Detecting Image Splicing Using Geometry Invariants And Camera Characteristics Consistency

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Motivation:
Image Forensics Research

- Too many tampered images circulate in our everyday life
  - Internet ’04
    - John Kerry spliced with Jane Fonda in an anti-Vietnam war rally
  - Front page of LA Times ’03
    - Spliced soldier pointing his gun at Iraqi people
  - TIME magazine cover ’94
    - O. J. Simpson’s skin color deliberately darkened
  - Inpainting [Beltamio, Sapiro, Caselles, Ballester ‘00]
    - Bungee jumping rope removed
- Tampered image collection: http://www.worth1000.com


Fonda Speaks To Vietnam Veterans At Anti-War Rally

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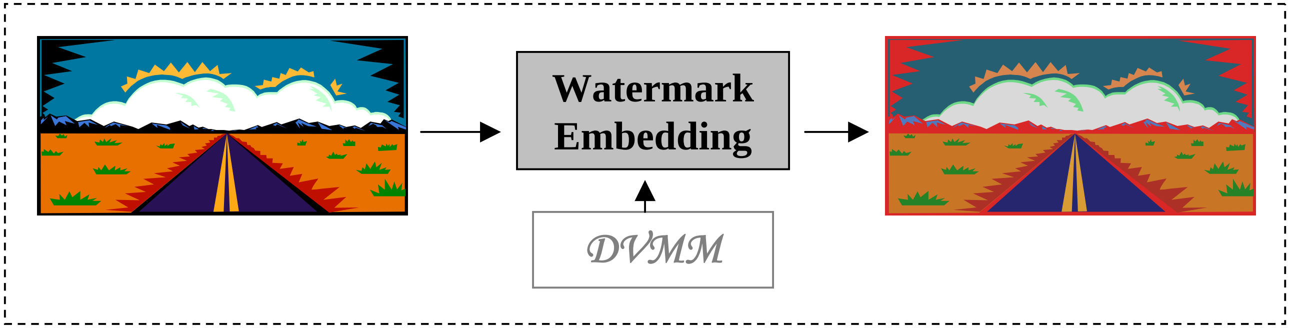
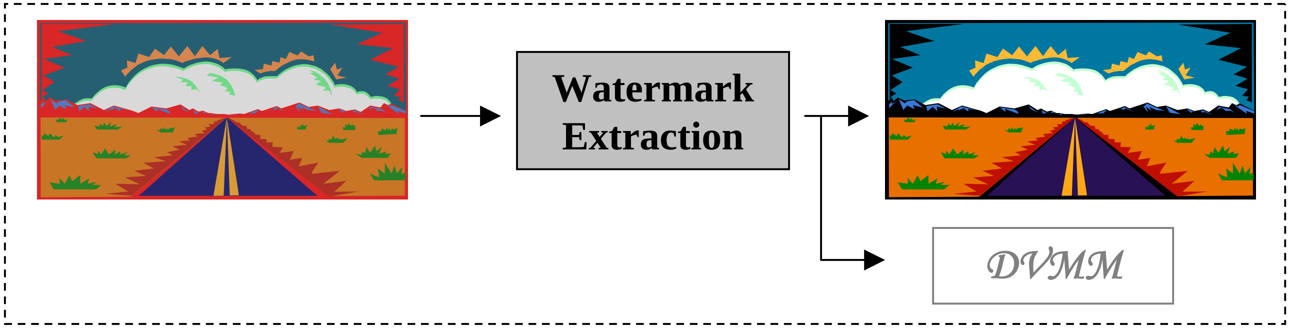
Active Image Forensics

- Active approaches: Watermarking

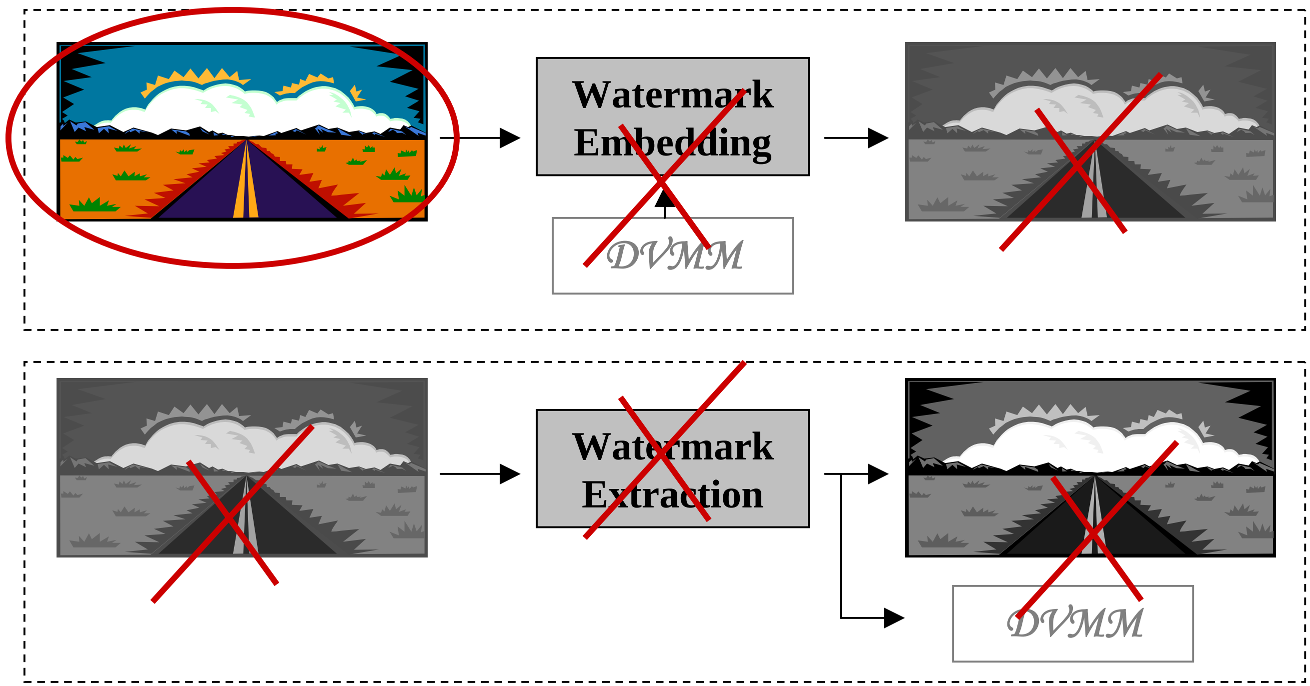




- Disadvantage
  - Need knowledge about Watermark Embedding and Watermark Extraction

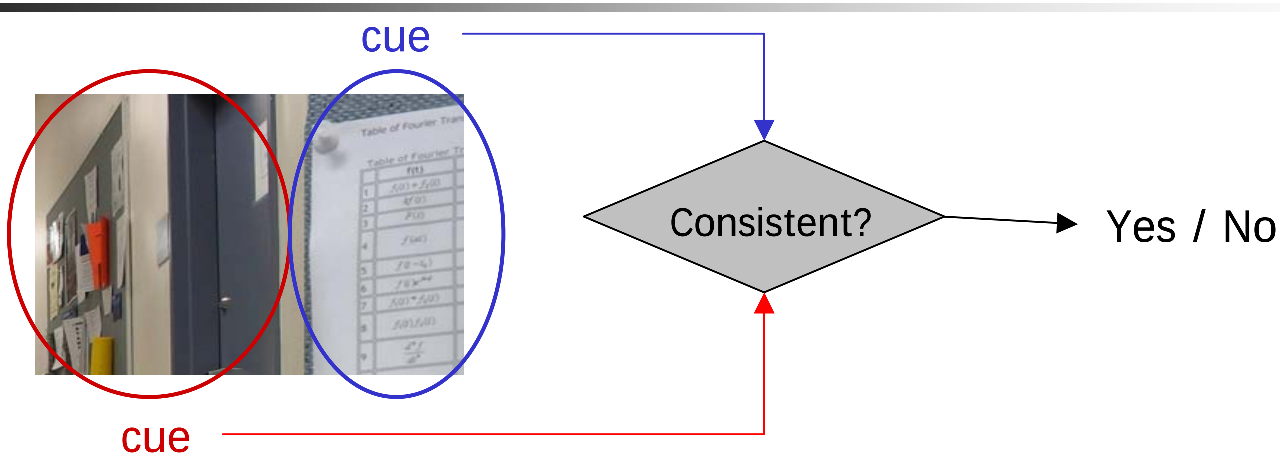
Passive Blind Image Forensics

- Passive blind approaches
  - Passive: no watermark is added into original image
  - Blind: no prior knowledge of watermarking scheme is needed



- Advantage
  - Applies to a wider range of images

Spliced Image Detection by Consistency Checking

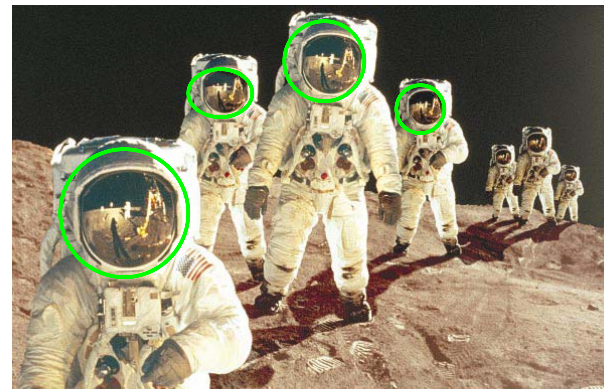


- Splicing = copy-and-paste (most common image tampering)
- Possible image cues
  - Natural scene quality
    - Lighting
    - Shadows
    - Reflections
  - Natural imaging quality
    - Imaging device (camera, scanner)

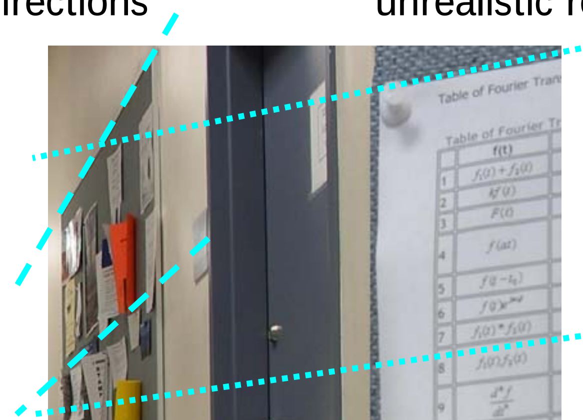
Spliced Image Detection

- Examples of spliced images with inconsistency

different lighting directions

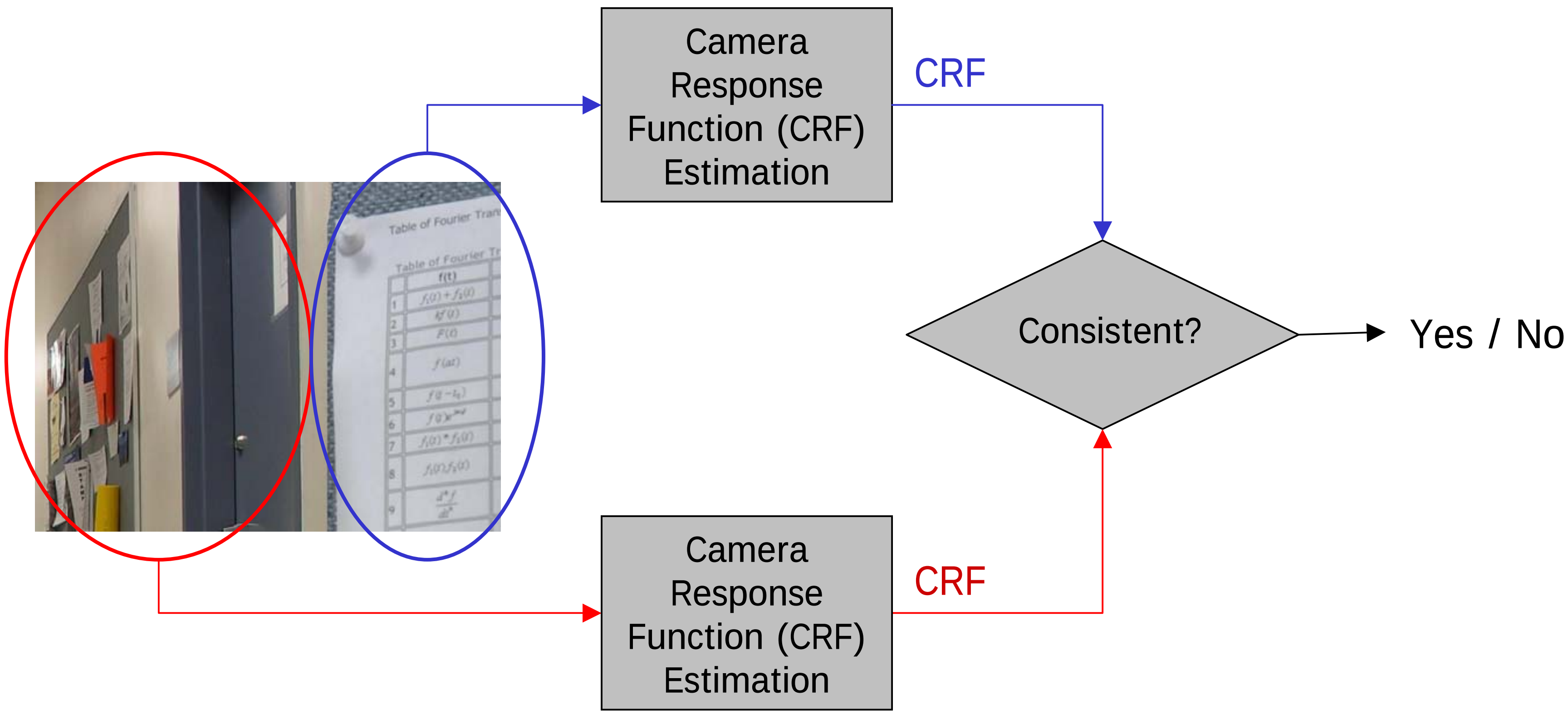


unrealistic reflections



different perspectives

Spliced Image Detection by Consistency Checking



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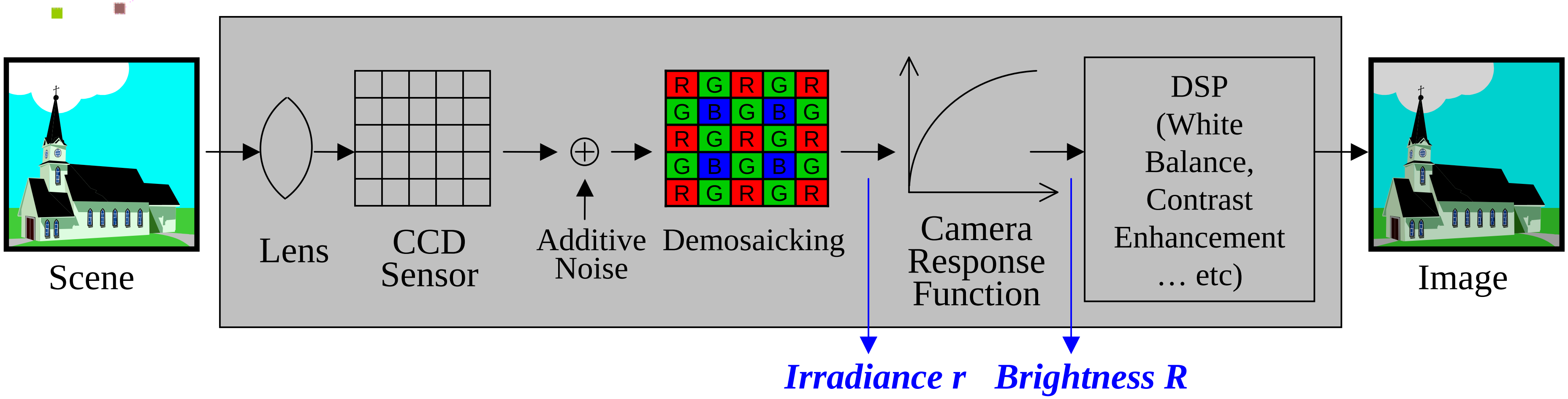
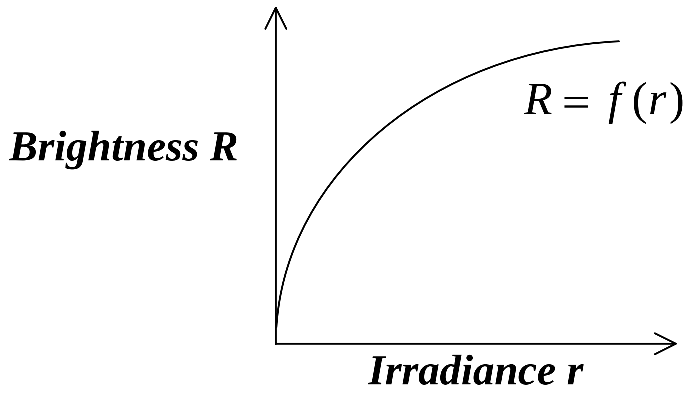
Camera Imaging Pipeline



- Demosaicking patterns
  - EM based demosacking pattern estimation [Popescu, Farid '05]
- CCD sensor noise
  - Camera source identification using sensor noise [Lukas, Fridrich, Goljan '05]
  - Spliced image detection using sensor noise [Lukas, Fridrich, Goljan '06]
- Camera response function
  - CRF estimation from a single color image [Lin, Gu, Yamazaki, Shum '04]
  - Spliced image detection using CRF abnormality [Lin, Wang, Tang, Shum '05]

CRF Estimation

- Camera response function



- Common forms of CRF
  - Gamma

$$R = f(r) = r^{\alpha}$$

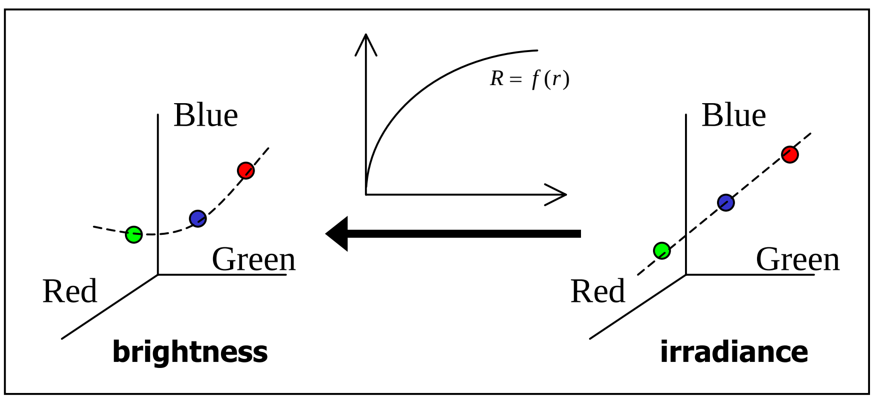
  - Linear exponent [Ng, Chang, Tsui ‘06]

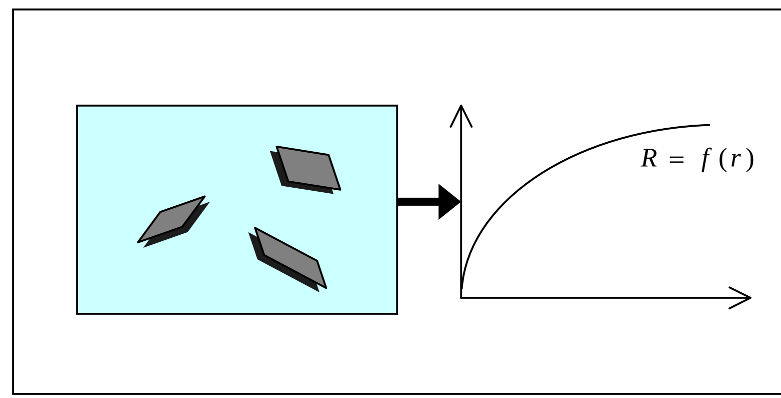
$$R = f(r) = r^{\alpha + \beta r}$$

CRF Estimation

- Multiple exposure images [Debevec, Malik ‘97] [Mann ‘00] [Grossberg, Nayar ‘04]

- Single image [Lin, Gu, Yamazaki, Shum ‘04] [Ng, Chang, Tsui ‘06]





- Spaces for CRF
  - Polynomials [Mitsunaga, Nayar ‘99]
  - PCA [Grossberg, Nayar ‘04]

CRF Estimation Using Geometry Invariants

- CRF

$$R = f(r)$$

- Geometry invariants [Ng, Chang, Tsui '06]
  - First partial derivatives

$$R_x = f'(r)r_x \qquad R_y = f'(r)r_y$$

  - Second partial derivatives

$$R_{xx} = f''(r)r_x^2 + f'(r)r_{xx}$$
$$R_{xy} = f''(r)r_x r_y + f'(r)r_{xy}$$
$$R_{yy} = f''(r)r_y^2 + f'(r)r_{yy}$$

irradiance geometry

  - If the irradiance ***r*** is locally planar
    - Ratios of 2nd partial derivatives cancel out irradiance geometries

$$\frac{R_{xx}}{R_x^2} = \frac{R_{xy}}{R_x R_y} = \frac{R_{yy}}{R_y^2} = \frac{f''(r)}{(f'(r))^2} = \frac{f''(f^{-1}(R))}{(f'(f^{-1}(R)))^2} = A(R)$$

    - Geometry invariant $Q(R) = \dfrac{1}{1 - A(R)R}$

CRF Estimation Using Geometry Invariants

- Physical meaning of *Q(R)*
  - Gamma form
    - Exactly equal to the gamma exponent ***α***

$$Q(R) = \frac{1}{1 - A(R)R} = \alpha$$

  - Linear exponent

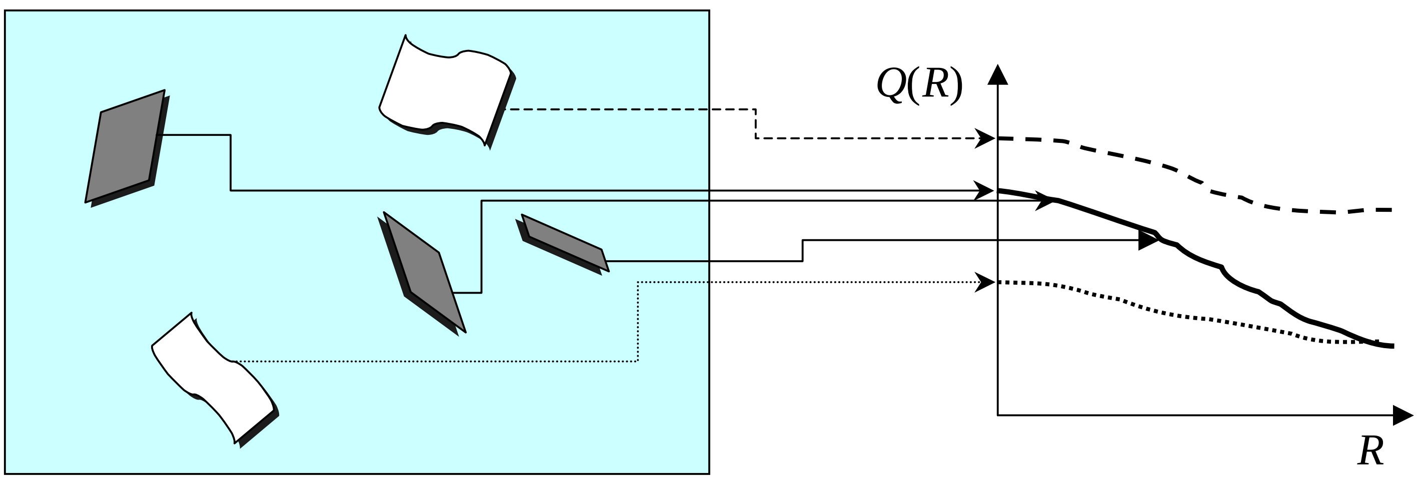
$$Q(R) = \frac{1}{1 - A(R)R} = \frac{(\beta r \ln(r) + \beta r + \alpha)^2}{\alpha - \beta r}$$

CRF Estimation Using Geometry Invariants

- Geometry invariants [Ng, Chang, Tsui '06]
  - Locally planar pixels

$$Q(R) = \frac{1}{1 - A(R)R}$$

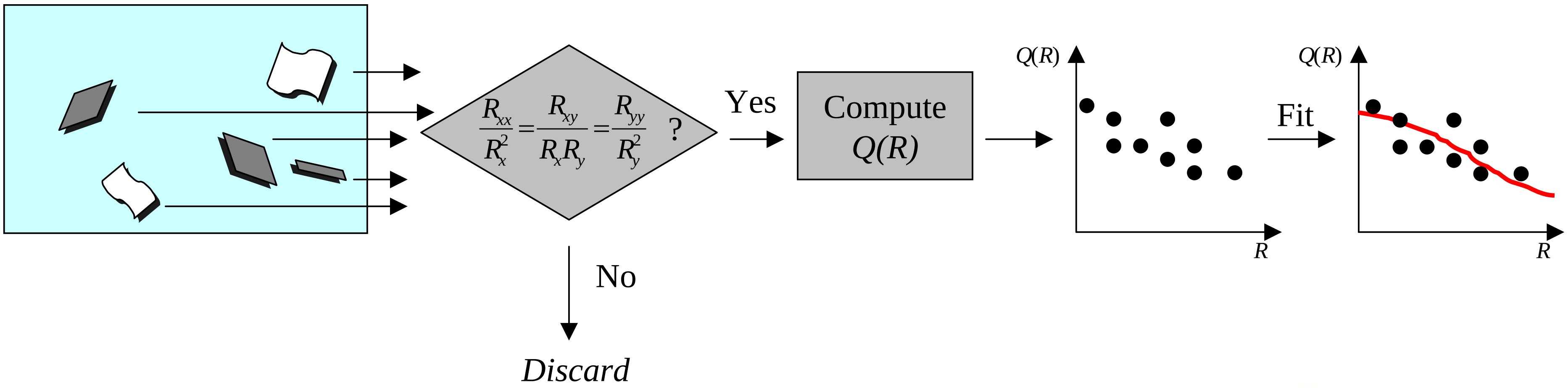
    - Yield same *Q(R)* curve, regardless of plane slope



CRF Estimation Using Geometry Invariants

- For a given image
  - Extract locally planar pixels
    - Check ratios of partial derivatives
  - Compute *Q(R)*
  - Fit *Q(R)* using linear exponent model

$$Q(R) = \frac{1}{1 - A(R)R} = \frac{(\beta r \ln(r) + \beta r + \alpha)^2}{\alpha - \beta r}$$



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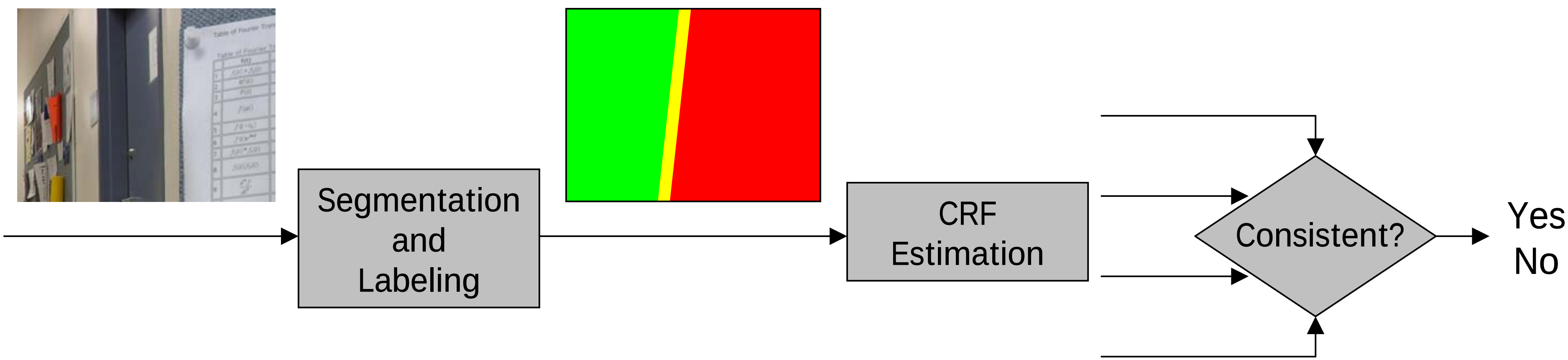
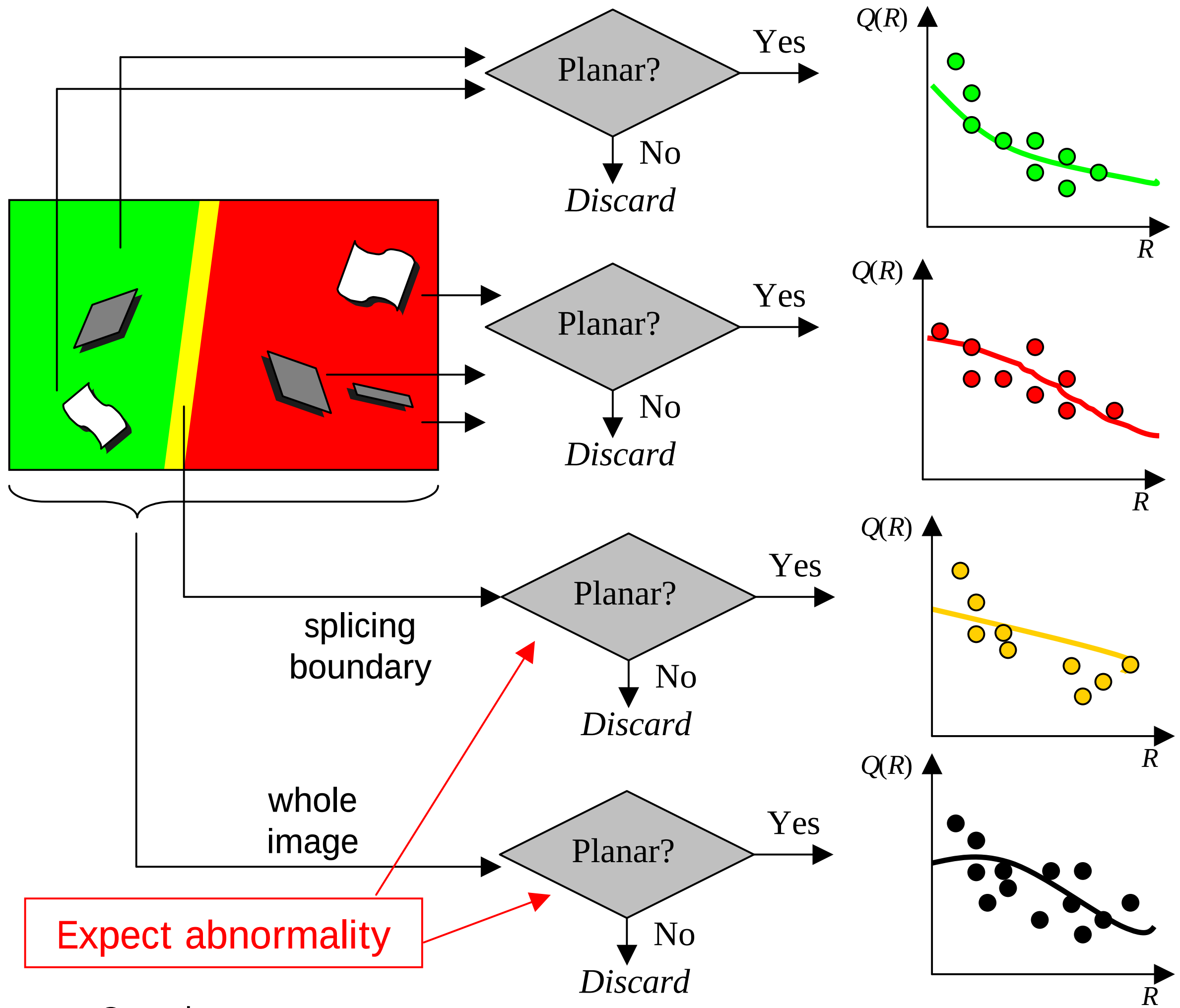
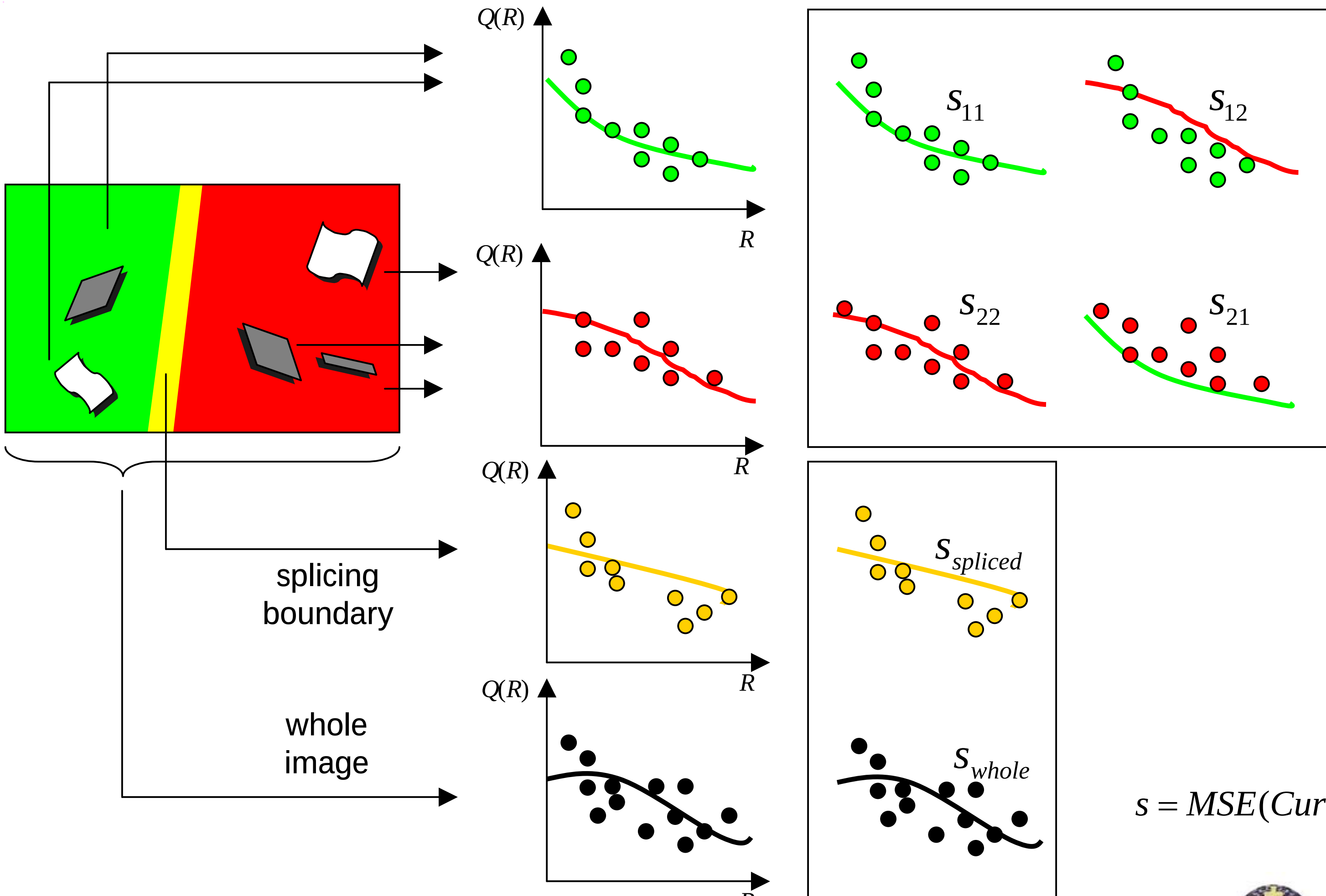
Spliced Image Detection by Consistency Checking



CRF Estimation – Labeled Regions



CRF Estimation And Cross-fitting



$$s = MSE(Curve, Samples)$$

Dataset

- A total of 363 color images from 4 cameras
  - Canon G3, Nikon D70, Canon Rebel XT, Kodak DCS330
  - 183 authentic, 180 spliced
  - Uncompressed images TIFF or BMP
  - Dimensions 757x568~1152x768
  - No post-processing
  - Mostly indoor scenes
  - 27 images, or 15% taken outdoors on a cloudy day


authentic


authentic

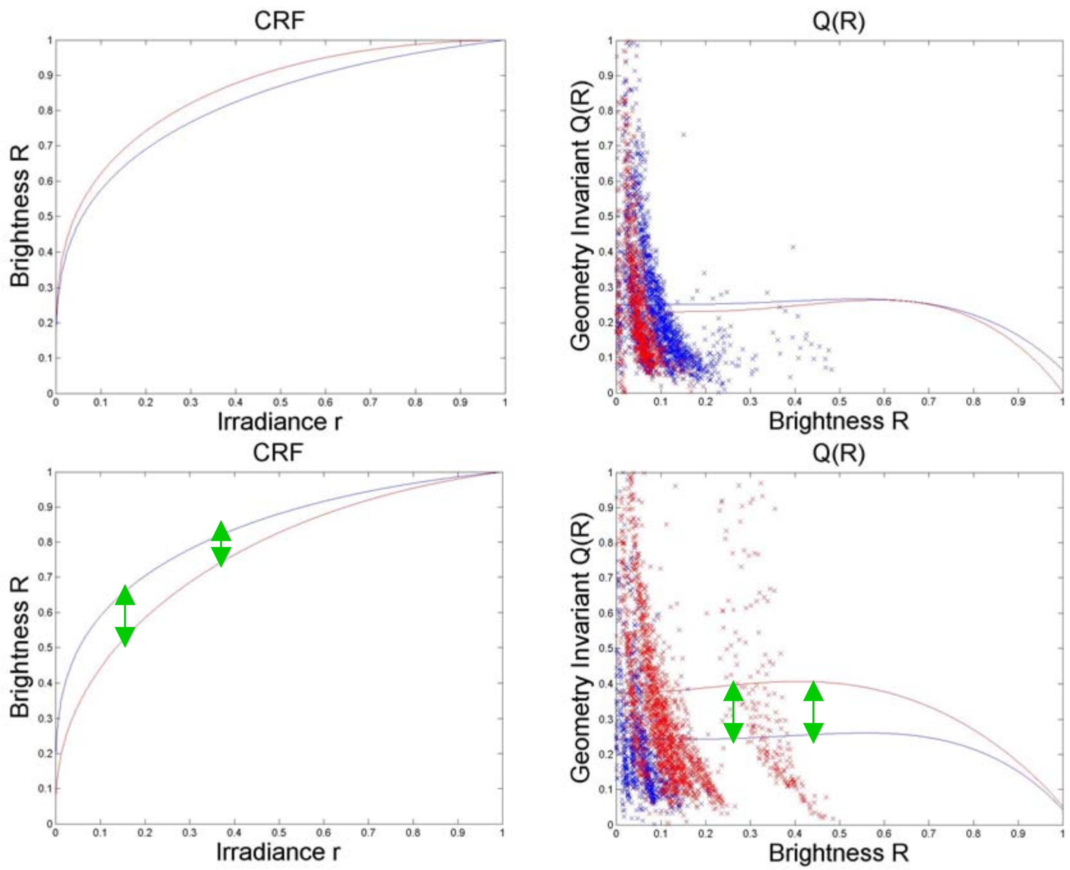

spliced


spliced

- Will be available for download soon
  - http://www.ee.columbia.edu/dvmm/newDownloads.htm

Effectiveness of *(Q,R)* Curve

- *(Q,R)* curve is much more distinguishing than CRF



authentic image

spliced image

SVM Classification

- SVM with cross validation in search of best parameters
  - Linear
  - RBF Kernel
- Confusion matrix of RBF kernel SVM is shown below

RBF Kernel SVM

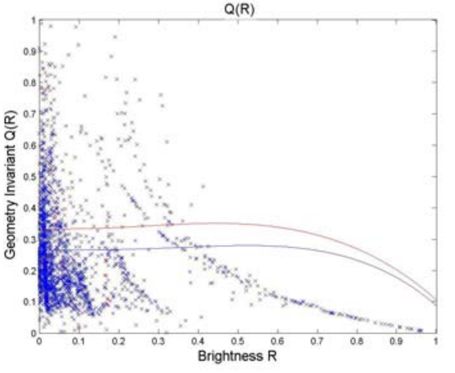
Overall Accuracy 85.90%

		Detected As	
		Au	Sp
Actual	Au	85.93%	14.07%
	Sp	14.13%	85.87%

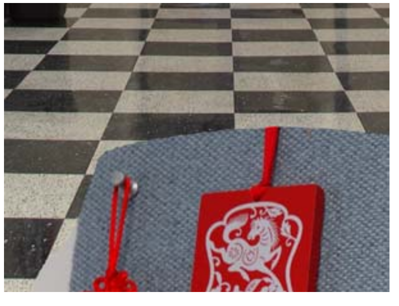
Discussion

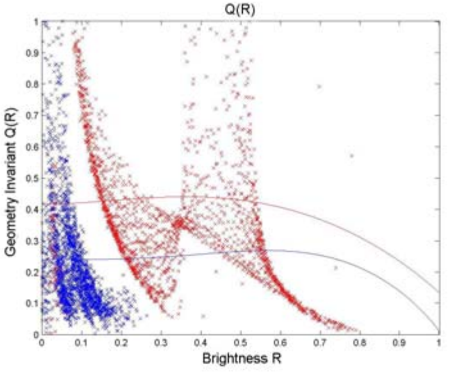
- Images that performed well
  - Generally those with very different *Q(R)* curves

Canon G3
Canon Rebel XT



Canon G3
Nikon D70





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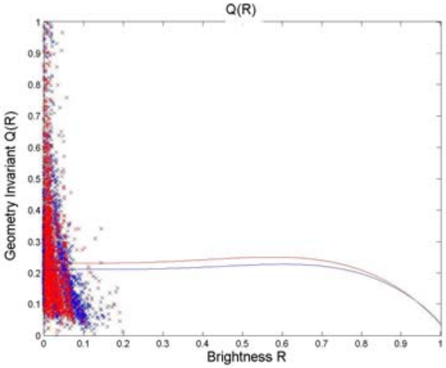
Discussion

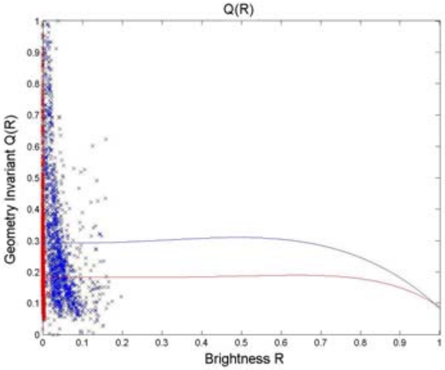
- Images that failed
  - Similar *Q(R)'s*
    - Similar CRF estimations from different cameras

Canon G3
Canon Rebel XT



  - Narrow range of brightness *R*
    - Affects accuracy of estimated *Q(R)*

Canon G3
Nikon D70



Issues

- Operations that might affect our technique
  - Smoothing of splicing boundaries
  - Other post processing
    - Contrast adjustment
    - Tone adjustment
  - Compression

Conclusion

- A spliced image detection method using CRF inconsistency
  - Single-channel CRF estimation using geometry invariants
  - Image region CRF cross-fitting, constructing the feature vector for the image
  - SVM classification with cross validation
- New authentic/spliced image dataset
  - Uncompressed color images with full EXIF information
- Good results
  - Nearly 86% detection rate using RBF kernel SVM
- Semi-automatic region labeling
  - Generally applicable when
    - Image content is simple
    - Suspicious splicing boundary is clearly targeted
    - eg. celebrity photographs
  - Image segmentation can be incorporated for other occasions

Thank You!