PhD Thesis proposal

Endovascular navigation guidance for complex catheterization

Thesis location: LTSI Inserm U1099 (Rennes), in collaboration with ISIR Inserm U1150 (Paris)
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Starting date: September 2019

1. Labex CAMI

Medical Interventions (surgery, interventional radiology, radiotherapy) can provide a significant boost for progress in terms of patient-specific optimal planning and performance. To fulfill patient's demand for Quality, Senior Operators demand to see beyond the immediately visible, to be assisted in their real-time vital decisions and to accede to enhanced dexterity, while junior operators request to "learn to fly" before being left alone, and Public Health Authorities and companies require demonstration of the Medical Benefit of innovations.

The Computer Assisted Medical Interventions LABEX (CAMI LABEX) strategic vision is that an integrated approach of medical interventions will result in a breakthrough in terms of quality of medical interventions, demonstrated in terms of medical benefits and degree of penetration of CAMI technology in routine clinical practice.

The Labex CAMI aims in particular in the next five years to address two challenges, including the development of endoluminal interventions. This thesis subject is part of this challenge.

2. Thesis topic

Among minimally invasive surgical techniques, endovascular therapies have experienced a very important development in recent years [1]. The endovascular technique has become the therapeutic reference for a large number of pathologies (stroke, stenosis, aneurysm). It is accompanied by permanent evolutions and innovations in terms of devices (coils, balloons, stents, bifurcated and fenestrated stent-grafts, transcatheter bioprosthetic valves, etc.) that must be navigated in the vascular structures until the lesion before operating their deployment.

The prerequisite for any endovascular treatment is to be able to access the target site quickly and efficiently. This navigation step, or catheterization, is performed by means of catheters and flexible guides co-manipulated by the practitioner with regard to interventional imaging (most often a temporal sequence of 2D X-ray images during the access phase). At the beginning or during the procedure, it is necessary to avoid iterative gestures, to minimize X-ray exposure (patient and medical team) and contrast medium injection (nephrotoxicity) [2]. During access to the treatment site, catheterization involves a technical gesture that can be very difficult, and sometimes impossible, in complex anatomical configurations [3]. This complexity is often related to the lack of catheter control during passages of vascular tortuosity [4-8]. These difficulties are accentuated by the lack of decision support tools. In addition, the ongoing evolution of endovascular devices and practices, the recent advances in active catheterization based on Memory Shape Alloy technology [9-11], offer new perspectives to overcome current limitations.

The aim of the PhD thesis is to study and propose solutions for guiding endovascular navigation through complex pathways as well as for secured and controlled access to target sites that are difficult or impossible to reach at present.

The CAMI LABEX is co-funded by the ANR within the Investissements d'Avenir programme
under reference ANR-11-LABX-0004

Fusion / augmented reality techniques [12] [13] could be better exploited by integrating functions for characterizing shapes and trajectories [14] in complex anatomical and pathological configurations (low-contrasted collateral arteries, supra-aortic trunks), for visualizing and quantifying deviations (error / drift detection) between planned trajectory / ideal configuration and actual observed course in order to adapt the gesture and the control of the catheter-guide system in real time during the intervention. If the proposed approach will take into account the access devices (guide - catheter) conventionally used in routine, one will particularly consider the case of new multi-curves active devices (guide - catheter) whose shape can be adapted to complex anatomical configurations that raise specific issues about their configuration and control by the operator. The work will address more specifically the following issues:

- Description of patient data from preoperative images (CT, MRI).
- Analysis, modeling and comparison of shapes.
- Matching (preoperative CT / MRI, intraoperative fluoroscopy) and representation.
- Catheterization guidance and endovascular navigation assistance.

4. Qualifications

Master degree in the field of information processing or biomedical engineering. The skills sought relate more specifically to image processing, computer vision, programming, machine learning and automatic control.

5. Application procedure

No longer open.

6. References

[1] Wilbring M, Rehm M, Ghazy T, et al. Aortic Arch Mapping by Computed Tomography for Actual Anatomic Studies in Times of Emerging Endovascular Therapies. Annals of Vascular Surgery 2016;30:181–91.

[2] Kaladji A, Dumenil A, Mahe G, Castro M, Cardon A, Lucas A, Haigron P. Safety and Accuracy of Endovascular Aneurysm Repair without Pre-Operative and Intra-Operative Contrast Agent. European Journal of Vascular and Endovascular Surgery. 2015 Jan 21:255-61.

[3] Werner M, Bausback Y, Bräunlich S, et al. Anatomic variables contributing to a higher periprocedural incidence of stroke and TIA in carotid artery stenting. Cathet Cardiovasc Intervent 2012;80:321–8.

[4] Macdonald S, Lee R, Williams R, et al. Towards safer carotid artery stenting: a scoring system for anatomic suitability. Stroke 2009;40:1698–703. doi:10.1161/STROKEAHA.109.547117

[5] Lam RC, Lin SC, DeRubertis B, Hynecek R, Kent KC, Faries PL. The impact of increasing age on anatomic factors affecting carotid angioplasty and stenting. J Vasc Surg 2007;45:875–880.

[6] Madhwal S, Rajagopal V, Bhatt DL, Bajzer CT, Whitlow P, Kapadia SR. Predictors of difficult carotid stenting as determined by aortic arch angiography. J Invasive Cardiol 2008;20: 200–204.

[7] Kaladji A, Dumenil A, Castro M, Haigron P, Heautot J-F, Haulon S. Endovascular aortic repair of a postdissecting thoracoabdominal aneurysm using intraoperative fusion imaging. Journal of Vascular Surgery 2013;57:1109-1112.

[8] Haulon S. Fenestrated and branched endovascular aortic repair has reached a state of maturity. Journal of Vascular Surgery 2017; 65(5):1247-1248.

[9] Lambert P, Szewczyk J, Renaud P. Actionneurs non conventionnels pour la robotique, Techniques de l'Ingénieur Conception, modélisation et commande en robotique, n° s7769, 2016.

[10] Li MM, Hamady MS, Bicknell CD, Riga CV. Flexible robotic catheters in the visceral segment of the aorta: advantages and limitations. doi: 10.23736/S0021-9509.18.10458-7. 2018.

[11] J. Szewczyk, E. Marchandise, P. Flaud, L. Royon and R. Blanc, Active Catheters for Neuroradiology, Journal of Robotics and Mechatronics, Vol 23(1), pp 105-115, 2011.

[12] Kaladji A, Daoudal A, Clochard E, Gindre J, Cardon A, Castro M, Haigron P, Lucas A. Interest of fusion imaging and modern navigation tools with hybrid rooms in endovascular aortic procedures. Journal of Cardiovascular Surgery. 2017; 58(3):458-466.

[13] Dumenil A, Kaladji A, Castro M, Goksu C, Lucas A, Haigron P. A versatile intensity-based 3d/2d rigid registration compatible with mobile c-arm for endovascular treatment of abdominal aortic aneurysm. International Journal of Computer Assisted Radiology and Surgery 2016;11:1713-1729.

[14] Feuillâtre H, Auffret V, Castro M, Le Breton H, Garreau M, Haigron P. Study of similarity measures for Case-Based Reasoning in Transcatheter Aortic Valve Implantation. Computing in Cardiology, 24-27 sept. 2017, Rennes, France.

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