Project Title:	Leg-based visual servoing of the MePaM	
Project Number	IMURA0508	
Monash Main Supervisor (Name, Email Id, Phone) **Monash Co-supervisor(s)** (Name, Email Id, Phone)	Dr Chao Chen, chao.chen@monash.edu	*Full name, Email*
Monash Department:	Mechanical and Aerospace Engineering	
IITB Main Supervisor (Name, Email Id, Phone) **IITB Co-supervisor(s)** (Name, Email Id, Phone)	Prof Abhishek Gupta abhi.gupta@iitb.ac.in	*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	S S Joshi	*Full name, email*
IITB Department:	Mechanical Engineering	

Research Academy Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1. **Advanced computational engineering, simulation and manufacture**
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

Most of control laws applied on actual robots are laws based on the measures obtained from the internal sensors, i.e. the actuator encoders **Error! Reference source not found.Error! Reference source not found.**. These measures are then considered as the input of the geometric, kinematic and dynamic models that are used for predicting the pose, velocity and acceleration of the end-effector in order to ensure the robot control. However, these models have inaccuracies and each encoder error is amplified via the use of these models **Error! Reference source not found.**. Moreover, for certain types of robots, such as the parallel robots, a given position of the encoders cannot ensure to know the end-effector pose because of the presence of numerous assembly modes in the robot workspace.

This is the main reason for which it is preferable, for applications requiring high-accuracy, to use external sensors that will be able to get measures as close as possible from the end-effector. Then new models for the end-effector pose, velocity and acceleration prediction must be computed in order to take into account these new measures. The efficiency of the use of external measures for the modeling, identification and control of certain parallel robots family has already been demonstrated for kinematics **Error! Reference source not found.Error! Reference source not found.** and dynamics **Error! Reference source not found.Error! Reference source not found.**.

Vision is a good approach for estimating the end-effector pose: the most common approach consists of the direct observation of the end-effector pose, but in some cases it may be impossible or difficult (e.g. in the case of a haptic

device where the user could prevent the observability of the end-effector). A good alternative for parallel robots is to observe the robot legs, which are usually designed with slim and rectilinear rods and can be modeled as cylinders. In this case, the result of the observation becomes a direct measure of an internal property, i.e. the kinematic configuration of the robot. Moreover, as the information is acquired through an external sensor, this technique allows estimating indirectly the pose of the end-effector from it which is an external property.

This method has been applied in [4], where a visual servoing scheme was derived by observing the legs of a Gough-Stewart parallel robot: the visual primitives were represented by the leg directions and the end-effector pose estimation was obtained from their reconstruction from the image. The same method was then applied to the Adept Quattro and other robots of the same family.

However, it was proven later that the approach proposed in [4] cannot be applied to any type of robot family: it was shown in [8] that it was not possible to estimate the pose of some particular families of parallel robots. This is the case of the MePaM, a haptic device made of a parallel robot architecture which has been developed at Monash university, for which the vision-based control scheme [4] cannot be used for controlling and estimating the end-effector pose.

References
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[7]   E. Ozgur, N. Andreff, P. Martinet, "Dynamic Control of the Quattro Robot by the Leg Edgels ", IEEE International Conference on Robotics and Automation, ICRA11, Shanghai, China, May 9-13th, 2011.
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Project aims

The first aim of the research project is to define a vision-based controller able to control the platform pose of the MePaM, not by the direct observation of the end-effector configuration, but of the robot legs. The second aim of this project is to obtain the dynamic parameters of the system by calibration. This work will utilize the developed dynamics model of the system and obtain the best estimate based on experiments.

In order to overcome the difficulties of the past controllers, we will show that more information than the leg direction is included in the image space, but also that we can get the position of the lines passing through the links attached to the moving platform. From this information, we will be able to estimate the platform pose and control it. However, the model involved to estimate the platform pose from the line space is not free of singularity. As a result, the singularity analysis of the new model must be studied in order to avoid issues of pose estimation accuracy near the singularity loci.

Several approaches for estimating the pose from the lines passing through the legs will be tested:
- Estimation based on a geometric model linking the leg space to the platform pose space
- Virtual visual servoing approaches
- Trying to find other relevant information to add in the controller in order to increase the estimation quality
- etc

Expected outcomes

One conference paper is expected every year during this program. At least two journal papers are expected for the entire program.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

This project is within the theme of "Advanced computational engineering, simulation and manufacture". Parallel manipulators have wide applications in manufacture, automation, robotics, and haptic virtual environment. The proposed project will enhance the motion/force control of general parallel manipulators and lead to more accurate manufacturing, material handling, and industrial automation.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

The student must have solid background in engineering/applied mathematics, programming, and mechanics. Skills on hand-on experiments are required.

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

Other collaborators:

Dr Briot Sebastien, Institut de Recherches en Communications et Cybernétique de Nantes (IRCCyN), France, is a cosupervisor.

Please provide a few key words relating to this project to make it easier for the students to apply.

Parallel manipulator, vision-based control, dynamics calibration, haptics.