Automatic Localisation of the Brain in Fetal MRI

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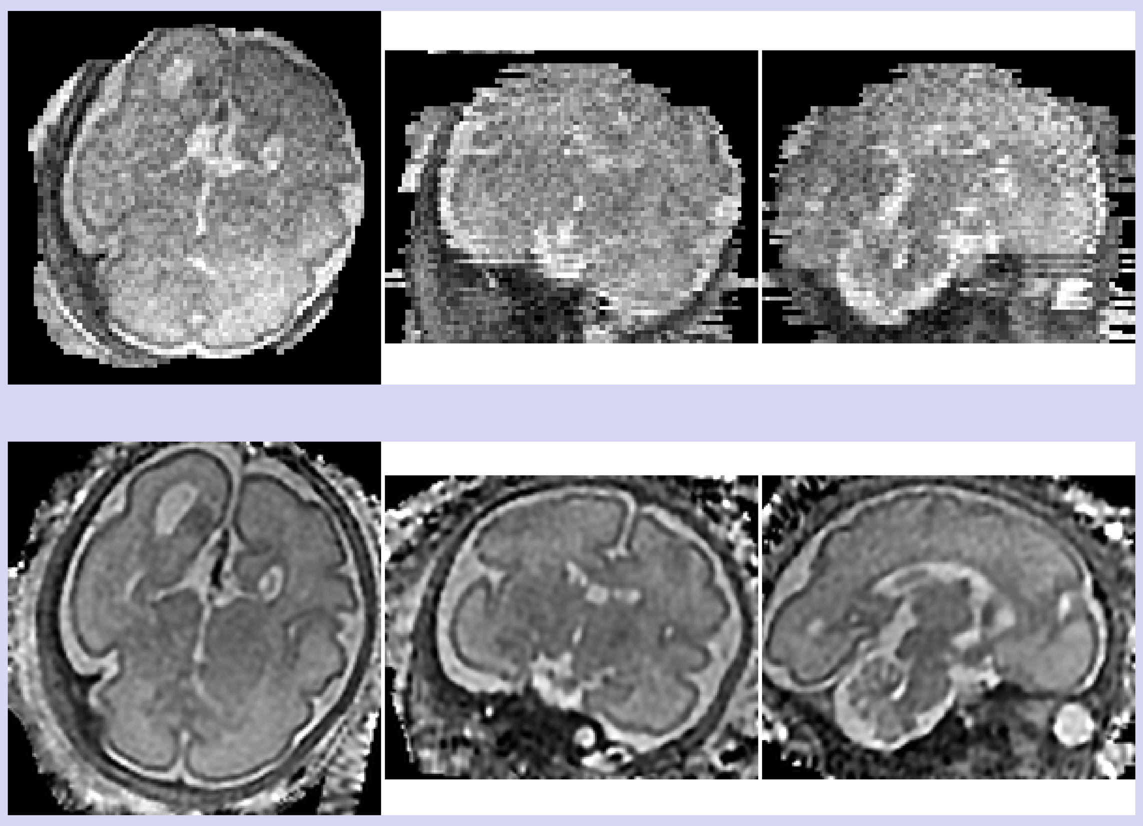
Background

Routine examinations during pregnancy rely on ultrasound imaging. However, when anomalies are suspected, an MR scan of the fetus is performed to provide images with a higher resolution and tissue contrast.

Due to fetal motion, such scans typically acquire data as stacks of 2D slices of real-time MRI, freezing in-plane motion. Moreover, to reduce the scan time while avoiding slice cross-talk artefacts, contiguous slices are not acquired sequentially but in an interleaved manner, thus emphasising motion artefacts. Motion correction methods have been developped to correct the misalignement between slices and provide a consistent 3D data[1].



MRI of a fetal brain before and after motion correction.

We propose a method to automatically find a precise bounding box around the brain in order to speed-up the pre-processing steps of the motion correction procedure.

References

[1] M. Kuklisova-Murgasova, G. Quaghebeur, M. Rutherford, J. Hajnal, and J. Schnabel, "Reconstruction of Fetal Brain MRI with Intensity Matching and Complete Outlier Removal," *Medical Image Analysis*, 2012.

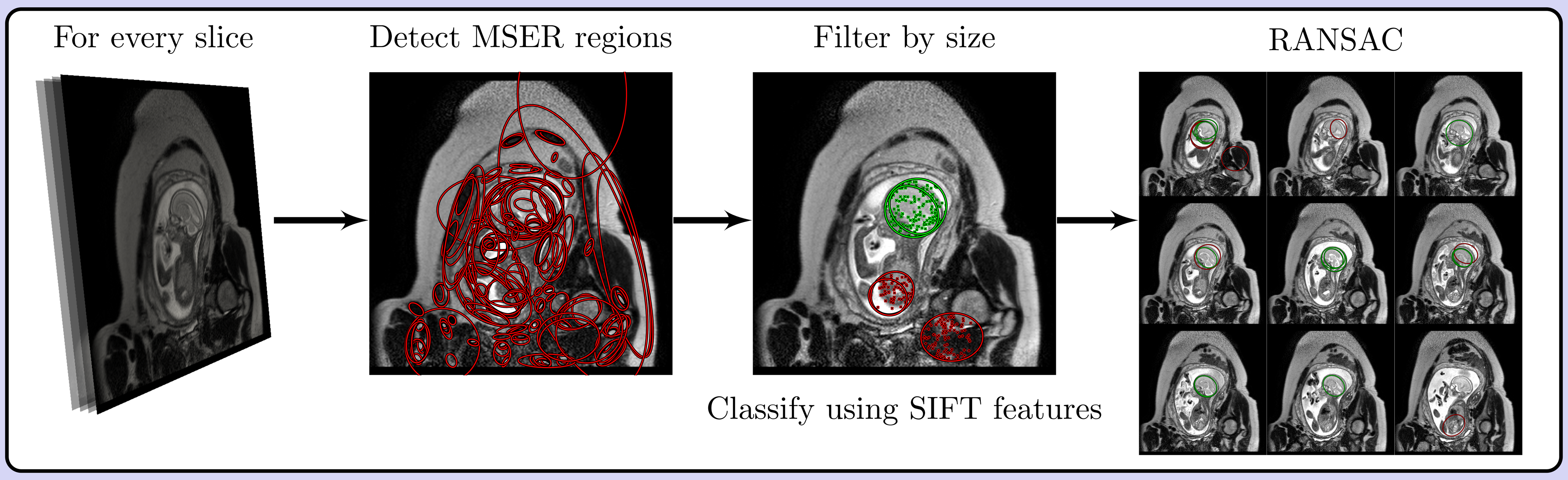
[2] J. Matas, O. Chum, M. Urban, and T. Pajdla, "Robust Wide Baseline Stereo from Maximally Stable Extremal Regions," in *BMVC*, pp. 384–393, 2002.

Brain localisation using bundled SIFT features

We propose a method for accurate and robust localisation of the fetal brain in MRI when the image data is acquired as a stack of 2D slices misaligned due to fetal motion. The key components of our method are:

- Size and shape constraints are defined based on prior knowledge of the fetal brain development.
- Instead of sliding a window over the image, *Maximally Stable Extremal Regions* (MSER[2]) are detected in 2D images as candidate locations for the fetal brain. These regions are then classified using histograms of SIFT features (called *bundled SIFT*).

Maximally Stable Extremal Regions (MSER[2]) are characterised by homogeneous intensity distributions and high intensity differences at their boundary. They can be seen as regions stable by floodfill operation with varying intensity thresholds.

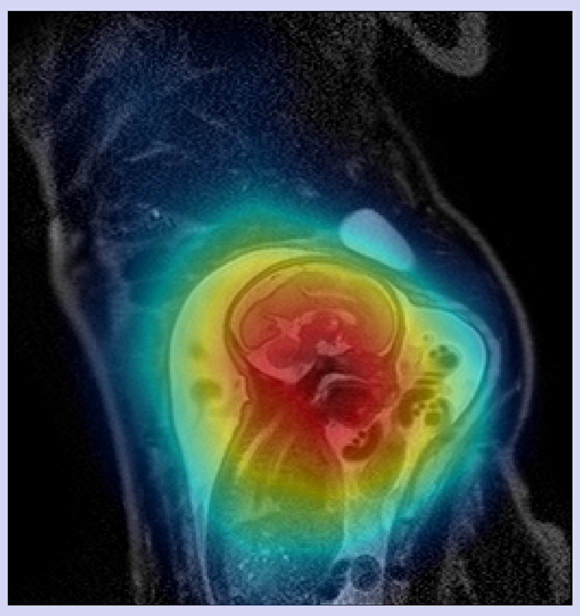


Pipeline for the automatic detection of the fetal brain.

Proceeding slice by slice, MSER regions[2] are first detected and approximated by ellipses. They are then filtered by size and aspect ratio before being submitted to an SVM classifier using histograms of 2D SIFT features. An expected size of the brain is inferred from the fetal gestational age and prior knowledge of the fetal development. Finally, a 3D bounding cube is fitted to the selected candidates with a RANSAC procedure.

Cross-validation experiment

We performed a 10-fold cross validation experiment on a database of 59 healthy fetuses (gestational age ranging from 22 to 39 weeks), for a total of 117 sagittal, 113 coronal and 228 transverse scans. As our detection pipeline is based on a Bag-of-Words model, we compared our method against sliding a window of fixed size with a Random Forest classifier on histograms of 2D or 3D SIFT features.

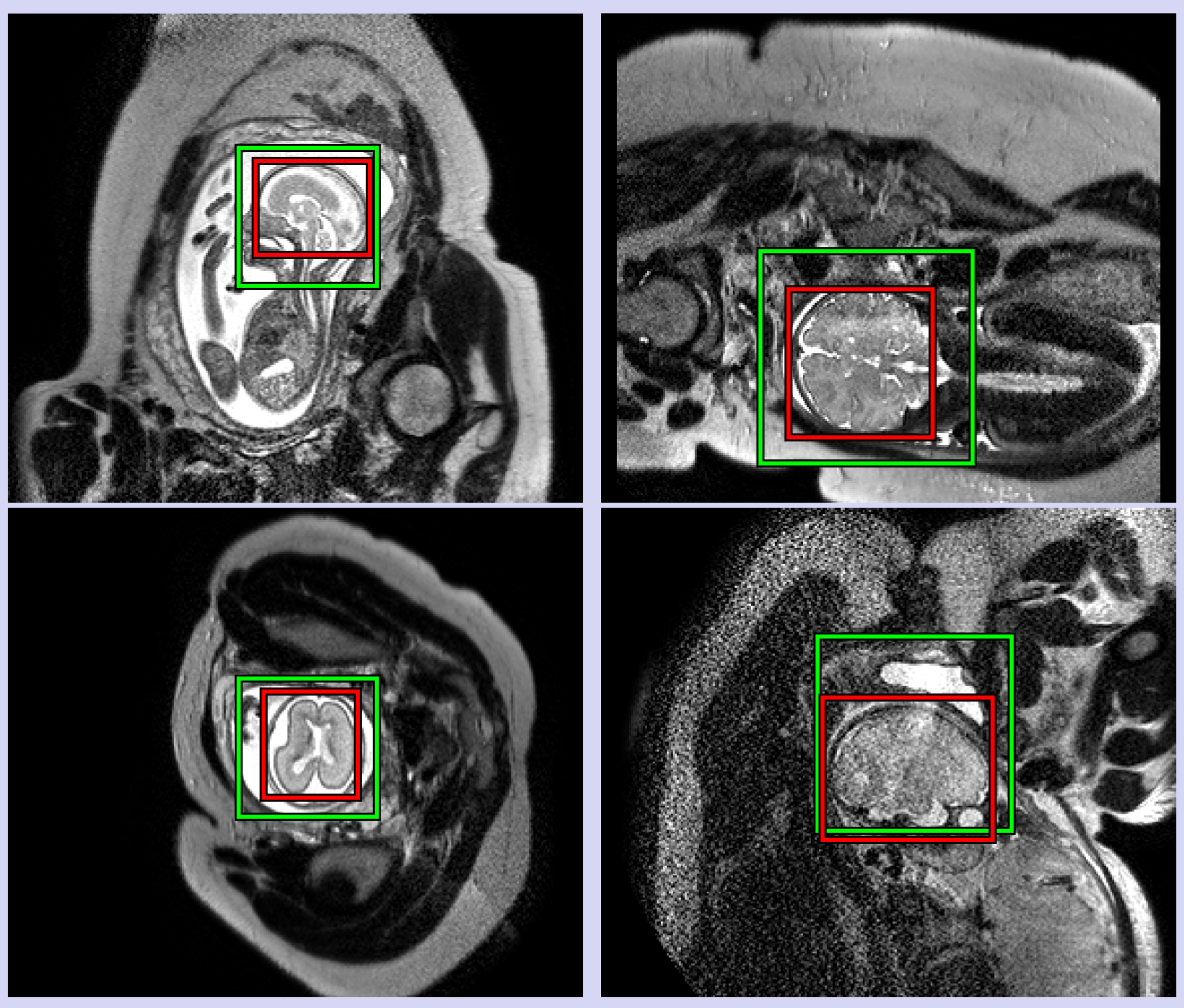


Probability map from 3D SIFT histograms.

For each stack of slices, we measured the distance between the center of the ground truth bounding box and the detected bounding box. We defined a correct detection as 70% of the brain being included in the detected box.

	Error (mm)		
Centiles	*2D SIFT*	*3D SIFT*	***Bundled SIFT***
25th	10.9	14.8	**4.0**
50th	15.5	20.8	**5.7**
75th	20.5	30.4	**8.4**
Detection	98%	85%	**100%**
Complete brain	38%	23%	**85%**

Results



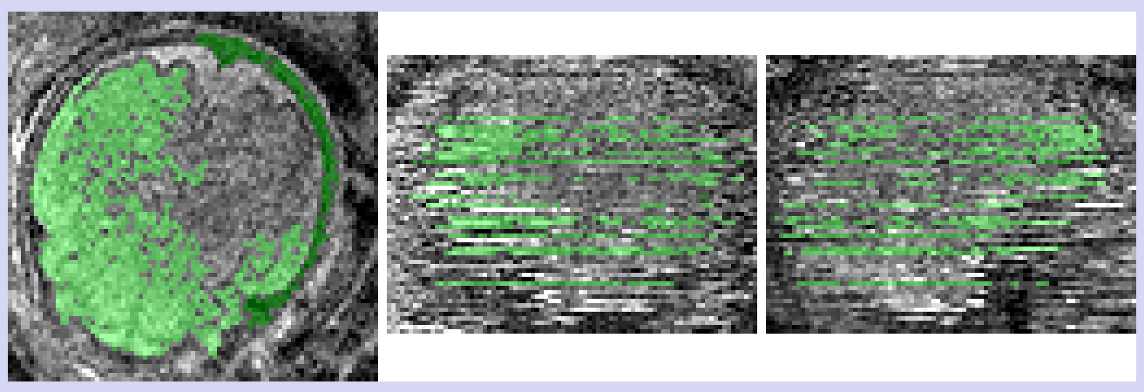
Automatic localisation in green, ground truth in red.

In 85% of cases, the detected bounding box contains entirely the ground truth bounding box. The method is not specific to the orientation of the scan and similar performance was obtained on sagittal, coronal and transverse acquisitions, with a median distance error of 5.7mm from the ground truth.

There has been no false detection or missed detection in the cross-validation experiment, with a worst case error of 25mm presented on the left, in the bottom right image.

Conclusion & Future work

We presented a novel automatic localisation method for the fetal brain in misaligned MR cross-sectional images. 2D candidate regions are selected based on an expected size of the brain and classified using histograms of SIFT features. A RANSAC procedure then removes outliers and fits a bounding box around the fetal brain.



Further segmentation to exclude maternal tissues for a better slice to volume registration could start from the detected box and selected MSER regions.