

Control of nonholonomic mobile manipulators

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http://www-sop.inria.fr/icare/robea/index_robea.html

A (rough) classification of robotic mechanisms

n_{conf} : dimension of the robot's configuration space

n_{dof} : number of degrees of freedom of the robot

n_{dom} : number of degrees of mobility of the end-effector

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$n_{conf} = n_{dof} \implies$ holonomic mechanism

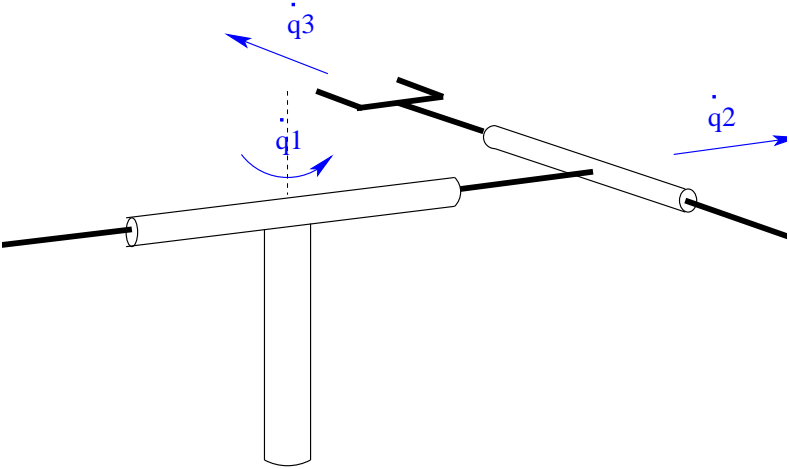
$n_{conf} > n_{dof} \implies$ nonholonomic

$n_{dof} = n_{dom} \implies$ non-redundant mechanism

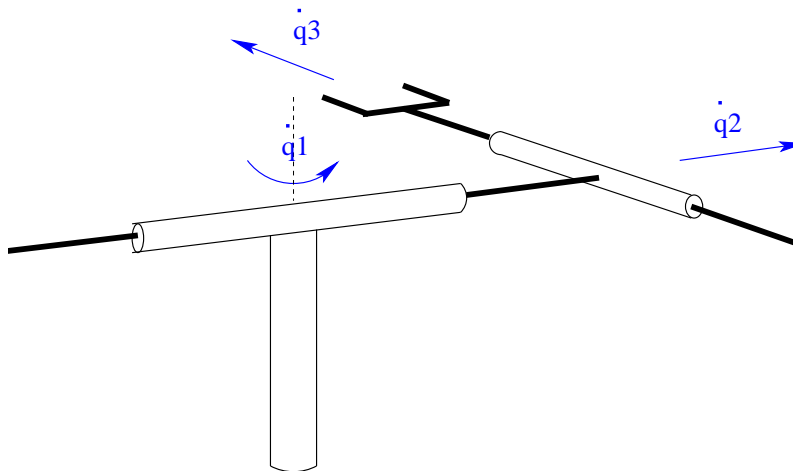
$n_{dof} > n_{dom} \implies$ redundant



Example 1 : manipulator arm



Example 1 : manipulator arm



$$n_{conf} = 3$$

$$n_{dof} = 3$$

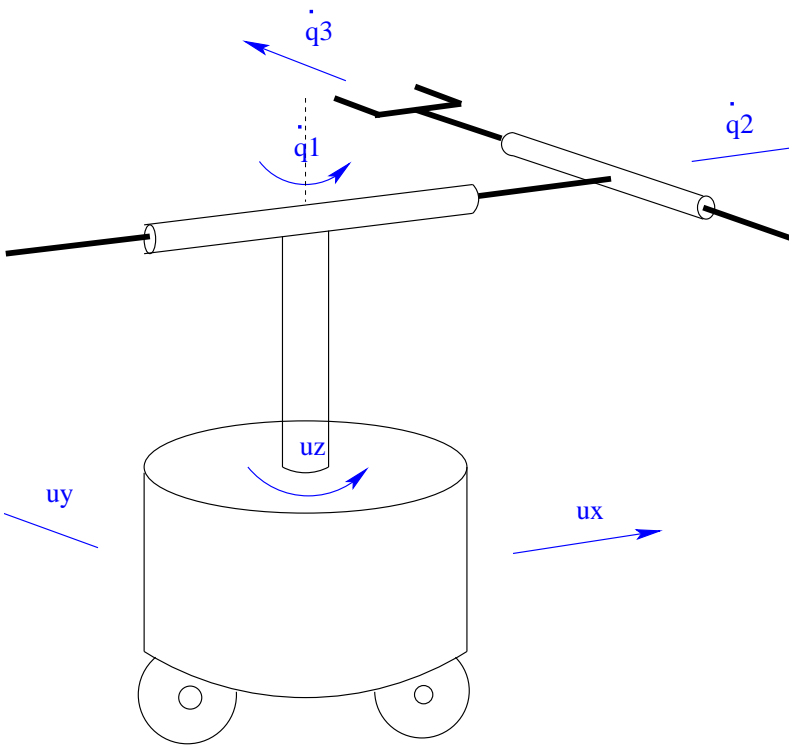
$$n_{dom} = 3$$

$$n_{conf} = n_{dof} = n_{dom}$$

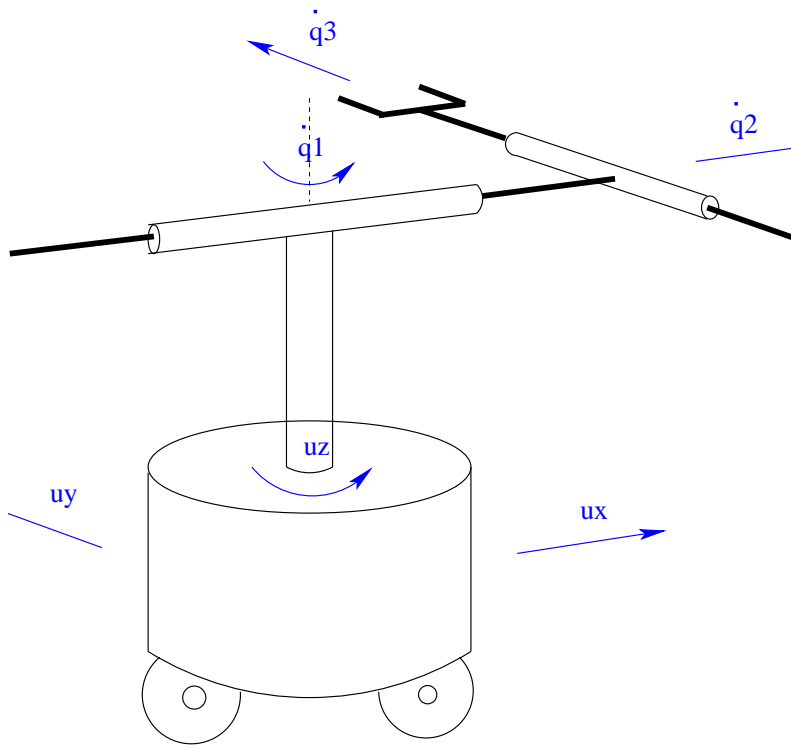


holonomic and not-redundant
(the classical case)

Example 2 : holonomic mobile manipulator



Example 2 : holonomic mobile manipulator



$$n_{conf} = 6$$

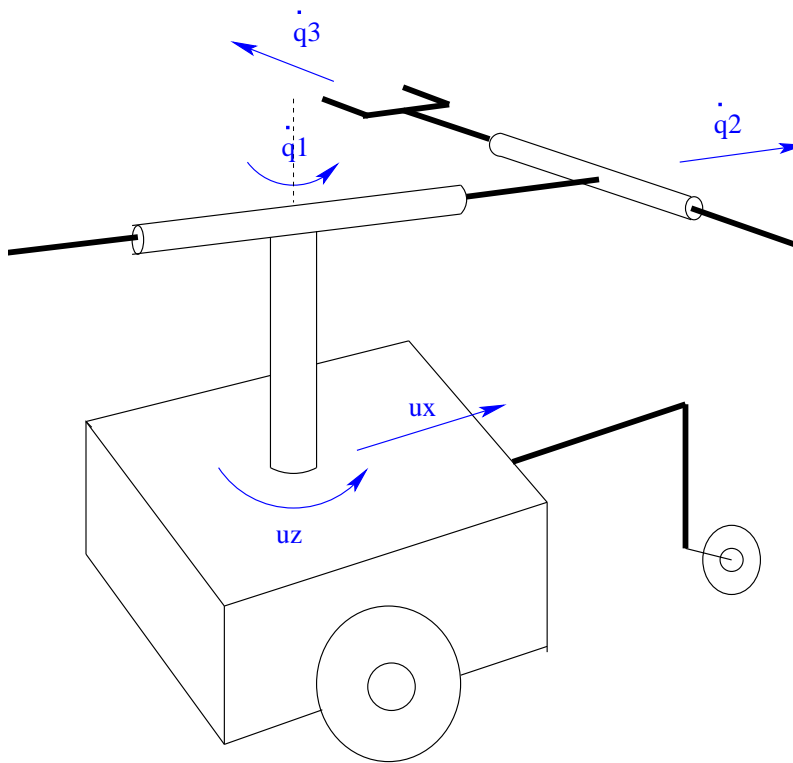
$$n_{dof} = 6$$

$$n_{dom} = 3$$

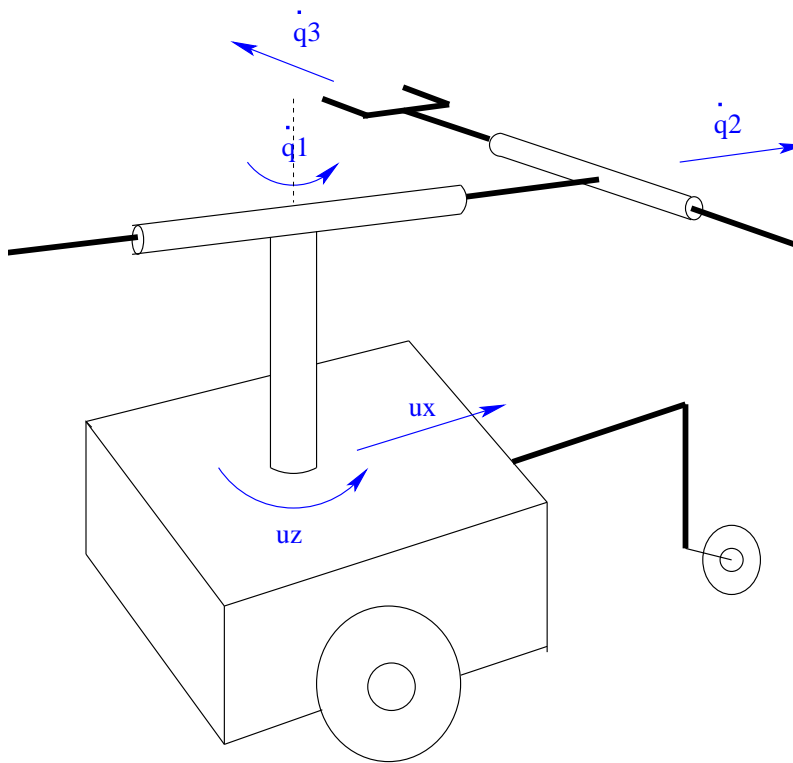
$$n_{conf} = n_{dof} \Rightarrow \text{holonomic}$$

$$n_{dof} > n_{dom} \Rightarrow \text{redundant}$$

Example 3 : nonholonomic mobile manipulator



Example 3 : nonholonomic mobile manipulator



$$n_{conf} = 6$$

$$n_{dof} = 5$$

$$n_{dom} = 3$$

$n_{conf} > n_{dof} \Rightarrow$ nonholonomic

$n_{dof} > n_{dom} \Rightarrow$ redundant

Outline of the research program (1)

Control theory/methodology

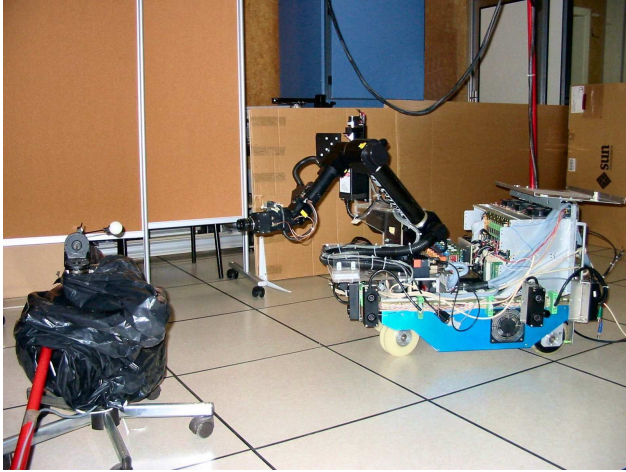
- **Redundancy** : adaptation/extension of solutions for robotic arms
- **Nonholonomy** : adaptation/extension of solutions for nonlinear driftless systems applied to nonholonomic wheeled mobile robots
- **Redundancy + nonholonomy** : mixing of abovementioned solutions into a coherent approach encompassing both holonomic and nonholonomic cases

Outline of the research program (2)

Experimentation/validation on physical benchmarks

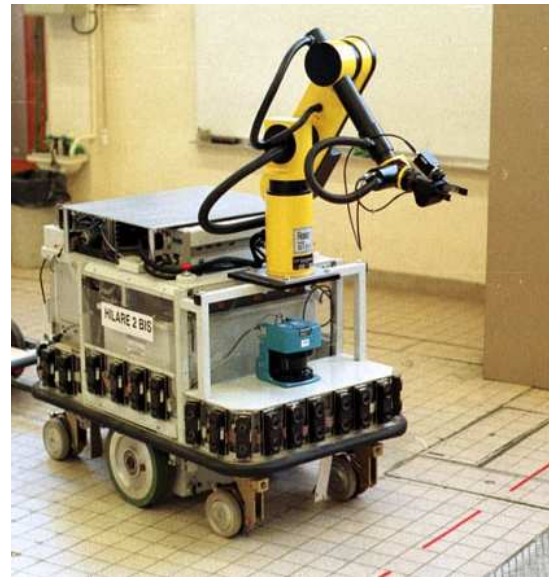
- *ANIS* at INRIA Sophia-Antipolis : 6 d.o.f. arm mounted on a unicycle type vehicle + video camera on the end-effector
- *H2bis + GT6A* at the LAAS : 6 d.o.f. arm mounted on a unicycle type vehicle + force sensor on the end-effector

Experimental platforms



Anis (INRIA Sophia-Antipolis)

H2bis + GT6A (LAAS)



Work during first-8-months period (1)

Project meetings (all partners, technical presentations, discussions,...)

- January 30, INRIA Sophia-Antipolis : Launch meeting
- May 30, LAAS Toulouse
- October 8, ENI Tarbes

Work during first-8-months' period (2)

Two PhD thesis initiated

- At ENI, Tarbes
 - Student's name: V. Padois (graduated from ENI)
 - Thesis title: *“Enchaînement de tâches pour manipulateurs mobiles”*

- At INRIA Sophia-Antipolis
 - Student's name: M. Fruchard (graduated from Ecole Centrale de Lille)
 - Thesis title: *“Commande de manipulateurs mobiles”*

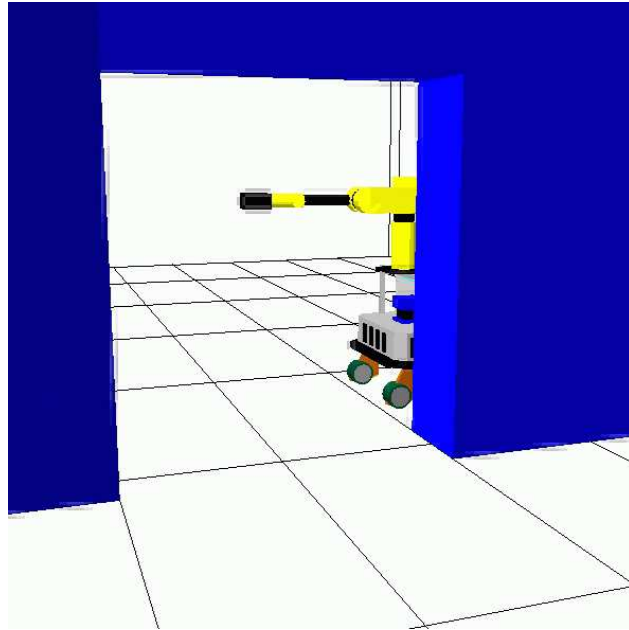
Work during first-8-months' period (3)

Research progress

● LAAS-LGP

- Modeling and control of nonholonomic wheeled mobile manipulators (B. Bayle, J.-Y. Fourquet, F. Lamiraux, M. Renaud)
- Description/classification of the geometry and kinematics of mobile manipulators via a set of *characteristic parameters*.
- Extension of the concepts of redundancy and manipulability to nonholonomic manipulators.
- Control design, in the case where end-effector's motion is pre-determined, based on the *method of constraints*.
Experimentation on *H2bis+GT6A*.

Trajectory shaping and obstacle avoidance



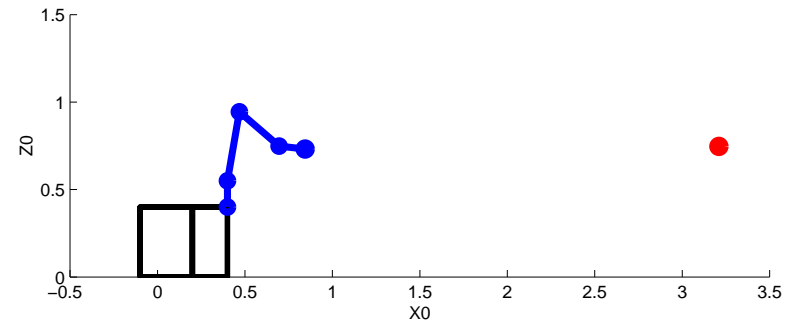
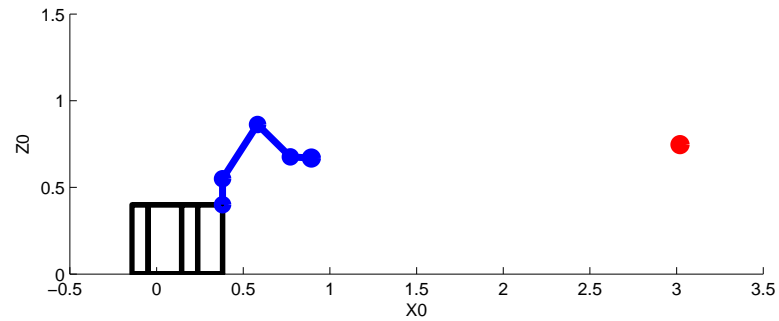
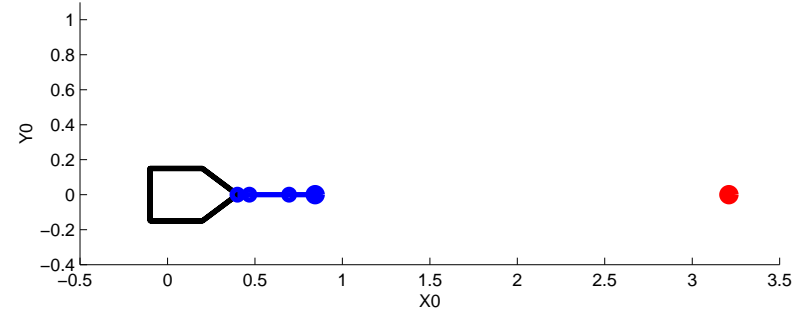
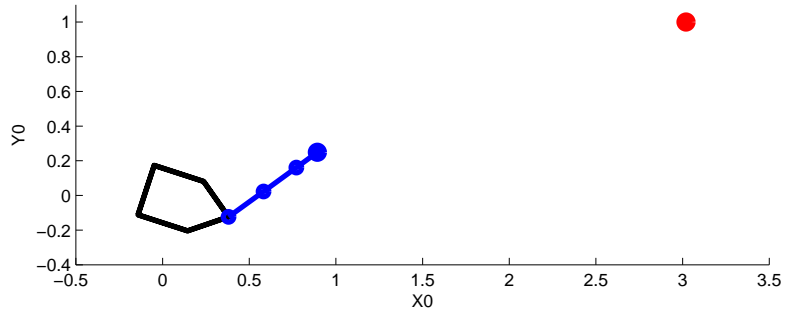
Passing a door

Work during first-8-months' period (4)

Research progress

- INRIA Sophia-Antipolis
 - Sensor-based control of redundant holonomic mobile manipulators : control design principles and validation in simulation (M. Fruchard)
 - Vision-based target tracking by a nonholonomic vehicle : focus on estimation/filtering problems, experimentation on *ANIS* of the *transverse function (TF) control approach* (G. Artus, PhD student)
 - New developments of the TF approach for *asymptotic* stabilization of reference trajectories (P. Morin, C. Samson)

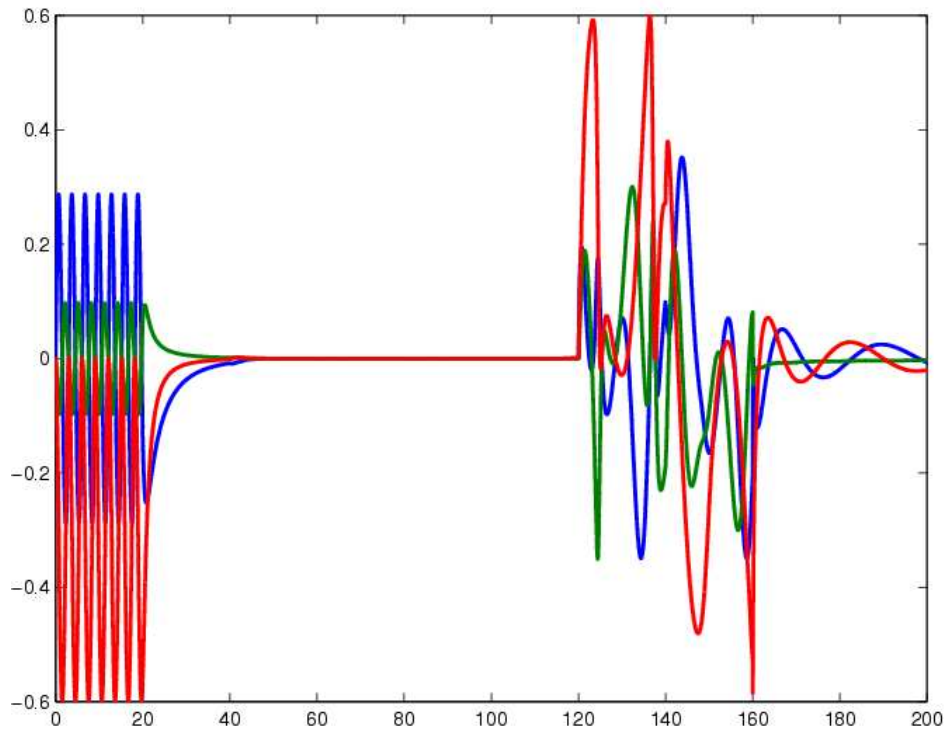
Target tracking for a redundant holonomic mobile robot



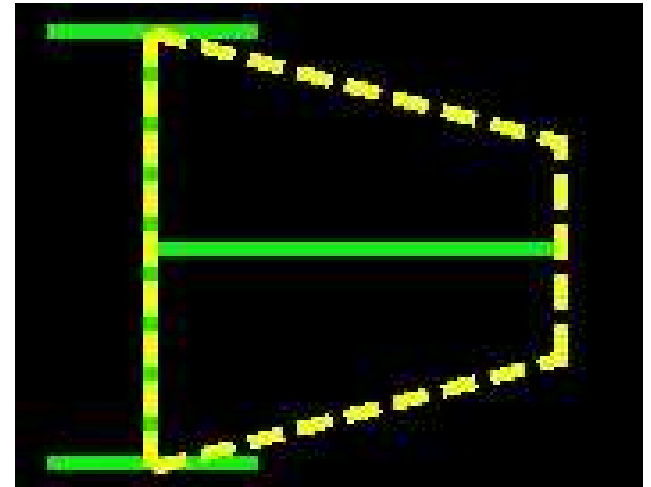
Fixed target, large initial errors

Mobile target, large initial errors

Tracking of a reference vehicle with a TF feedback control



Evolution of x , y , and θ vs. time





Initial position/orientation

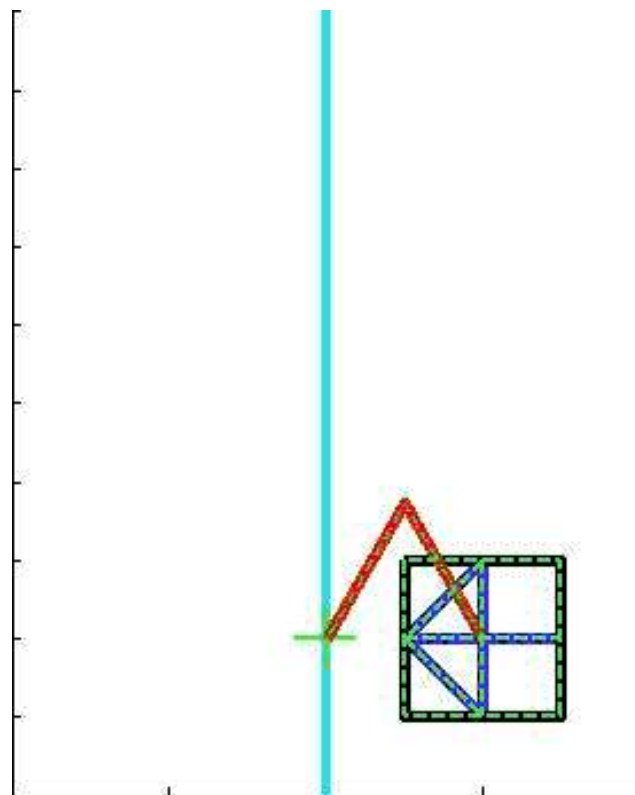
Work during first-8-months' period (5)

Research progress

LGP

-  Contact-force-based control of nonholonomic mobile manipulators : bibliographical work, modeling, and testing in simulation. Apprenticeship of hardware and software available at the LAAS (V. Padois)
-  First applications and simulations of the TF control approach : a two-stage strategy based on motion control of the mobile platform alone (using TFs) complemented with classical control of the arm's end-effector and pre-compensation of the vehicle's motion (A. Carriay)

Application of the TF approach to mobile manipulation



Wall painting