Morphological Operations Applied to Digital Art Restoration

M. Kirbie Dramdahl

Division of Science and Mathematics
University of Minnesota, Morris
Morris, Minnesota, USA

29 April 2014
UMM CSci Senior Seminar Conference
University of Minnesota, Morris

Why?

Art restoration preserves objects of artistic, cultural, or historical value. However, this process demands many resources.

Digital art restoration provides:

- a comparatively inexpensive alternative.
- a nondestructive tool.
- an approximation of the initial appearance.

Cornelis et al

Outline

Outline

Criteria

Terms

Edge boundaries between areas of varying intensity

Intensity brightness or dullness of a color

1. Accuracy - low error rate
2. Localization - minimal distance between detected and actual edge
3. Uniqueness - only one response to a single edge

Canny Algorithm

1. Smooth image by applying Gaussian filter.
2. Take gradient of image.
3. Identify regions containing significant jumps in intensity.
4. Search regions for local maximum.
5. Compare remaining pixels to two thresholds.

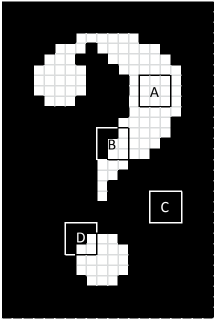
Outline

Morphological Operations

Binary and Greyscale Images

Two Inputs:

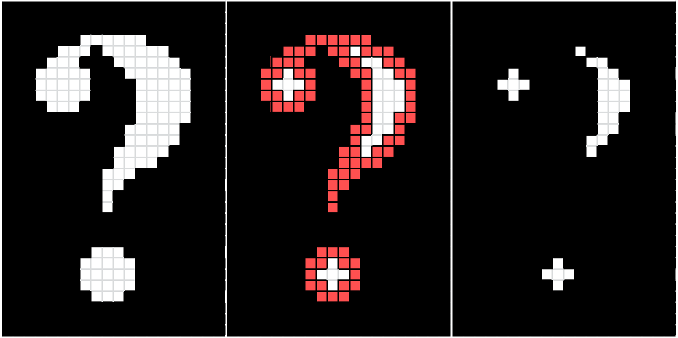
- Original Image
- Structuring Element



Erosion

Erosion strips away pixels from the boundaries of foreground regions.

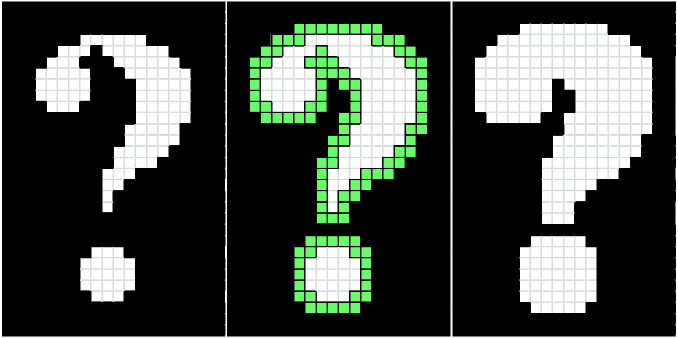
$$g = f \ominus s$$



Dilation

Dilation adds pixels to the boundaries of foreground regions.

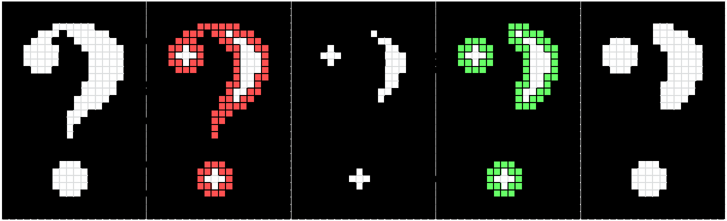
$$g = f \oplus s$$



Opening

Opening strips away pixels from the boundaries of foreground regions while preserving foreground regions that fit the shape and size of the structuring element.

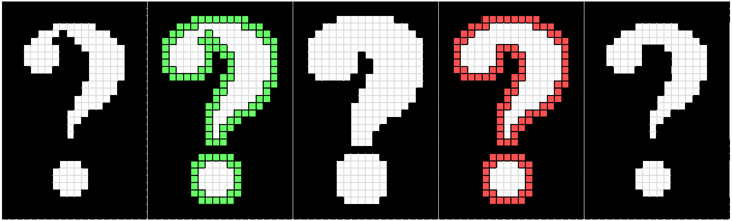
$$g = f \circ s = (f \ominus s) \oplus s$$



Closing

Closing adds pixels to the boundaries of foreground regions while preserving background regions that fit the shape and size of the structuring element.

$$g = f \bullet s = (f \oplus s) \ominus s$$



Outline

1. Edge Detection
2. Morphological Operations
3. Methods of Crack Detection
   - Top-Hat Transform
   - Alternative Method
4. Inpainting
5. Results
6. Conclusions

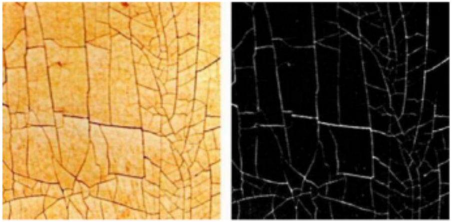
Top-Hat Algorithm

Three Variations: Black Top-Hat, White Top-Hat, Multiscale Top-Hat

Black Top-Hat

darker details on
lighter background

$$BTH = (f \bullet s) - f$$

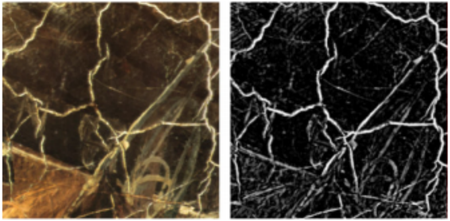


Spagnolo and Somma

White Top-Hat

lighter details on
darker background

$$WTH = f - (f \circ s)$$



Spagnolo and Somma

Alternative Method

1. Set threshold; pixels exceeding threshold are determined to be cracks.
2. Closing is applied to image, grouping isolated pixels.
3. Previous two steps form binary crack mask.
4. Canny edge detection algorithm implemented on original image to obtain edge mask.
5. Dilation applied to edge mask.
6. Crack and edge mask joined to form binary mask.
7. Binary mask iteratively eroded until certain percentage of edge information is lost.

Outline

Inpainting Process

The image is broken down into regions, which are further broken down into neighborhoods. For each defective pixel i:

1. Find the context of i.
2. Examine all other neighborhoods within the region of i.
3. Find neighborhood most similar to context of i by sum of squared differences.
4. If the sum of squared errors is below a set threshold, replace all defective pixels in the neighborhood of i with corresponding pixels from most similar neighborhood.
5. Otherwise, replace pixel i with the median value of all non-defective pixels within its neighborhood.

Outline

Definitions

Categories:

- True Positives
- False Positives
- True Negatives
- False Negatives

Equations:

- False and True Positive Rate

$$FP = fp/(fp + tn)$$

$$TP = tp/(tp + fn)$$

- Precision and Recall

$$P = tp/(tp + fp)$$

$$R = tp/(tp + fn)$$

Statistics

Method	Classification	*tp*	*fn*	*tn*	*fp*	*TP* (or *R*)	*FP*	*P*
Top-Hat Transform	Crack Thickness - Thin	220	30	230	20	0.880	0.080	0.917
	Crack Thickness - Medium	232	18	231	19	0.928	0.076	0.924
	Crack Thickness - Thick	235	15	238	12	0.940	0.048	0.951
	Number of Cracks - Few	242	8	245	5	0.968	**0.020**	0.980
	Number of Cracks - Medium	245	5	241	9	**0.980**	0.036	0.965
	Number of Cracks - Many	243	7	243	7	0.972	0.028	0.972
	Crack Connectivity - Low	215	35	219	31	**0.860**	**0.124**	0.874
	Crack Connectivity - High	218	32	221	29	0.872	0.116	0.883
Alternative Method	Edge Information Lost - 1%	-	-	-	-	**0.932**	-	**0.497**
	Edge Information Lost - 30%	-	-	-	-	0.857	-	0.594
	Edge Information Lost - 70%	-	-	-	-	**0.530**	-	**0.704**

Results

Original Image

Cornelis et al

Restored Image

Cornelis et al

Outline

Conclusions

The top-hat transform has been demonstrated to outperform the alternative examined here.

Further Work:

- implement other methods of crack detection
- examine effects of various forms of edge detection and inpainting
- study the detection and removal of other defects

Thanks!

Questions?

References