

**Tutoriel n°3:**  
***“SOFA: Modeling, Simulation, and Control of soft-robots with SOFA  
and the SoftRobot plugin”***

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**ABSTRACT**

This workshop will provide a series of in-depth tutorials on how to use the open source simulation framework SOFA and the SoftRobots plugins made by the DEFROST research team to model, simulate and control deformable robots. At the end of the tutorial session, we expect attendees to be capable of modeling and controlling basic soft robots with SOFA including being able to precisely model contact with inverse control.

[SOFA](#) is a modelling and simulation framework based on Finite Element Methods and providing state-of-the-art solutions to compute deformations and multi-contact response with friction in real-time. In recent years, the DEFROST team built on this framework to provide a new numerical platform dedicated to the community of soft robotics. These tools are made freely available to the community for research purposes.

[SoftRobot](#): is a plugin for SOFA that brings components dedicated for Soft Robotics among which: sensors, pressure and cable actuators, direct and inverse models for control as well as connectors for serial/arduino and ROS to access commonly used hardware.

[DEFROST](#) (DEFormable RObotics SofTware) is a research team (Inria / University of Lille in France) that develops a platform based on SOFA that gathers algorithms for modeling, simulation and control of soft robots.

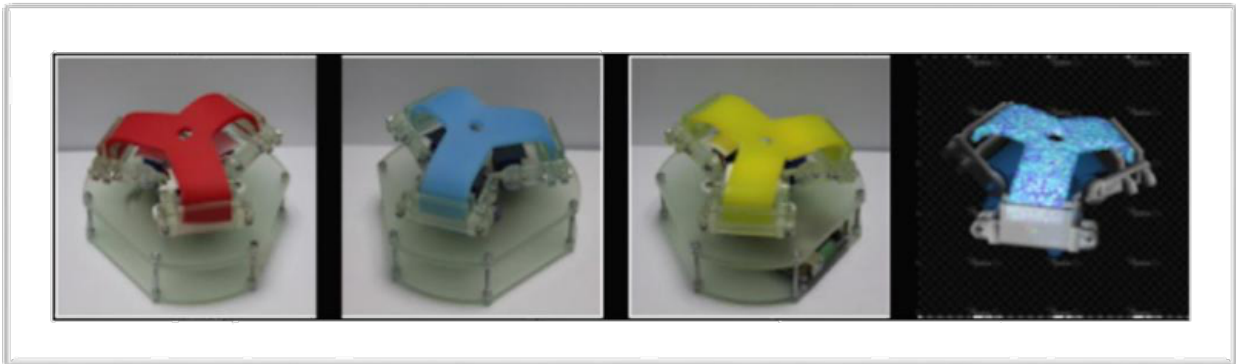


Fig. 1 The tripod soft robots used for the hands-on and numerical twin in SOFA

## DESCRIPTION

This workshop will provide a series of in-depth tutorials on how to use the open source simulation framework SOFA and the SoftRobots plugins to model, simulate and control deformable robots. At the end of the tutorial session, we expect attendees to be capable of modeling and controlling basic soft robots with SOFA including being able to precisely model contact with inverse control.

Throughout the tutorial we will alternate between the theoretical aspects of the SOFA modeling and practical, “hands-on”, sessions. During these hands-on sessions, participants will have the opportunity to practice on the “Soft Tripod”. This “tripod” is an open-hardware learning platform available on <https://handsonsoftrobotics.lille.inria.fr/> specifically designed for tutoring soft robotics.

### Session 1: Modeling of soft robot on SOFA (1h30)

In the first 30 minutes of the session we will present the SOFA community and the SOFA concepts: SceneGraph, Object, Node, Data, Mapping and ForceField. Then the attendees will have the opportunity to model a very simple scene. During this session, we will model and simulate a soft robot tripod. This tripod is an open-hardware, cheap and easy to replicate for soft robots experiments that were designed specifically as a teaching platform. It is composed of three servo motors actuating and deforming an elastic deformable part. Attendees will learn how to model and simulate this robot through the step-by-step tutorial covering: deformable mechanical modeling, constraints, coupling rigid and deformable parts and contact modeling.

**30 min:** Presentation of SOFA & general concepts (presentation)

**30 min:** Modeling with FEM, placement of the servomotors (presentation and practice)

**30 min:** Deformable-Rigid coupling (presentation and practice)

Sofa & Soft Robotics: First Steps Tutorial

### Session 2: Real-time Simulation, inverse model and control (2h)

The second session will focus on connecting the simulation to the hardware, for introducing control of physical robots. We will then present how to add an inverse model for open loop inverse control. The session will terminate on closing the loop by using ROS to get real world robot's positions from a LeapMotion tracker.

**30 min:** Constraint based modeling (presentation)

**30 min:** Contact modeling (presentation and practice)

**30 min:** Inverse Kinematic for open-loop control (practice)

**30 min:** Closed loop control and applications (practice)

Training a Neural Network for Soft-Robots control using the SOFA simulator

In the last session of the day, we'll be providing some examples of applications and use cases from the Soft-Robotics community of users and an open discussion on how participants can apply or use what they have learned in their respective projects.

**Tutorial requirements:** Binary versions of SOFA packaged with our plugins are available. Thanks to the support of the [Sofa-consortium](#), ready to install packages are available in our download [\[Page\]](#).

## TENTATIVE SCHEDULE

TIME	TALK	TOPIC
30 min	Hugo Talbot	<i>SOFA and general concepts (présentation)</i>
30 min	Christian Duriez	<i>Modeling with FEM (présentation &amp; practice)</i>
30 min	Félix Vanneste	<i>Deformable-Rigid coupling (practice)</i>
(Pause)		
30 min	Yinoussa Adagolodjo	<i>Constraint based modeling (présentation)</i>
30 min	Christian Duriez	<i>Contact modelling (présentation &amp; practice)</i>
30 min	Damien Marchal	<i>Inverse kinematics for open-loop control (practice)</i>

30 min	Damien Marchal	<i>Closed loop control and applications (practice)</i>
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## **PLAN TO SOLICIT PARTICIPATION**

This tutorial will be very interactive and will mix theoretical, implementation and experimental aspects. Our software will be distributed freely to each participant and we expect to teach enough to the participants to make them able to use the platform for their own projects. We hope that this original approach, very concrete, will gather a large participation of people among the community of soft-robotics.

This day will be advertised to the SOFA community ([www.sofa-framework.org](http://www.sofa-framework.org)) through the SOFA consortium and to the list of users that have already downloaded our plugin. For the session on applications, we will also make a call through the SOFA community of users, to solicit presentations of people that are using our tools to develop robotic and soft-robotic applications.

## **PLAN TO ENCOURAGE INTERACTION AMONG PARTICIPANTS**

Instead of doing a "static" teaching, we are working with step-by-step practical sessions where participants are actively involved, using SOFA and working on the physical robots. We provide all the material needed for the tutorials including the robots.

Our large team of organizers will help people to use the platform during the tutorial so that people will not be lost if they miss a step in the tutorial.

## **EQUIPMENT**

It would be very nice to know the number of participants 2 weeks before the tutorial, so that we can bring a good number of tripod robots.

We would like to gather participants in groups of 3-4 persons. Each group will have a robot to control and should have a table and access to 120~230V so that participants can use their laptop the whole day without problems of battery.