A NOVEL APPROACH TO IDENTIFYING VASCULAR STRUCTURES FROM INFRARED IMAGING BASED ON STRUCTURAL FLUX RESPONSES

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BACKGROUND

Motivation

• Despite being a common medical procedure, the insertion of cannulae can often require multiple attempts in healthy adults, resulting in an increasing necessity for technologies which can assist with intravenous cannulations.[1]

• The prevalence of near-infrared (NIR) light as a method for delineating vascular structures has increased in recent history, promoting the development of devices which indicate the location of veins on the surface of a subject's skin.

Existing Modelling Methods

• Existing methods of modelling blood vessels have proven to be effective in obtaining data related to most factors pertaining to cannulations. These approaches have traditionally relied on *computed tomography* and *x-ray fluoroscopic angiography*.

• This work aims to asses the applicability of existing modelling techniques to the new NIR imaging medium.

• May enhance visualisation tools, providing the potential to assist clinicians in performing intravenous cannulations.

Factors Influencing Cannulations

• Aside from a knowledge of the vessel's position beneath the skin, a clinician's ability to successfully cannulate a vein will be influenced by:

- Straightness of vessel segment
- Length of vessel segment
- Calibre (diameter) of vessel segment
- Proximity of vessel segment to bifurcations

• Law and Chung's *Spherical Flux Computation* is highly efficient and accurate in its analysis of vascular structures, simultaneously identifying centrepoints of vessels at regular intervals, as well as the radius of the vessel at each of these points, thus returning information about the *vessel structure* and the *calibre of each vessel segment*.[2]

• Building on a knowledge of the vascular structure obtained using this approach, the aforementioned factors may be analysed.

METHOD

Image Enhancement

• Prior to any processing, NIR images of veins have low contrast and veins are difficult to distinguish from surrounding skin. (Fig. 1)

• Contrast stretching enhances the difference in intensity between the veins and the surrounding tissue. (Fig. 2)

• Application of the Frangi filter[3] to the enhanced image greatly reduces noise by using a measure of likelihood that image artefacts are blood vessels, filtering out a majority of background noise. (Fig. 3)

Flux Response

• The circular flux response algorithm which is applied to the enhanced image will return a higher response the larger the circle is at a point, within a vessel. The maximum response will be given when the radius of the circle matches that of the vessel and is enclosed fully within it. Once the circle begins to enlarge beyond the width of the vessel, the value will decrease.

• Points which return the highest flux values in the image will be the centrepoints of vessels, where the circle will be fully enclosed, with the circle's radius giving the radius of the vessel at this point.

Bifurcations (Branching Points)

• Bifurcations are branching points in the vasculature and are to be avoided when cannulating. (Fig. 5)

• A grid passed over an area of the image which contains a bifurcation will be characterised by a reversal in the majority direction of gradient vector flow at vessel edges, between the top and bottom quadrants of the grid. (Fig. 6)

Straightness and Length

• A measure for straightness is derived from the eccentricity of an ellipse which encloses an individual component of the vasculature; the more that a segment deviates from straightness, the more circular the ellipse is required to be, giving a lower value of eccentricity. (Fig. 7)

• The major axis of the ellipse is used as a measure of the length across which the individual segment extends.

RESULTS

• This image processing pipeline can be visually verified to accurately reproduce a model of the vasculature and identify relevant features, though clinical validation is still required.

Future Work

• Given that NIR images involve imaging vasculature by illuminating their position on the surface of the skin, an uneven surface results in shadowing. Future work is planned to develop methods of distinguishing vasculature from shadows.

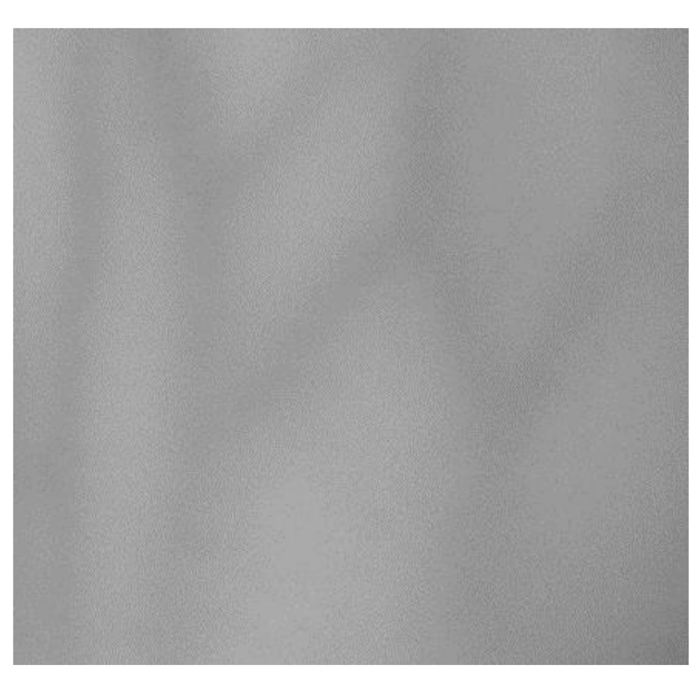

Fig. 1. NIR Image of dorsal venous network in a hand.

Fig. 2. Contrast stretched image.

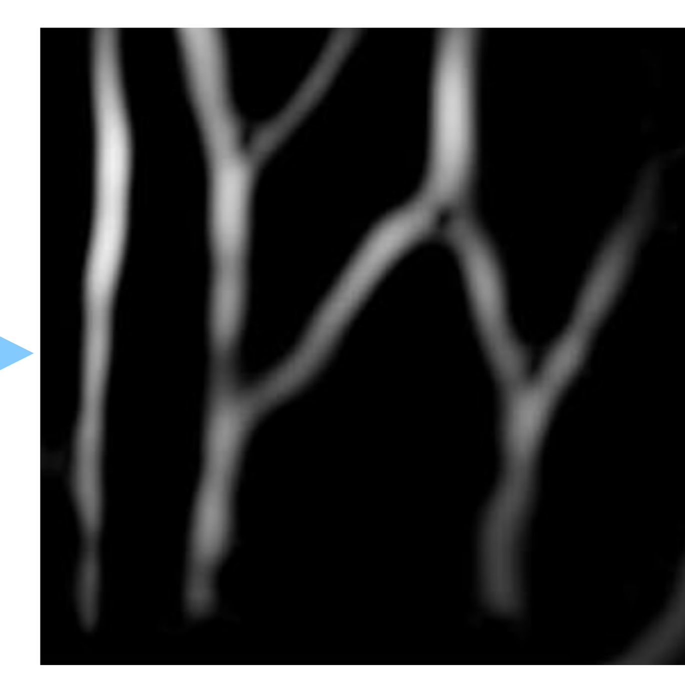

Fig. 3. Frangi filtered image.

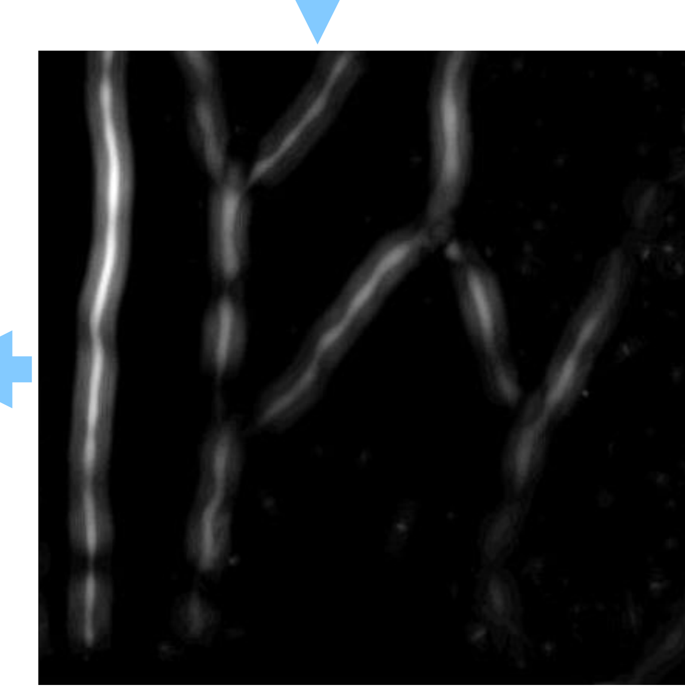

Fig. 4. Structural flux response of Frangi filtered image. Areas of highest intensity along the centrelines of the vessels indicate higher flux values at these points.

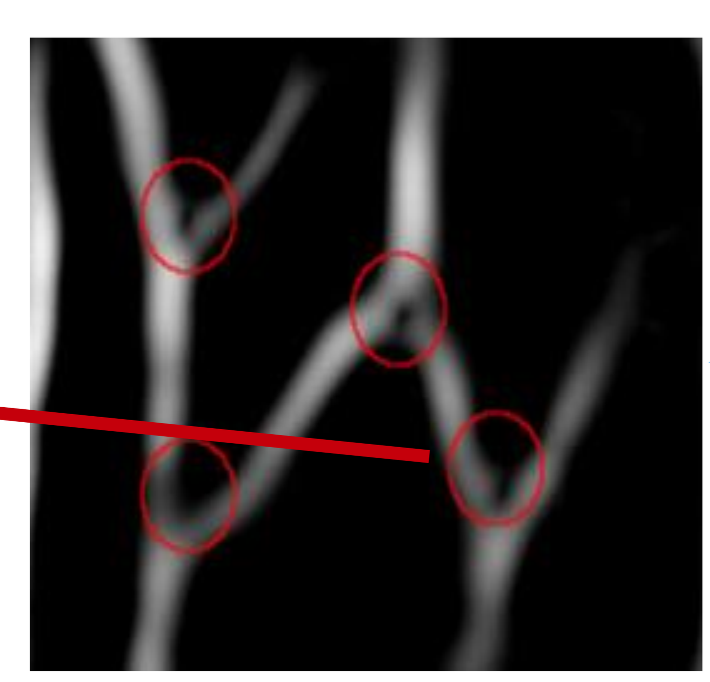

Fig. 5. Bifurcations detected in the vascular structure by analysis of gradient vector flow.

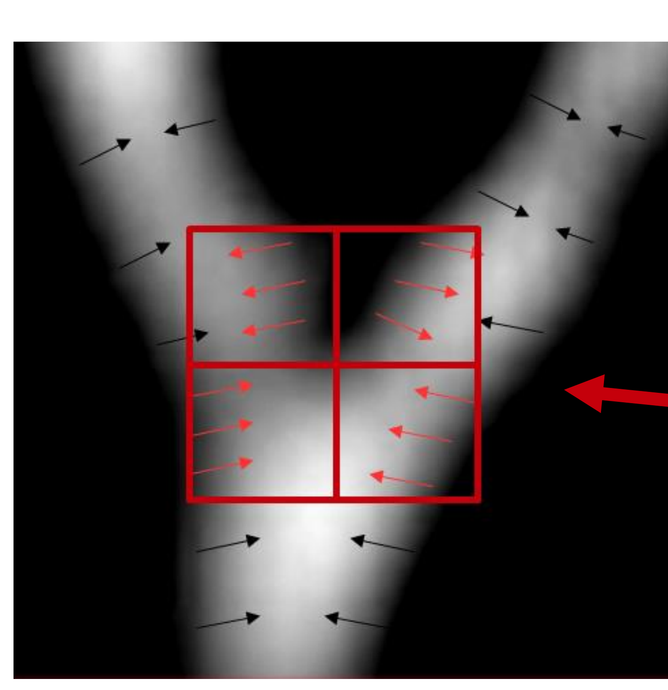

Fig. 6 (above). Arrows representing gradient vector flow show change in majority direction of flow between the top and bottom quadrants of a grid overlaying a bifurcation.

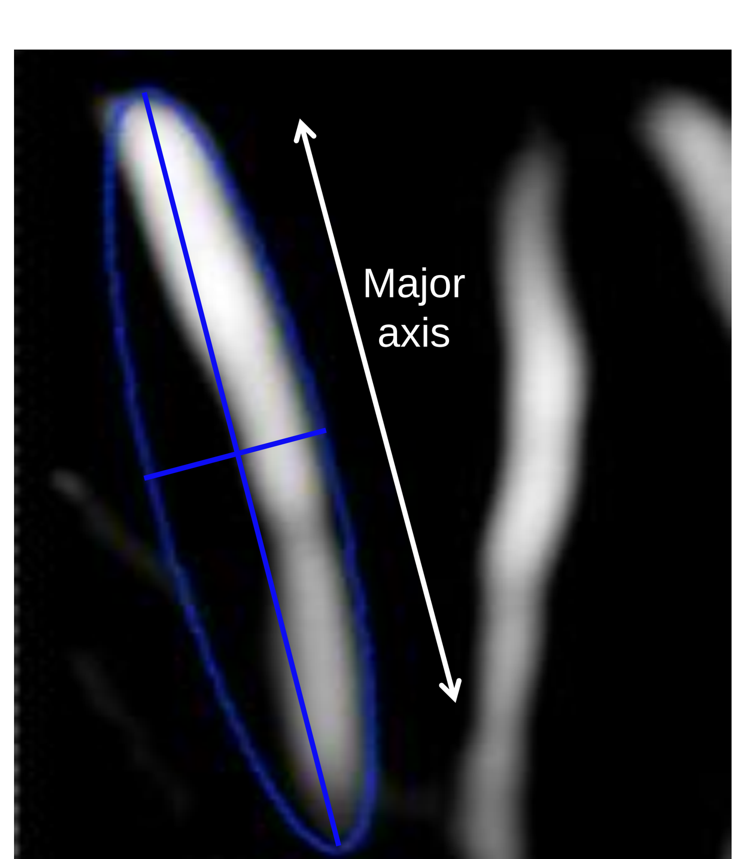

Fig. 7 (left). Ellipse around vessel segment indicates characteristics of the vessel; eccentricity of the ellipse is indicative of the straightness of the segment, whilst the length of the major axis informs the length of the vessel segment.

REFERENCES

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3. Frangi, Alejandro F., et al. "Multiscale vessel enhancement filtering." *Medical Image Computing and Computer-Assisted Intervention—MICCAI'98*. Springer Berlin Heidelberg, 1998. 130-137.