

## **ABSTRACT**

### **A Beefy Frangi Filter for Noisy Vascular Segmentation and Network Connection in PCSVN**

**By**

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**May 2018**

Recent statistical analysis of placental features has suggested the usefulness of studying key features of the placental chorionic surface vascular network (PCSVN) as a measure of overall neonatal health. A recent study has suggested that reliable reporting of these features may be useful in identifying risks of certain neurodevelopmental disorders at birth. The necessary features can be extracted from an accurate tracing of the surface vascular network, but such tracings must still be done manually, with significant user intervention. Automating this procedure would not only allow more data acquisition to study the potential effects of placental health on later conditions, but may ideally serve as a real-time diagnostic for neonatal risk factors as well.

Much work has been to develop reliable vascular extraction methods for well-known image domains (such as retinal MRA images) using Hessian-based filters, namely the (multiscale) Frangi filter. It is desirable to extend these arguments to placental images, but this approach is greatly hindered by the inherent irregularity of the placental surface as a whole, which introduces significant noise into the image domain. A recent attempt was made to apply an additional local curvilinear filter to the Frangi result in an effort to remove some noise from the final extraction.

Here we propose an alternate extraction method. First, we use arguments from Frangis original paper to provide a proper selection of parameters for our particular image domain. Using the same arguments from differential geometry that gave rise to the Frangi filter, we calculate the leading principal direction (eigenvector of the Hessian) to indicate the directionality of curvilinear

features at a particular scale. We are then able to apply an appropriately-oriented morphological filter to our Frangi targets at select scales to remove noise. This approach differs significantly from previous efforts in that morphological filtering will take place at each scale space, rather than being performed one time following multiscale synthesis. Noise removal performed in this way is expected to aide in coherent interpretation of targets that should appear in a connected network.

Finally, we discuss an important advancement in implementation—scale space conversion for differentiation (i.e. gaussian blur) via Fast Fourier Transform (FFT) rather than a more traditional convolution with a gaussian kernel, which offers a significant speedup. This thesis will also contain a general, in depth summary of both multiscale Hessian filters and scale-space theory.

We demonstrate the effectiveness of our improved vascular extraction technique on several of the following image domains: a private database of barium-injected samples provided by University of Rochester, uninjected/raw placental samples from Placental Analytics LLC, a collection of simulated images, the DRIVE and STARE databases of retinal MRAs, and a new collection of computer-generated images with significant curvilinear content.

Time permitting, this research will be extended to include a method of network connection, so that a logically connected vascular network is realized (i.e. network completion).

# **A Beefy Frangi Filter for Noisy Vascular Segmentation and Network Connection in PCSVN**

## **A THESIS**

Presented to the Department of Department of Mathematics and Statistics

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In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Applied Mathematics

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B.S., 2013, University of California, Los Angeles

May 2018

WE, THE UNDERSIGNED MEMBERS OF THE COMMITTEE,  
HAVE APPROVED THIS THESIS

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## **ACKNOWLEDGEMENTS**

Acknowledgments go here.

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# **CHAPTER 1**

## **INTRODUCTION**

### **The Applied Problem**

Reference Nen's paper and latest autism risk paper.

### **Context in Image Processing**

- brief background of math image processing methods
- what's been tried in this applied problem
  - nen [1]
  - catalina's paper
  - kara's paper
  - other domains

### **Research Goals**

Segue from previous paragraph, talk about strengths and weaknesses of other methods and what this research aims to accomplish. Include 'research questions' that could allow a reader to answer the question "will this research work for my problem?". "Elevator pitch" maybe goes here.

### **Roadmap**

Outline of the thesis ("firstly" bullshit)

## CHAPTER 2

### MATHEMATICAL METHODS

*(Note: this can be 50 pages long. Don't focus on brevity—rather make it basically self-contained, within reason)*

Relevant math in no particular order. Focus on mathematics (primarily on a general image, rather than focusing on a particular image domain)

#### Overview of Differential Geometry in Image Processing

##### Basics, Definitions

- basic definitions from differential geometry in  $\mathbb{R}^3$
- basic image processing setup and nomenclature

##### Calculating Derivatives of Discrete Images

- Pretend the image is continuous surface in  $\mathbb{R}^3$ .
- Why gaussian blur is the way to go (see paper i forget whose)

##### Frangi Filter

##### Intro to Hessian-based filters

Describe  $H_{xx}, H_{xy}, H_{yy}$ . What the principal curvatures and directions are and mean. Basic properties and observations. Why these filters make sense. Basic strengths and weaknesses.

##### Overview of Frangi vesselness measure

keep it simple. this maybe should just go in the next chapter

##### Implementation Details: Convolution Speedup

how you do fourier stuff. as long as necessary

## **Linear Scale Space Theory**

**Why it matters**

**Overview of Theory**

**methods of "merging"**

**Other Odds and Ends**

Finding the placental plate? Morphology stuff like skeletonization.

## **CHAPTER 3**

### **RESEARCH PROTOCOL**

List. All. Decisions. You Make. Be very explicit.

Pseudocode?

## **CHAPTER 4**

### **RESULTS AND ANALYSIS**

#### **Data Set**

Specifics of your data set. Barium placentas, other datasets.

NOTE: FIND YOUR TRACING PROTOCOL.

NOTE: Be specific about each so it's easy to gauge for others whether or not these methods would apply to their own research

Preprocessing

#### **Results**

Show stuff who the fuck knows

#### **Answer Research Questions**

## **CHAPTER 5**

### **CONCLUSION**

What it did well. What it didn't. People who want to expand—where should they start?

## APPENDICES



**APPENDIX A**  
**APPENDIX TITLE**

Put code here (and on github)

## BIBLIOGRAPHY

## BIBLIOGRAPHY

- [1] Nen Huynh. *A filter bank approach to automate vessel extraction with applications*. PhD thesis, California State University, Long Beach, 2013.