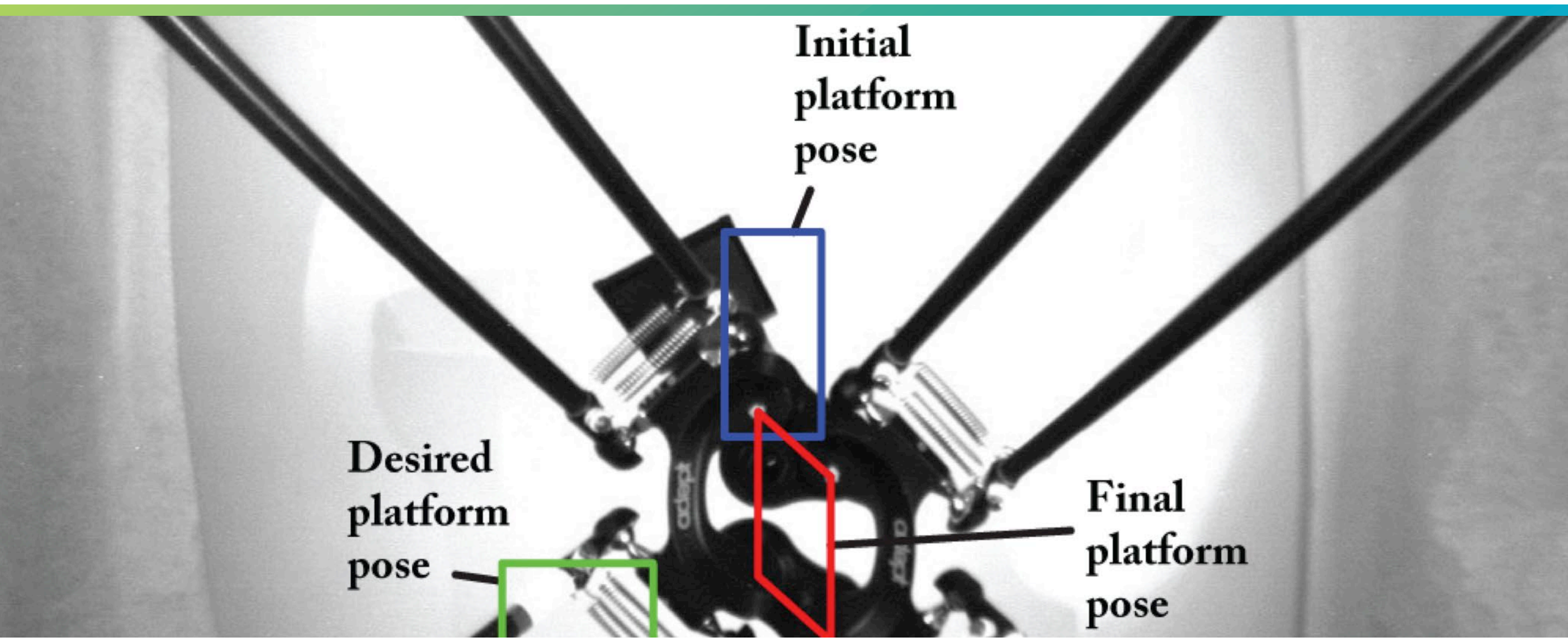
IRCCyN

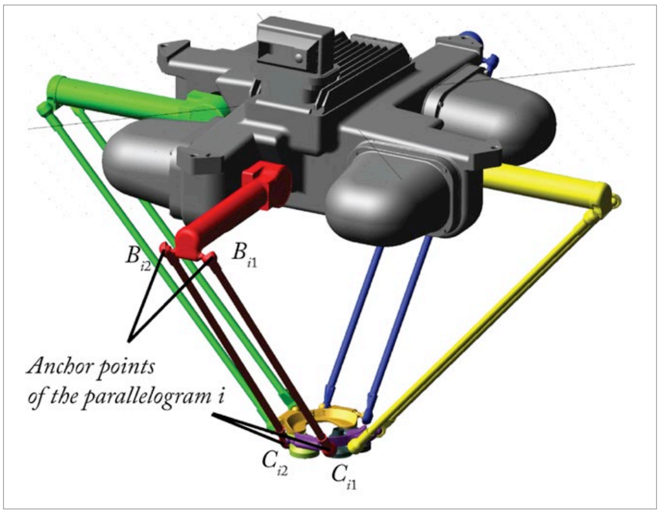
Adams simulation helps validate a concept called the “hidden robot model” to improve visual serving accuracy



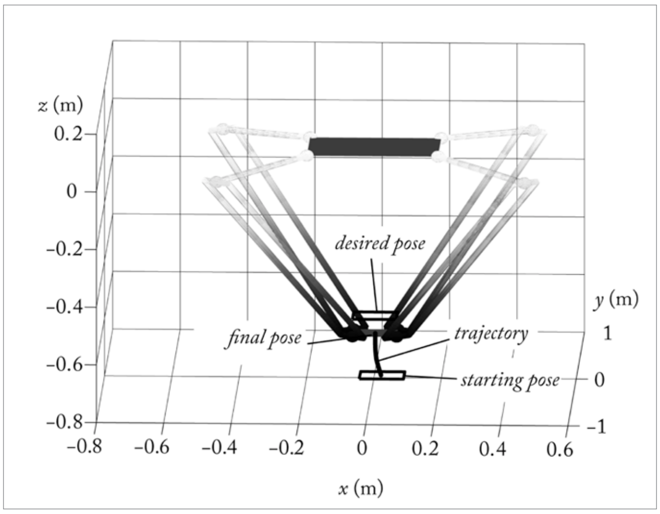
Introduction

The vast majority of robots are controlled through the use of encoders that measure joint rotation. But even when encoders with very high levels of accuracy are used, the ability of robots to move to an absolute XYZ position and ABC orientation is limited by deflection, thermal expansion and manufacturing variation.

Some applications, such as placement of a disk drive read head, require very higher levels of positioning accuracy that can only be achieved with a very expensive, special purpose robot. This challenge is being addressed with visual servoing technology that uses a vision system to acquire an image that determines the relative positions of the robot end-effector and the target. The robot controller generates a motion command to move the end-effector towards the target. The vision system acquires new images and the robot controller updates its motion command accordingly. This process is repeated until the vision system determines that the robot end-effector has reached the prescribed position. Visual servoing can achieve placement accuracies of just a few microns without requiring a very expensive robot.



Adams model of a parallel robot (Adept Quattro)



Adams simulation predicted that parallel robot was not able to reach the desired position and orientation

Complications arise in applications where it is not possible for the vision system to be placed on the end-effector nor to acquire an image of the end-effector. For example, the end-effector of a metal-cutting tool is often buried in the workpiece and may be further obscured by chips and coolant. In applications like this an alternate approach is to acquire an image of the legs of the robot and use them to control the end-effector position. IRCCyN researchers developed a visual servoing system to control a parallel robot based on observation of the legs of a parallel robot.

A parallel robot is made of several legs assembled in parallel and connecting the robot base to the end-effector and it uses several linear or revolute actuators each of whose position is independent of the others to support the end-effector. In contrast, serial robots are designed with a series of links connected by motor actuated joints. The approach was applied to several types of parallel robots, such as the Adept Quattro and other robots of the same family.

Challenge

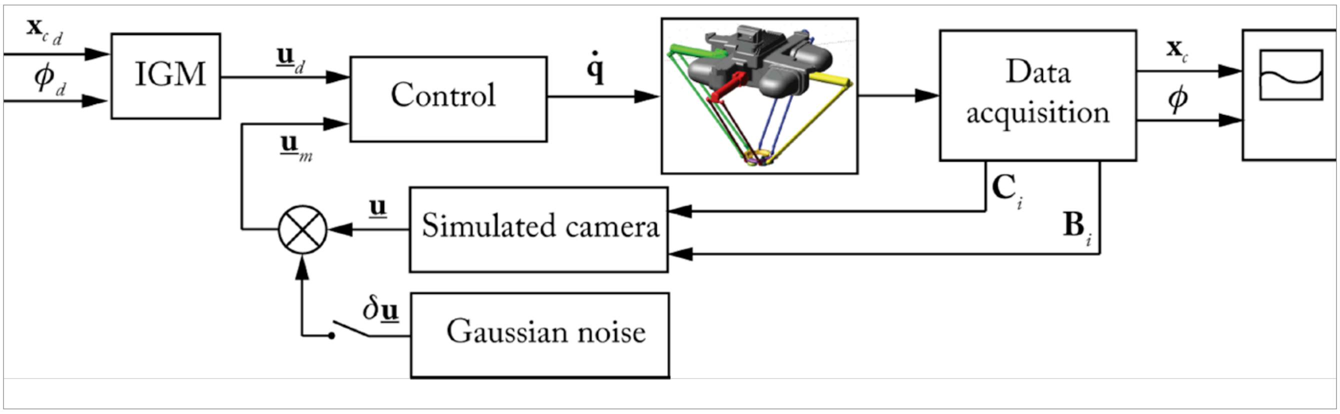
But in some cases when the legs of the robot were moved as planned the end-effector did not end up in the expected position. It was clear that this behavior arose from the mapping between the observations of the vision system and the real world but at this time the nature of the mapping was not understood and there were no tools available to analyze the correlation. IRCCyN researchers discovered that this problem could be explained by the fact that visual servoing based on the leg observation was equivalent to controlling another robot hidden in the controller with assembly modes and singular configurations different from those of the actual robot.

The hidden robot is a virtual robot whose kinematics represents the mapping between the leg direction space and the end-effector position and orientation space. The researchers demonstrated using robot theory that the concept of the hidden robot model fully explains the possible nonconvergence of the observed robot to the desired final position and orientation. IRCCyN researchers decided to attempt to determine a general method to define the hidden robot model for any type of parallel robot controlled by visual servoing based on the observation of the legs. These investigations were based on theoretical calculations, but they also needed to validate their theoretical results.

Solution

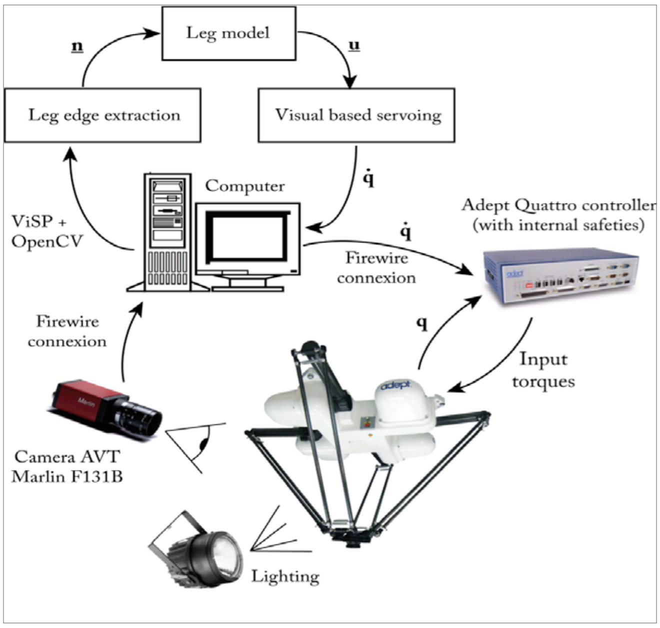
“Adams simulation of the parallel robot integrated with a Simulink model of the robot controller provided the ideal platform to validate our theoretical work,” said Sébastien Briot, Researcher at IRCCyN. In a recent example, IRCCyN researchers used theory to define the hidden robot model in the robot controller based on three different control schemes. In case 1, the robot was controlled based only the observation of its leg directions. In case 2, the robot controller also incorporated partial observations of the direction and location in space of lines passing through the axes of the cylinders driving the robot. Finally, in case 3, researchers further added full observations of the direction and location in space of a line passing through the robot’s legs.

Key highlights:
Product: Adams
Industry: Scientific Research
Benefits:
Adams simulation accurately predicted position and orientation of the robot.
Simulation played an important role in validating the theoretical work
Complex equations are no longer needed to predict the dynamics of parallel robots



Adams and Simulink co-simulation of the visual servoing of a parallel robot

The initial configuration of the robot end-effector was z0 = 0.20 m, 0 = -0.90º, and o0 = -0.10º. The goal was to reach the end-effector configuration of zf =0.40 m, øf = -0.90º, and øf = +0.10º. The three controllers described above -- cases 1, 2, and 3 – were integrated with the Adams model and used to simulate the robot behavior over one second of model time. With the case 1 controller based on leg directions only, the robot was not able to attain the final end-effector configuration. With the controller of case 2 based on the leg directions plus the coordinates of the leg cylinders, the robot reached the final end-effector position but not the correct orientation. Finally, with the case 3 controller which includes the leg directions and the coordinates of the legs themselves, the robot achieved the correct position and orientation of the end-effector. IRCCyN researchers also performed physical experiments that correlated well with the simulation results.



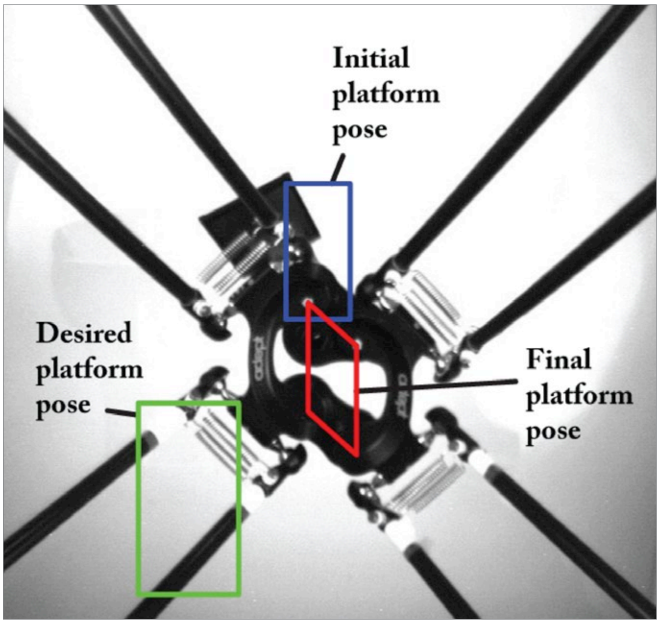
Experimental setup used to validate the Adams-Simulink co-simulation

Results/benefits

"The concept of the hidden robot model is a powerful tool able to analyze the intrinsic properties of some controllers developed by the visual servoing community," Sébastien Briot concluded. "Adams simulations have played an important role in validating our theoretical work on hidden robot models. The integration of Adams with Simulink through Adams/Controls eliminated the need for us to write complex equations for predicting the dynamics of parallel robots and also provided graphical results that gave us a better understanding of robot behavior."

About IRCCyN

The Research Institute in Communications and Cybernetic of Nantes (IRCCyN) is a scientific institution linked to the French National Centre for Scientific Research (CNRS). Its purpose is to innovate in several fields, among which robotics, automatic control, production theory and image processing.



Results of experiment validated Adams simulation

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