Benjamin Calmé

PhD in Robotics
Speciality : Medical Robotics

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Education

- **PhD in Robotics** — March 2023
  Montpellier University — *France*
  The defence took place in person on 17 March 2023 in Montpellier in front of the following defense commitee:
  - Michaël GAUTHIER - Senior Researcher - Femto-st Institute (France)
  - Jérôme SZEWCZYK - Full Professor - Sorbonne University (France)
  - Jacques GANGLOFF - Full Professor - Telecom-physique Strasbourg (France)
  - Simon HENEIN - Associate Professor - EPFL (Switzerland)
  - Yassine HADDAB - Full Professor - Montpellier University (France)
  - Lennart RUBBERT - Associate Professor - Strasbourg University (France)

- **Master in Mechanical Engineering** — 2019
  Reims University — *France*

- **Doctor of Podiatric Medicine** — 2017
  Faculty of Medicine and Maieutic Lille - Lille Catholic University — *France*

Professional experience

- **Lecturer** — Montpellier university
  Department of Electronics, Energy and Control, and Department of Digital Science for Health — *Current*
  - **Classes**: Dynamic systems and control (Undergraduate), Robotic manipulation (Graduate) and Medical robotics (Graduate).

- **Thesis in robotics** — Montpellier university
  Collaboration between DEXTER/LIRMM Montpellier and RDH/ICube Strasbourg — *2019-2023*
  - **Subject**: Integration of functions for endoscopy by designing multistable mechanisms produced by additive manufacturing.
    The thesis was carried out within DEXTER team of LIRMM in Montpellier and within RDH team (formerly AVR) of ICube laboratory in Strasbourg. The project was supervised by Prof. Yassine Haddab (LIRMM) and Assoc. Prof. Lennart Rubbert (ICube) and supported by the LabEx CAMI (Computer Assisted Medical Interventions).

- **Research internship** — INSA Strasbourg
  RDH/ICube, European project SPIRITS — *2019*
  - **Subject**: Design and fabrication of a surgical needle with controllable flexibility.
  - **Summary**: Modelling, simulation, optimisation, and design of flexible mechanisms. Development of a prototype in partnership with the Instant Lab (EPFL - École Polytechnique Fédéral de Lausanne).

- **Research internship** — ENSAM Paris
  George Charpak Institute of Human Biomechanics, ParisTech. — *2018*
  - **Subject**: Design of an artificial foot simulating physiological movements using a 6-axis robotic arm.
  - **Summary**: Analysis and modelling of the kinematics of the foot during sports movements (overrun in rugby) using an opto-electronic system (VICON). Use of the collected data for the control of a 6-axis ABB robotic arm. Design and simulation of a prosthetic foot simulating 3 DoF. Implementation of a validation protocol on a pressure platform after assembly of the prosthetic foot on the robot.

Technical skills

- **Programming**: Python, Matlab/Simulink, Julia, C, Assembly, Arduino, Labview.
- **CAD**: Creo Parametric, Catia V5/V6, Solidworks, Autodesk Fusion 360.
- **Finite element analysis**: Abaqus, Ansys, Comsol.

Research activities

Endoflex project (thesis): Design of a discrete polyarticulated robot for endoscopy using multistable structures.

This project aims to propose and develop a new generation of endoscope compatible with minimally invasive surgery, also known as "scarless". It is the result of a collaboration between AVR-ICube (Strasbourg) and DEXTER-Lirmm (Montpellier) teams, and is supported by the LabEx CAMI.

During surgery, the trauma to a patient is proportional to the invasiveness of the procedure. In order to reduce it, surgeons now seek to exploit natural orifices as a gateway to the rest of the body. However, this choice imposes significant dimensional constraints on robotic devices and on the ability to perform complex trajectories.

In order to meet the miniaturisation constraint, this work is inspired by mechanisms used in the aerospace and high-precision watchmaking fields. These have enabled the design of multi-positional sub-units, i.e. capable of maintaining positions without a continuous supply of energy, which is not the case with the devices currently used. Their assembly makes it possible to obtain a fully controllable robot whose multiple configurations are precisely identifiable and obtained at a low energy cost. The structure developed also aims to offer superior performance to traditional endoscopes as, unlike a cable drive, it offers a solution without friction or mechanical play.

During this work, I designed the mechanical architecture of the robotic system. I dimensioned and made the boards for the embedded electronics. I carried out a first phase of control by means of the direct and inverse geometrical models of the structure. I am worked on dynamic programming problems for path planning. And I am currently working on the use of machine learning to select the optimal configuration specific to the robot's task taking into account the interaction with the environment.

In parallel, I am working on the design of a structure with an integrated actuator in electroactive polymer that can be produced by additive manufacturing. This research allows me to consider the fabrication of the robot with integrated actuators that can be produced monolithically.

- **International peer-reviewed journal**:
  - B. Calmé, L. Rubbert and Y. Haddab, "Towards a Discrete Snake-Like Robot Based on SMA-Actuated Tristable Modules for Follow the Leader Control Strategy", in IEEE Robotics and Automation Letters, vol. 8, no. 1, pp. 384-391, Jan. 2023, doi: 10.1109/LRA.2022.3224659.
  - B. Calmé, L. Rubbert and Y. Haddab, "Towards a compact XYZθ positioning system with built-in actuators using 3D printing of conductive polymer", - Journal of Micro-Bio Robotics [Submitted - final decision pending]
  - B. Calmé, L. Rubbert and Y. Haddab, "Three beam bistable mechanism for improved lifetime and manufacturability by hyperstatism analysis using screw theory", - Mechatronics [Submitted - final decision pending]
  - B. Calmé, L. Rubbert and Y. Haddab, "Modeling, control and path planning for a dicrete snake-like robot based on compliant mechanims", - IEEE/ASME Transactions on Mechatronics [Submitted]
- **International peer-reviewed conferences**:
  - B. Calmé, L. Rubbert and Y. Haddab, "External load modelling for the use of the environment in the selection of stress minimising configurations of a modular endoscope", - Conference on New Technologies for Computer and Robot Assisted Surgery (CRAS), 2023 [Submitted]
  - B. Calmé, L. Rubbert and Y. Haddab, "Towards a Discrete Snake-Like Robot Based on SMA-Actuated Tristable Modules for Follow the Leader Control Strategy", - IEEE International Conference on Robotics and Automation, 2023 [Accepted]
  - B. Calmé, L. Rubbert and Y. Haddab, "Towards a compact and low-cost mesoscopic XY positioning system using 3D printing of conductive polymers", 2022 IEEE International Conference on Manipulation, Automation and Robotics at Small Scales (MARSS), Toronto, ON, Canada, 2022, pp. 1-6, doi: 10.1109/MARSS55884.2022.9870471.

Teaching activities

- **Summary**:

Class	Institution	Academic year	Level	Format	Eq TD
Basics of robotics	INSA Strasbourg	2019-2020	Undergraduate	TD 22,5h	22,5h
Mechatronics project	INSA Strasbourg	2019-2020	Undergraduate	TD 24h	24h
Automatique continue	INSA Strasbourg	2019-2020	Undergraduate	CM 2h	3h
Robotic integration project	INSA Strasbourg	2019-2020	Graduate	TD 16.5h	16.5h
Computer Architecture	IUT Béziers	2020-2021 2021-2022	Undergraduate	TP 20h TD 15h, TP 20h	55h
Signal processing	IUT Béziers	2020-2021	Undergraduate	TP 15h	15h
Data acquisition and coding	IUT Béziers	2020-2021 2021-2022	Undergraduate	TD 9h, TP 20h TD 9h, TP 20h	58h
Dynamic Systems and Control I	FoS Montpellier	2022-2023	Undergraduate	TD 18h	18h
Dynamic Systems and Control II	FoS Montpellier	2022-2023	Graduate	TP 18h	12h
Introduction to robotics	FoS Montpellier	2022-2023	Graduate	CM 13.5h, TP 3h	22.25h
Programming for Robotics	FoS Montpellier	2022-2023	Graduate	TP 6h	4h
Medical robotics I	FoS Montpellier	2022-2023	Graduate	CM 16.5h, TP 24h	40.75h
Medical robotics II	FoS Montpellier	2022-2023	Graduate	CM 15h, TP 24h	38.5h
Robotic Manipulation	FoS Montpellier	2022-2023	Graduate	CM 24h, TP 18h	48h
*FoS : Faculty of Science,	TD : Tutorials,	TP : Practicals,	CM : Lecture		377,5h

- **Basics of robotics**: The aim of this module is to introduce students an introduction to key areas of robotics through the creation of a mobile robot. During the tutorials, the students discover and manipulate actuation and measurement technologies commonly used in robotics (MCC, encoders, sensors). Students are introduced to open and closed loop control methods using LEGO Mindstorm NXT and the Labview programming language.
  The project part of this class have not been carried out due to the COVID-19 pandemic. As a part of the project, the students were supposed to work in pairs to design a multimodal robot. I have rewritten the tutorials to go more in details in the aspects of modelling (electrical and mechanical modelling) and automation (transfer functions, correctors, state representation and Bode diagram). Each of these points was illustrated using Labview or Matlab.
  The class was led by Assoc. Prof. Lennart Rubbert (lennart.rubbert@insa-strasbourg.fr).
- **Mechatronics project**: I co-supervised with Assoc. Prof. Lennart Rubbert and Assoc. Prof. Renaud Kiefer several mechatronic projects of undergraduate students. During the second semester, a follow-up of the students was done every week through thematic meetings per pair (mechanical design, automation, electronics,...). The students were evaluated on their investments, their reports, and their project defenses. The list of proposed subjects is as follows :
  - Design and control of AGV robots (2 groups, one with holonomic wheels and one without);
  - Continuation of the Insa de Strasbourg Automobile Concept (ISAC) project [Participation in the Shell Eco-Marathon];
  - Design and control of a VTOL UAV (drones);
  - Continuation of the MyoHand project, resuming the actuation and control of a robotic hand prosthesis;
  - Design and control of an urban mobility drone.
- **Control Systems I**: I did this course as a substitute for Assoc. Prof. Lennart Rubbert. It concerned the control of a DC motor (Maxon F2260). The students had to calculate the transfer function and synthesise a position corrector that would cancel the dynamic error for a parabolic command.
- **Robotic integration project**: In this class students studied and control four types of robots:
  1. an industrial robot: Fanuc robot
  2. a parallel robot: 3-RRR plane robot
  3. a mobile robot: a rover with holonomic wheels.
  4. a collaborative robot: UR5 robot

  The evaluation of this module is based on 2/3 of the mark for the project and 1/3 of the mark for the presentation and the result of the project. Some of these projects were conducted in simulation because of the pandemic.

- **Computer Architecture**: The aim of this module was to develop an understanding and use of numbering and coding systems, the basic components of digital equipment and their organisation. The students are required to express information (numerical or alphanumerical) in different bases (binary, hexadecimal) and coding systems. Different equipments (PC, server) are dissected during practicals in order to identify the internal components. Other practicals are carried out on a simulator emulating an ARMv4 architecture processor. Students are introduced to the ARM architecture, instruction sets and assembler programming: data instructions, memory assignment and allocation, branch instructions, shift instructions, software interrupt instructions.
  This class is led by Assoc. Prof. Sebastien Druon (sebatien.druon@umontpellier.fr).
  In addition to supervising this class, I participated in creating the practicals.
- **Signal processing**: The objective of this module is to provide the students with the means to manipulate usual signals. A reminder of the functions for networks and telecoms is given. The students are then introduced to periodic signal models, pseudo-harmonic functions, oscillations, and envelopes. I then introduced the notions of advance, delay, compression, and dilation. The representation and characterization of signals was done on TIMS racks.
  This class is led by Mr. Daniel Pouget (daniel.pouget@umontpellier.fr).
- **Data acquisition and coding**: The objective of this class is to help students understand the electronic functions used in signal digitisation. My teaching aimed at supporting them to master the principle of digitization and restitution of analog signals, the dimensioning, and the serialization of information. During the practical sessions, the students had to analyse signals before and after sampling in the time and the frequency domain. They had to deal with sampling, quantization and coding, and the characterization of filters (anti-aliasing filter and restitution filter). These exercises are carried out in the context of various applications: sound card, G.711 codec and audio CD.
  This class is led by Assoc. Prof. Agnès Pujas and Prof. Philippe Pujas.
  (agnes.pujas@umontpellier.fr, philippe.pujas@umontpellier.fr).
- **Dynamic Systems and Control I and II**: The aim of this class is to introduce students to the principles of modelling a physical system in order to control it. The tutorials cover modelling of a system in the form of differential equations and the use of Laplace transform to solve them in the form of a polynomial equation. It also covers the stability criteria of a system, its identification, and the establishment of a corrector. For the Master 1 students, the aim was to develop control laws for multivariable systems and to simulate their behaviour in Python (inverse pendulum, 2DDL manipulator robot, unicycle...). These classes are led by Prof. Andrea Cherubini (andrea.cherubini@lirmm.fr).
- **Introduction to robotics**: The objective of this class is to propose to the students an introduction to the modelling and control of robotic manipulator. The fundamental elements to derive the kinematics model for trajectory generation, collision-free motion planning, force control, and hybrid approach for task-and-motion planning. Practicals were done on ROS2/Gazebo and on a humanoid robot Poppy. For this class, I was in charge of creating all the content (lectures, tutorials, and practical work).
- **Medical robotics I and II**: The objective of this course is to give students an introduction to the field of surgical robotics. The aim is to understand the needs expressed by the clinicians and to show through some examples the approach which allows the design and fabrication of robots used for surgical acts. Some elements of design and control strategies are given while insisting on the need to guarantee the safety of the patient and the medical team. For these classes, I was in charge of creating all the content (lectures, tutorials, and practical work).
- **Robotic Manipulation (Teached in English)**: This teaching unit covers the strategies necessary for kinematic and dynamic modelling, and control for robotic manipulators. This course is divided into four axes: 1) Modelling of manipulator robots using Denavit-Hartenberg representation 2) Introduction to the dynamics of robotic manipulators: Euler-Lagrange formalism, Newton-Euler formalism, algorithms for the calculation of dynamics. 3) Joint and operational control in unstructured environments. 4) Control in constrained space: interaction models and compliance, position/force control, impedance and admittance control. The application of these various points is made on a UR10 robot. For this class, I was in charge of creating all the content (lectures, tutorials, and practical work).
- **Student project supervision**: I supervised two Master 2 projects. The projects concerned the control and mechanical optimisation of a robot with a remote centre of motion. I also supervised two Master 1 projects on the design of mobile robots ("snake-like robot" and "walker").
- **Internship supervision**: In addition to my teaching mission, I supervised three Master 2 interns. The first internship concerned the design and finite element analysis of a flexible thermomechanical actuator. The second internship concerned the realization of an electronic board and communication protocols for the control of a poly-modular snake-like robot. The third internship concerned the selection of an optimal configuration of a hyperredundant robot for a specific task using machine learning.

Responsabilités, implication, diffusion scientifique

- **Teaching and administrative responsibilities**:
  - LIRMM - UM
    - Elected member of the Laboratory Council
    - Elected member of the doctoral students' council
    - Elected member representing doctoral students on the doctoral school council
  - Reims University
    - Member of the evaluation committee of the Master BMS
  - Recipient of an M2 internship grant in the context of a call for projects 2023 (Transversal robotics-AI Research)
  - Recipient of the Research and Higher Education Grant 2023
- **Involvement in the scientific community**:
  - Co-organiser of the Young Robotics Researchers Day 2021 (JNRR of the GDR Robotics))

    I took part in the organisation of a presentation day in a hybrid format for PhD students from the ISIR laboratory in Paris. In this process, we interacted with the GDR Robotics, the directors of the different French robotics laboratories and the PhD students. We were in charge of organising everything, from the call for applications to the selection of presentations and posters. With the support of the GDR, we had to organise the schedule, reserve the room, manage the meals, and choose and set up a videoconference platform.
  - Volunteer for the organisation of the IEEE ICRA* Paris 2020 conference (*International Conference on Robotics and Automation)

    I carried out various tasks ranging from contacting authors, to administering the platform and managing questions.
- **Editorial responsibilities**:
  - Reviewer for IEEE Robotics and Automation Letters, IEEE Transactions on Industrial Electronics, ASME IDETC

    Mechanism Design, Medical Robots and Systems, Soft Robot Applications
- **Scientific communication and popularisation activities**:
  - Radio programme - France Culture

    "Assisted surgery: hello Dr Robot". What are surgical robots for? Are they really useful? What can we expect from these machines for the future of medicine?
    https://www.franceculture.fr/emissions/la-methode-scientifique/chirurgie-assistee-bonjour-dr-robot
  - Member of the jury of the RoboCupJunior regional final (Occitanie)

    Rescue league: robots must save people in a reconstructed disaster site

Referees

Professor Yassine Haddab, head of Dexter team, Dept. of Robotics, LIRMM laboratory, Montpellier
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Professor Philippe Poignet, head of the LIRMM lab, Dept. of Robotics, LIRMM laboratory, Montpellier
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