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(International Master)

Centrale Nantes,
Assignment Optimal Walking

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Design a cyclic reference trajectory by optimization (LAB2) :

The purpose is to design a periodic walking of duration T. The stages to solve the problem are the following :

1. Write the main program. At the beginning of this program we can define the physical parameters. The initial set of optimization variables should be defined. You can define the instruction to call *fmincon*. After by using the solution for the optimization variables you can plot the interesting variables. The number of optimization variables must be determined considered that you want to design a periodic walking gait with the compass biped. Another problem is to choose which optimization variables.
2. Write the program *optimwalk* as a Matlab function with the optimization variables as inputs.
3. At the beginning of this program *optimwalk* let us consider the impact model to deduce $\dot{q}^+$.
$$\begin{gathered} A(q(T))_{4\times 4}(\dot{q}^+ - \dot{q}^-) = J_2^\top I_2 \\ J_2\dot{q}^+ = 0 \end{gathered} \tag{1}$$
4. Please check that you are able to define the polynomial functions, by considering coefficients connected to an initial configuration, an intermediate configuration a final configuration, an initial velocity and a final velocity to define $q_1^d(t)$ and $q_2^d(t)$.
5. Consider the reduced dynamic inverse model of the compass robot in single support :
$$A(q)_{2\times 2} + H(q,\dot{q})_{2\times 1} + G(q)_{2\times 1} = \Gamma_{2\times 1} \tag{2}$$
We can determine the ground reaction $\vec{R}$ using the following balance equation in the center of mass :
$$M\vec{\gamma}_G = M\vec{g} + \vec{R} \tag{3}$$
6. Define the criterion :
$$\mathcal{C} = \frac{1}{L_{step}}\int_0^T \Gamma^\top\Gamma \mathrm{d}t \tag{4}$$
We propose to evaluate this integral using the backward difference method by using a sampling period $\Delta = T/100$.
$$\mathcal{C} = \frac{1}{L_{step}}\sum_{k=1}^{N=100} \Gamma^2(k\Delta)\Delta \tag{5}$$

7. The choice of the constraints : $L_{step} > 0.2$ m, $R_y > 0$, $I_y > 0$, $\left[\dfrac{R_x}{R_y}\right] < 0.7$, $\left[\dfrac{I_x}{I_y}\right] < 0.7$, $|\dot{q}_1| < 3$rd/s and $|\Gamma_i| < 50$ N.m $(i = 1, 2)$.
8. Using the software *fmincon* to find give the optimization variables which minimize $\mathcal{C}$.
9. Give the profiles of q_i, $\dot{q}_i$, R_x, R_y, and Γ_i.

1. The main program to call *fmincon*
   (a) global any parameters you need : masses, inertia, etc.
   (b) Jsolcons0 = [? ? ? ? ?] ; initial optimization variables
   (c) Call to *fmincon*
      i. lb = [? ? ? ? ?] ;
      ii. ub = [? ? ? ? ? ?] ;
      iii. options = optimset('Display','iter','MaxFunEvals', ? ?,'MaxIter', ? ?,'LargeScale','off') ;
      [Jsolcons,Fval,EXITFLAG] = fmincon('resol',Jsolcons0,[],[],[],[],lb,ub,' constraint',options) ;
2. The program *resol*.
   function Criteria=constraint(Jsolcons)
   global gt gteq
   definition of polynomial functions
   impact equation
   Computation of the inverse dynamique system
   Computation of the criterion $\mathcal{C}$ and nonlinear constraints
   gteq = [] ;
   return
3. The program *constraint* taking into account the constraints.
   function [gt,gteq]=constraint(Jsolcons)
   global gt gteq
   gt=gt ;
   gteq = [] ;
   return