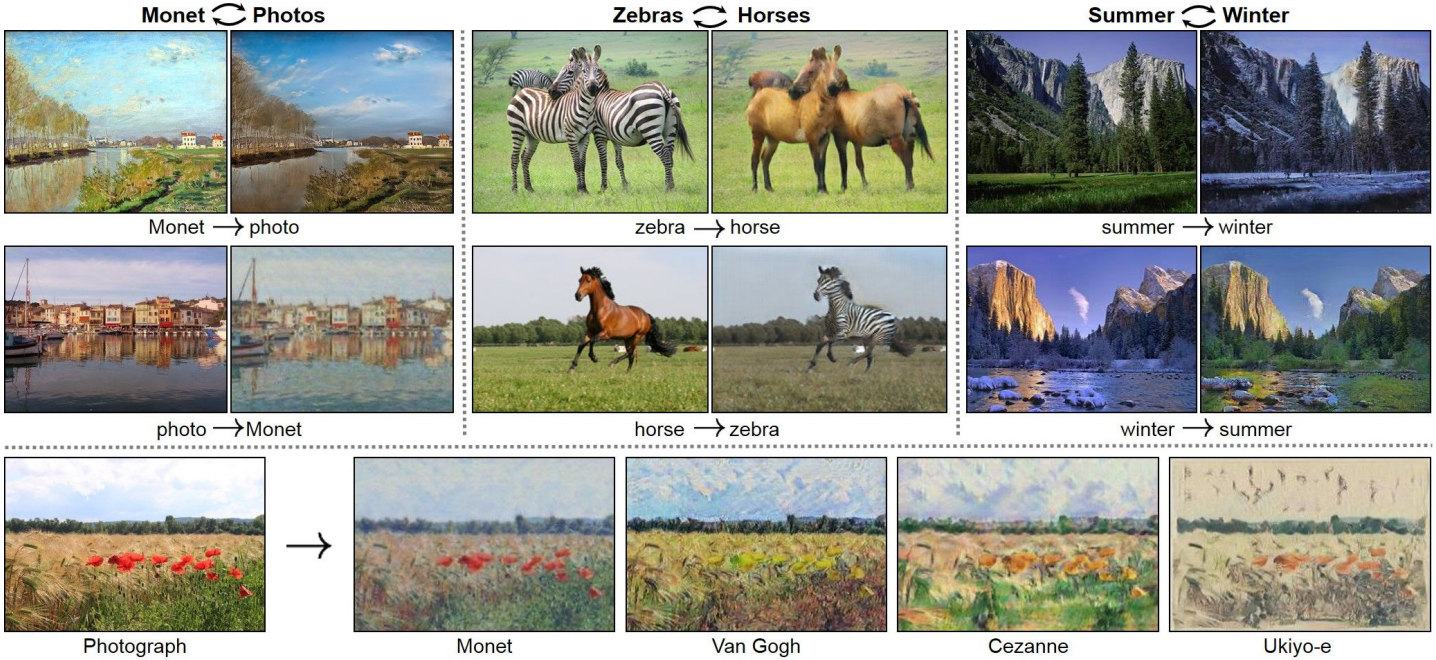
Big Picture

- Goal is to determine whether or not a given image is authentic
- An ill-posed question
  - What counts as being manipulated?
- Several common image manipulations
  - JPEG compression
  - Red-eye correction
  - Watermarking for Digital Rights Management
  - And more on the next few slides

Seam Carving

Inpainting

Generative Adversarial Network (GAN)

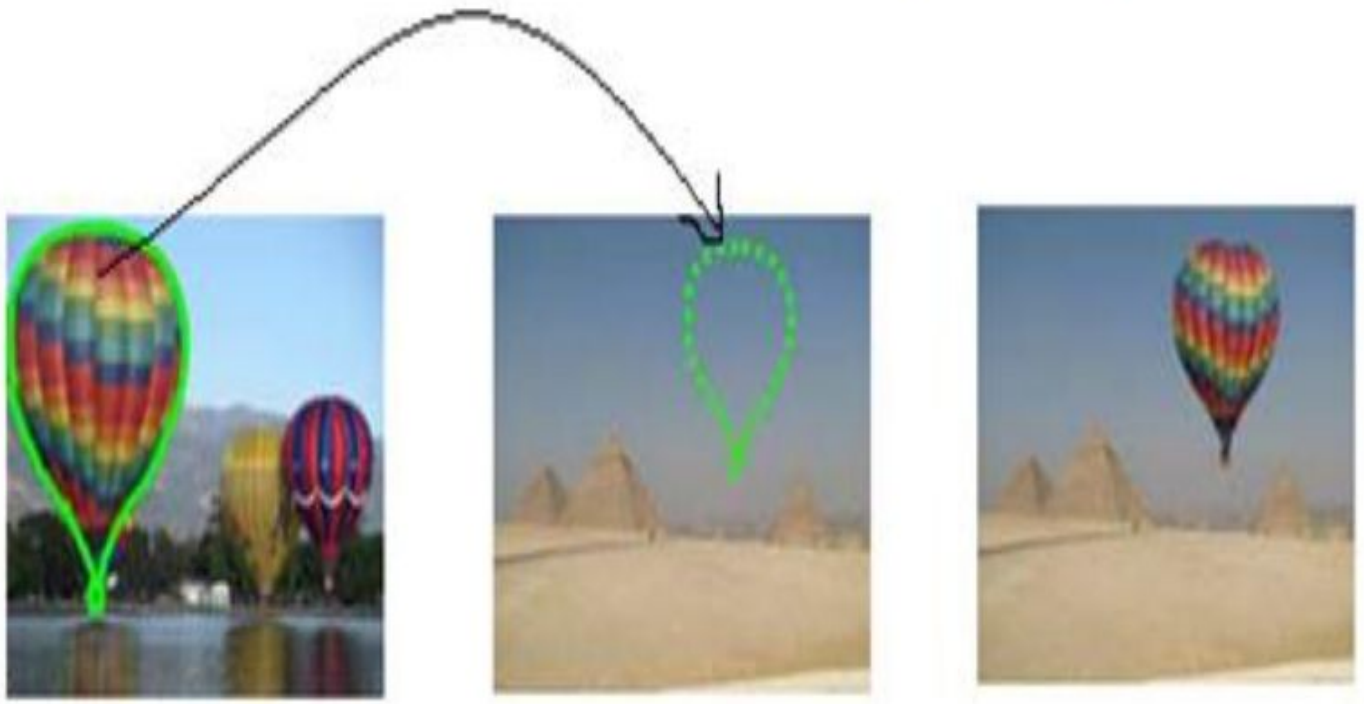


Images taken from CycleGAN paper

GAN - cont

Images created from CycleGAN github code

Copy Paste



Project 2

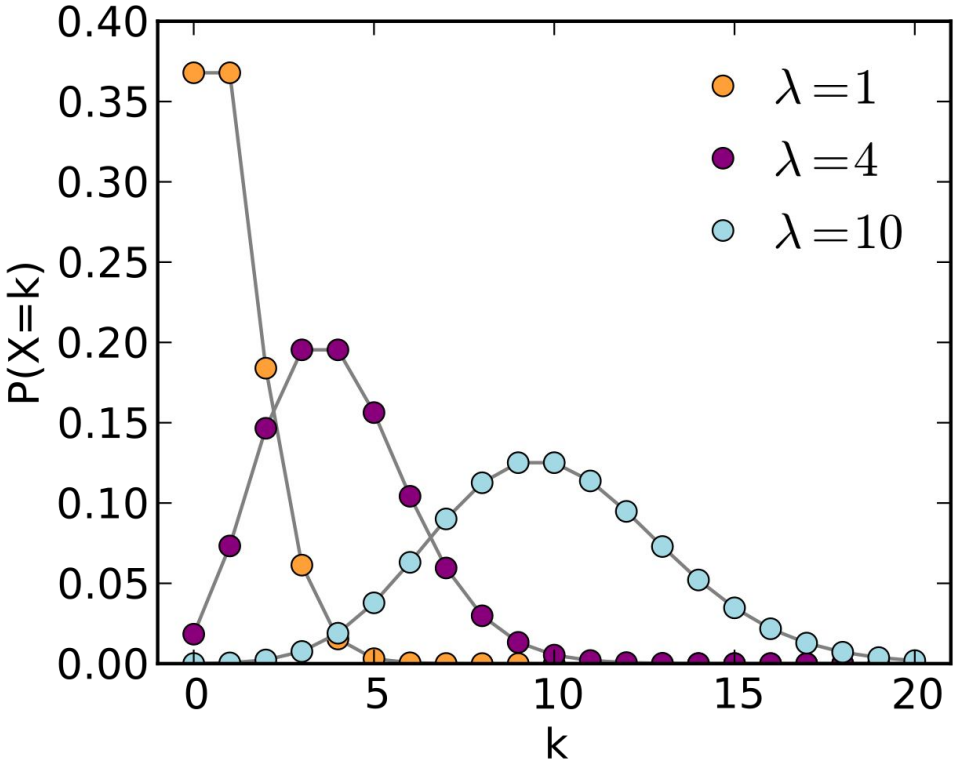
- **Localize copy-paste forgery**
- Often when splicing images, there will be a mismatch of scales
- If the different resampling factors can be detected between two different regions, the copied region can be localized
- This is only a small portion of image forensics, but an important and visually interesting one
- Successful results have been achieved without using deep learning methods

Probabilistic Approach

- Image noise is more easily characterized than image content
- For any given image, we may assume that there is some ground truth scene which produces the image
- The noise is then defined to be the difference between observed image and ground truth
- Using sensor properties, this noise can be more rigorously parameterized, and is present in almost every natural image

Probabilistic Approach - cont

- Shot noise is one example of image noise
- Photons and charge are inherently discrete
- Image pixel values will follow Poisson distribution for some unknown rate



Shot Noise Application

Why do photographers at the Olympics use such big lenses?

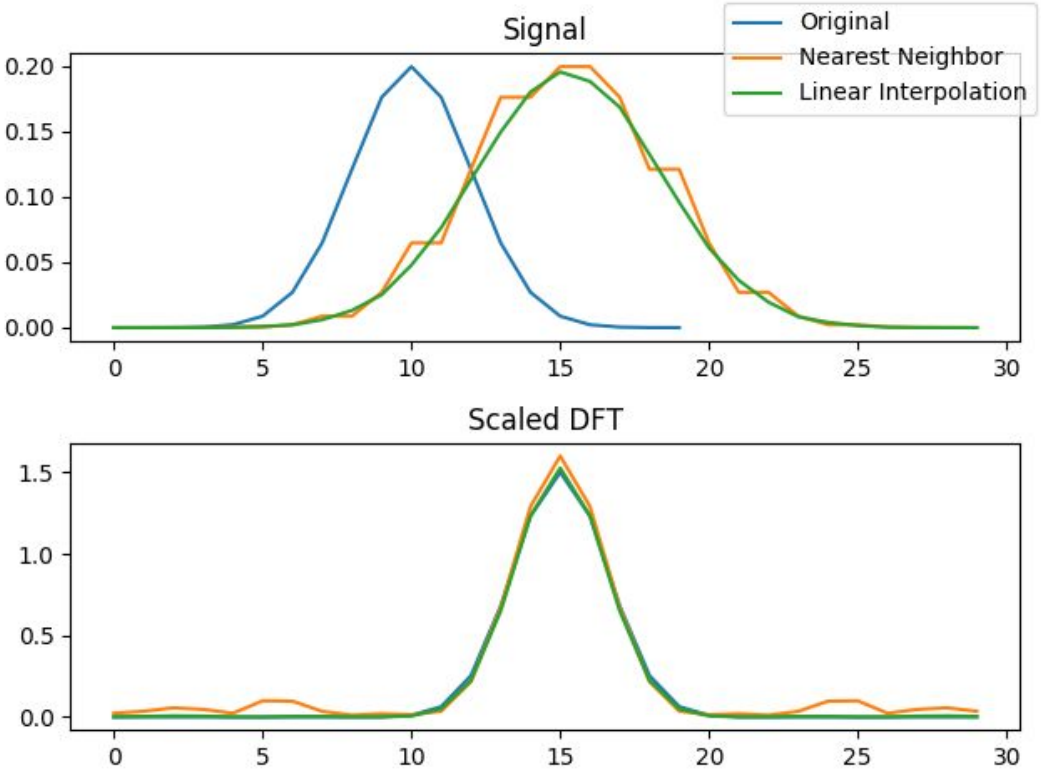
Uncertainty in Tampering Detection

- Given any image, it is not possible to claim with 100% accuracy anything about its processing history
- With shot noise alone, any image could be produced by any scene (though the probability of such a thing happening could be extremely small)
- The certainty will decrease with respect to image size
- What size image is large enough to classify with high accuracy?
- We would like to produce a per-pixel mask of which images were spliced in, is this possible?

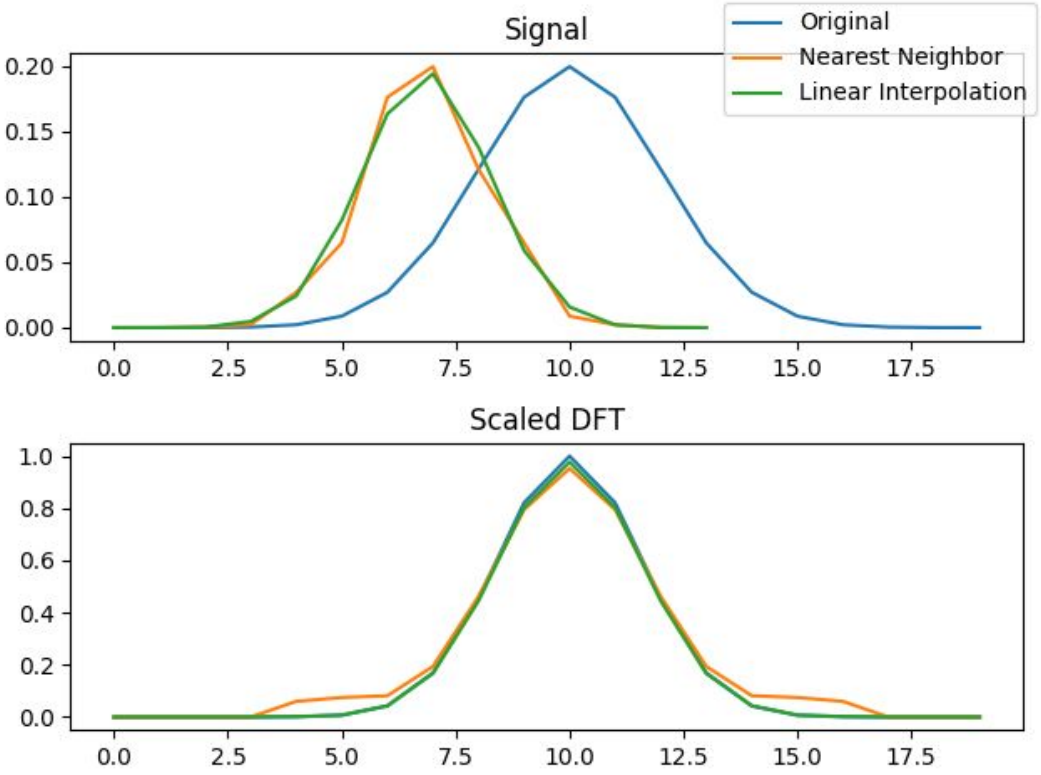
Resampling Methods

- Should preserve as much content as possible
- Nyquist resampling is rarely used in practice
  - Equivalent to interpolation with a sinc
- Nearest Neighbor: New pixel is equal to its nearest neighbor in the original image space
- Bilinear Interpolation: Linearly interpolate in horizontal and vertical directions

Upsampling Example - 1D

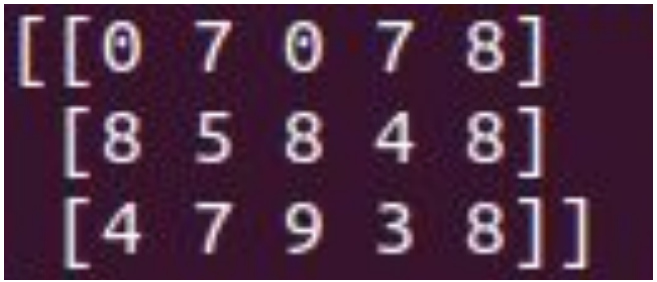


Downsampling Example - 1D



A Very Simple Detection Method

- Can upsampling with nearest neighbor interpolation be easily identified?
- Compare the image left and its upsampled version right



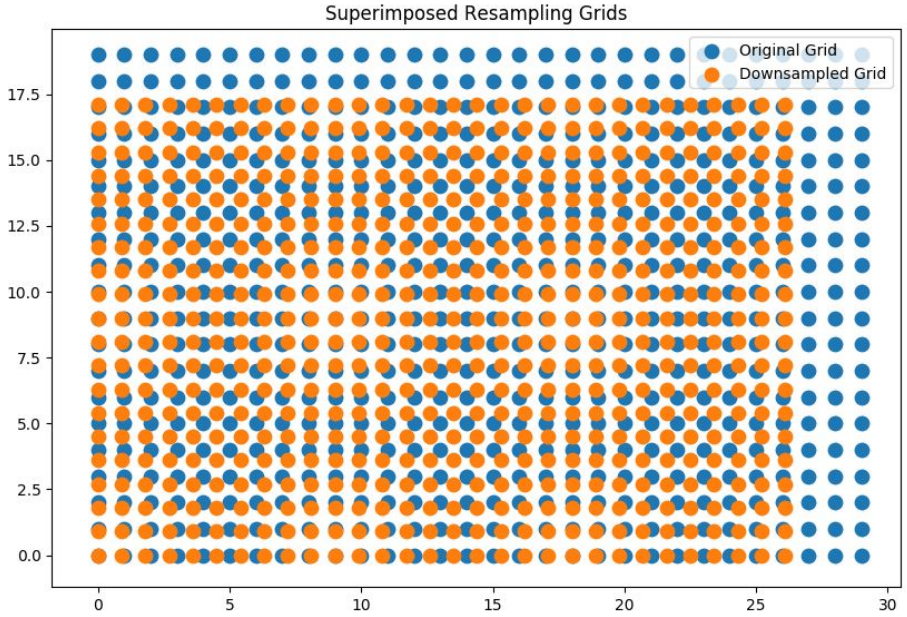
SVD Based Method

- Assume image A is of size l x n
- With high probability, A will be full rank due to noise
- If A is upsampled by a factor of α using bilinear interpolation, what will its new rank be?
- What if nearest neighbor is used?
- What about downsampling?

Vázquez-Padín, David, Pedro Comesana, and Fernando Pérez-González. "An SVD approach to forensic image resampling detection." 2015 23rd European Signal Processing Conference (EUSIPCO). IEEE, 2015.

Spectrum Based Methods

- Previous method works well for upsampling, but fails in downsampling
- Shown right is a resampling grid for a 10% downsampling
- Notice the periodic pattern
- Will assume bilinear interpolation for the next few slides



Spectrum Based Methods - cont

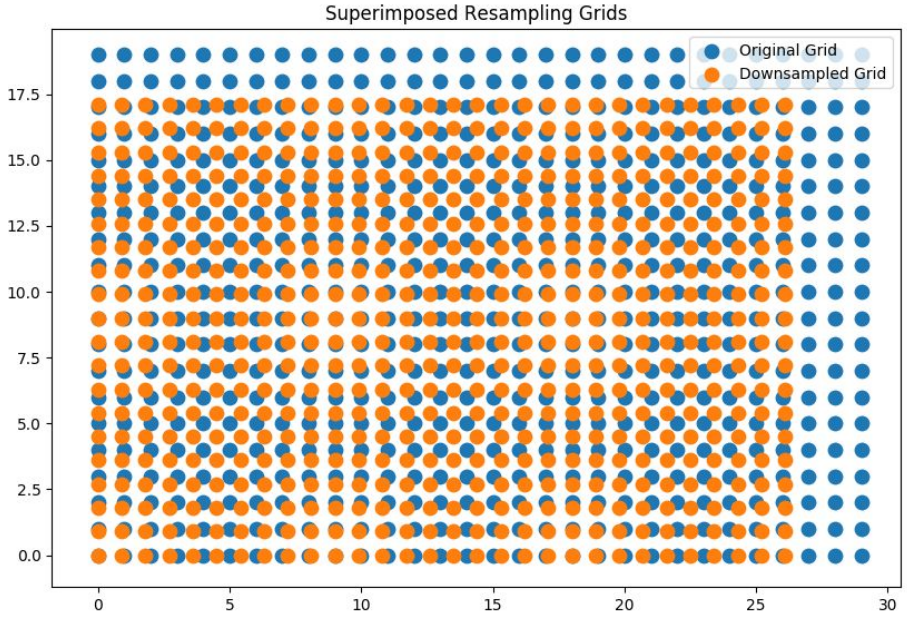
- Consider the region of the resampling pattern shown right
- The transformation in this small region is very close to identity

Spectrum Based Methods - cont

- Now consider the center orange pixel
- With bilinear interpolation, this value will be equal to the average of its 4 neighbors, i.e. low-pass filtered
- This will reduce the relative noise variance at this point

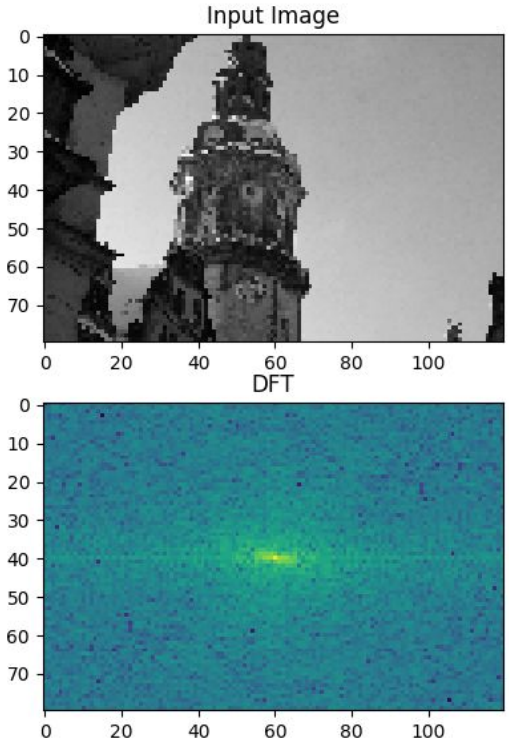
Spectrum Based Methods - cont

- Based on previous two examples, periodicities in noise energy will correspond to resampling factor
- Now how to estimate the noise energy?



Content Removal Filter

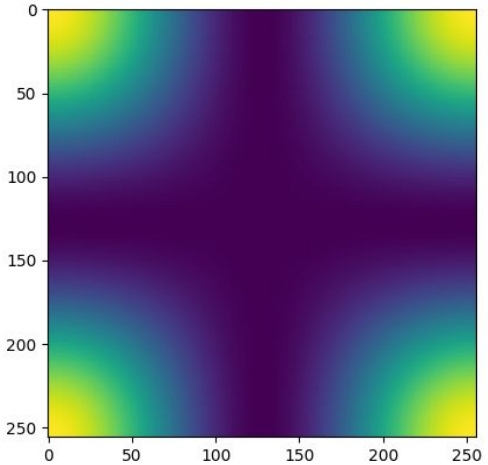
- To estimate noise parameters, first preprocess out as much content as possible
- Shown right is a image and its DFT
- Majority of energy is concentrated near origin, and along the two axes



Content Removal Filter

- An often used content removal filter is shown right, along with its zero-padded DFT

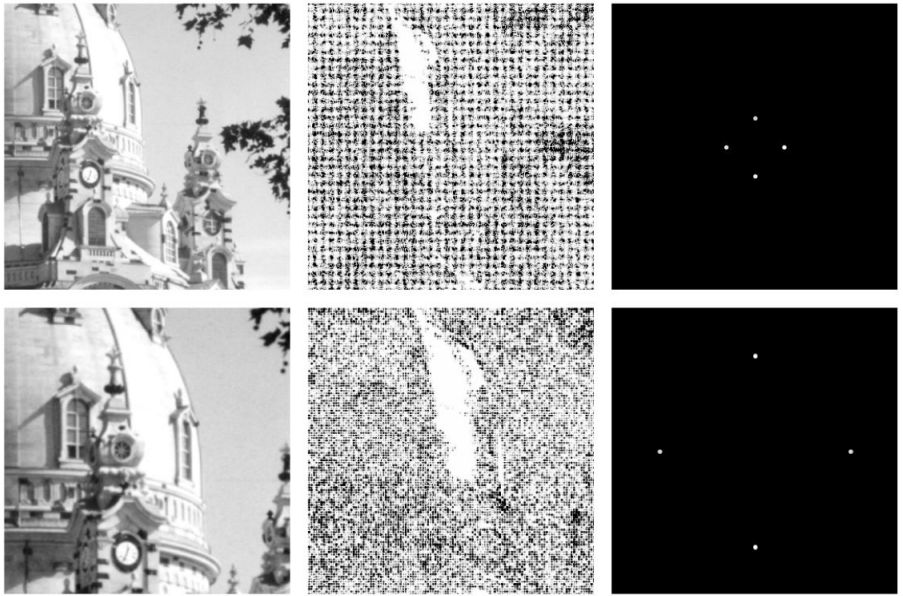
-1/4	1/2	-1/4
1/2	-1	1/2
-1/4	1/2	-1/4



Kirchner, Matthias. "Fast and reliable resampling detection by spectral analysis of fixed linear predictor residue." Proceedings of the 10th ACM workshop on Multimedia and security. ACM, 2008.

Post-Filtering Steps

- Filter gives an estimate of the noise at each point, but need an estimate of the variance
- Ideally, the square function would be the best estimator
  - In practice, many other even functions are used
- Finally, find peaks in the DFT



Input image, filter residual, and DFT plot. Post-processing has been done to produce the clean DFT plot seen here

Other Ideas

- There are many other variations of the spectral analysis published
- Investigate tradeoff between patch size and localization precision
- Combinations of several methods and patch sizes
- You may want to first tackle the problem of simple resampling estimation, then apply this to localization
- Another method detects JPEG block artifacts
  - Tentatively, all source images will be originally JPEG compressed
- Deep learning is allowed, but not required

Data Provided

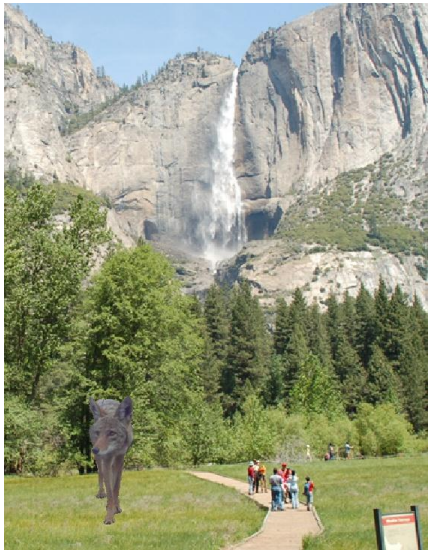
- All images are public domain, and taken from National Parks Services website
- 10 images for development, 10 for test
- Each image will have either a single copy-paste or none
- All images will be JPEG compressed with quality factor of 95 after copy-paste

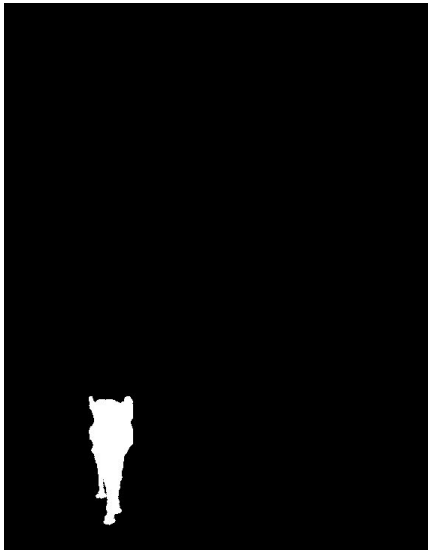
Data Provided - Dev Set

- Everything needed to generate a manipulated image
- Code to reproduce them (and generate more for your own tests)
- Original images + object segmentation map
- Output image with segmentation map
- Parameters used to generate output image

Data Provided - Dev Example

Inputs





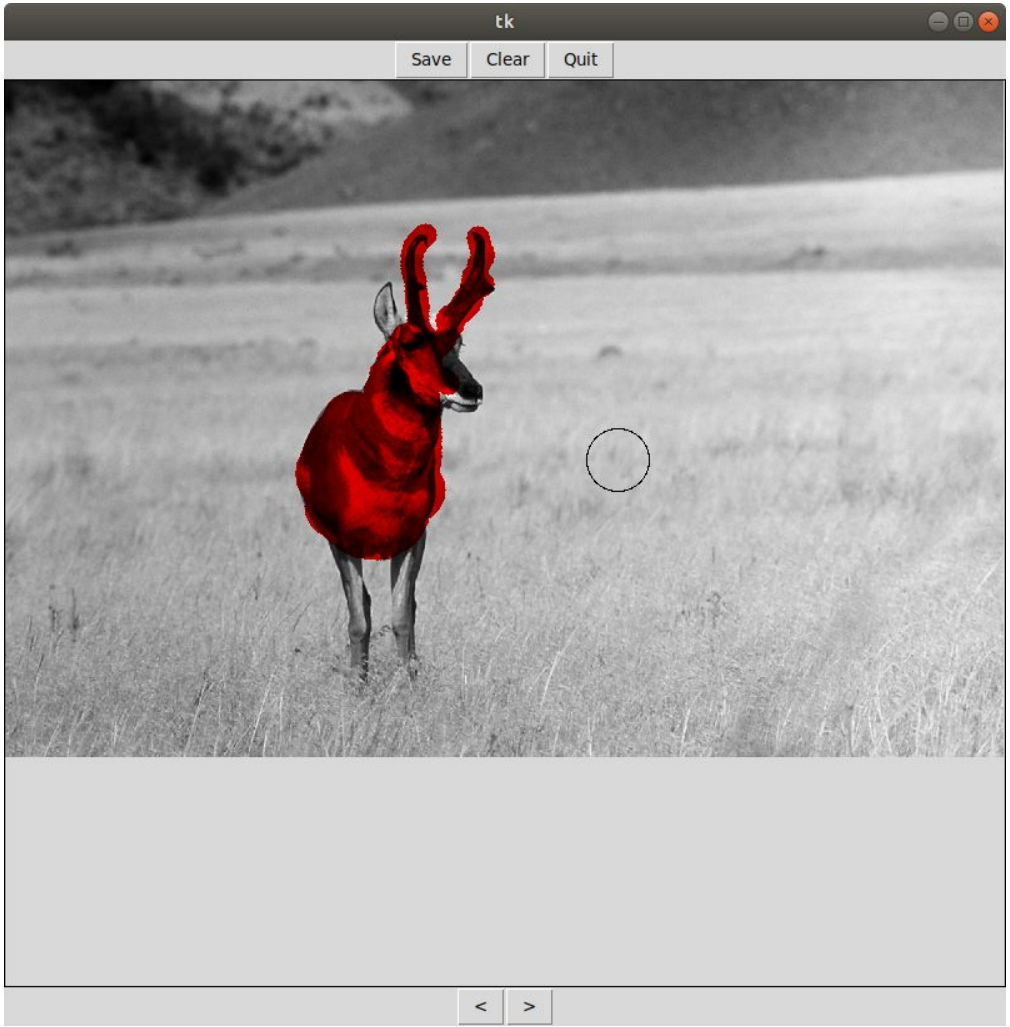
Outputs

Data Provided - Dev Example

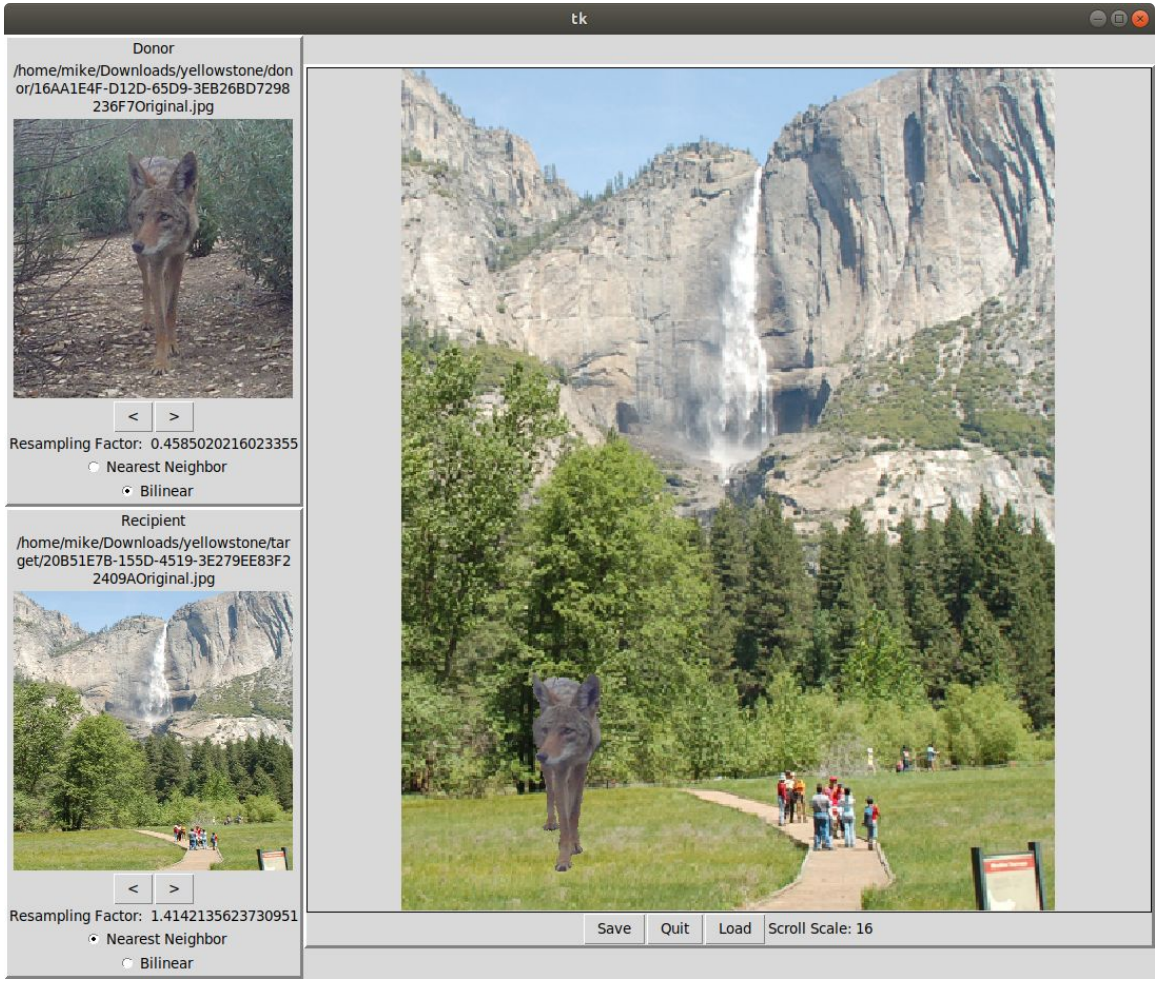
x: 16
y: 498
donor_file: /home/mike/Downloads/yellowstone/donor/16A26F7Original.jpg
recip_file: /home/mike/Downloads/yellowstone/target/20B51E7B49AOriginal.jpg
rs_donor: 0.4585020216023355
recip_file: 1.4142135623730951
method_donor: 2
method_recip: 0

Method macros: 0 = nearest neighbor, 2 = bilinear

Segmentation Tool



Stitching Tool



Final Notes On Project

- It is recommended that you start with published papers on resampling
  - You are welcome to make modifications to these
  - Be creative in how you merge prediction masks
- Start simple, by testing methods on resampled patches
- The detection maps need not be perfect - pixel level accuracy is quite difficult for most images