Mechatronic design and development of a robotic needle insertion device

– Summer school Montpellier'13 –

Nitish Kumar

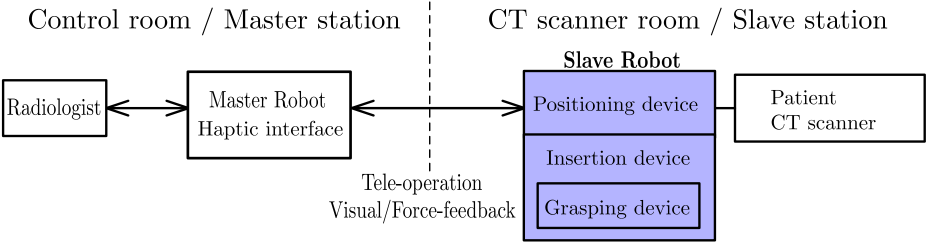
Thesis supervisors: Bernard BAYLE, Olivier PICCIN

AVR, ICube
Strasbourg

Project **ProteCT**

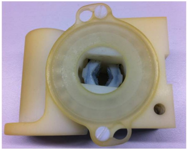
Main goal is to :

- Provide robotic assistance to remotely manipulate and insert needles under CT guidance
- To protect the radiologist from exposure of x-rays

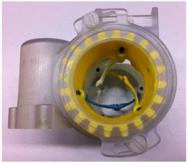


Need for needle grasping device (NGD)

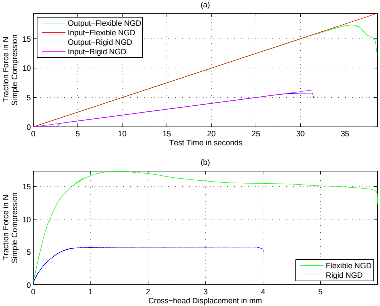
- Insertion of the needle is done in several steps
- After each step, needle needs to be released while inserted to minimize tissue lacerations
- As part of CT-Bot project two versions of NGD were developed



RigidNGD



FlexibleNGD

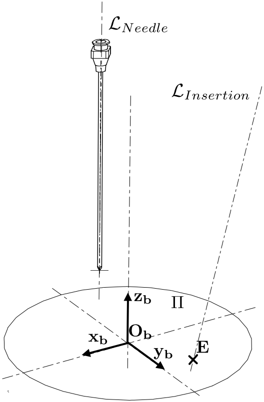


Force vs time/displacement

Development of the positioning device

Minimal task definition

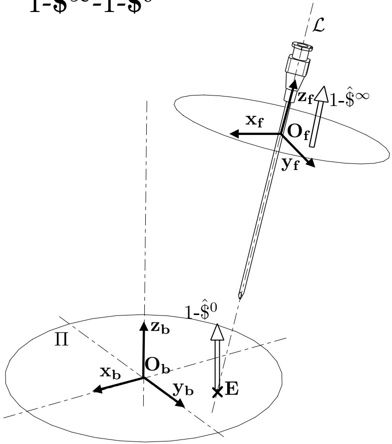
- Point of entry translates in *x*-*y* plane
  - 2-translational degrees of freedom(2T)
  - parameterized by *x* and *y* coordinates of point of entry
- Axis of needle orients around point of entry
  - 2-rotational degree of freedom(2R)
  - parametrized by angles needle makes with *x* and *y* axes
- Need for mechanism with 2T2R mobility
- Presence of a remote center of motion (RCM)



Task definition

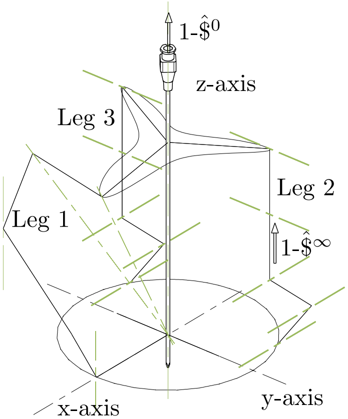
Type synthesis of 2T2R PM

- **Identification of Constraints** : 1-$\hat{\$}^\infty$-1-$\hat{\$}^0$



Constraints for 2T2R PM

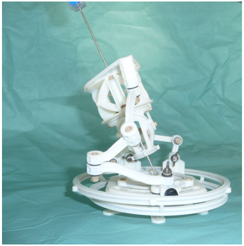
- Twist system : 2-$\$^\infty$-2-$\$^0$

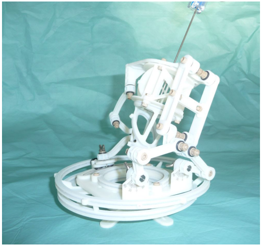


Architecture candidate
for 2T2R PM

First Prototype

- First prototype fabricated using rapid prototyping machine





- Limited workspace of PM calls for systematic dimensional synthesis for optimizing the size of workspace
- Concerns for presence of voids, singularities inside the work space need to be addressed

Results of dimensional synthesis

- An algorithm based on geometric analysis of the singularities
- Principle : Workspace boundaries are locus of the singularities
- Characteristic dimension of 100 mm for the slave robot
- Translational Workspace
  - $\pm 20\ mm$ along x and y axes
- Orientation Workspace
  - Symmetrical workspace constraint
    - Achieved a orientation range of at least $\pm 30^\circ$ about z axis
  - Asymmetric workspace
    - Achieved a orientation range of at least $\pm 60^\circ$ about z axis for two quadrants of the workspace
- Removal of voids from the workspace

Future work/Perspectives

- **Positioning device** :
  - Choice of the actuation and transmission technology
- **Insertion tool** :
  - Development/Choice of suitable force sensor for haptic force feedback
- **Integration** :
  - Integration of the positioning device, insertion tool and needle grasping device into one single system

Publications/References

1. Piccin, O.; **Kumar, N.**; Meylheuc, L.; Barbé, L. and Bayle, B. : Design, development and preliminary assessment of grasping devices for robotized medical applications. Proceedings of the ASME 2012 International design engineering technical conferences, IDETC, 2012
2. Piccin, O.; **Kumar, N.**; Meylheuc, L.; Barbé, L. and Bayle, B. : Device for grasping an elongated body, such as a needle, and robotized device comprising the same, **Provisional** US Patent 61/681,264, 2012
3. **Kumar, N.**; Piccin, Olivier and Meylheuc, L.; Barbé, L. et Bayle, B. : Compliant grasping device for robotized medical applications, 21éme Congrés Français de Mécanique, Bordeaux, 26 au 30 aout 2013
4. **Maurin, B.** et. al. : A patient-mounted robotic platform for CT-scan guided procedures, IEEE transactions on bio-medical engineering, 2008, vol. 55, pages : 2417–2425

Thank you for your attention.

Questions ??