Robotics II

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With reference to the scheme in Fig. 1, consider a one-dimensional force control problem in which the robot is modeled as a mass m in contact with a compliant environment having mass m_w, stiffness k_w, and viscous damping d_w. A control force u acts on the robot mass m. Let x_1 and x_2 be the position of the robot mass and, respectively, of the environment mass. A force sensor having stiffness k_s is used to measure the contact force f_c. All physical data can be assumed to be positive.

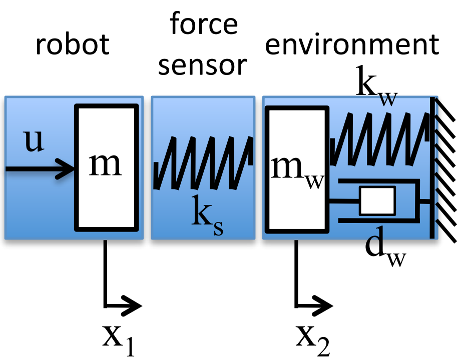

Figure 1: A one-dimensional contact with a dynamic environment

We want to regulate the contact force to a constant positive value f_d, by means of the following control law:

$$u = k_p(f_d - f_c) + k_f f_d - k_v \dot{x}_1 \tag{1}$$

where k_p is a proportional feedback gain on the contact force error, k_f is a force feedforward gain, and k_v is a gain on the robot mass velocity.

1. Derive the dynamic equations describing the robot-environment system when a generic force input u is applied to the robot mass.
2. Draw a block diagram of the control scheme when using eq. (1) and write the associated closed-loop equations.
3. Study the equilibrium configurations of the closed-loop system. In particular, choose suitable (interval of) values for k_p, k_v, and k_f such that the controlled system is asymptotically stable and has a zero force error at steady state.

   Optional: in this case, 60 minutes of additional time are available.

4. If feasible, perform a simulation with the resulting controller. For the simulation, use the following system parameters: $m = 1$ [kg], $m_w = 10$ [kg], $k_w = 1000$ [N/m], $d_w = 1000$ [N·s/m], $k_s = 100$ [N/m]. The system is initially at rest and in equilibrium. The desired force has a step variation of $f_d = 10$ [N].

[90 minutes; open books]