CROWN - Labcom I3M

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1 Methods Task 1

Whether measuring diameters and angles or classifying Willis polygon variants, the methodology chosen by the Labcom I3M team is the same: recover the twelve points of interest which constitute the arterial branches of the Circle of Willis (CoW).

We chose to develop an atlas based approach. The goal is to register new data into this newly generated atlas, obtain the annotations and return to the image domain with the newly generated points.

The figure 1 presents on the left a schematic view of these twelve points, and on the right all the branches and initiation arteries in axial view.

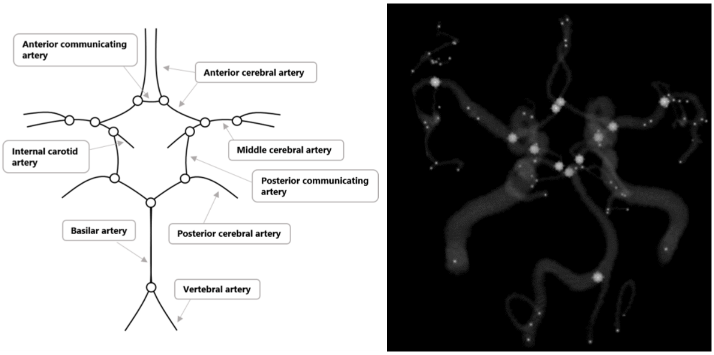

Fig. 1: On the left, a diagram of the main arteries of the polygon of Willis with their intersections in circles. On the right a view of a patient from the database whose CoW intersections. The twelve points have been dilated for better visibility.

1.1 Atlas generation

To achieve automated retrieval of these twelve points, the proposed algorithm consists of resampling, elastic registration and a search for the nearest point in relation to a specific atlas.

This first step is to register all the subjects (originally with variate image shapes) into the same space with identical image shape. The chosen shape is (512, 512, 256) but centrally cropped to (256, 256, 128), high enough to have the necessary resolution but low enough to ensure a decent computation time. To remove remaining tissues and keep only the arterial vessels, maximum entropy thresholding is performed on each patient. Objects with a connectivity of less than 2000 voxels has been removed.

A patient from the challenge database and presenting a complete polygon of Willis, i.e. with an anterior and posterior Lippert class of type A is chosen as the reference patient. All the other patients have undergone an elastic registration with this patient as a reference and a specific atlas can thus be created. The twelve points of interest have been manually selected by a senior neuro-radiologist in this atlas.

1.2 Classes evaluation

The figure 2 shows the workflow used by our team. A new patient whose annotation is desired undergoes the same preprocessing as stated above. Once registered in the common space, the image is then skelotonized and a connected graph is recovered. Each node in the graph represents either an artery bifurcation or endpoint. For each node of interest, a spatial search (approx. 4mm based on voxel size) is defined to find the corresponding node from the annotation made in the atlas. If the distance (based on atlas) is outside the original spatial search, the node is rejected.

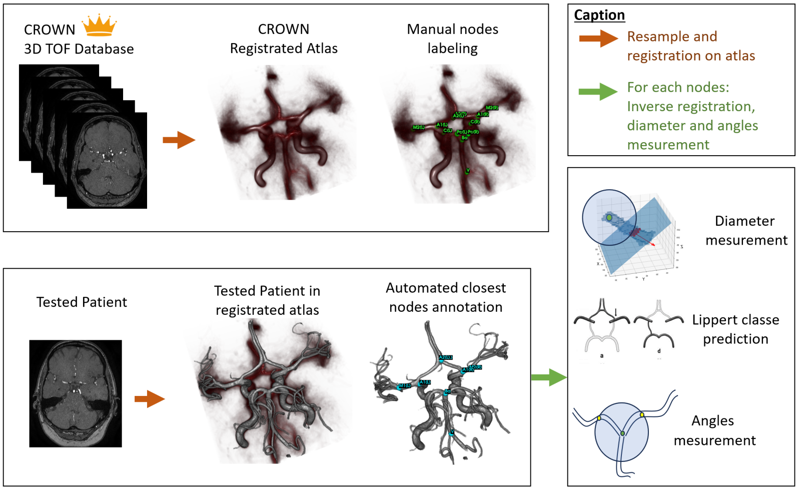

Fig. 2: Workflow proposed by the Labcom I3M team. Each patient tested is registered in a common space to determine the intersections of the CoW.This allows for each node to calculate the diameter and the angle of bifurcation

The presence or the absence of the nodes, and their vicinity, give us a first good idea of its class. Task 2 of this challenge and more precisely the ratio of certain artery diameters allows us to conclude on the precise type when necessary. For example, for the posterior class, classes A-C are complete, class C is characterized by bilateral fetaltype posterior cerebral arteries with both precommunicating segments of the posterior cerebral arteries patent, when class A does not present this. Then the diameter of the posterior cerebral arteries and the precommunicating segment provide information on the specific class.

Due to the uneven distribution of classes in the Lippert and Pabst scale, the dataset for the challenge only includes variations with a minimum of 10 instances in the training set. One of the great strengths of this methodology is the ability to determine all Lippert and Pabst classes without an annotated database and with unbalanced classes.

2 Methods Task 2

For Task 2, which involved measuring the main CoW diameters and bifurcation angles, the same methodology, the same methodology as for task 1 was chosen: recover the twelve points of interest which constitute the branches arteries of the Circle of Willis (CoW).

For each of the retrieved nodes, an reverse elastic registration was performed to return to the original patient space. The registration previously made to recover the nodes is elastic, so the arteries have been deformed, which prevents the measurement directly in the space of the atlas. Figure 2, schematically shows on the right how the diameters and angles were calculated for each of the points.

Figure 3 shows the annotation and the position of the diameters to be calculated for each artery, as well as the position of the bifurcation angles to be measured.

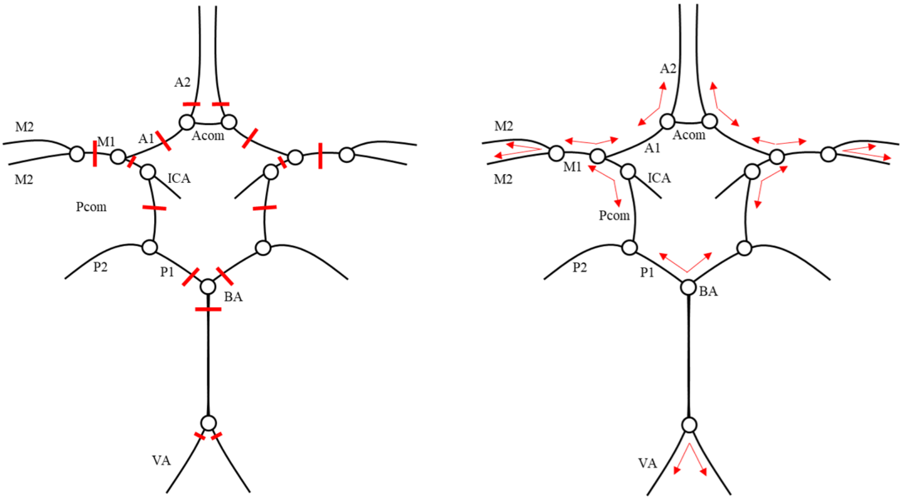

Fig. 3: Schematic representation of circle of Willis with annotations used in the CROWN challenge. Left: artery diameter annotations. Right: bifurcation angle annotations.

To calculate A2, P1, ICA, VA and BA diameters, a sphere of 5mm radius is created to obtain the intersection of the vessel at this distance. An orientation parameter is given to select the correct vessel if the sphere intersects several segments.

Euclidean rather than geodesic distance was chosen for computational reasons, considering that at such a close distance, the vessels do not exhibit a curvature that impacts the measurement. A orthogonal plane to the skeleton of the vessel has been created at the sphere-artery intersection point to recover the ellipse whose diameter must be calculated. Currently, only the maximum diameter in *mm* of the ellipse is calculated.

For A1, M1, Pcom, the plane recovering the ellipse is placed halfway between the two nodes characterizing the beginning and the end of these arteries.

The same methodology was used to calculate the angles. A sphere with a radius of 5 *mm* has been produced to recover the sphere-vessel skeleton intersection. Same orientation parameter is deducted from the graph to help the algorithm to choose the right vessels for angle computation.

Once the three points of interest have been recovered, the formula given in equation 1 allows $\widehat{P2P1P}3$ to be measured where the vector V1 is defined by P1-P2 and the vector V2 by the point P1-P3.

$$\text{angle} = \arccos\left(\frac{\mathbf{v1} \cdot \mathbf{v2}}{\|\mathbf{v1}\| \cdot \|\mathbf{v2}\|}\right) \tag{1}$$