Time to Go Augmented in Vascular Interventional Neuroradiology?

René Anxionnat¹, Marie-Odile Berger²,³, and Erwan Kerrien²,³

¹ Therapeutic and Diagnostic Interventional Neuroradiology Dept, Univ. Hospital, Nancy, F-54000, France
² Inria, Villers-lès-Nancy, F-54600, France
³ Université de Lorraine, Loria, UMR7503, Vandœuvre-lès-Nancy, F-54600, France

This editorial paper reports on our experience in introducing augmented reality (AR) in interventional neuroradiology environments. Our expectations about the next AR tools, in particular for more advanced visualization, are also put forward. For practical reasons, the references will be restricted to our contributions. For further information, the last recommendations concerning the medical management of aneurysm induced hemorrhages can be found in [1].

1 Interventional Neuroradiology

Interventional neuroradiology is a medical discipline that leverages minimally invasive techniques to operate on vascular lesions of the nervous system. The treatment is performed through the inside of the blood vessels, using medical imaging as visual feedback. Such endovascular procedures are mainly performed to treat aneurysms. Intracranial aneurysms are sacciform ectasias of arteries located on the brain surface. The main associated risk is their rupture, leading to an hemorrhage with dramatic clinical consequences. Their size (diameter) varies between 2 mm and a few tens of millimeters. An endovascular treatment (EVT) progressively occludes the aneurysm with very soft spiral-like coils. EVTs were introduced in the 60’s but really took off in the 90’s after controlled detachable coils were developed. EVT has now replaced neurosurgery as the first choice treatment of intracranial aneurysms.

EVTs are performed in interventional vascular operating rooms where X-ray imaging enables the precise analysis of the lesions and their treatment. X-ray Angiography still remains the imaging modality of reference thanks to its optimal spatial and temporal resolution. The endovascular navigation followed by the EVT itself are performed under the real-time visual feedback of a low dose and high frame rate (15 fps on average) angiography image acquisition called fluoroscopy. However, these low quality images are projection images that do not contain any 3D information. Several viewpoints are required for an easier guidance through complex vascular networks and a better control of the treatment. Therefore aneurysm EVT are usually performed in biplane mode, providing simultaneous Antero-Posterior (AP) and Lateral (Lat) fluoroscopic views. No significant improvements were brought in the last few years in the control of
EVTs using fluoroscopy. The development of Augmented Fluoroscopy very recently modified this status by introducing, for the first time, Augmented Reality in vascular interventional neuroradiology.

2 Augmented Fluoroscopy: Principle and Clinical Interest

The idea of enriching fluoroscopy images with 3D data was born shortly after the development, in 1997, of 3D rotational angiography (3DRA) [2], a cone-beam tomography reconstruction techniques that produces a volume from angiography images acquired during a rotation of the vascular C-arm. 3DRA allows for an optimal treatment planning thanks to a precise analysis of the aneurysm morphology: its size, its shape and its neck, where it connects with its parent vessel [3]. From 3DRA, a working view can be defined that best identifies the aneurysmal neck and clearly reveals the limits for the coil positioning. 3DRA rapidly became a must-have imaging modality for EVT planning, to improve treatment safety and expand their indications. However, over a decade was necessary to actually integrate 3DRA with fluoroscopy thereby building the first augmented reality tool suitable for use in clinical practice.

During EVT, superimposing 3DRA onto the fluoroscopy sequence provides the physician with a stereoscopic vision of the morphology of vascular bifurcations, of the aneurysm and its relations with neighboring vessels. Endovascular guidance is made easier and coil deployment is better controlled.

Augmented Fluoroscopy (AF) is based on 3D/2D registration between 3DRA and fluoroscopy in any C-arm orientation. A prototype was developed in close collaboration between the research team (Inria Nancy Grand-Est), the manufacturer (GE Healthcare) and the medical staff (Department of Neuroradiology University Hospital of Nancy, France). The geometric accuracy of the implemented machine-based registration was first measured [4]. The next step consisted in further evaluating the prototype in the clinical conditions of an aneurysm EVT. Validation criteria were designed to address the clinical requirements met in the operating room, in terms of geometric accuracy and visualization. Visualization should indeed both preserve the visibility of the EVT tools (microcatheters, guidewires, and coils) and clearly depict the vascular topology in 3D.

The geometric accuracy was first estimated on a silicon phantom of the cerebral vasculature under various orientations of the C-arm. It was proved to be less than 0.5 mm and therefore compatible with the clinical objective [5]. This first conclusion was confirmed on clinical cases.

Concerning visualization, we chose to blend the 3DRA volume in Volume Rendering onto the fluoroscopic images. Easy to implement, this solution presents as a further advantage that it barely impacts the usual physician’s environment (see Figure 1). Using AF in clinical conditions confirmed the relevance of this choice, and helped to significantly improve this prototype with functionalities such as interactive tuning of the vessel transparency to reach an optimal consensus between vascular relief and envovascular material visibility. After these successive improvements, AF was launched as a product in 2007.