

$$\left(-P_x S_{23} - H x_{23} \right)^2 + \left(2 \left(-P_x^2 - H^2 \right) - \left(x_{34}^2 - P_x^2 - H^2 - x_{23}^2 - S_{23}^2 \right) \right)^2 \geq 0$$

$$4 \left(P_x^2 S_{23}^2 + H^2 x_{23}^2 - 2 P_x H S_{23} x_{23} \right)$$

$$+ 4 \left(P_x^2 x_{23}^2 + H^2 S_{23}^2 + 2 P_x H S_{23} x_{23} \right)$$

$$- \left(x_{34}^4 + P_x^4 + H^4 + x_{13}^4 + S_{23}^4 - 2 P_x^2 x_{34}^2 - 2 H^2 x_{34}^2 - 2 x_{23}^2 x_{34}^2 - 2 S_{23}^2 x_{34}^2 \right. \\ \left. + 2 P_x^2 H^2 + 2 P_x^2 x_{23}^2 + 2 P_x^2 S_{23}^2 + 2 H^2 x_{23}^2 + 2 H^2 S_{23}^2 + 2 x_{23}^2 S_{23}^2 \right) \geq 0$$

$$4 P_x^2 \left(S_{23}^2 + x_{23}^2 \right) + 4 H^2 \left(S_{23}^2 + x_{23}^2 \right) - \left[x_{34}^4 + P_x^4 + H^4 + x_{13}^4 + S_{23}^4 - 2 P_x^2 x_{34}^2 - 2 H^2 x_{34}^2 - 2 x_{23}^2 x_{34}^2 - 2 S_{23}^2 x_{34}^2 \right. \\ \left. + 2 P_x^2 H^2 + 2 P_x^2 x_{23}^2 + 2 P_x^2 S_{23}^2 + 2 H^2 x_{23}^2 + 2 H^2 S_{23}^2 + 2 x_{23}^2 S_{23}^2 \right] \geq 0$$

$$2 P_x^2 \left(S_{23}^2 + x_{23}^2 \right) + 2 H^2 \left(S_{23}^2 + x_{23}^2 \right) - \left[\left(x_{34}^4 + P_x^4 + H^4 + x_{13}^4 + S_{23}^4 - 2 P_x^2 x_{34}^2 - 2 H^2 x_{34}^2 - 2 x_{23}^2 x_{34}^2 - 2 S_{23}^2 x_{34}^2 \right. \right.$$

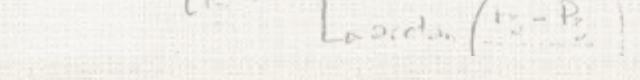
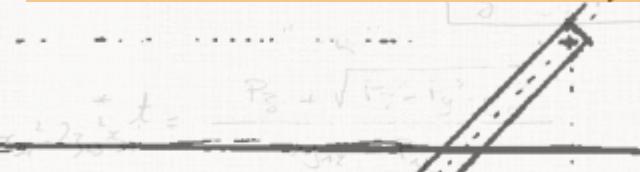
$$\left. \left. + 2 P_x^2 H^2 + 2 P_x^2 x_{23}^2 - 2 H^2 x_{23}^2 + 2 x_{23}^2 S_{23}^2 \right) \right] \geq 0$$

$$- \left(\left[-x_{34}^2 + P_x^2 + H^2 - x_{23}^2 - S_{23}^2 \right]^2 - 4 x_{23}^2 \right) \geq 0$$

$$- \left(-a + b + c - d \cdot e \right)^2 - 4ad - 4ae \geq 0$$

L'effectuer, dans le repère ci-dessus, n'appartient pas au
 x_{23}) et de rayon $\approx x_{34}$.

MPC TRICOOL GÉNÉRATRICE
: FACILEMENT DÉJURE DE CONTRA



$$\begin{cases} S_{34} = N_{2-3} & N_x = -S_{2-3} \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$

$$\begin{cases} S_{34} = 0 & N_x = 0 \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$

$$\begin{cases} S_{34} = 0 & N_x = 0 \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$

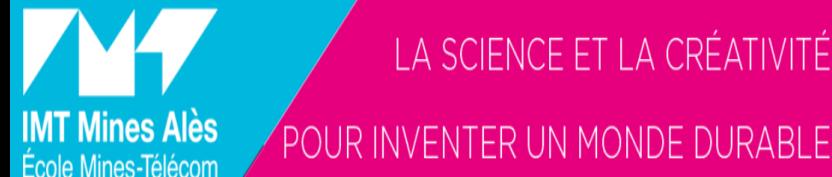
$$\begin{cases} S_{34} = 0 & N_x = 0 \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$

$$\begin{cases} S_{34} = 0 & N_x = 0 \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$

$$\begin{cases} S_{34} = 0 & N_x = 0 \\ c_1 S_y + s_1 S_z = 0 & c_1 N_y + s_1 N_z = 0 \\ -s_1 S_y + c_1 S_z = S_{2-3} & -s_1 N_y + c_1 N_z = 0 \\ 0 = 0 & c_1 A_y + s_1 A_z = c_2 \\ 0 = 0 & 0 = 0 \end{cases}$$



SOMMAIRE



1

- RAPPEL DU CAHIER DES CHARGES
- NOTRE SOLUTION
- ORGANIGRAMME

2

- MÉCANIQUE
- ÉLECTRONIQUE
- LOGICIEL

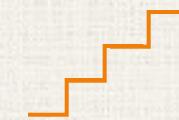
3

- SIMULATION
- CAS D'USAGES

RAPPEL DU CAHIER DES CHARGES



Franchir un palier de 30 cm



Franchir une configuration escalier

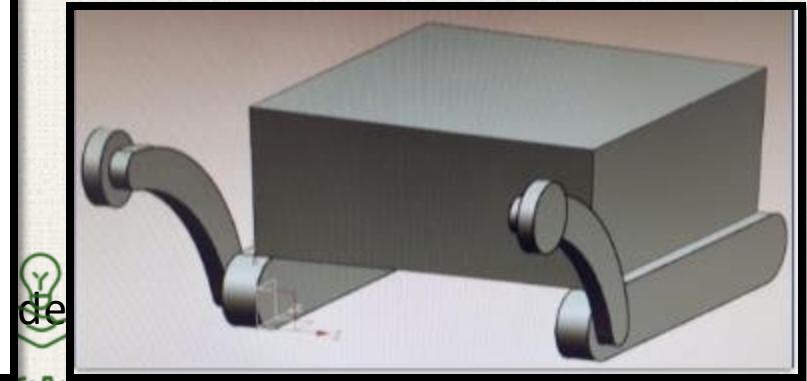
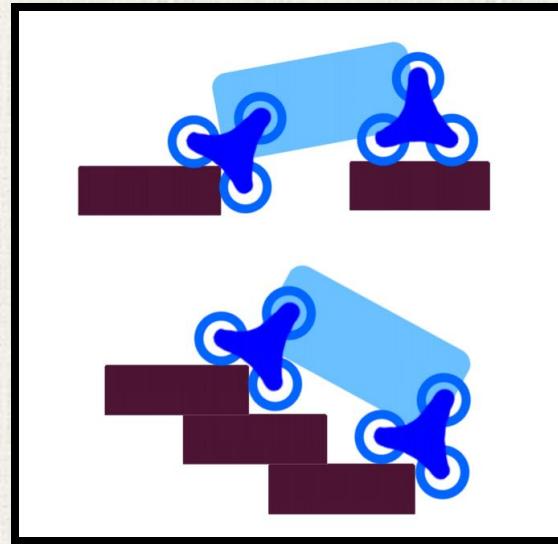
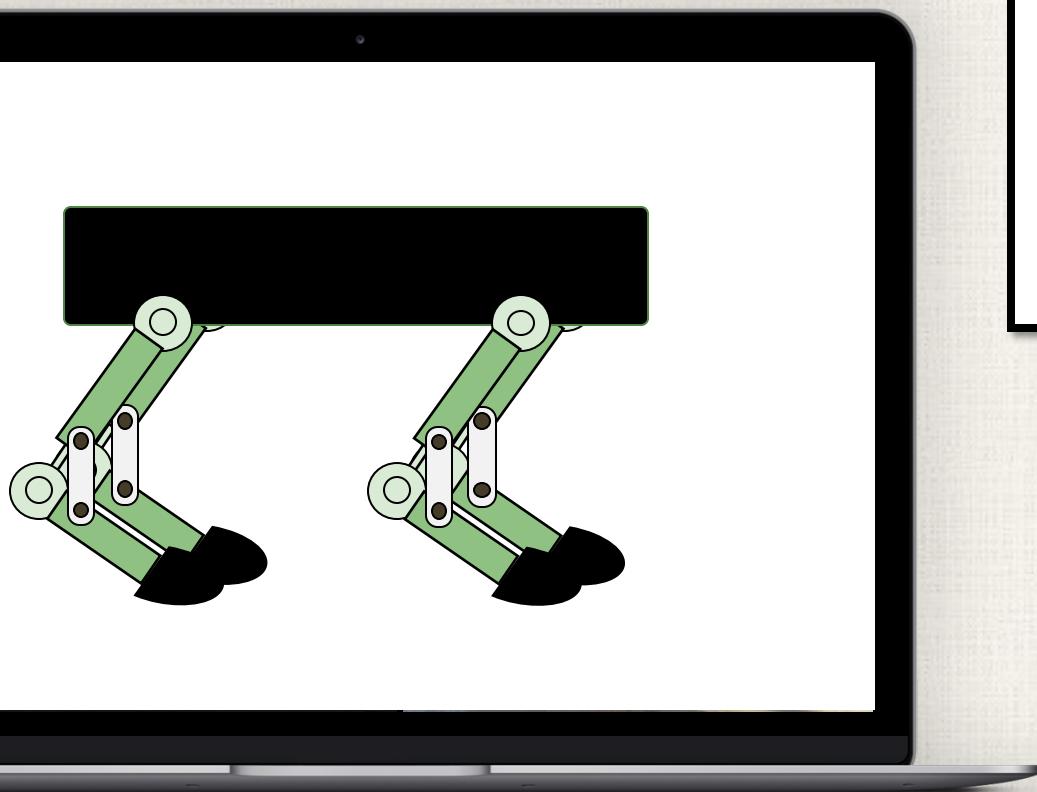


Franchir une fosse de 30cm

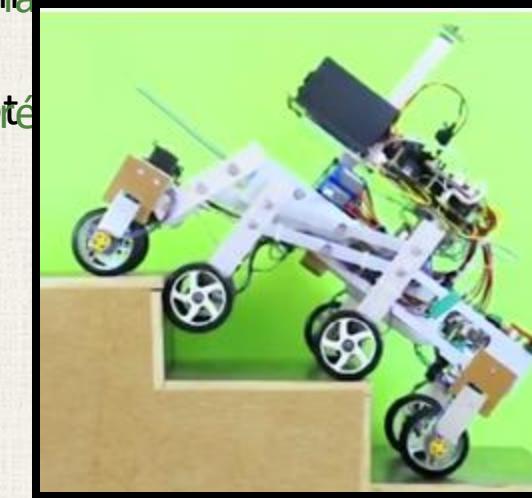


Discontinuité du terrain

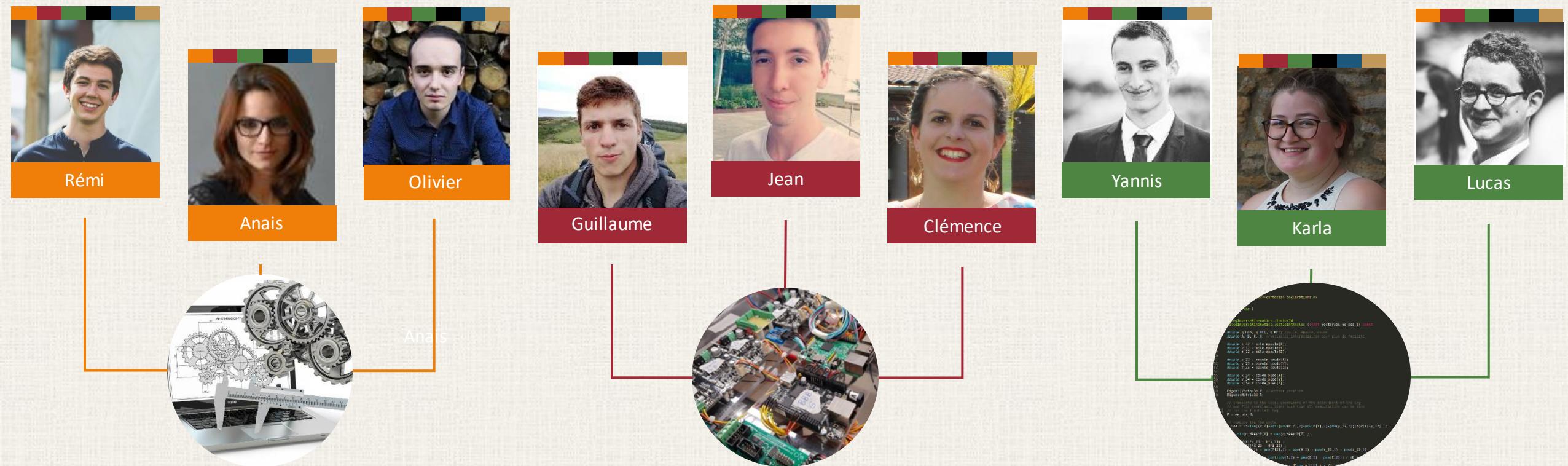
NOTRE SOLUTION



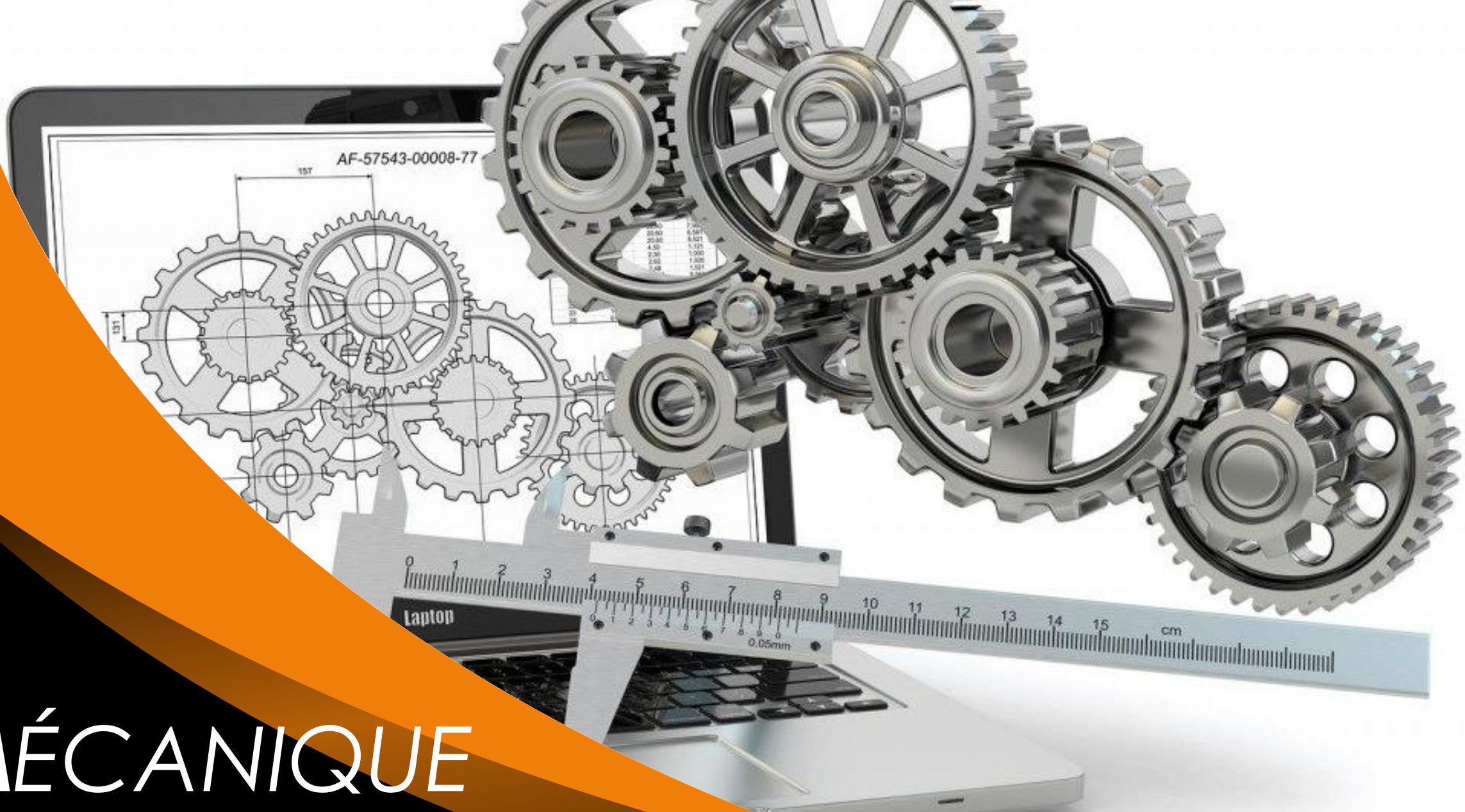
- Mini Cheetah
- Spot



ORGANIGRAMME



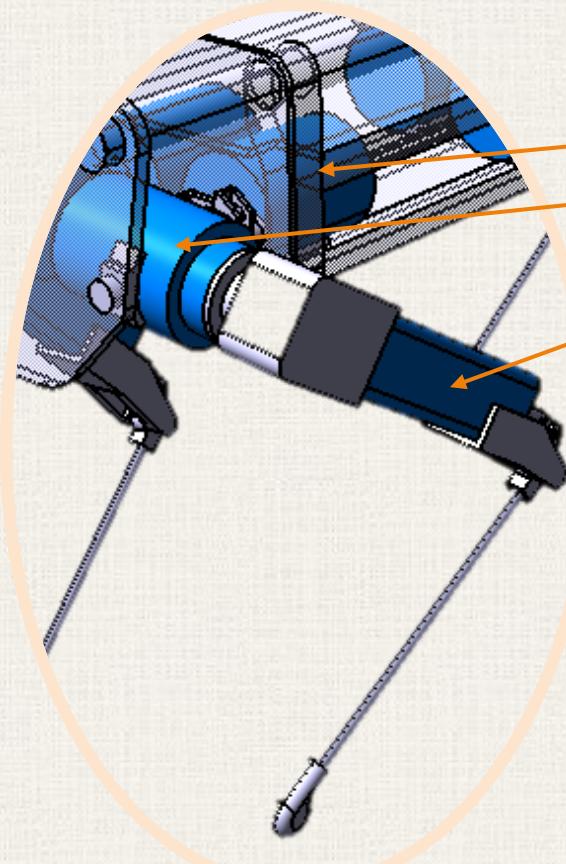
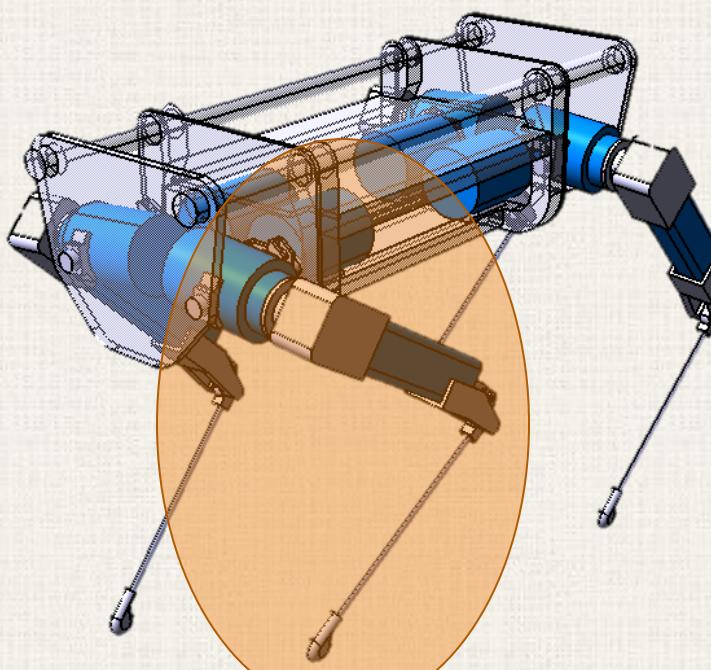
MÉCANIQUE



DESCRIPTION DU ROBOT

Robot quadrupède :

- 1 corps
- 4 pattes



3 ACTIONNEURS :

- Aile
- Épaule
- Coude



CHOIX DES ACTIONNEURS

MOTORÉDUCTEUR AILE



MR 977 – CBF MOTOR

Vitesse max avec charge : 26 tr/min
Couple max : 120 Nm
Plage d'articulation aile : $[-22^\circ; 22^\circ]$

MOTEUR ÉPAULE + RÉDUCTEUR ÉPAULE



MY1016 – CSMOTO

Vitesse max avec charge : 27,5 tr/min
Couple max : 122 Nm
Plage d'articulation épaule : $[0^\circ; 180^\circ]$

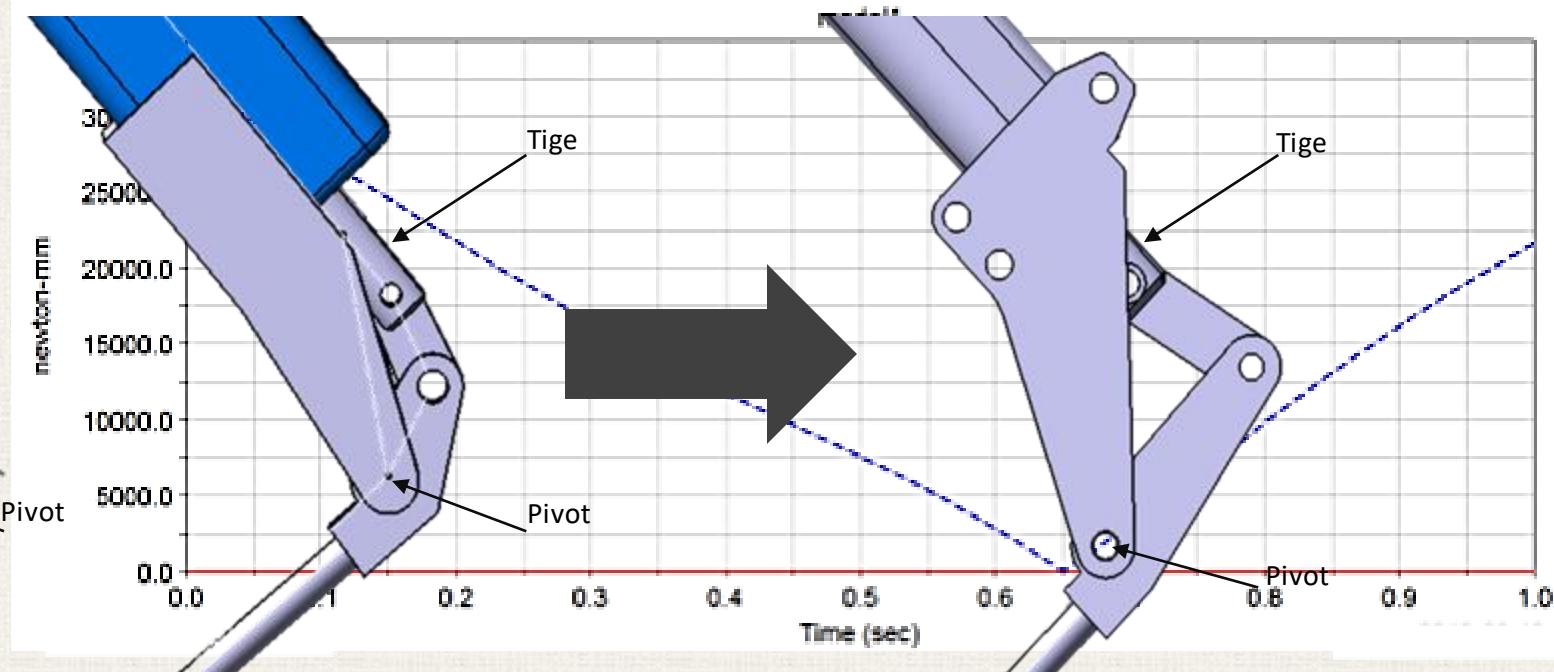
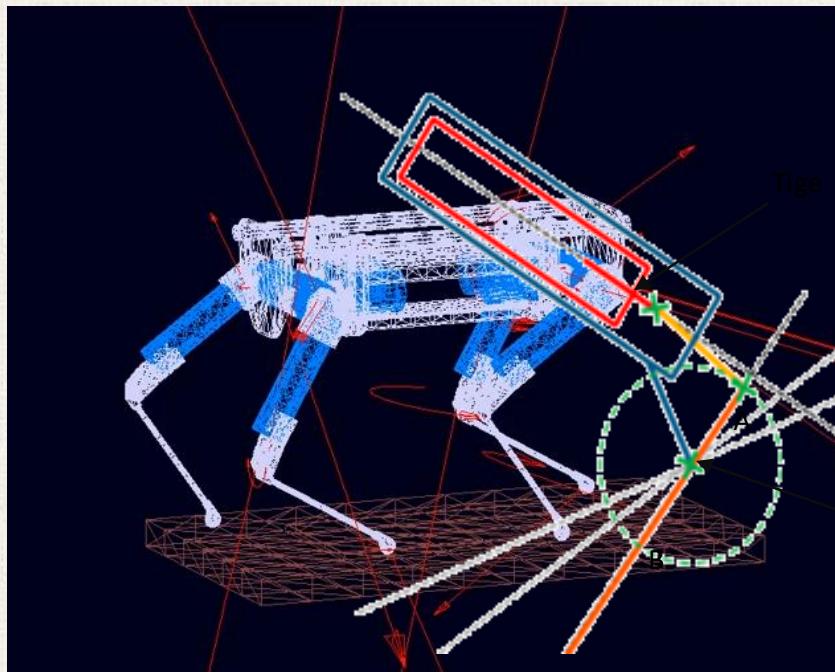
VÉRIN COUDE



MA2 – TiMotion

Vitesse max avec charge : 22,0 mm/s
Charge de poussée max : 2000 N
Plage d'articulation coude: $[15^\circ; 125^\circ]$

RÉSILIENCE

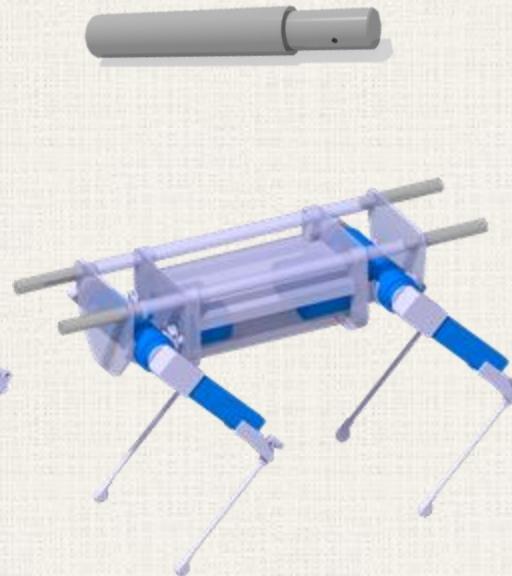


ACCESSOIRES

Socle



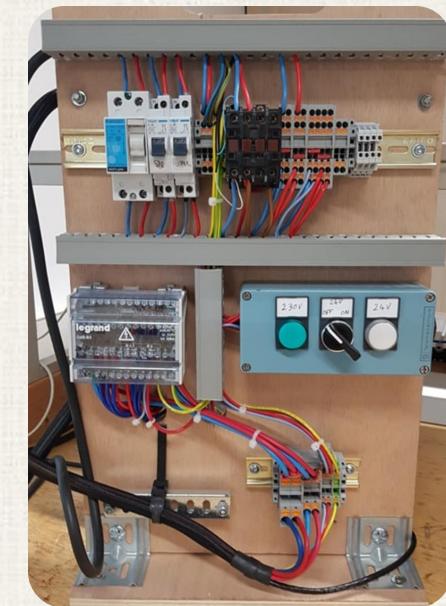
Poignées (x4)



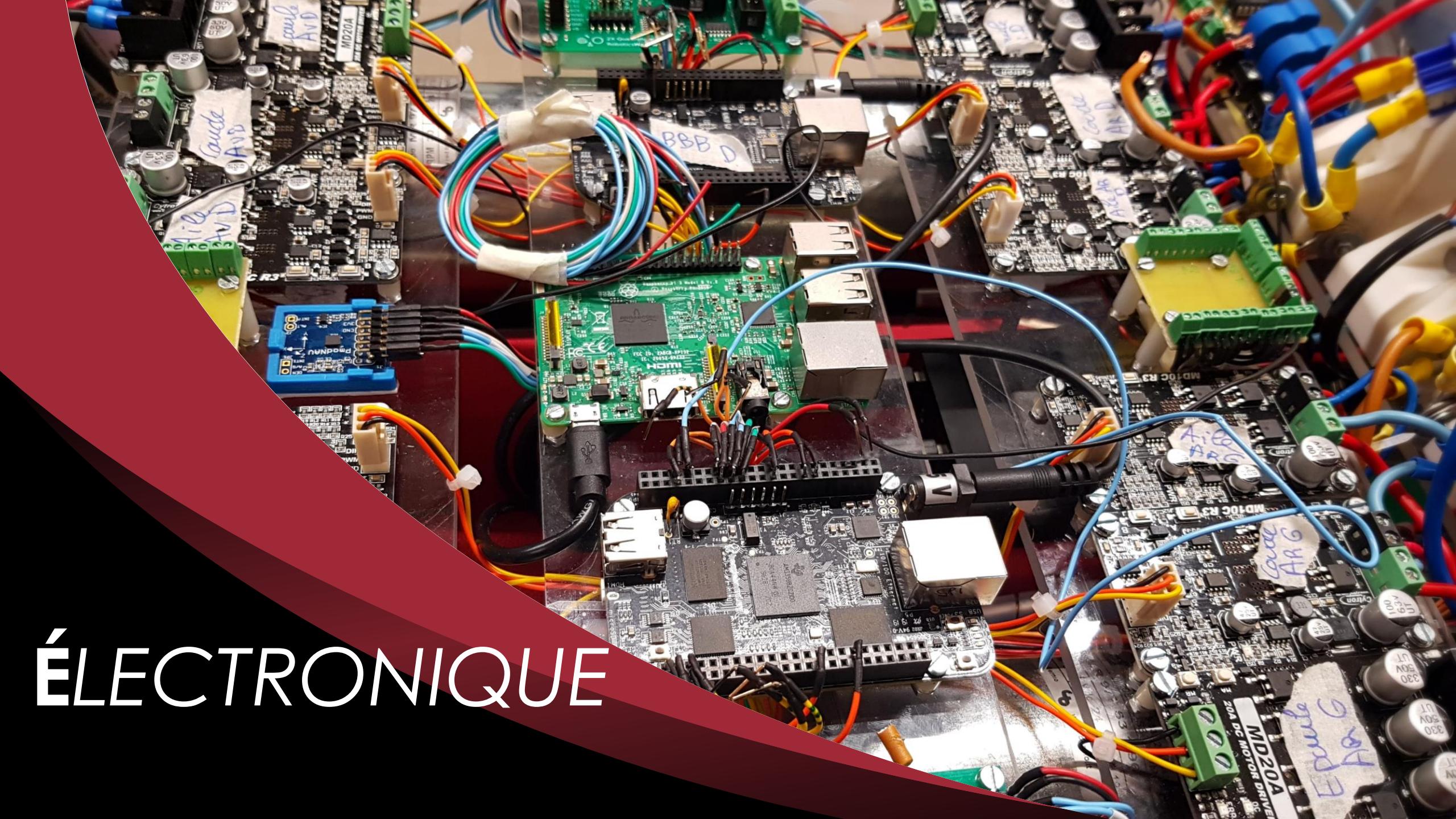
Pieds



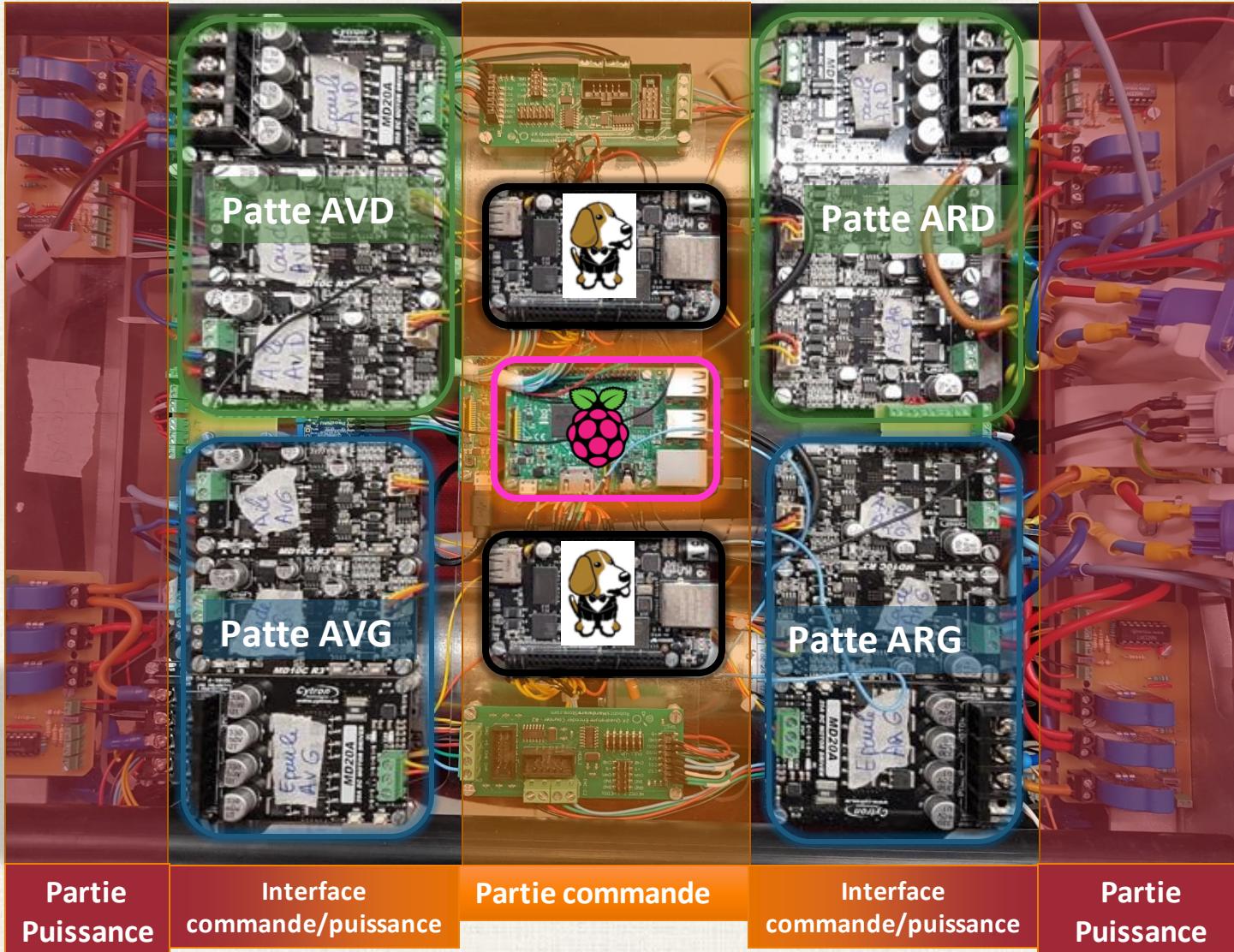
Platine d'alimentation



ÉLECTRONIQUE



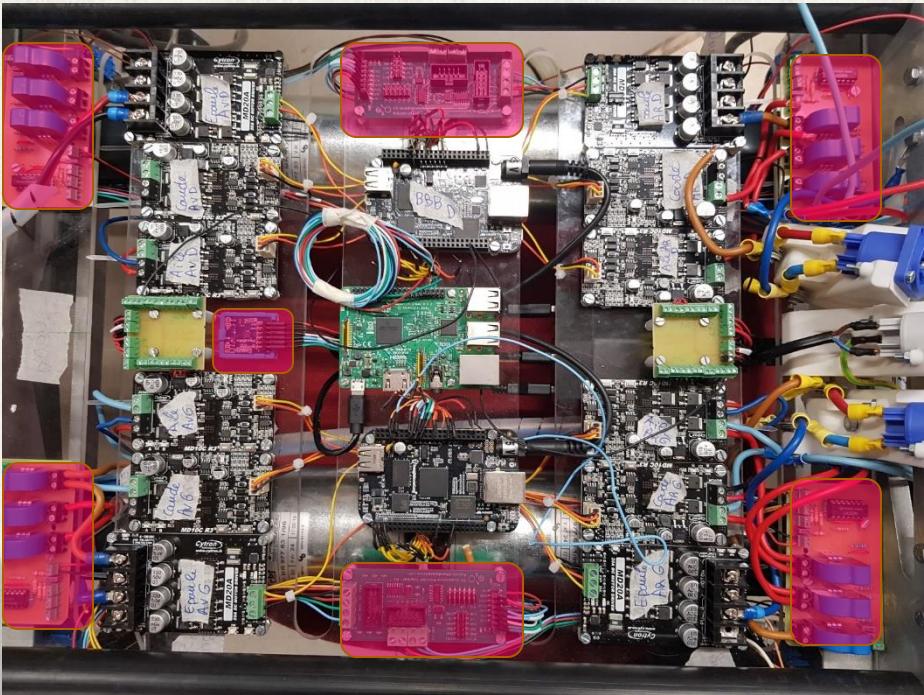
PLACEMENT DES CARTES



Bracelet Bonne Patte
3 cartes contrôleur par patte

- Gestion des châssis
- Par actionneurs
- Pilote les cartes IPB
- Commande de la puissance

CAPTEURS



1 IMU

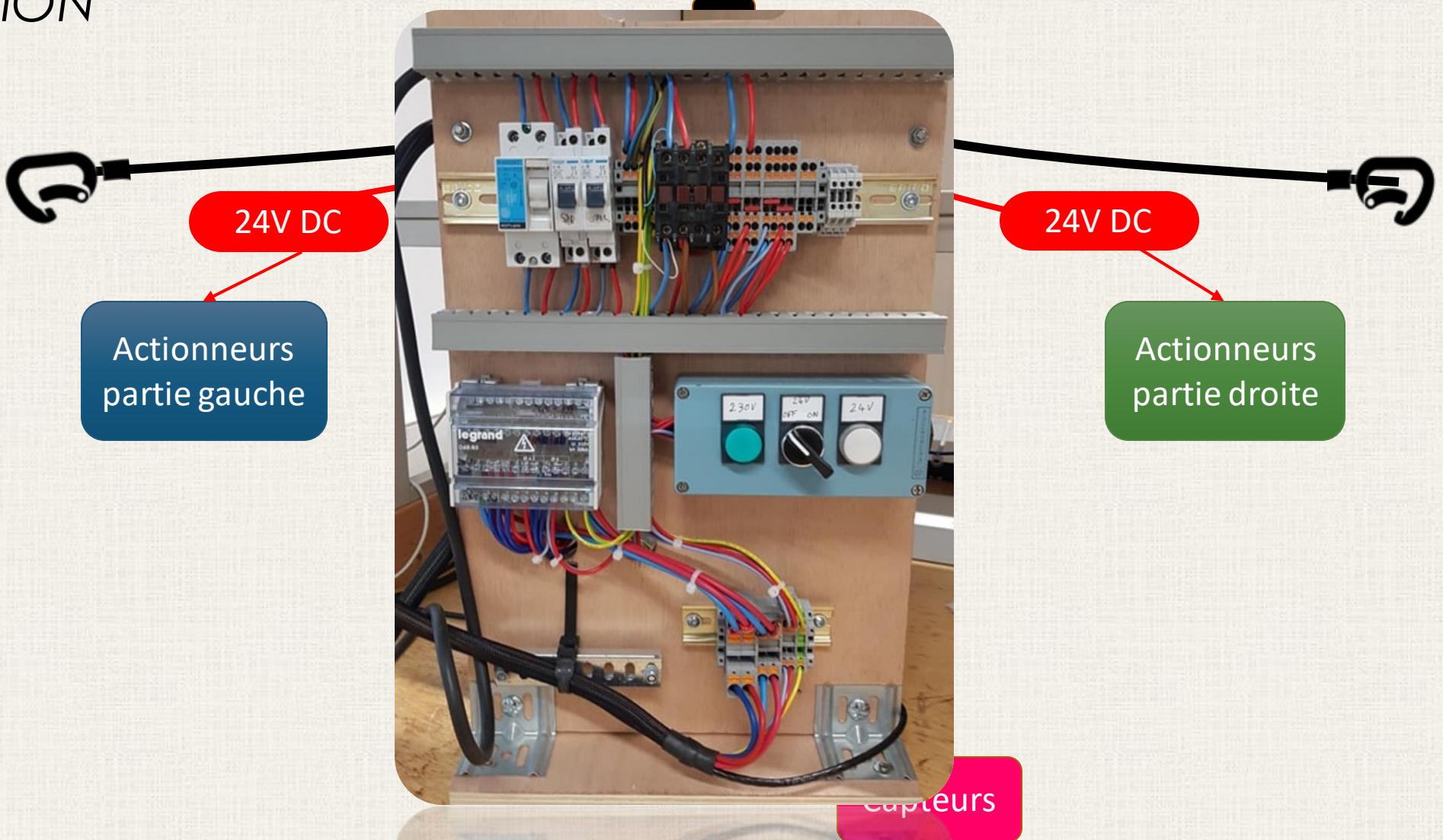
4 Roues codeuses

8 Capteurs de position

4 Cartes capteur de courant



ALIMENTATION



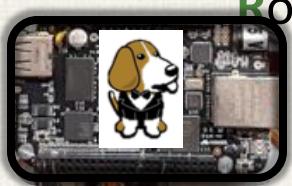
```
40
41 PopilegInverseKinematics::Vector3d
42 PopilegInverseKinematics::GetJointAngles (const Vector3d& ee_pos_B) const
43 {
44     double q_HAA, q_HFE, q_KFE; //aile, épaule, coude
45     double A, B, C, H; //variables intermédiaires pour plus de facilité
46
47     double x_12 = aile_epaule[X];
48     double y_12 = aile_epaule[Y];
49     double z_12 = aile_epaule[Z];
50
51     double x_23 = epaule_coude[X];
52     double y_23 = epaule_coude[Y];
53     double z_23 = epaule_coude[Z];
54
55     double x_34 = coude_pied[X];
56     double y_34 = coude_pied[Y];
57     double z_34 = coude_pied[Z];
58
59     Vector3d ee_pos_B; //vecteur position
60
61     //vecteur position
62
63     //compute intermediate variables
64
65     A = pow(x_12,2) + pow(y_12,2);
66     B = 2*x_12*y_12;
67     C = pow(x_23,2) + pow(y_23,2);
68     H = sqrt(A+C-2*B);
69
70     q_HAA = atan2(B,H);
71     q_HFE = atan2(y_12,x_12);
72
73     //compute joint angles
74
75     q_KFE = atan2((sqrt(A)+sqrt(C)-H),sqrt(H*(A+C-H)));
76
77     ee_pos_B[X] = A*cos(q_HAA)*cos(q_KFE);
78     ee_pos_B[Y] = A*cos(q_HAA)*sin(q_KFE);
79     ee_pos_B[Z] = C*cos(q_KFE);
80
81     return ee_pos_B;
82 }
```

coordinate of the attachment of the leg
such that all computations can be done

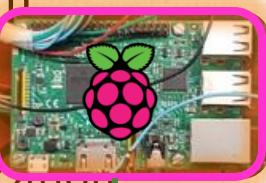
LOGICIEL

PRÉSENTATION DES DIFFÉRENTS OUTILS

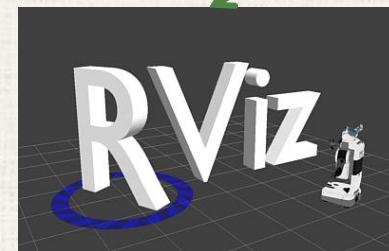
ROS.org



Robot Operating System



Un ensemble d'outils pour contrôler des robots
Un cadre de communication



Simulation graphique



Simulation physique

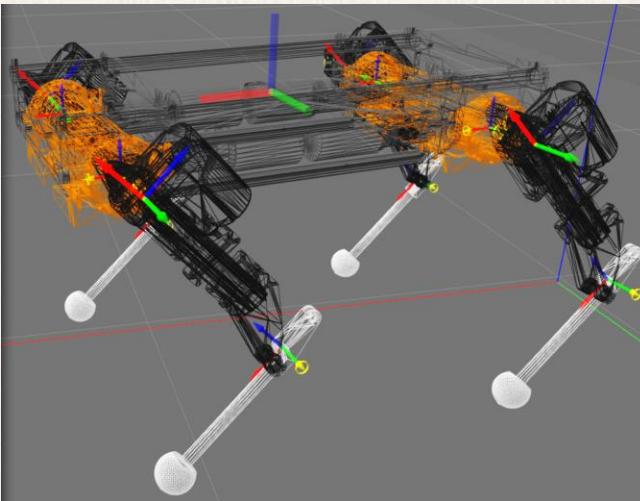
Intégration

Solidworks

URDF

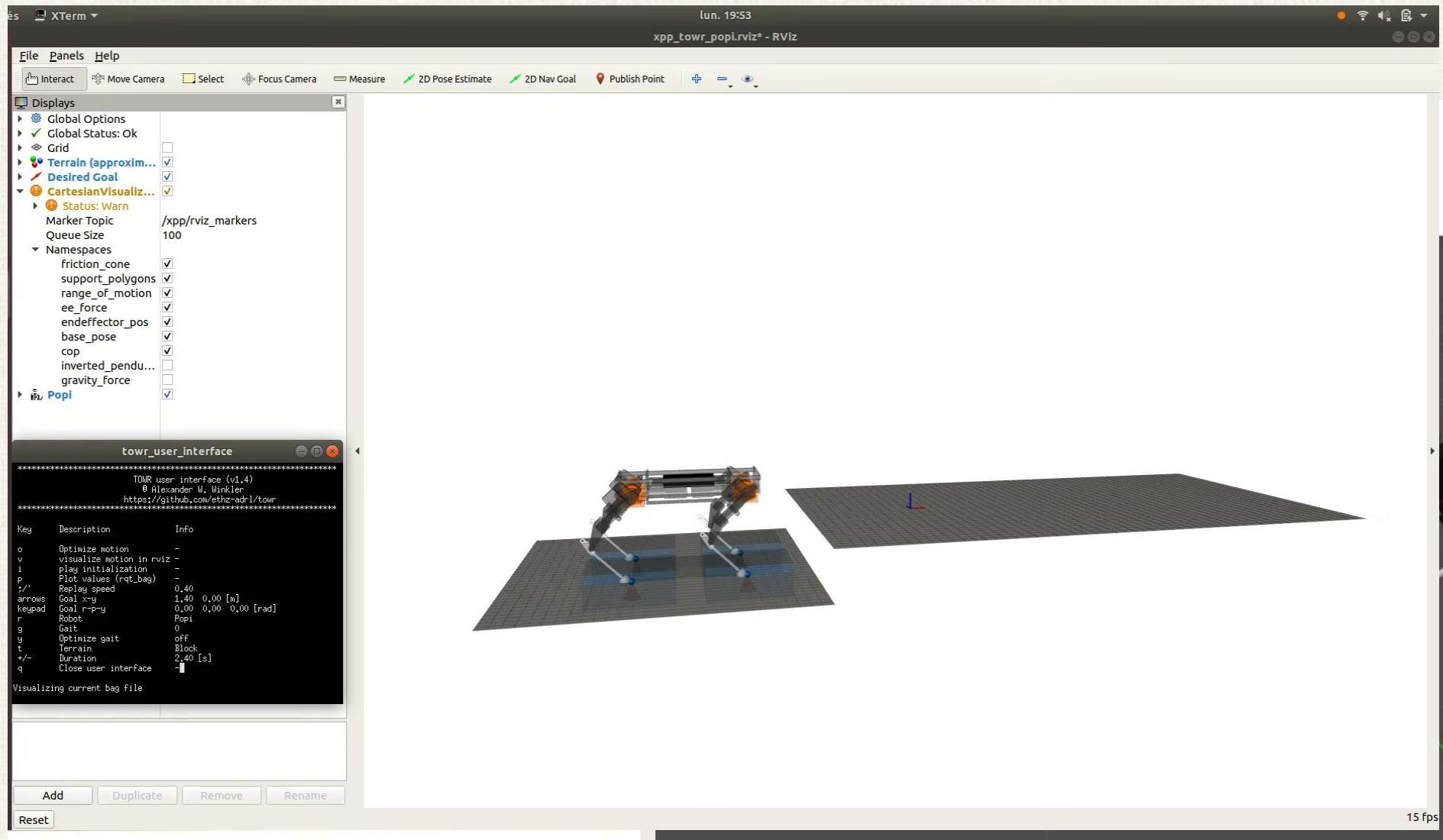
Simulation

Développement



```
40
41 PopilegInverseKinematics::Vector3d
42 PopilegInverseKinematics::GetJointAngles (const Vector3d&
43 {
44     double q_HAA, q_HFE, q_KFE; //aile, épaule, coude
45     double A, B, C, H; //Variables intermédiaires pour plus
46
47     double x_12 = aile_epaule[X];
48     double y_12 = aile_epaule[Y];
49     double z_12 = aile_epaule[Z];
50
51     double x_23 = epaule_coude[X];
52     double y_23 = epaule_coude[Y];
53     double z_23 = epaule_coude[Z];
54
55     double x_34 = coude_pied[X];
56     double y_34 = coude_pied[Y];
57     double z_34 = coude_pied[Z];
58
59     Eigen::Vector3d P; //vecteur position
60     Eigen::Matrix3d R;
61 }
```


SIMULATION



CAS D'USAGES INNOWTECH



CAMPUS
DES MÉTIERS
ET DES
QUALIFICATIONS
Process et technologies
en milieux sensibles
Occitanie



IMT Mines Alès
École Mines-Télécom



AIRBUS
HELICOPTERS



TiMOTION
MOTION WITH INTELLIGENCE

EWELLIX

MAKERS IN MOTION

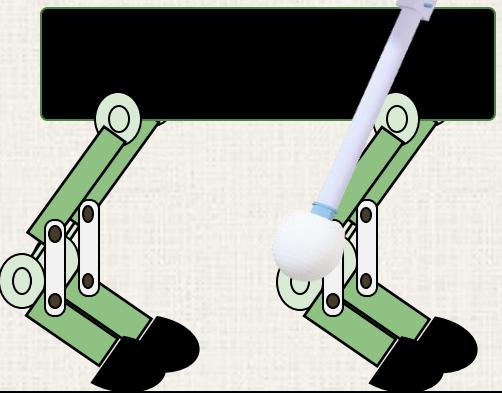
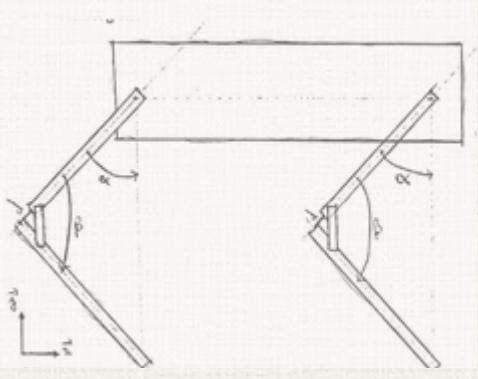


C Y L E O N E

Key AI Technology towards interoperability

**FOURÉ
LAGADEC**
GARD





MERCI DE VOTRE ATTENTION

