Computer-aided detection of brain metastases using a three-dimensional template-based matching algorithm

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Introduction

Brain metastases occur in approximately one quarter of adult cancer patients. The cognitive and motor signs caused by brain metastases decrease life quality and can even threaten patients' life without proper treatment in time. Therefore, it is of vital importance to detect brain metastases in their initial stage.

Computer-aided diagnosis (CAD) plays a key role in assisting radiologists in a more accurate diagnosis. Current work is a three-dimensional (3D) template-based matching algorithm and a segmentation-based method applied to magnetic resonance imaging (MRI) brain images with the aim to identify brain metastases.

Materials and methods

Nineteen patients were studied with contrast-enhanced T1 weighted-image at 1.5 T. Three-dimensional templates (Fig. 1) were cross-correlated with the brain volume. Those pixels whose normalized cross-correlation coefficient (NCCC) exceeded the 75% of the maximum NCCC were considered brain metastases. As shown in the flow chart of Fig. 2 each lesion candidate was segmented by means of level sets in the three orthogonal views (Fig. 3) as a previous step to remove elongated structures such as blood vessels. Afterwards, it was measured the major distance in vertical or horizontal in each view and calculated a quick approximation of the degree of anisotropy to distinguish between true positives (TP) and false positives (FP). All the slices of the 3D structure were turned to FP if the difference between considered TP slices and FP slices normalized by the number of slices was greater than one third of the slices and the majority were FP slices.

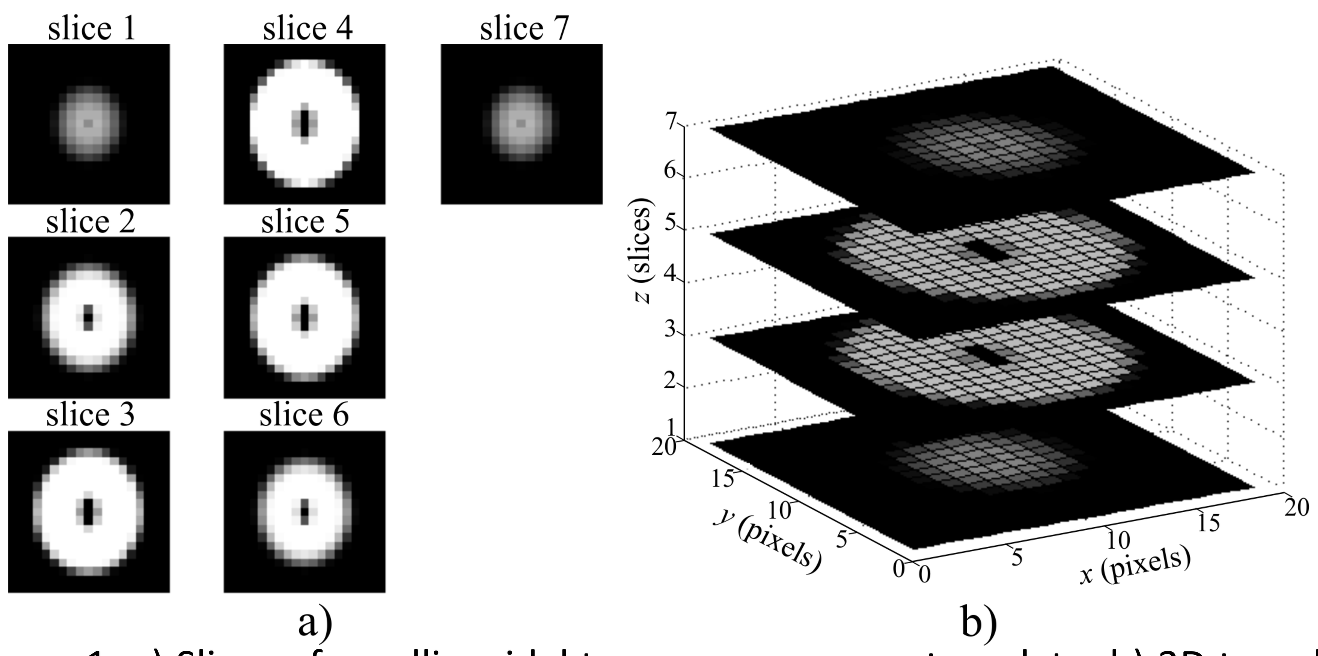

Figure 1. a) Slices of an ellipsoidal tumor appearance template. b) 3D template representation in grey colormap for visual purposes.

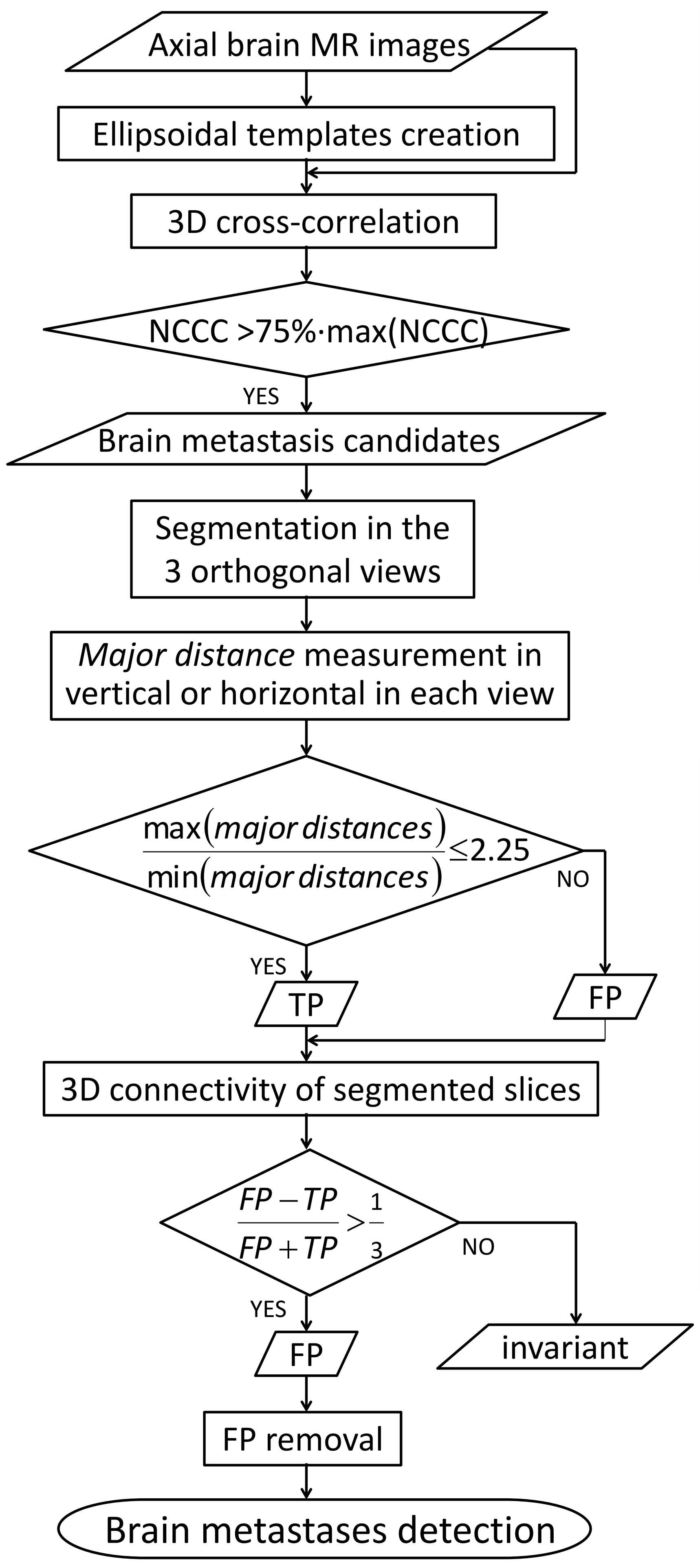

Figure 2. Methodology flow chart. NCCC: normalized cross-correlation coefficient, TP: true positive; FP: false positive.

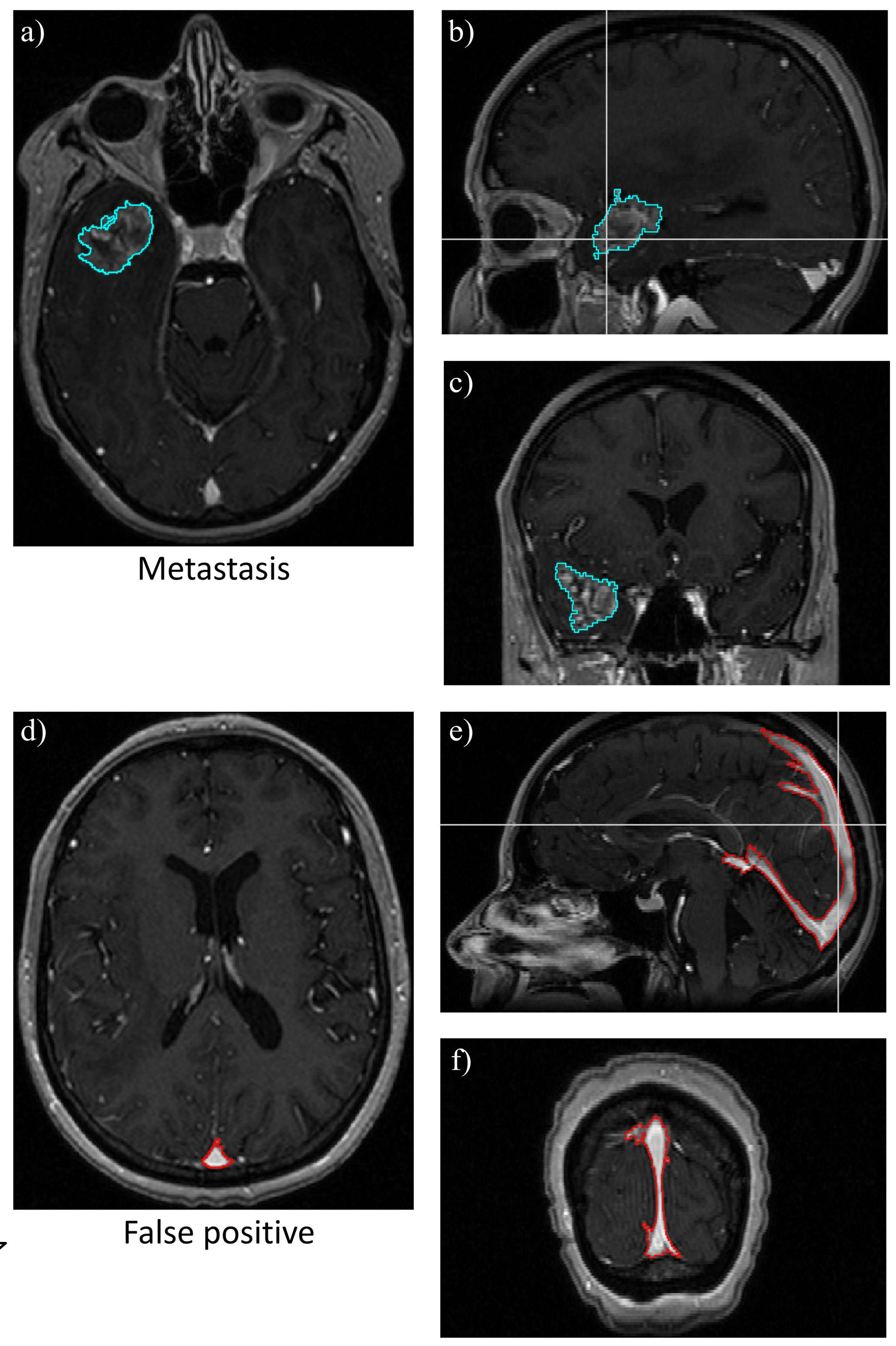

Figure 3. Metastasis segmentation in cyan: a) axial, b) sagittal and c) coronal. False positive segmentation in red: d) axial, e) sagittal and f) coronal. This segmentation allows to calculate the ratio between maximum and minimum of the major vertical or horizontal distance in each view.

Results

Dataset containing 62 brain metastases shows the following results (Table I).

Method	Measures	
	Sensitivity	False positive rate per slice
Templates	93.55%	0.64
Segmentation	91.94 %	0.15

Table I. Obtained results for a nineteen patient database containing 62 brain metastases.

Discussion

Vessels as the superior sagittal sinus are almost circular in axial images, as depicted in Fig. 3d, leading a ratio between maximum distances close to 1 and being classified as TP. So, for FP removal, the three orthogonal views are needed.

Future lines

After applying an algorithm to segment each lesion, it is desirable to calculate precisely how elongated the objects are. One reliable form is calculating the degree of anisotropy (DA) in 3D. The fastest method is the Ellipsoid of Inertia.

Fig. 4 shows the completely segmented brain metastasis and false positive of Fig. 3, whose 3D DA is 1.5 (almost isotropic) and 8.5 (very anisotropic), respectively.

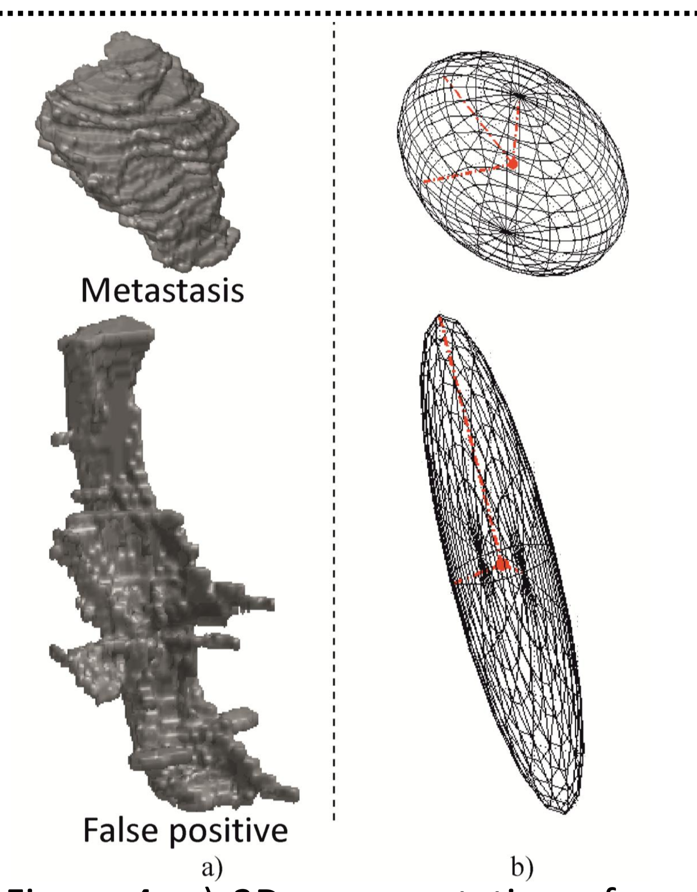

Figure 4. a) 3D representation of a metastasis (above) and a false positive (below). b) Corresponding Ellipsoid of Inertia with the inertia axes displayed in red.

Conclusions

Brain metastases follow general patterns of 3D morphology and signal intensity profiles in MRI and therefore can be detected by 3D templates, using cross-correlation and a precise similarity measure. Current results are encouraging as they present a high detection rate of brain metastases and a manageable number of false positives. This tool serves as a support to the radiologic diagnosis.

Acknowledgements

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