Contexte et atouts du poste

In computer-assisted interventions, correctly aligning preoperative data to real-time acquired intra-operative images remains a challenging topic, especially when large deformations are involved and only sparse input data is available. This is typically the case when trying to provide an augmented view of an organ during surgery. In this context, just about 30% of the surface of the organ is visible due to the limited field of view of the laparoscopic camera or size of the incision [2]. Several works have demonstrated the benefits of physics-based models, particularly patient-specific biomechanical models, for accurate registration between different preoperative 3D anatomical model and intraoperative data [3,4,5,6]. These models are usually derived from continuum mechanics theory, where finite element methods are preferred due to their ability to numerically solve the complex partial differential equations associated with the constitutive models.

In this thesis, we consider the general case of tracking a target during an intervention using real-time imaging. Different techniques can provide intraoperative images, ranging from laparoscopic cameras to selective MR imaging. In all cases, these images cannot provide sufficient information (due to lack of resolution, limited contrast, noise or other issues). Therefore, a computational model, reconstructed from preoperative medical images, is required to bring key information at the time of the procedure. In addition, the computational efficiency of the finite element method is essential. To this end, various solutions have been proposed, with different trade-offs regarding the ratio between computation time and model accuracy [8,5,7]. The choice of the model, and its parameterization, are obviously key to an accurate registration. It is usually acknowledged that a registration of internal structures below 5mm is needed for best clinical impact, such as targeting relatively small tumors.

[4] Clements, L. W., Chapman, W. C., Dawant, B. M.,
Mission confiée

We propose to solve the registration problem using a shape optimization approach, where model accuracy, computation time, image data are considered as constraints: to this aim, the constitutive model will be derived from hyperelasticity theory and the main unknown of the optimization problem will be the considered organ. A first step will consist in deriving a relevant shape functional, involving the knowledge of image data, modeling the discrepancy between the observation and the model. In a second time, we will imagine and use an iterative optimization algorithm based on the so-called Hadamard shape derivative, to take into account the sensitivity of the considered functional with respect to shape variations. In a nutshell, we will need to combine in a clever way the numerical resolution of the hyperelasticity system, the Hadamard boundary variation method for calculating the sensitivity of the minimized function of the domain, and the organ mesh update strategy.

In a second stage, we will also investigate how to control, in an optimal way, the image acquisition process itself. Most imaging devices allow to control some parameters of the system, such as the view point or number and location of the slices. Optimizing these parameters to get the best possible image data is expected to lead to improved accuracy in the tumor tracking process. Such issue are possibly related to the so-called observation and control theory, providing a rigorous framework to investigate the well-posed character of inverse problems. In such a case, it is likely that the considered problem is intrinsically ill-posed. To overcome this difficulty, we will adapt recent strategies for locating sensors,


Consignes pour postuler

Sécurité défense :
Ce poste est susceptible d’être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L’autorisation d’accès à une zone est délivrée par le chef d’établissement, après avis ministériel favorable, tel que défini dans l’arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l’annulation du recrutement.

Politique de recrutement : Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.

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where the location of slices is obtained by minimizing a dedicated functional involving a reconstruction quality factor and a last square functional to take into account observations.

Accuracy will be evaluated using a phantom model, ex vivo and in vivo porcine and patient data obtained through our collaborations with IHU Strasbourg and Paul Brousse Hospital.

**Principales activités**

The Ph. D. student will carry out his thesis within the Mimesis (INRIA) and MOCO (IRMA) teams. He will be trained in the following fields: biomathematics, modeling analysis and simulation of partial differential equations, control theory and shape optimization. The presence in these laboratories of researchers specialized in problems related to physics-based simulation, real-time simulation should be of the greatest benefit to the future student.

**Avantages**

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

**Rémunération**

1982€ gross/month for 1st and 2nd year. 2085€ gross/month for 3rd year.

Monthly salary after taxes: around 1596,05€ for 1st and 2nd year. 1678,99€ for 3rd year. (medical insurance included).