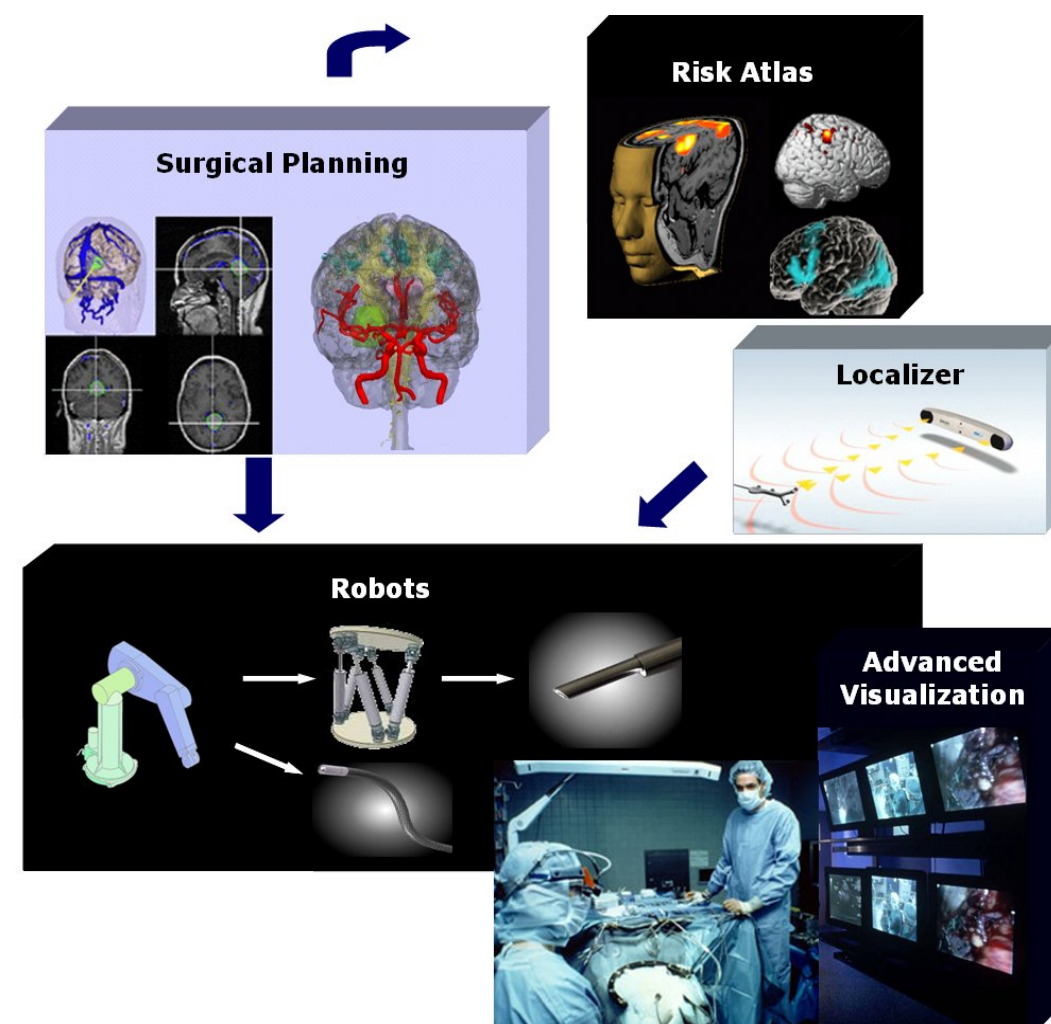
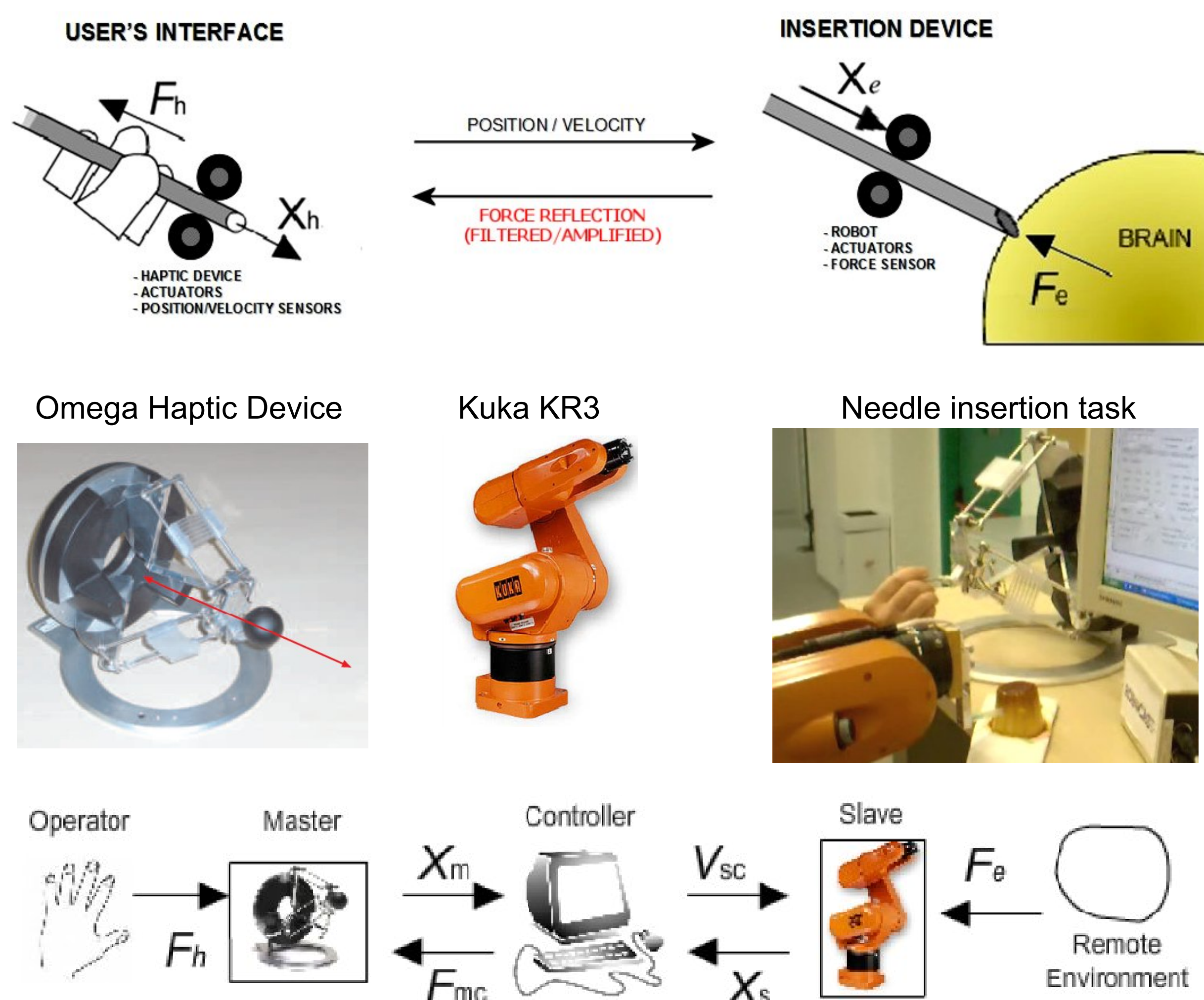


Introduction to RoboCAST

The RoboCAST project aims to develop ICT scientific methods and technologies which focus on robot assisted keyhole neurosurgery. A modular master-slave telemanipulation system will be developed. The slave system will integrate 2 robots and one active bio-mimetic probe, able to cooperate among themselves in a biomimetic sensory-motor integrated framework. The master interface (SIRSLab WorkPackage) allows the surgeon to remotely control the probe motion and provides the force-feedback.

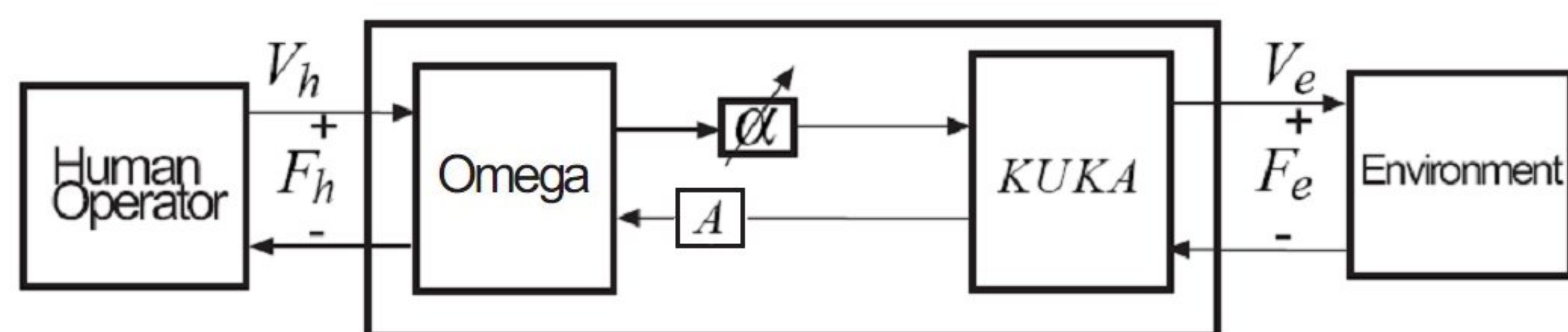


SIRSLab Research



Control approaches

1. Time Domain Passivity Control [Ryu et al., IEEE T.Ro. 2004]:



Passivity observer (PO):

$$E_{PO}(k) = E_{PO}(k-1) + T_c A F_e(k) V_e(k)$$

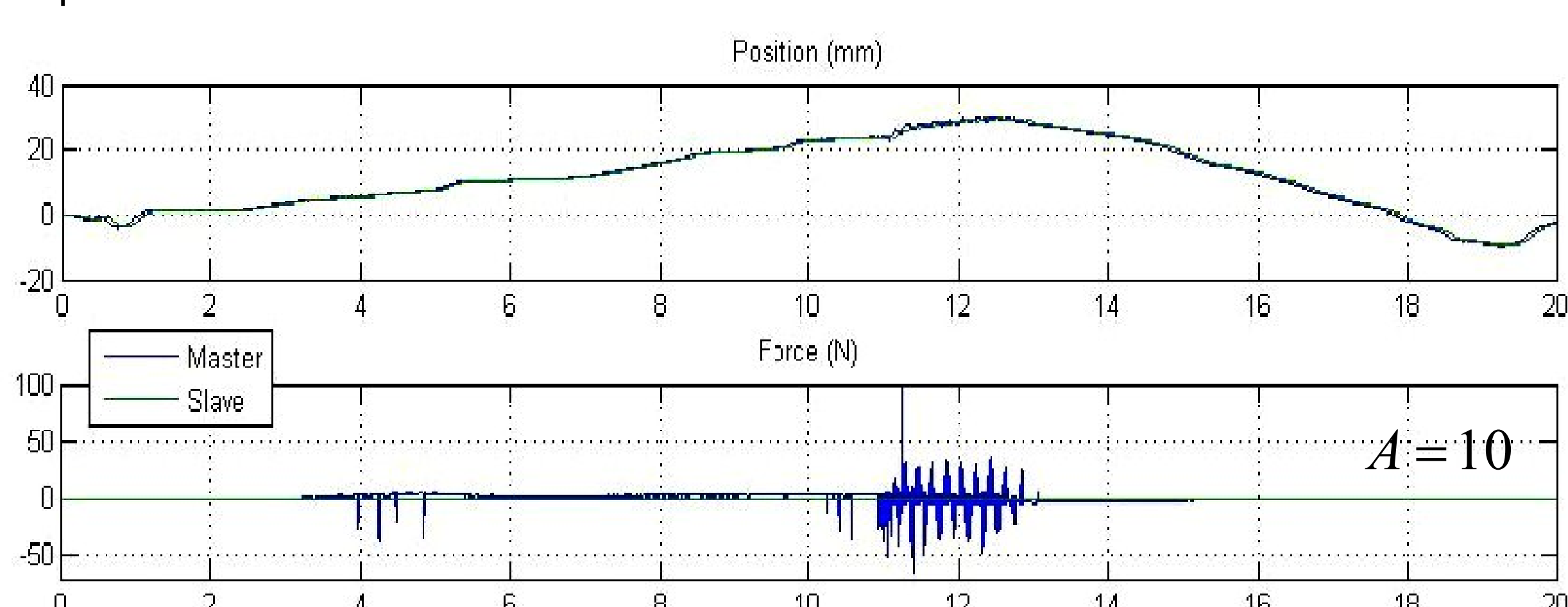
Passivity controller (PC):

$$V_h(k) = V_e(k)$$

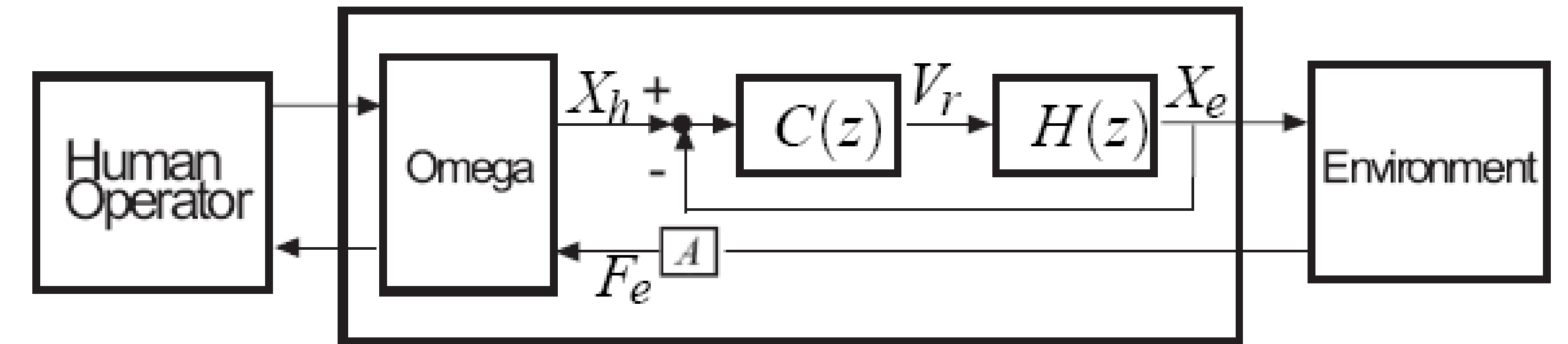
$$\alpha(k) = \begin{cases} -\frac{E_{PO}(k)}{T_c V_e(k)^2} & \text{if } E_{PO}(k) < 0 \\ 0 & \text{if } E_{PO}(k) \geq 0 \end{cases}$$

$$F_h(k) = A F_e(k) + \alpha(k) V_e(k)$$

Experiments:

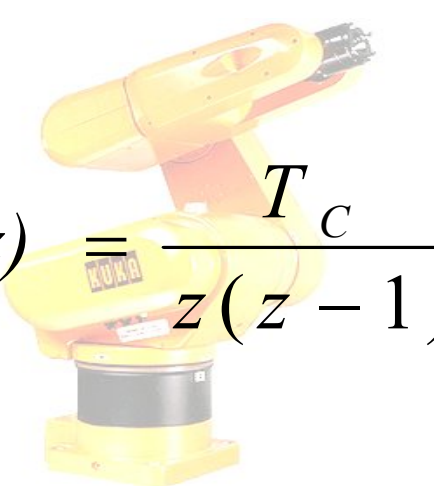


2. Classical PD controller, using a dynamical model of the slave for parameter designing:

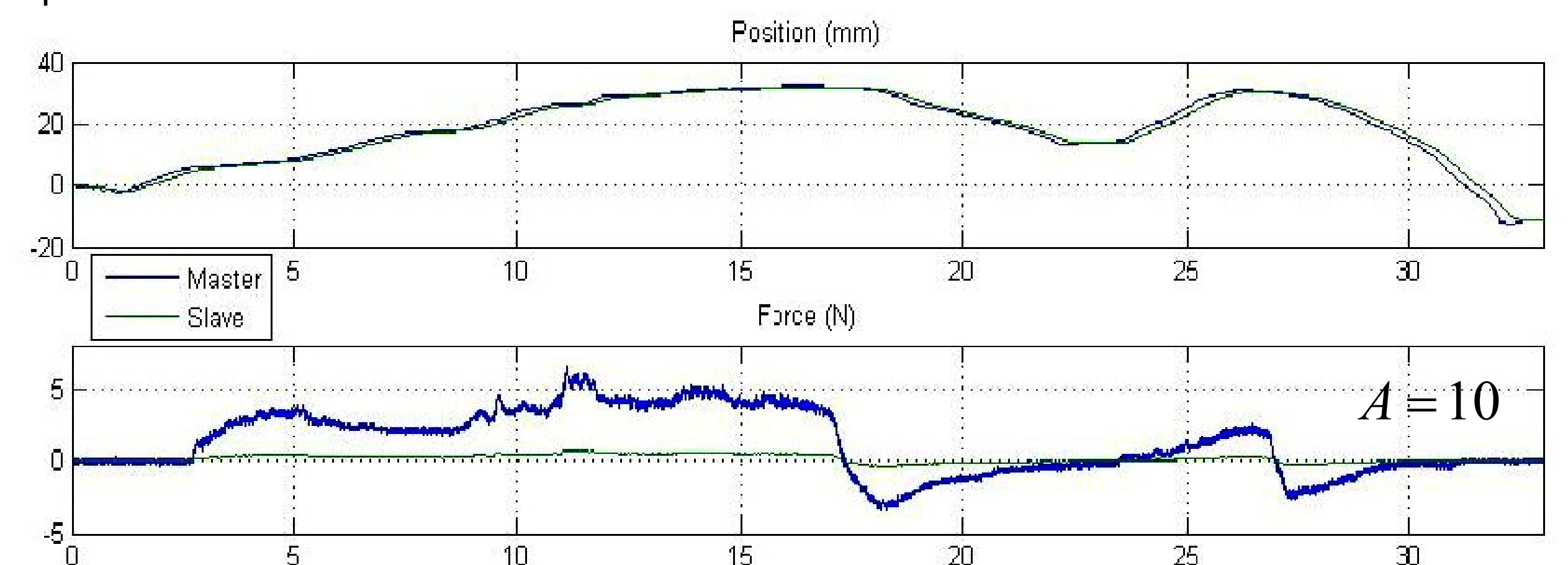


$$PD: C(z) = k_p - \frac{z-1}{T_c z} k_D$$

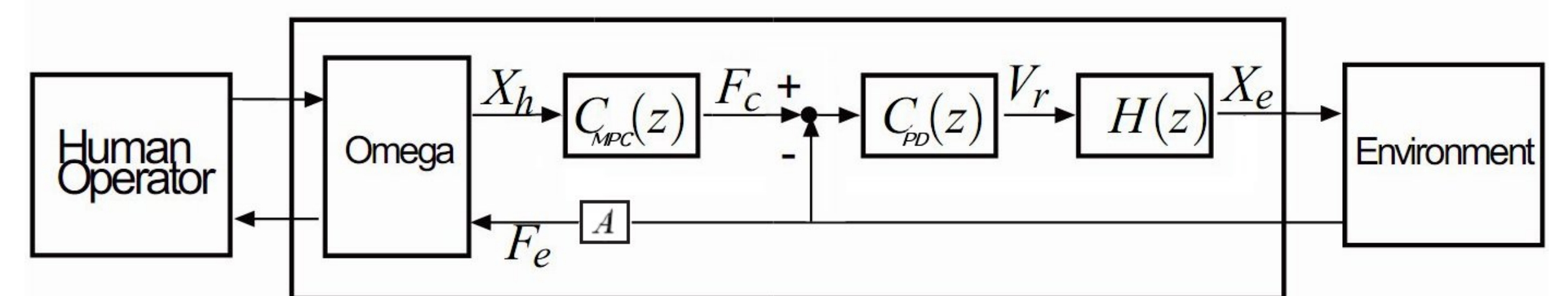
$$\text{Slave model: } H(z) = \frac{T_c}{z(z-1)}$$



Experiments:



3. Switching MPC controller and PD controller series, using dynamical models of the brain and of the slave device:



The brain model switches between two modes [Frasson et al., EMBS08,2008]:

1) brain membrane not pierced:

$$m_n \ddot{X}_e = -k_b X_e - \beta_{b1} \dot{X}_e + F_c \quad (X_e < 20)$$

2) needle inside the brain:

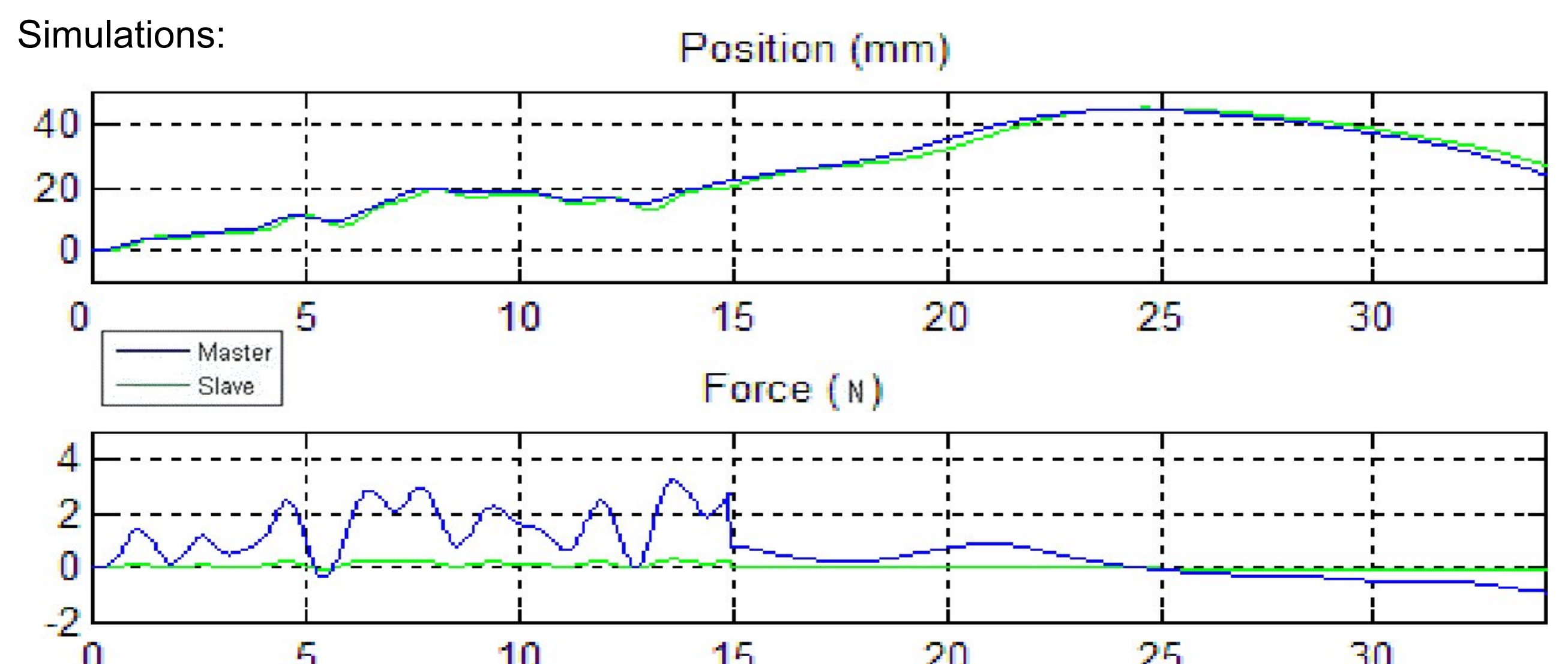
$$m_n \ddot{X}_e = -\beta_{b2} \dot{X}_e + F_c \quad (X_e \geq 20)$$

Model Predictive Control:

$$\min_{\Delta F_c} \sum_{k=0}^{T-1} |W_e (X_e(k) - X_h(k))|^2 + |W_c \Delta F_c(k)|^2$$

$$-10 \leq \Delta F_c \leq 10 \quad 0 \leq X_e \leq 100$$

Simulations:



References

J. Semmoloni, R. Manganelli, A. Formaglio, and D. Prattichizzo. *Control design issues for a microinvasive neurosurgery teleoperator system*. In Proceedings of IEEE Int. Conf. on Advanced Robotics ICAR09, Munich, Germany, June 2009