# Multiple Internship Offers for Research Projects related to Robotic Manipulation of Rigid and Deformable Objects through Computer vision, Computer graphics and Deep learning

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**1. Context and main aims**

Dexterous manipulation of objects is a core task in robotics. Because of the design complexity needed for robot controllers even for simple manipulation tasks for humans, *e.g.*, pouring a cup of tea, robots currently in use are **mostly limited to specific tasks within a known environment**. While humans learn their dexterity over time and manipulate objects through dynamic hand-eye coordination using visuo-tactile feedback [Johansson&Randall_Flanagan2009], most recent research work on robotic manipulation is data-driven, primarily based on visual perception, to learn a one shot manipulation model which cannot generalize when objects or environments come to change [Bohg_et_al.2014, Mousavian et al.2019]. In this research project, we aim to **investigate computer vision methods for perception and deep understanding of the scene** to enable **AI empowered general purpose flexible and adaptable robotic systems for dexterous manipulation of objects** so that grasping robots can easily adapt to complex and unknown objects in rapidly changing, dynamic and unpredictable real-world environments.

Specifically, in this research project, we aim to develop computer vision models for deep understanding of the scene, and cover objectives:

- Rigid object detection, segmentation and tracking for grasp location predictions
- Deformable object modeling for robot grasping and manipulation

Despite uncountable number of potential applications enabled by such a robotic manipulation system, we will focus our attention on three use cases that we have been implementing through 4 research projects, namely 1) bin-picking widely required in logistics and industrial assembly line, 2) waste sorting for better waste recycling and environment protection, and 3) assistance systems for "stick-to-bed" patients or elders with limited physical ability in their daily life object manipulation tasks, *e.g.*, fetching a bottle of water and pouring it into a glass. They are closely related to the ongoing research projects within the group, namely the 3-year LEARN-REAL project, the PSPC FAIR WASTES project, the CHIRON project, Aristotle project and Rhino project..

**2. Hypothesis and approach**

Regarding rigid objects, they can be of very different materials and have unknown shape and physical properties. Occlusions can also occur. Because of the general purpose nature of the targeted manipulation robot for use in unstructured environments, we aim to develop a "all-in-one" computer vision model to generalize well and can adapt quickly despite variations within a given environment, *e.g.*, lighting, object texture, shape and pose, and changes of environments, *e.g.*, background, but not at the cost of large labeled data which are not available. The starting point could be our recently proposed deep encoder and multicameral decoders [Grard et al.@IJCV2020].

As for deformable objects, the major challenge for a robot involved in object manipulation is to understand how an object deforms when it is subjected to an external force. So far, most manipulation

applications focus on rigid objects, which do not require deformation modelling. However, to manipulate deformable objects, it is absolutely essential to model their deformations, which is the goal of this project. These objects can be categorised as elastic or inelastic, volumetric or thin-shell. In our previous works [Parashar et al, CVPR2017], we have shown that deformations can be modeled with a high accuracy with local geometric properties of the objects under consideration. Such a modeling has been shown to be fast, accurate and therefore, effective for the 3D reconstruction of various deformable objects, including elastic [Parashar et al, CVPR2020] and volumetric objects [Parashar et al ICCV2015], from monocular images.

**3. Internship Projects**

**3.1 Modeling deformable objects**

In this project, we will extend the use of local geometric properties to jointly model rigid and deformable objects so that they can be easily manipulated by the robots. We consider some of the common real-life objects, available in YCB dataset. Given a robot which is equipped with multiple imaging and depth sensors, we will use these local geometric properties of deformation to predict the robot-object interaction that yields the best manipulation possible.

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**3.2 Generating 3D volumetric meshes of fruits**

In this project, our goal is to generate the 3D volumetric meshes into the partial/occluded views of a fruit to generate 3D representation of the fruit for robotic manipulation. Given that a fruit is detected through the robot's camera, we will fit a template volumetric mesh onto the fruit in order to generate its 3D representation for better grasp.

For further details, visit the description of the internship here.

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**3.3 Learning to manipulate fruits using tactile feedback**

Touch feedback is a key element for human dexterity, especially for the manipulation of delicate and deformable objects. Toward this end, high-resolution optical tactile sensors are increasingly used in robot learning environments thanks to their ability to capture large amount of data directly relating agent-environment interactions.

In this project, based on the work by Lin et al.@IROS2022, we aim to demonstrate that a simple sim-to-real approach can be used with vision-based tactile sensors to achieve strong real-world performance through three physically-interactive tasks requiring a sense of touch: object pushing, edge following, and surface following.

https://arxiv.org/abs/2207.10763
https://sites.google.com/my.bristol.ac.uk/tactilegym2

Going further, our ultimate goal is to use the robot's tactile sensors to generate feedback to accurately estimate the deformability of a fruit which may vary drastically depending on its ripening state or due

to the incurred damages due to handling. This will help the robot to improve its prediction for the best possible object manipulation that goes beyond a pre-learnt model.

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**3.4 Study of Material Point Method (MPM) simulation for robot grasping of fruits**

In this project, we will study the MPM framework to model deformable objects. Our goal is to understand whether such a formulation yields any benefits over the mesh-based framework that will rely on local geometric properties.

For further details, visit the description of the subject here.

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**3.5 Self-supervised learning all-in-one model for Object 6D pose estimation through Transformer**

In this project, we will study the accuracy of state of the art learning-based 6D pose estimation methods for manipulating objects, in particular fruits. We are focusing on the paradigm of self-supervised learning paradigm, e.g., Transformer, to develop an all-in-one model for object detection, instance segmentation and their pose estimation, for the purpose of deep scene understanding and object manipulation.

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**3.6 3D hand pose estimation and gesture recognition in cobotics**

We interact with the world using our hands to manipulate objects, machines, tools and socialize with other humans. Researchers have given much interest to develop smart representations to the human hands in order to recognize and understand their different movements.

More particularly, gesture recognition and 3D hand pose estimation are the most challenging and fast-growing research topics, which have received contiguous attention recently. In fact, they have a wide range of applications in different domains and more particularly in industrial context.

In this project, we are interested in the improvements of online hand gesture interpretation in the context of industry and more precisely in human robot interaction scenarios; either in real life or in virtual environments using 3D data acquired using depth sensors.

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**4. Advisors**

The project will be jointly supervised by :

- Prof. Liming Chen (liming.chen@ec-lyon.fr),
- Associate Prof. Emmanuel Dellandrea (emmanuel.dellandrea@ec-lyon.fr)
- Dr. Shaifali Parashar (shaifali.parashar@liris.cnrs.fr)

- Dr. Rim Salami (rsalmi@cesi.fr)
- Associate Prof. .Florence Zara (florence.zara@univ-lyon1.fr )

**5. Requirements and Application**

Interested candidates at M2 level with excellent academic records should drop an email with CV and transcript.

Requirements:

1. Strong background in computer vision, machine learning and mathematics
2. Strong programming skills in C++ and python
3. Fluency in English
4. 2 reference letters

Project duration: 6 months starting February 2023

Location: Campus Ecole Centrale de Lyon