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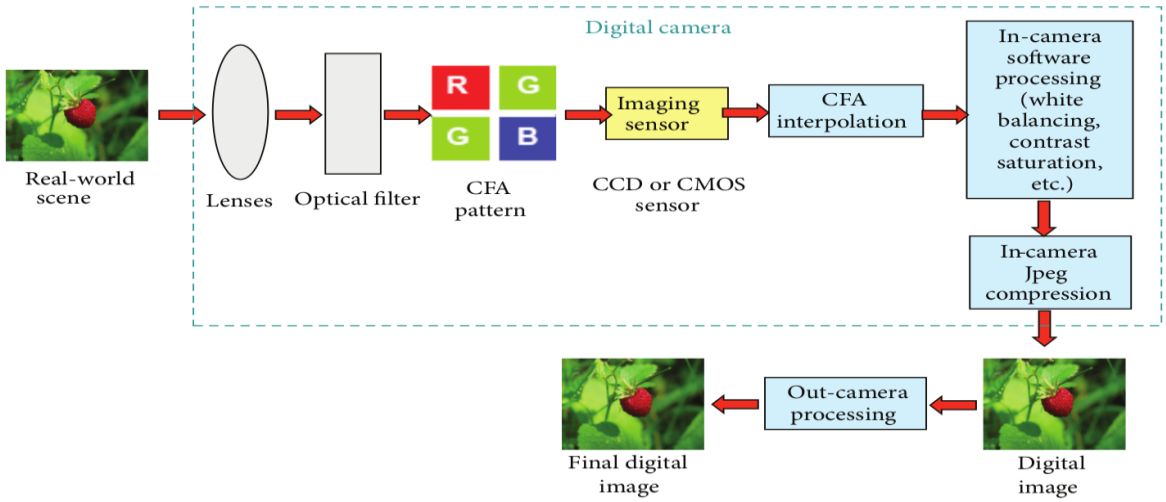
Project2: Image Forensic

Method:

The first basic question comes to our mind that what are changes take place on image when it is captured by a digital camera. Are these changes permanent and unique to each camera? If it is true, we can identify the copy-paste forgery on images. With this thought, I have started to work on the project and found from a survey paper that at each stage of digital image life cycle some unique fingerprints are added to image. At the first stage of image acquisition, a special type of noise, which is called Photo Responsive Non-Uniform (PRNU), added to the image. PRNU is unique to each camera. Using Maximum Likelihood estimator, parameters of PRNU can be estimated, however we need to have training set of images from same camera and donor and recipient images should be from different cameras. We did not know camera related information for our datasets, therefore this approach was not useful for this project.

Life Cycle of a Digital Image



Pic Reference: A. Piva. "An overview on image forensics," ISRN Signal Processing 2013 (2013).

CFA interpolation is the second level of image acquisition where unique fingerprint is added. When we capture an image from digital camera, light passes through a Color Filter Array before reaching to detector. At each pixel location on detector, it has only a single color either Red or Blue or Green. For an RGB image, others two channels are estimated from neighboring pixels. This introduces a unique correlation in the image which depends on interpolation filter. Popescu and Farid[1] claims that that using Expectation/ Maximization Algorithm, we can find this unique relationship which is effected when we add some other sub-image to original image. Therefore, modified content in the image can be found using this algorithm. I have started working on algorithm.

Algorithm:

/* Initialize */
choose $\{\alpha_{u,v}^{(0)}\}$ randomly
choose N and σ_0
set p_0 as 1 over the size of the range of possible values of $f(x,y)$

$n = 0$
repeat
  /* expectation step */
  for each sample location (x,y)
    $r(x,y) = \left| f(x,y) - \sum_{u,v=-N}^{N} \alpha_{u,v}^{(n)} f(x+u, y+v) \right|$ /* residual error */
  end
  for each sample location (x,y)
    $P(x,y) = \frac{1}{\sigma_n \sqrt{2\pi}} \exp\left[-r^2(x,y)/2\sigma_n^2\right]$ /* conditional probability */
    $w(x,y) = \frac{P(x,y)}{P(x,y)+p_0}$ /* posterior probability */
  end

  /* maximization step */
  compute $\{\alpha_{u,v}^{(n+1)}\}$ as the solution of the linear system in Eq. (??)
  $\sigma_{n+1} = \left(\frac{\sum_{x,y} w(x,y) r^2(x,y)}{\sum_{x,y} w(x,y)} \right)^{1/2}$ /* new variance estimate */
  $n = n + 1$
until ($\sum_{u,v} \left| \alpha_{u,v}^{(n)} - \alpha_{u,v}^{(n-1)} \right| < \epsilon$) /* stopping condition */

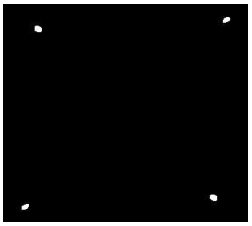
As you see in the above algorithm, closed form solution for alpha is not given. First, I found the closed form solution in matrix form. This algorithm gives the probability map(p-map) as an output of an image. According to paper, Fourier transform of p-map should be symmetric if there is no modified content in the image. In the paper, donor image did not have any kind of interpolation, so Fourier transform of it was not symmetric. However, in our datasets, both donor and recipient images have different kind of interpolation relationship, therefore Fourier transform p-map of donor and recipient images should be different and we can identify the modified content.

But this was not the case, I could not find any kind of relationship between Fourier transform of p-map of donor and recipient image

Postprocessing:

I. p-map is interpolated to reduce sharp frequency due to edges
II. Fourier transform of p-map is high pass filtered, blurred and scaled to [0,1]
III. For better display, gamma correction is applied with exponent of 2

Results:

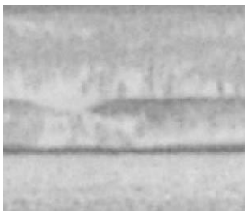


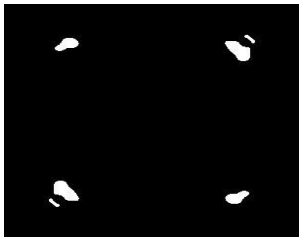
Original Image

Fourier Transform

P-Map

Fourier Transform





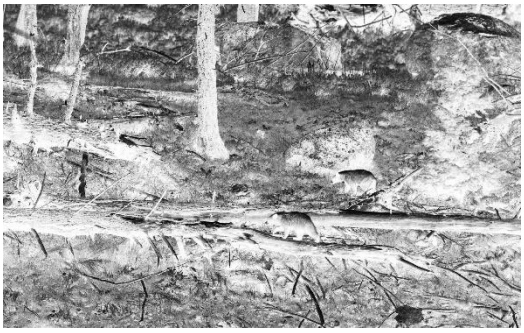
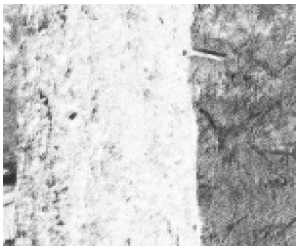
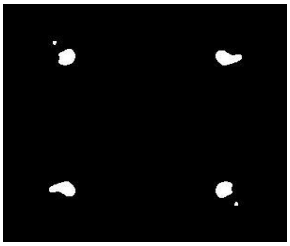
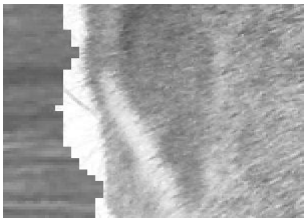
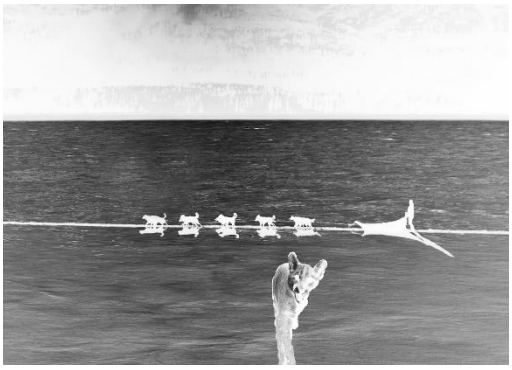
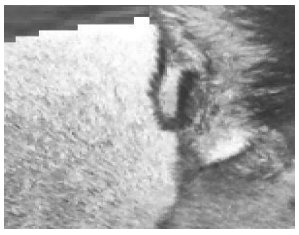




Image from Test Data Set:


As we see, donor image has different Fourier transform than recipient image's original content in some of the images, however it is not true in general. Therefore, it is difficult to distinguish between the Fourier transform of between donor and recipient images.

Contribution:

1. Written this algorithm in python from scratch.
2. Closed form solution for parameter update
3. Tried different methods to improve the results like high pass and low pass filtering
4. Tried to find p-map for smaller blocks, but convergences issues were coming

Reference:

1. **Alin C. Popescu and Hany Farid "Exposing Digital Forgeries in Color Filter Array Interpolated Images (2005)"**
2. **A. Piva. "An overview on image forensics," ISRN Signal Processing 2013 (2013)**