1. Study of "smart material"-based medical tools

Promoter: Pierre Lambert **Supervisor:** Loïc Blanc – loic.blanc@ulb.ac.be

Description: The goal of this project is to study and characterize smart materials for controllable stiffness solutions. Indeed, in the medical field and especially in Endoluminal Surgery and biomedical engineering, the development of new endoscopic tools and catheters could benefit from adaptive stiffness principles (Blanc et al., 2017). Indeed, a flexible state is required to adapt to tortuous paths of the human body and painful contact force with the patient tissues, while a stiffer mode is needed to transmit force and for accurate positioning. Multiple solutions for controllable stiffness mechanisms has been proposed in the literature and the focus of this work is towards smart materials as Shape Memory Polymers and Low Melting Point Materials.

The **Shape Memory Polymers** are polymers that may present a huge change in stiffness (Young Modulus) around their glass transition temperature, for a little variation of temperature. Furthermore, these materials present a shape memory action which is beneficial for actuation. In the laboratory, a 3D printable Shape Memory Polymer is available.

The **Low Melting Point Materials** can be polymers or metals. These materials change of phase at low temperature (typically lower than 65°C). The gallium is melting at 29.8°C and is a Low Melting Point Metal available in the lab. The polycaprolactone is melting at 42°C or 62°C and is a Low Melting Point Polymer available in the lab.

Goal: The goal of this project is to study the application of these materials that enable the change of stiffness. The performances in the rigid and flexible states have to be quantified, compared and justified. Experimental work will put into practice the theoretical models and principles.

Tasks:

- Literature review / understanding of the project
- Characterization of the materials:
    - Fabrication of the samples (molding / 3D printing)
    - (Thermo-)mechanical tests (bending test, tensile test, heating)
    - Model / study of the results (FEM if known by candidate, analytical model, statistic study, etc.)
- Proof of concept

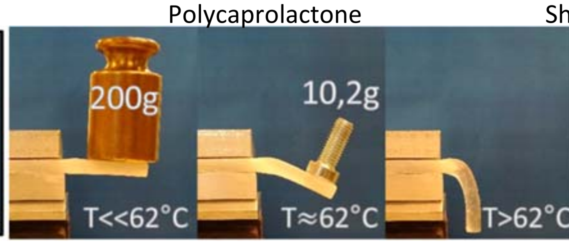
References:

Blanc, L.; Delchambre, A.; Lambert, P. (2017) Flexible Medical Devices: Review of Controllable Stiffness Solutions. Actuators 2017, 6, 23.

Leng, J., Lan, X., Liu, Y., & Du, S. (2011). Shape-memory polymers and their composites: stimulus methods and applications. *Progress in Materials Science*, *56*(7), 1077-1135.

Gallium

Polycaprolactone



Shape Memory Polymer

2. Industrial collaboration in micro-assembly: experimental characterization and modelling of a capillary pick-and-place tool

Coupled with an internship

Promoter: Pierre Lambert

Context:

The collaboration is with a Swiss company active in micro-assembly, which is bthe industrial field in charge of assembling complex products from separate elements. This include feeding components, picking them up, placing them in the product and releasing them. The process can also include some quality control.

The partner currently develops machines to pick and place 200µm components at a throughput larger than 10 components/s. The current picking solution is based on a venture gripper (vacuum gripper).

Goals:

To overcome a series of current limitations, we have started to develop an alternative solution, based on capillary forces to pick and handle components [Lambert2007, Lambert2013]. Existing prototypes are being tested on the company machines, and the goal of this project is to collect and analyse experimental data from this process. Then, the student will be asked to model (physically) the process in order to improve or optimize the gripping prototype.

Tasks:

- From August to October 2018: internship in the company (La Chaux de Fonds, Switzerland)
- From November 2018 to May 2019: master thesis in TIPs department, including the following work:
    - Understand the limitations of the current solution (based on experimental data and models)
    - Design of an improved gripper solution, including all the dimensions of the problem: liquid drop dispensing, gripper geometry design, wettability issues related to the gripper and/or the component, industrial process dynamics…
    - Manufacture the new prototype in ULB thanks to the Nanoscribe GT Photonics 3D printer, with a submicron resolution (see Nanoscribe.de or the ULB platform micromilii.ulb.be)

References:

Pierre LAMBERT, Capillary forces in microassemly, Springer (2007)

Pierre LAMBERT, Surface Tension in Microsystems, Springer (2013)

3. Industrial collaboration in mechanical modelling: mechanical modelling of daily activities from smartphone sensors (gyroscopes and accelerometers)

Promoter: Pierre Lambert

Context:

The Piko Technologies company develops an smartphone application to collect mechanical data from embedded accelerometers and gyroscopes.

Goals:

The goal of this project is to reconstruct the smartphone trajectory and identify the related mechanical signature of typical daily activities (walking, running, cycling…)

Tasks:

- Identify with the company typical trajectories and collect related data
- Build a kinematic model to reconstruct the smartphone trajectory (modelling and matlab simulation)
- Build biomechanical models for these typical activities

References:

- Suprem et al. Orientation and Displacement Detection for Smartphone Device Based IMUs , IEEE access, November 18 (2016), https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=7748482
- M.B. del Rosario, Tracking the Evolution of Smartphone Sensing for Monitoring Human Movement, Sensors 15(8):18901-18933
- Alex T. Mariakakis, DirectMe: A Mobile Phone Algorithm for Direction Detection, https://ece.duke.edu/sites/ece.duke.edu/files/GWDD2013_Mariakakis_0.pdf

4. Break up of liquid bridge between two nonparallel surfaces

Promoter: Pierre Lambert **Supervisor:** Youness Tourtit – ytourtit@ulb.ac.be

Context:

Liquid bridge formation between two surfaces is encountered in nature and in many industrial applications such as offset printing processes, capillary adhesion, drop deposition, liquid dispensing systems… When both surfaces are not parallel (Figure below), instability of the liquid bridge formed may appear. So the liquid bridge may move itself towards to the confined region. This phenomenon can be used for example for harvest condensed water drops [1], mixture separation [2], liquid dispensing through a liquid bridge stretching …

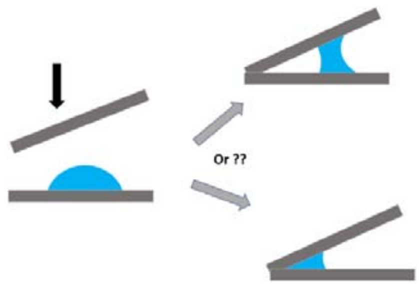


Figure 1: Liquid bridge between two non-parallel surfaces

Goals:

The objective of this study is to understand why such liquid bridge instabilities are observed between two nonparallel surfaces? What are the critical parameters that influence the liquid bridge stability? What will be the amount of liquid transferred to the inclined surface when the rupture of the liquid bridge occurs in the two cases? In which case will we have a maximum of transfer? Starting by a literature review, an experimental parametric study will be conducted by the student to answer these questions taking account all the parameters that can have influence on the liquid bridge instability, the tilt angle of the upper surface, the characteristics of the liquid, the contact angle of the liquid on the surfaces… Design of experiments methodology will be applied, and data will be further analysed with Matlab / Python / Octoave.

References:

[1] X. Heng, C. Luo, Bioinspired plate-based fog collectors, ACS Appl. Mater.Interfaces 6 (2014) 16257–16266.

[2] Wei Xu, Zhong Lan, Benli Peng, Rongfu Wen, Yansong Chen & Xuehu Ma, Directional Movement of Droplets in Grooves: Suspended or Immersed?, Scientific Reports 6, Article number: 18836 (2016)

Suggested additional reading:

- Satish Kumar, Liquid Transfer in Printing Processes: Liquid Bridges with Moving Contact Lines, Annu. Rev. Fluid Mech. 2015. 47:67–94
- Mohammadmehdi Ataei, Tian Tang, Alidad Amirfazli, Motion of a liquid bridge between nonparallel surfaces, Journal of Colloid and Interface Science 492 (2017) 218–228
- Cheng Luo and Xin Heng, Separation of Oil from a Water/Oil Mixed Drop Using Two Nonparallel Plates, Langmuir 2014, 30, 10002−10010

5. Instrumented nasal cast for nose-to-brain drug delivery

Promoters: Benoit Haut & Pierre Lambert

Context:

Nose-to-brain drug delivery is a very promising way to deliver drugs. For this purpose, the airflow generated by a spray device mush convey the drug particles through the nose and deposit them in the so-called olfactive area. Since each patient nose anatomy is different, this process must be optimized to become patient specific.

Goals:

According to the student profile, we can consider two different goals:

- Transform a nose cavity MRI image into a CAD file used in Ansys-Fluent and model the transport equations to be implemented in the digital simulation
- Transform a nose cavity MRI image into a stl file to be printed and adapted to include sensors (pressure, PIV…) to analyse the air flow and drug deposition experimentally

References:

- A. Dastan, O. Abouali, G. Ahmadi. CFD simulation of total and regional fiber deposition in human nasal cavities. Journal of Aerosol Science 69 (2014) 132–149
- R. Hughes, J. Watterson, C. Dickens, D. Ward and A. Banaszek. Development of a nasal cast model to test medicinal nasal devices. Proc. IMechE, Vol. 222 Part H: J Engineering in Medicine (2008) 1013–1022
- K. Inthavong, Q. Ge, C. Se, W. Yang, J. Tu. Simulation of sprayed particle deposition in a human nasal cavity including a nasal spray device. Journal of Aerosol Science 42 (2011) 100–113
- K. Inthavong, Z. Tian, J. Tu, W. Yang, C. Xue. Optimising nasal spray parameters for efficient drug delivery using computational fluid dynamics. Computers in Biology and Medicine 38 (2008) 713–726
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- J. Xi, F.E. Yuan, Y. Zhang, D. Nevorski, Z. Wang, Y. Zhou. Visualization and Quantification of Nasal and Olfactory Deposition in a Sectional Adult Nasal Airway Cast. Pharmaceutical Research 33 (2016) 1527–1541
- J. Xi, Z. Wang, D. Nevorski, Th. White, Y. Zhou. Nasal and Olfactory Deposition with Normal and Bidirectional Intranasal Delivery Techniques: In Vitro Tests and Numerical Simulations, Journal of Aerosol Medicine and Pulmonary Drug Delivery 30 (2017) 118–131