Error Analysis in Pixel Duplicated Images of Diabetic Retinopathy

M. Mehrubeoglu and L. McLauchlan, "Error analysis of filtering operations in pixel-duplicated images of diabetic retinopathy," SPIE Optics and Photonics, San Diego, CA, August 1-5, 2010.

Introduction

- In early diabetic retinopathy, clinician is interested in the extraction and analysis of
  - hemmorhages
  - optic nerve constriction
  - aneurisms
  - other stresses on blood vessels
- Pixel duplication is an image enlargement method for image enhancement and detail retention
- Pixel duplication followed by filtering is expected to retain more information than filtering alone
- Pixel duplication can be thought of reverse sub-pixel analysis for superresolution images

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Motivation and Objectives

- Many interpolation methods have been developed to retain information in the images during and after image processing operations, such as filtering
- Pixel duplication: memory intensive, but
  - complementary method to pixel interpolation
  - allows working with integers without the added complexity of working with floating point operations
  - more feasible for real-time classic hardware implementations (FPGA)
- Motivation: investigate error introduced by pixel duplication to support this image enlargement method as a complementary technique to pixel interpolation
- Objectives:
  - use pixel duplication, smoothing, and normalized correlation methods to detect aneurisms in diabetic retinopathy
  - Analyze error introduced by the method to show its advantages for detecting small structures

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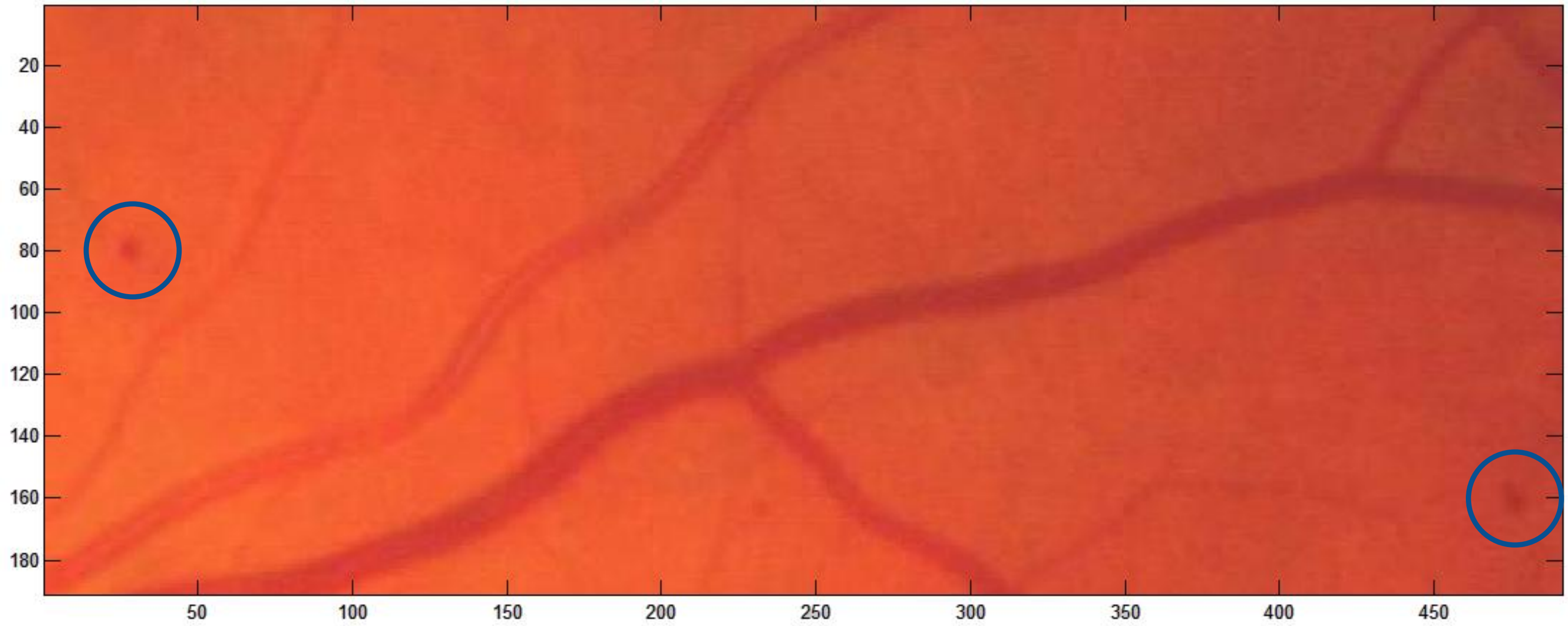
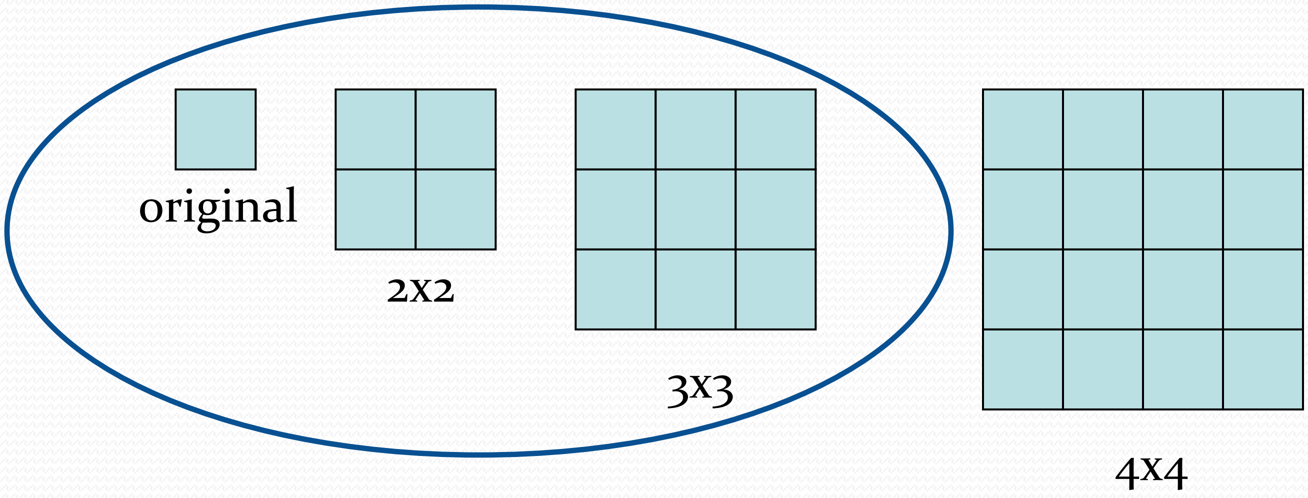
Methodology

- Effectiveness and error analysis of detecting microaneurysms in early diabetic retinopathy through
  - Pixel duplication
  - Filtering
  - Template matching through normalized cross correlation
  - Minimizing false positives detection when eliminating (0) false negatives



Methodology

- Retinal Image Processing:
  - Pixel Duplication



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Methodology

- Retinal Image Processing:
  - Pixel Duplication – Modified Reverse Gaussian Pyramid

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Methodology

- Retinal Image Processing:
  - Mean Filtering (smoothing)

kernels

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

3x3

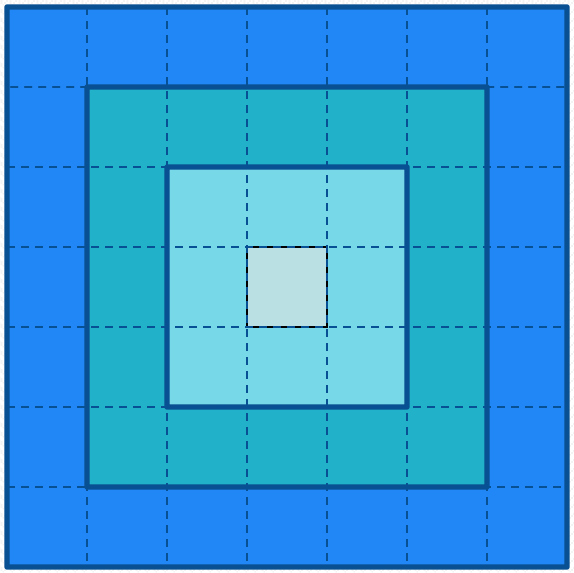
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25

5x5

1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49

7x7

How much information is retained during spatial low pass filtering?



Original image	Retained Pixel Information (weight)	
mean filter	**Horizontal, Vertical**	**Overall**
(3x1, 1x3) (3x3)	1/3	1/9
(5x1, 1x5) (5x5)	1/5	1/25
(7x1, 1x7) (7x7)	1/7	1/49

Graphical representation of smoothing:

1/9	1/9	1/9
1/9	1/9	1/9
1/9	1/9	1/9

3x3

1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25
1/25	1/25	1/25	1/25	1/25

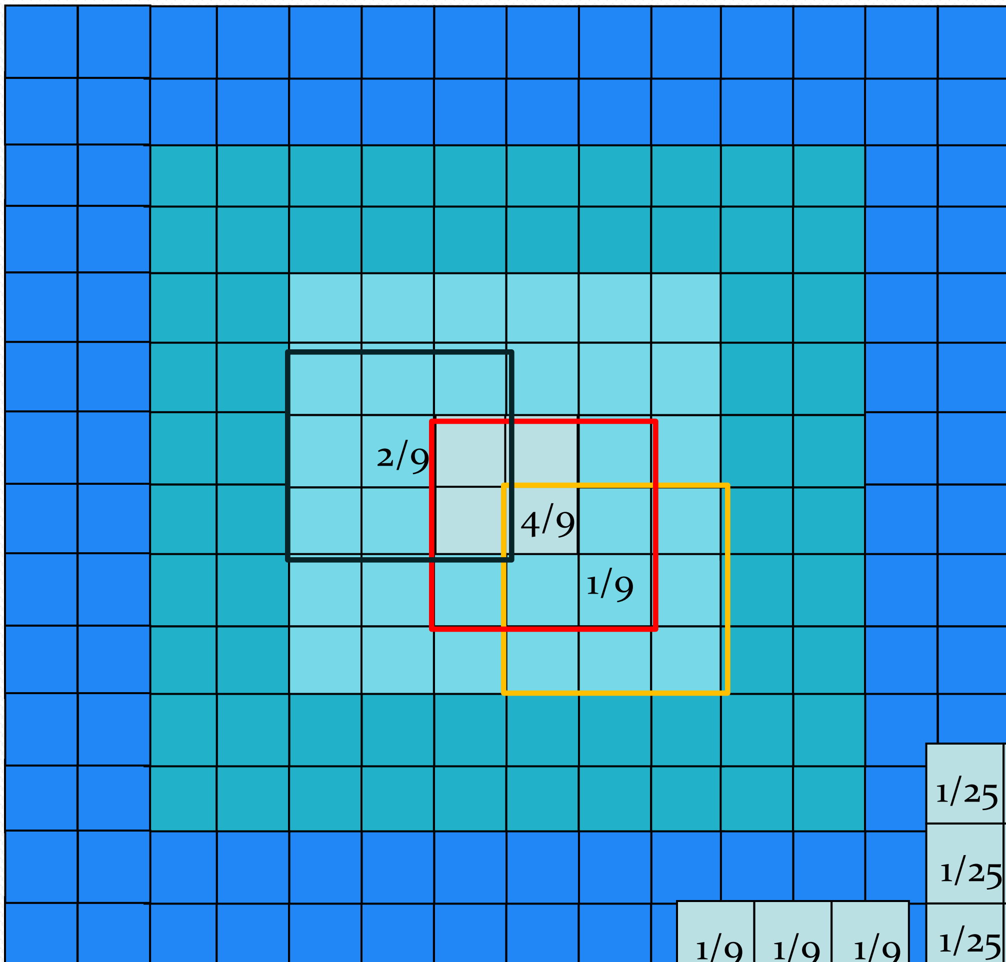
5x5

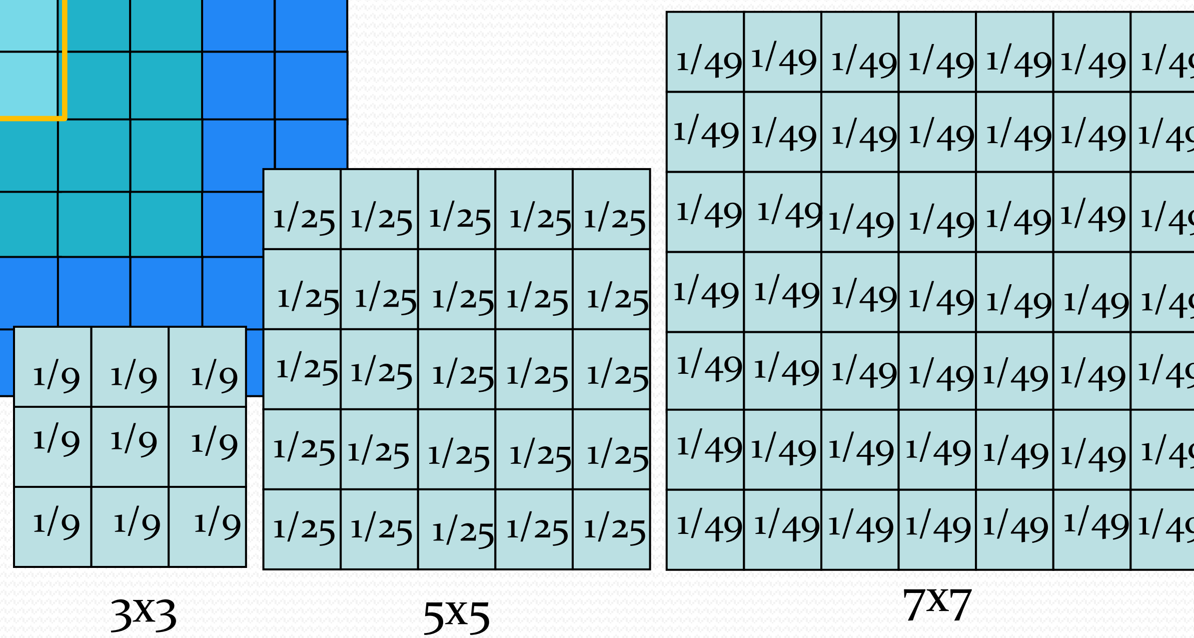
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49
1/49	1/49	1/49	1/49	1/49	1/49	1/49

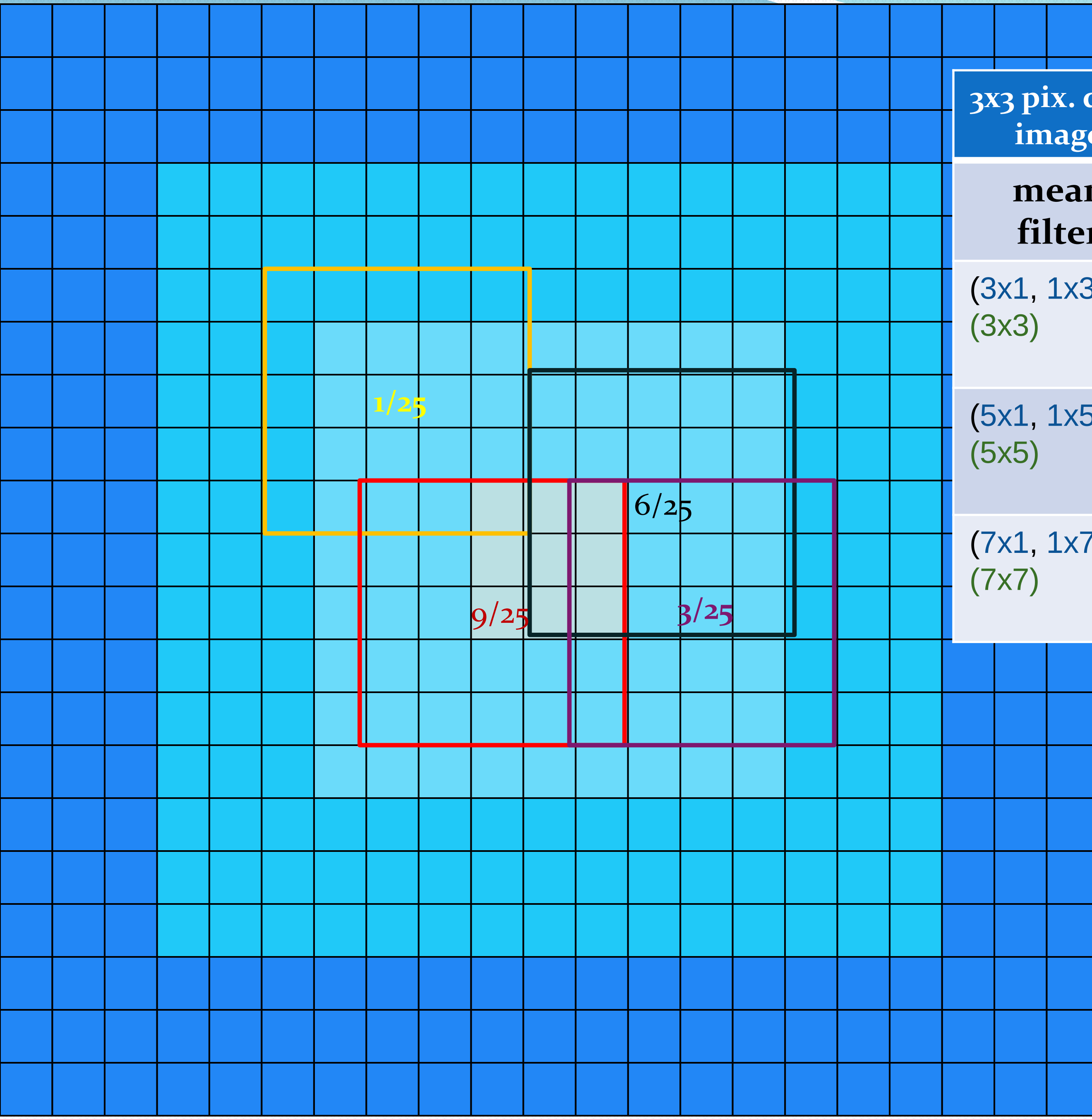
7x7

How much information is retained during spatial low pass filtering?

2x2 pix. dup. image	Retained Pixel Information (weight)	
mean filter	**Horizontal, Vertical**	**Overall**
(3x1, 1x3) (3x3)	1/3, 2/3	1/9, 2/9, 4/9
(5x1, 1x5) (5x5)	1/5, 2/5	1/25, 2/25, 4/25
(7x1, 1x7) (7x7)	1/7, 2/7	1/49, 2/49, 4/49







3x3 pix. dup. image	Retained Pixel Information (weight)	
mean filter	**Horizontal, Vertical**	**Overall**
(3x1, 1x3) (3x3)	1/3, 2/3, 3,3	1/9, 2/9, 3/9, 4/9, 6/9, 9/9
(5x1, 1x5) (5x5)	1/5, 2/5, 3/5	1/25, 2/25, 3/25, 4/25, 6/25, 9/25
(7x1, 1x7) (7x7)	1/7, 2/7, 3/7	1/49, 2/49, 3/49, 4/49, 6/49, 9/49

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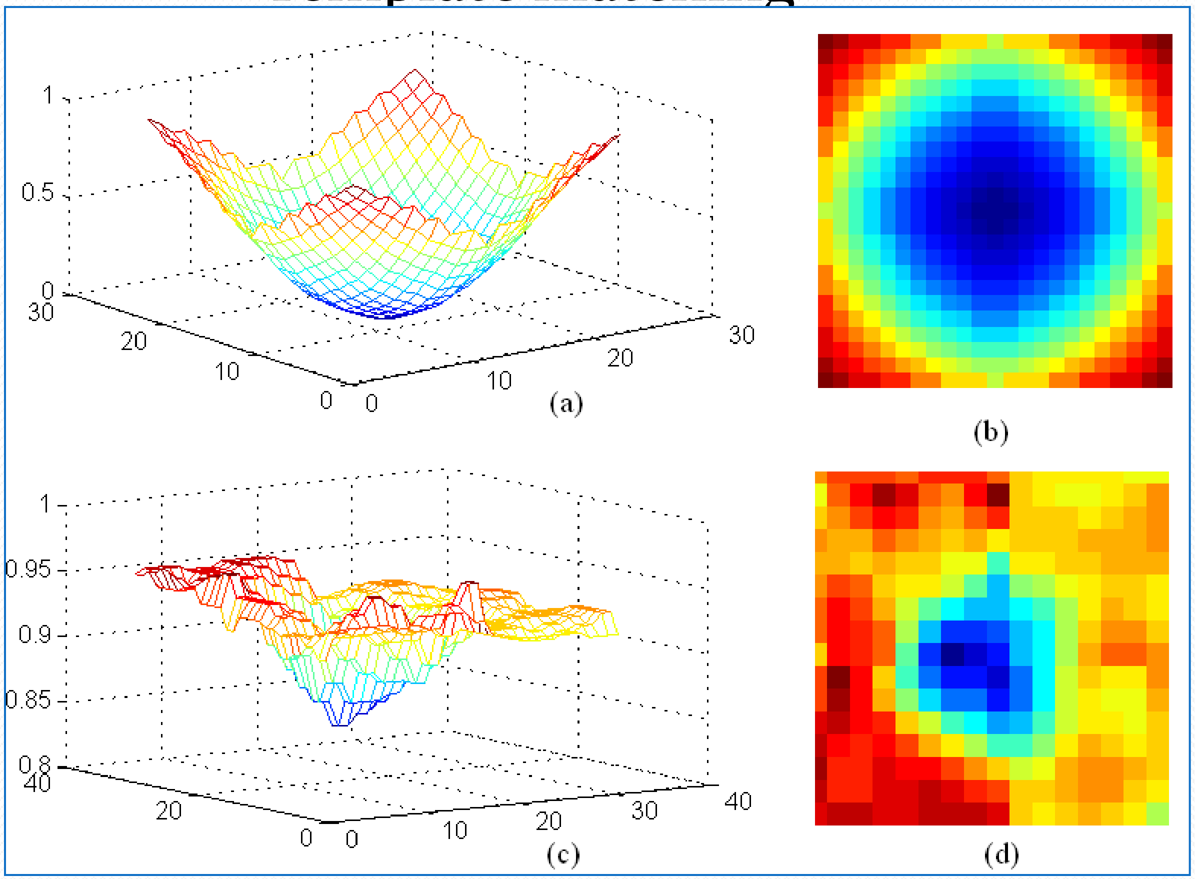
Methodology

- Retinal Image Processing:
  - Template matching



microaneurysm dot model (template)

sample microaneurysm profile from a raw image file

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Methodology

- Retinal Image Processing:
  - Normalized Cross Correlation
  - NCC was applied to
    - Original, 2x2 pixel duplicated, and 3x3 pixel duplicated images (no filtering)
    - 3x3 mean filtered: original, 2x2 pixel duplicated, and 3x3 pixel duplicated images
    - 5x5 mean filtered: original, 2x2 pixel duplicated, and 3x3 pixel duplicated images
    - 7x7 mean filtered: original, 2x2 pixel duplicated, and 3x3 pixel duplicated images

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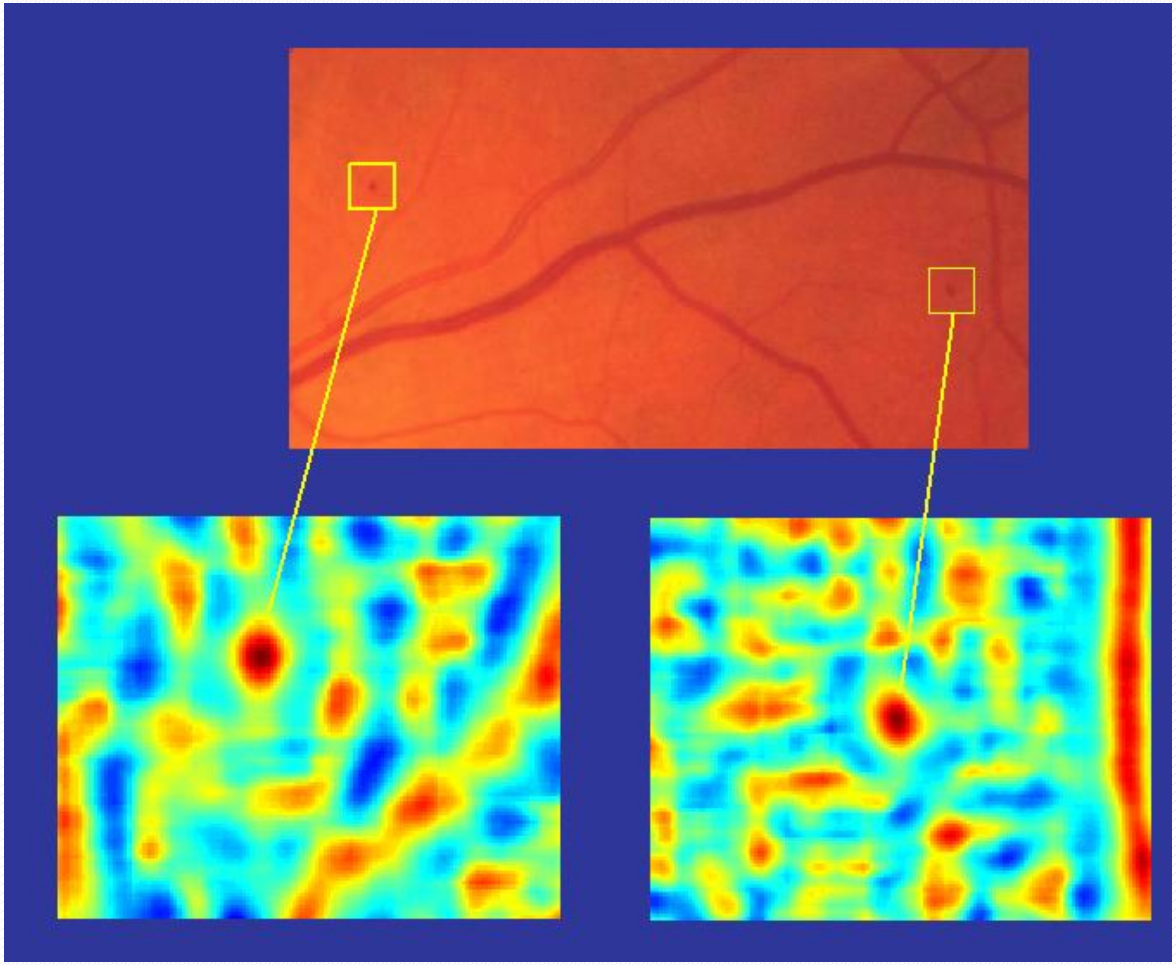
Results

- Detection of microaneurysms through NCC



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Results:
Detection of small structures

- Specificity= True negative / (true negative + **false positive**)
- Sensitivity =TP / (TP + FN);

Condition FN = 0; sensitivity = 1

- Sensitivity = 1 (do not want to miss any microaneurysms)

- So goal → optimize parameters
  - For sensitivity = 1
  - To minimize false positive rate

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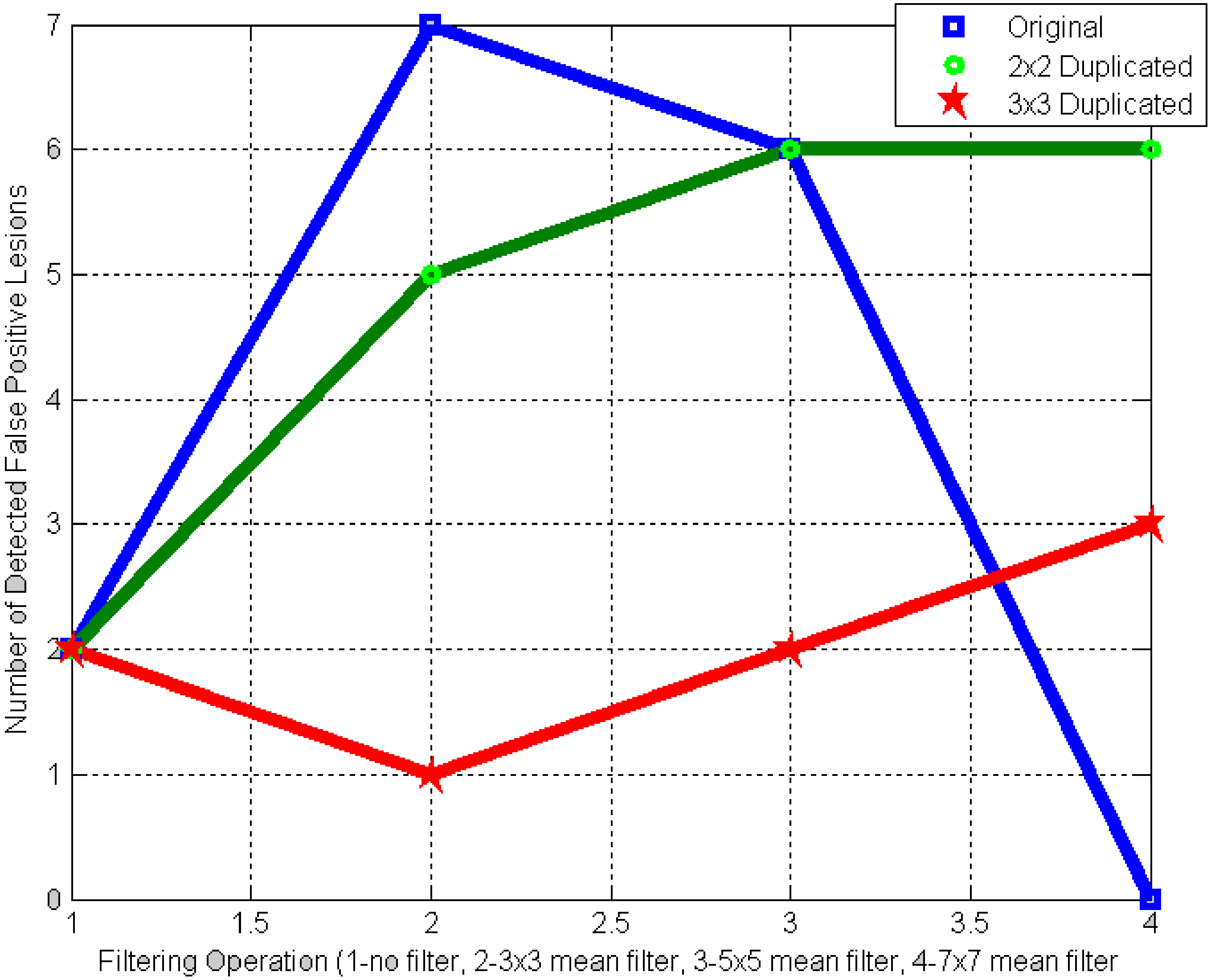
Table 1. False Lesion Detection Results with Various Image Processing Operations

a. Minimum number of false positives is reported per location and neighborhood. Multiple detections within 1-pixel neighborhoods are omitted from this count

Results



Summary

- Effects of pixel duplication in reducing false positive detection of aneurysms with some exceptions are demonstrated.
- The exceptions could be attributed to to idealized conditions.
- More tests are underway to validate the preliminary results
- Microaneurysms were chosen as a structure of interest in this case. NCC is not the best technique to identify microaneurysms, but was used here to demonstrate the proposed technique.