X-Ray Fused With Magnetic Resonance (XFM) applied to Image-Guided Embolization of Venous Malformation in an XMR Suite

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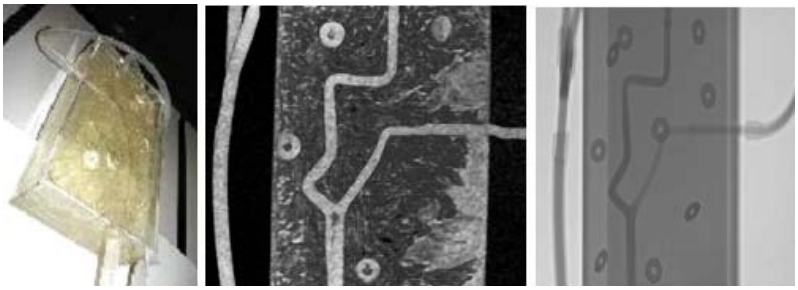
Introduction: We have developed and validated a method for registration, fusion and display of X-ray fused with MRI (XFM). This technique is adapted for an XMR suite, a multimodality setup that offers an easy access to MR and angiography imaging during interventions. Due to the absence of integrated visualization platforms to guide the procedures, groups have developed their own registration methods[1-4]. Their approaches require an optical tracking system or a large number (over 15) of external multimodality markers to reach adequate accuracy. Our technique achieves sub-millimetre accuracy using as few as 4 markers together with information found in the MRI and X-ray DICOM header of the image files. Our display interface overlays representations of MR volumes, like MPR or thin MIP, of any MR acquisition onto fluoroscopy images obtained during the intervention. Validation was performed on a carotid phantom and proof of concept was carried out on patients undergoing embolization of venous malformations.

Methodology: Our XMR suite consist of a 1.5 Tesla Avanto MR imager (Siemens, Erlangen, Germany) next to an angiography room equipped with an AXIOM Artis dTA (Siemens, Erlangen, Germany) and a table mounted on rails (Siemens Miyabi table). Registration and fusion are performed using external multimodality markers (IZI Medical Products, Baltimore, USA) through a custom-made graphical user interface. Previous to the intervention, two x-ray acquisitions, taken at different C-Arm angles and an optimized, high resolution MR sequence (T1-weighted 3D turbo spin-echo sequence with TE / TR / FA = 7.1 ms / 245 ms / 180º and a quasi-isotropic resolution at 1.2 x 1.2 x 1.3 mm^3) allows a precise localization of the fiducials. At first, the user roughly identifies the location of the markers in the MR volume. Then, automated optimization increases accuracy of the markers' positions. The XMR environment ensuring minimal patient movements during the transfer to and from the angiography room, geometric transformations between angiography and MR rooms are computed using the DICOM headers. The fiducials are then projected to generate a 2D mapping of their relative positions before registration. This way, manual identification of the markers on X-ray images is made simpler. Registration is determined through a constrained non-linear least square optimization. The result allows automatic registration of subsequent images taken at any C-arm angle with any MR volume. The precision of the registration, with respect to the number of fiducials used, was evaluated on a carotid phantom and tested offline using clinical images obtained from embolization of venous malformations.



From left to right: carotid phantom; Thin MIP of a T1-weighted MRI (coronal view) of the phantom; Fluoroscopic image of the phantom

Results: Registration accuracy is evaluated by computing the mean errors on 10 markers' positions after registration using different C-Arm orientations. We reach 1.0 ± 0.8 mm accuracy using as few as 3 markers. Our results suggest that a realistic clinical setup would only require a single MR volume, 2 X-ray images and 4 external markers. We also find that a single X-ray view is sufficient to reach equivalent accuracy for registration on images taken at the same C-arm orientation. In these cases, 0.8 ± 0.6 mm precision is reached using 4 markers. Evaluation of the technique on patients undergoing image-guided procedures show promising results, as can be seen in the figure on the right showing the embolization of a venous malformation in the foot.

From left to right: X-ray of a foot during embolization; thin-MIP of a T1 MRI of the foot, retroprojected on the x-ray image plane; XFM using 3 markers.

Conclusion: We show that XFM using as few as 4 fiducial markers is practicable during fluoroscopy guided embolization of venous malformation. To our knowledge, the level of accuracy reached by our method is only reported for techniques requiring more than 15 markers. The first results applied to embolization of venous malformations are very promising for clinical use. Validation on clinical cases is set to take place in the short future.

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