# Simulation of Mars Rover on granular soil

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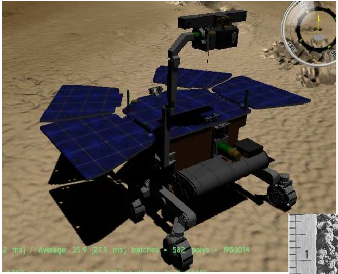
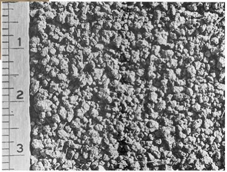
# Outline

1. Motivation and Objective
   - Background
   - Objective
2. Dynamical system and contact model
   - Dynamical system
   - Contact Model
3. Numerical Example
   - Rover with disks in 2D
   - Rover3D with plane contact

# Outline

# Mars Rover and Granular Soil






- Part of ESA Mars exploration plan

# Mars Rover and Granular Soil

## Features

### Mars Rover

- A 6 wheel robotic mission to Mars
- With 21 DOF

### Granular Soil

- Comprised of small particles
- Solid and no viscosity in general.
- Could be treated as small solid balls

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# Platform Siconos and HuMAns Toolboxs

## Siconos

- Siconos is a free software, dedicated to modeling, simulation and control of Non Smooth Dynamical Systems.
- Rover is a mechanical systems with contact, impact and friction that is a kind of NSDS.

## HuMAns Toolbox

- HuMAns was originally developed for the modeling, the control and the analysis of humanoid motion, being that of a robot or a human.
- Dynamical system of rover could be modeled by HuMAns.
- Contact models for rover with granular soils need to be developed.

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# Objective

- Create dynamical system for rover
- Develop more complex contact model for HuMAns toolbox
- Code in C++ for simulation of rover on granular soils
- Develop code for VRML visualization

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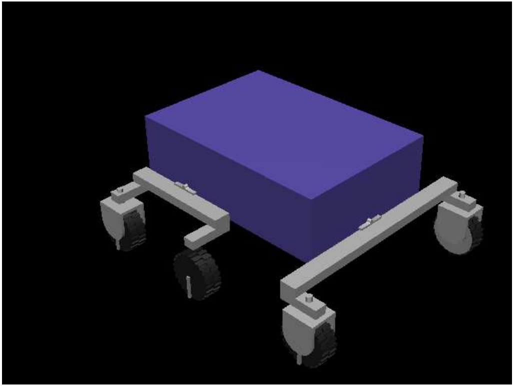
# Dynamical system
## Geometry



# Dynamical system

## Equations

A typical dynamic modelisation of a free system can be set in the form:

$$M(q,z)\ddot{q} + NNL(\dot{q},q,z) + F_{Int}(\dot{q},q,t,z) = F_{Ext}(t,z) + p \quad (1)$$

# Dynamical system

## Modeling structure

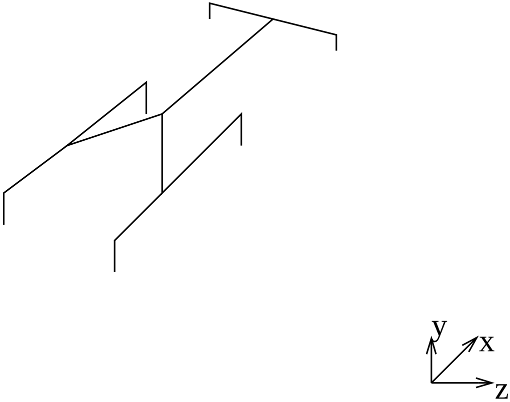
**Input for HuMAns**

- **KinematicData.maple**
- **DynamicData.maple**
- **AdditionnalData.maple**
- **ModelGeneration.maple**

**Output**

- **Tags.c**
- **Inertia.c**
- **NLEffects.c**
- **JacobianQNLEffects.c**
- **JacobianVNLEffects.c**

# Dynamical system
## KinematicData



# Dynamical system

## KinematicData

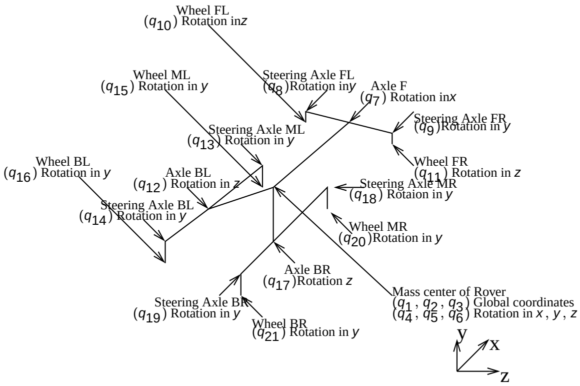



Figure: Articular notations of Rover

# Dynamical system

## DynamicData and AdditionnalData

### DynamicData

Inertial parameters were defined in DynamicData.maple

- The vector Gravity
- The segment masses
- The positions the segment centers of mass in the frame
- The inertia matrix relative to the center of the frame

### AdditionnalData

- Tags are some characteristic points on the model
- They are specified in **AdditionnalData.maple**
    - number of the segment it is attached to
    - position in the frame

# Outline

# Contact Model

In order to import contact model into Siconos, we need two plugin functions

- $h$ function to compute the distance between contact points
- $G$ is the transformation matrix of velocity of contact points from the global frame to the local frame

# Contact Model
## Wheel Plane Contact

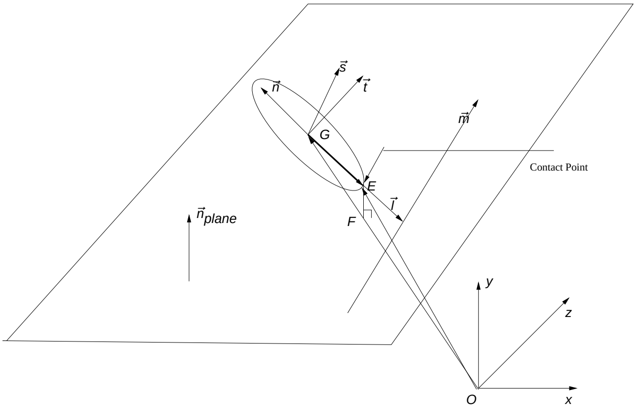



Figure: Wheel/Plane Contact

# Contact Model

## Wheel Sphere Contact

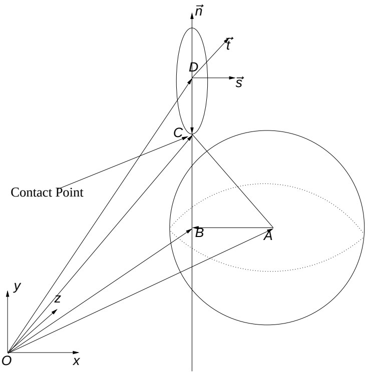



Figure: Wheel/Sphere Contact

# PID controller

## Equations

A PID controller is used for the steering system of the rover. A typical PID control scheme could be write in the form

$$MV(t) = P_{out} + I_{out} + D_{out} \tag{2}$$

## Application in our model

To simplify the model, we do not imply integral term in our case.

$$P_{out} = K_p(q(i) - q_0(i)) \tag{3}$$
$$D_{out} = K_d(v(i) - v_0(i)) \tag{4}$$

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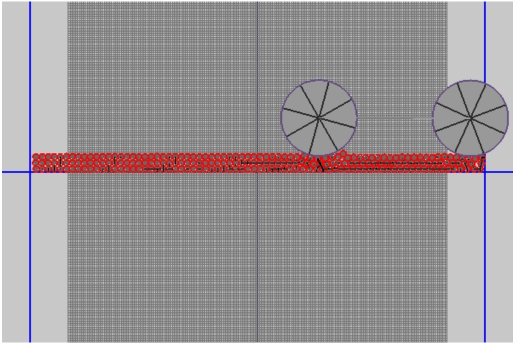
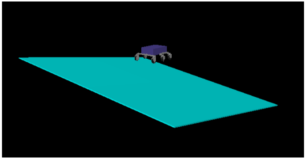
# Rover with disks in 2D



# Outline

# Rover3D with plane contact

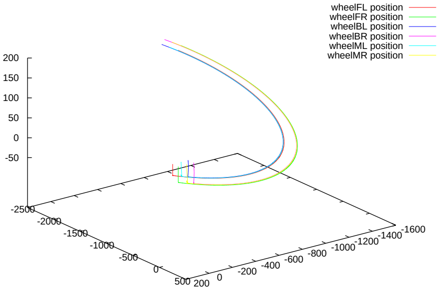


## Initial Value

- Total mass 90 KG
- Coefficient of friction 0.7
- Coefficient of restitution 0.3

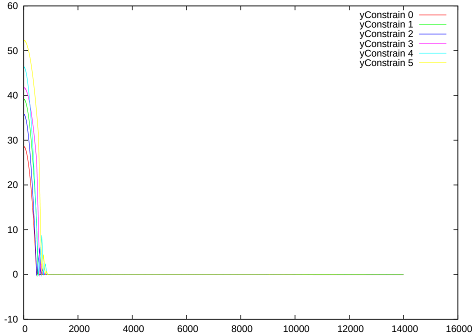
# Rover3D with plane contact

## Result Wheel Track



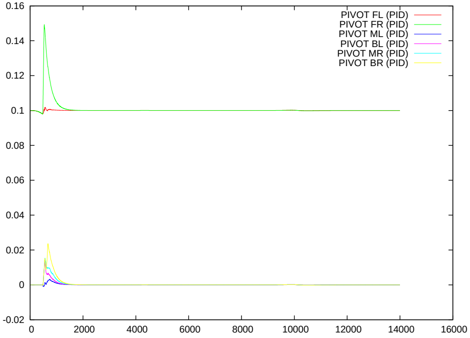
# Rover3D with plane contact

## Result Contact distance



# Rover3D with plane contact

## Result PID controller



# Rover3D with Spheres