Consistent automated planning of irregular ROI's for intracranial MRA MIP's

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Introduction

For many application areas, Regions Of Interest (ROI's) are drawn by an operator in MRI images to aid in diagnosis. Applications include measurement of tumor size, cut-out-and-keep of vessel structure before making a Maximum Intensity Projection (MIP), and (semi-)automatic delineation of nerve fiber bundles in fiber-tracking. Drawing ROI's, potentially with complex shape, is usually done manually and can be extremely time-consuming and error-prone. As an alternative, automated segmentation can be used to delineate a ROI that includes a part of the anatomy. However, automated segmentation algorithms are often dependent on very strict requirements regarding the contrast characteristics of the analysed image. Moreover, automated delineation of ROI's may differ from the preference of the radiologist about the shape, size, location or orientation of the ROI's.

Scan planning in MRI can also be tedious and error-prone especially in complex anatomies[1-4], and this has been successfully addressed by applying automated scan planning (ASP). This has been shown to improve the MRI acquisition workflow and yields consistent image orientations as preferred by the radiologist. To date methods have described automated positioning of one or more box-shaped geometries using automated segmentation.

We propose an extension of this technology to provide automated positioning of arbitrarily shaped geometries based on the same anatomy recognition results, also following the radiologist's preference. The newly extended technology is intended to improve the workflow and consistency by automating the drawing of ROI's. For the present study we investigated the planning of ROI's for MIP of intra-cranial MRA, where a 'cut-out-and-keep' ROI is used to exclude irrelevant signals which obscure the vessel structures..

Methods

As reported previously[1-4], the ASP method consists of two main modules – (i) an anatomy recognition module, which is carried out on a dedicated survey scan, covering the anatomy of interest in 3D and (ii) a geometry learning and planning module. The first module results in a set of landmarks that describe the position and orientation of parts of the anatomy. The second module now includes the extension from box-shaped geometries to arbitrarily shaped geometries. During a training phase which is performed on a limited number of patient examinations, a set of landmarks and an example geometry are stored for each examination. During a new examination, the stored sets of landmarks corresponding to the stored example geometries are elastically registered to the new set of landmarks describing the anatomy of the patient currently under examination, and the resulting elastic transformation is applied to the stored example geometries to derive the shape, size, location and orientation of the new geometry.

Twenty-seven healthy volunteers were scanned on a Philips Achieva MRI scanner to acquire both a dedicated survey scan and a 3D MRA dataset. MIP's of the unprocessed 3D MRA datasets were generated in 3 orthogonal directions. These MIP's were used by four experienced operators to draw 'cut-out-and-keep' ROI's manually. The manually drawn 3D ROI's were represented by thirty control points per examination per operator. For each control point, the average manual position over the four operators was calculated, resulting in a representation of an average manual ROI for each examination. Twenty out of the twenty-seven examinations were randomly selected and used as training datasets by storing the average ROI together with the landmarks. For the other seven examinations, automated ROI's were generated, using the combination of the landmarks of each examination with the stored information from the training phase.

To quantify the success of automated ROI planning, the deviation δ of the automatically generated position from the average manual position was calculated for each control point, as well as the standard deviation σ of the manually generated positions over the four operators. An automatically generated position of a control point was considered an outlier if the automatic deviation δ was more than twice the manual standard deviation σ. However given the limited number of operators, it is statistically likely that the ideal position of a control point itself deviates more from the average manual position than twice the manual standard deviation. Therefore, we allow up to two of the 30 control points to be outliers.

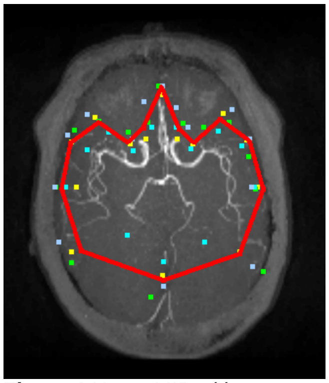

Figure 1 Uncut MIP with contour illustrating 2D view of automatically planned 3D ROI. Dots show manually planned ROI's by 4 operators

Results

As shown in figure 1, the automatically planned ROI is very similar to the manual planned ROI's. With a total of 210 control points (7 x 30), only two out of the seven examinations each contained one outlier (0.95%). 99.05% were within 2σ of the manually planned average position, of those 93.33% were within 1σ. Visual inspection of these two datasets showed that the outlier was in fact positioned reasonably well. Changing the random selection of training datasets resulted in comparable results. As an extra validation, figure 2 shows for each control point all automatic deviations δ and all manual standard deviations σ for all seven examinations together to give an indication of what deviations are reasonable for each anatomical position. It can be appreciated that the range of automatic deviations δ is lower than the range of manual standard deviations σ.

Discussion

These results are encouraging that the automated planning algorithm can be extended from simple box geometries to irregular user-defined ROI's. Further work is necessary to evaluate if fully automated ROI definition is reliable for creating MIP's of intracranial MRA's, or if user intervention will be required to some extent. However even a semi-automated ROI definition is likely to improve consistency for this rather repetitive yet complex task.

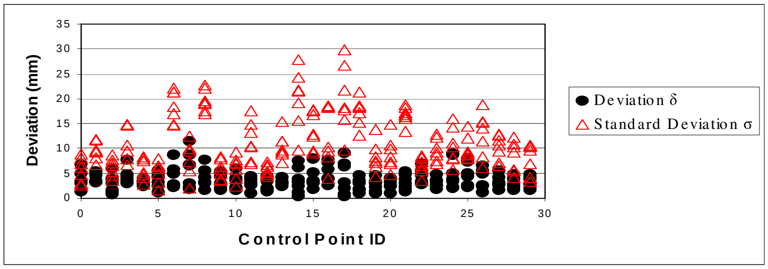

Figure 2 For each control point, all automatic deviations δ and all manual standard deviations σ of all examinations are plotted together in mm. Typically, automatic deviations δ are comparable or lower than manual standard deviations σ.

References

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