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Training of robot to assigned geometric and force trajectories

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Robotics for restorative medicine

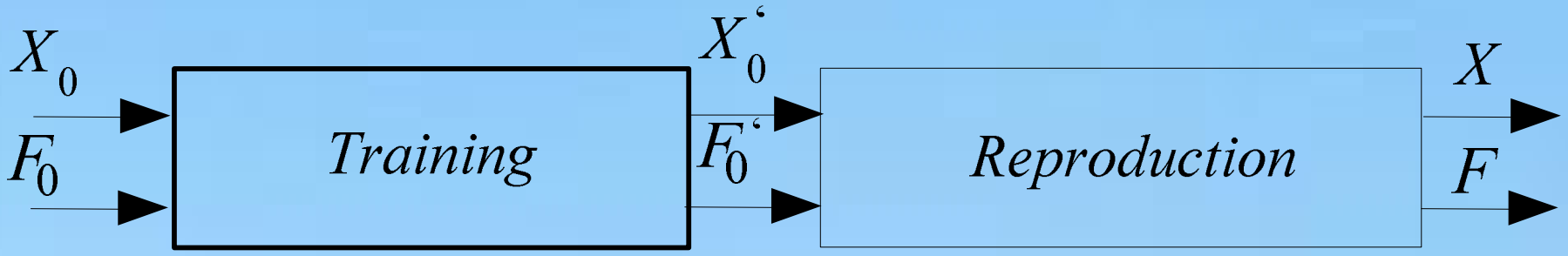
- Mesrob 2013 Robotics in restorative medicine
- Mesrob 2014 Expansion of ergonomic functions in medical robotics
- Mesrob 2015 Training of robot to assigned geometric and force trajectories

The tasks of control in Robotics for restorative medicine problems:

- to generate and to remember set of points characterizing form and state of soft tissues,

- to perform the manipulations on soft tissues using training points or curves.

Input methods in robot $\boldsymbol{X}_0(t)$ and $\boldsymbol{F}_0(t)$

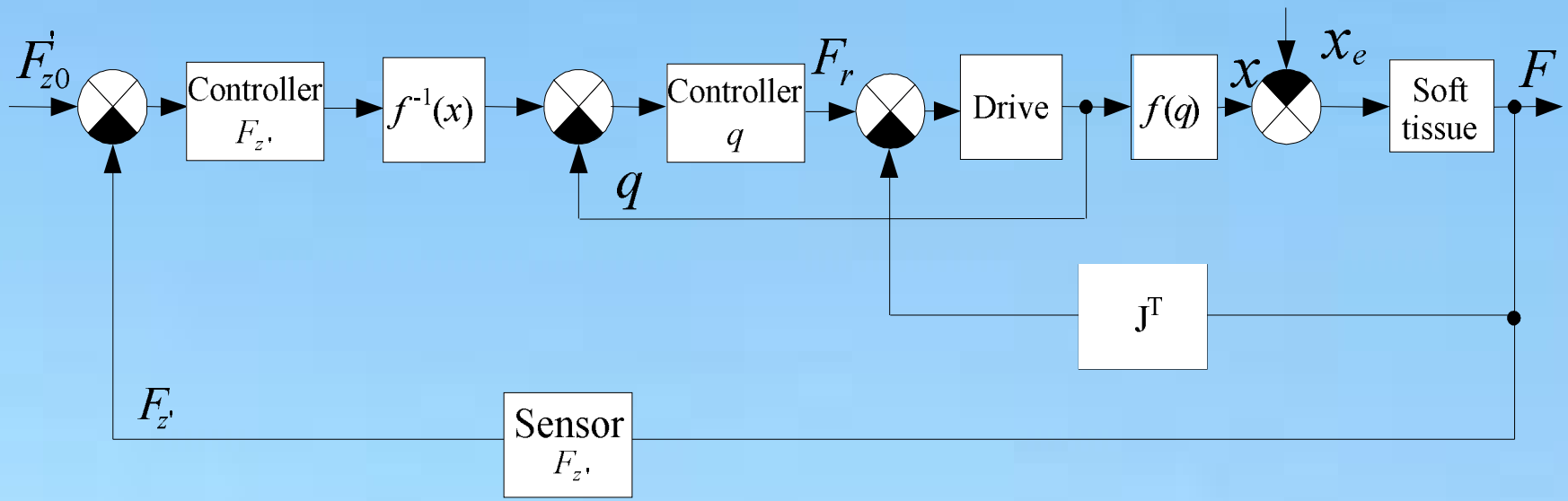


- training by line segments,
- training of geometric points,
- training of geometric curve by demonstration,
- training of force points,
- training of force curve by demonstration,

Training for painting

Training by demonstration for arc welding

System of force points training



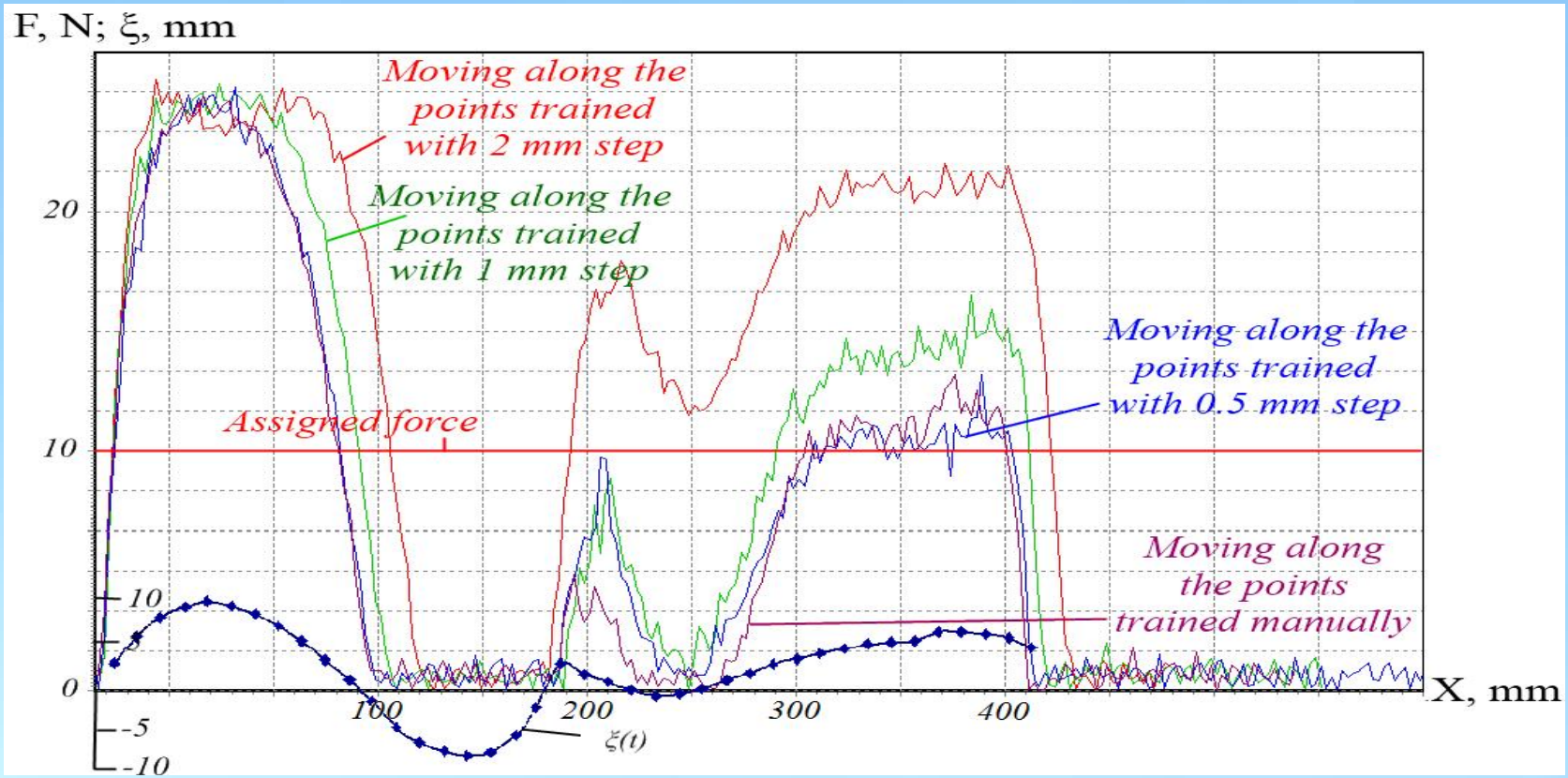
$$A_i = (x, y, z, o, a, t, F_x, F_y, F_z, M_x, M_y, M_z)$$

$$if F_{Z'} \le F_{Z'0} - \Delta F then \Delta z'_{i+1} = \Delta$$

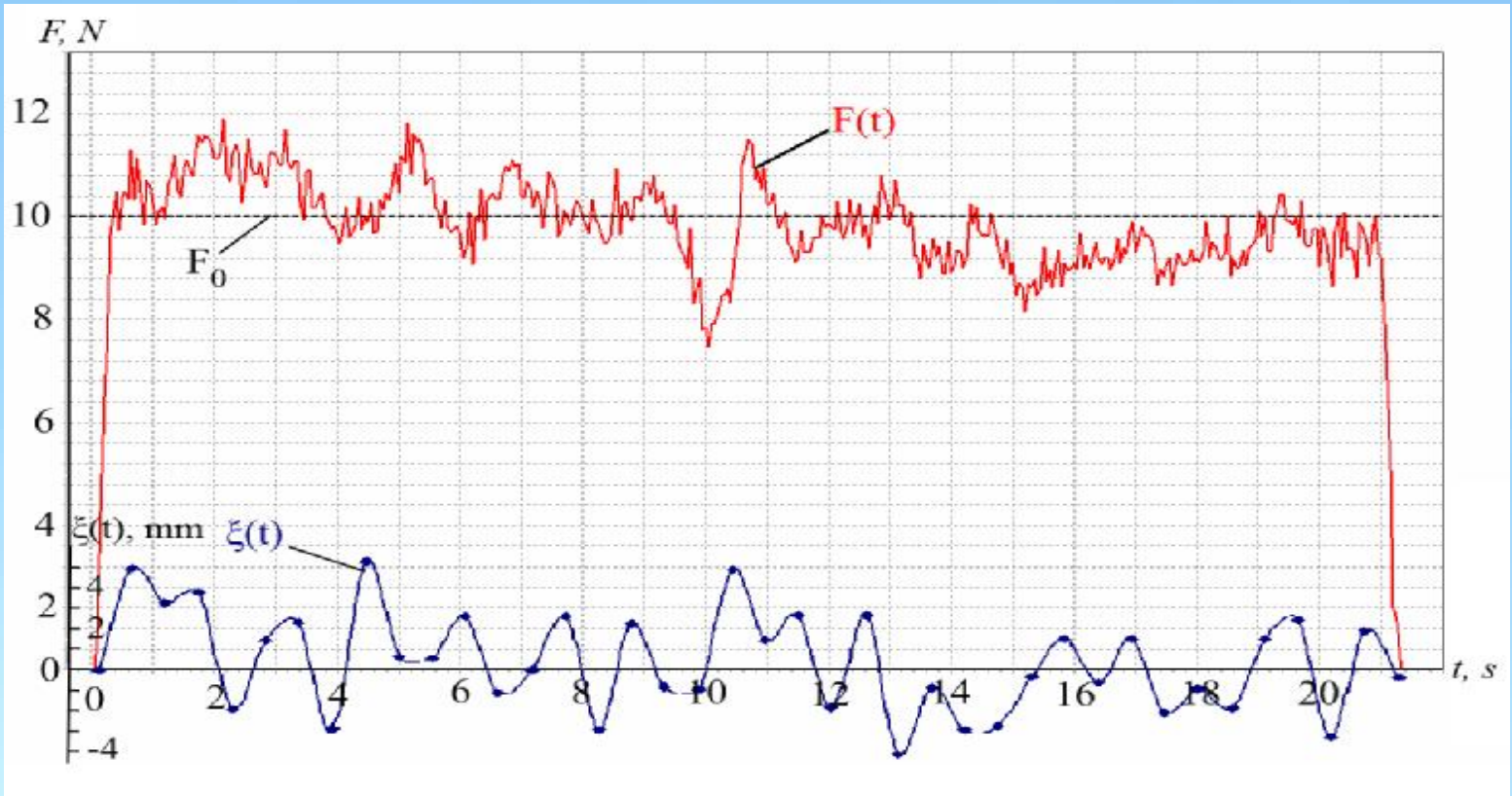
$$if F_{z'0} - \Delta F < F_{z'} < F_{z'0} + \Delta F then \Delta z'_{i+1} = 0$$

$$if F_{z'} \ge F_{z'0} + \Delta F then \Delta z'_{i+1} = -\Delta$$

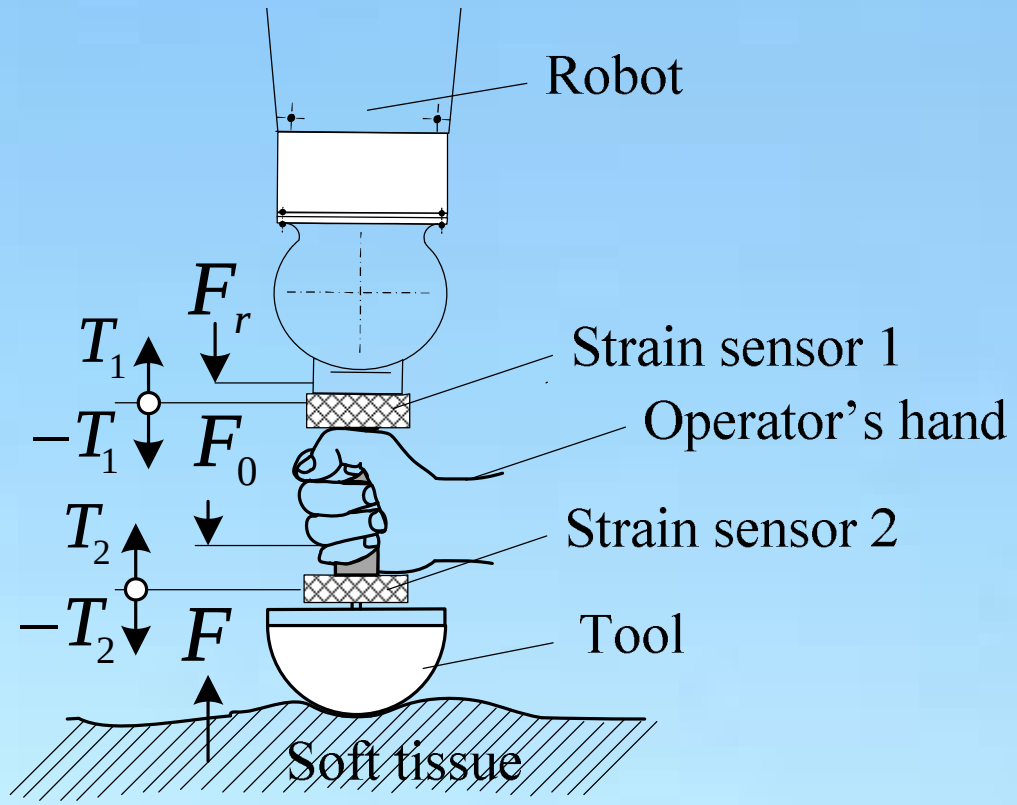
Curves $F(t)$ arising at passage of points trained with various steps



Curves of $F(t)$ and $\xi(t)$ obtained at passage along patient's long muscles



Forces (moments) acting on robot end-effector



Differential equation of robot interacting with soft tissue and masseur's hand

$$H(\mathbf{q})\ddot{\mathbf{q}} + \mathbf{h}(\mathbf{q}, \dot{\mathbf{q}}) + \mathbf{C}(\mathbf{q}) = \mathbf{F}_r + J^T(\mathbf{q})\mathbf{F}_e,$$

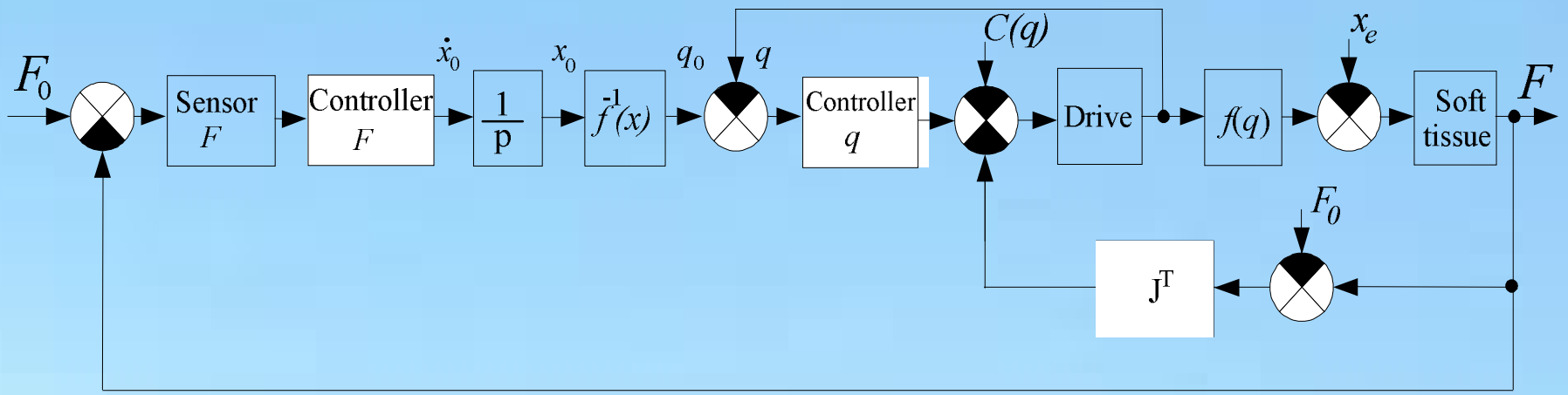
If $$H(\mathbf{q})\ddot{\mathbf{q}} = \mathbf{h}(\mathbf{q}, \dot{\mathbf{q}}) = 0,$$

then $$\mathbf{C}(\mathbf{q}) = \mathbf{F}_r + J^T(\mathbf{q})\mathbf{F}_e,$$

where $$\mathbf{F}_e = \mathbf{F}_0 - \mathbf{F}.$$

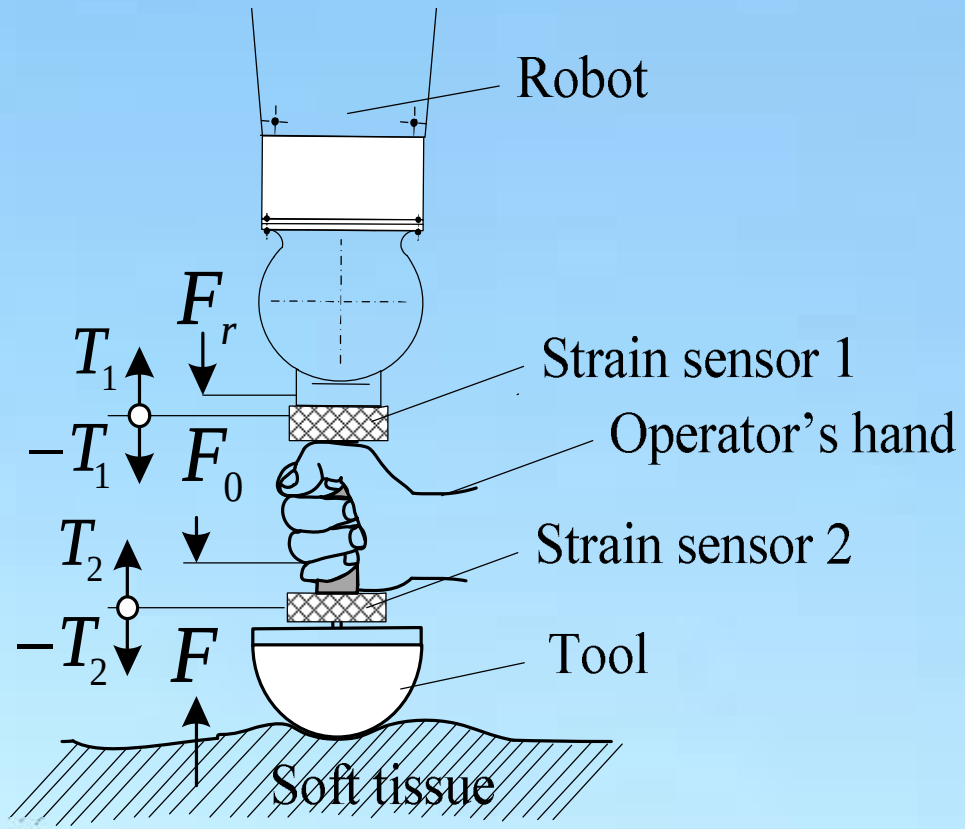
Finally $$\mathbf{C}(\mathbf{q}) - J^T(\mathbf{q})(\mathbf{F}_0 - \mathbf{F}) = \mathbf{F}_r$$

System of training by demonstration in view of soft tissue deforming

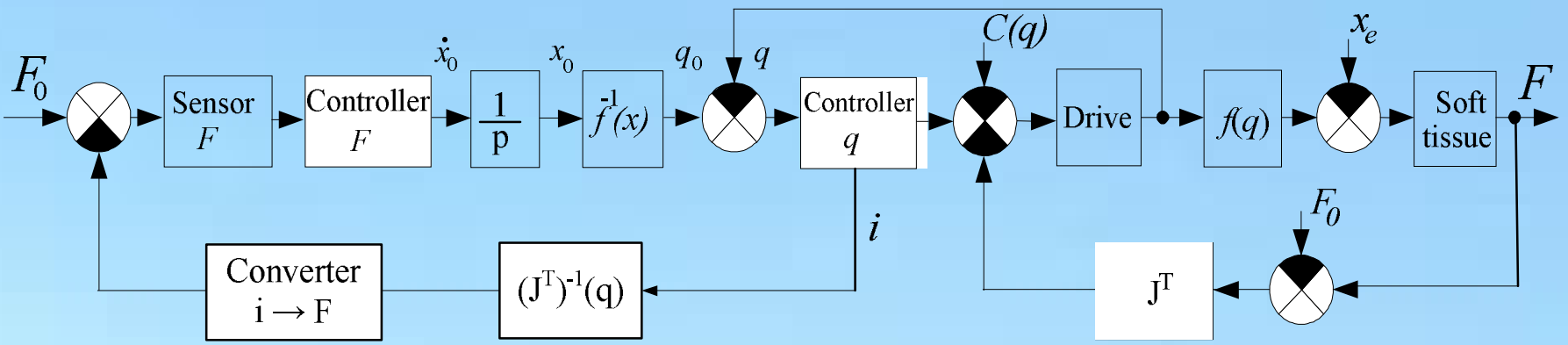


Forces measured by sensors

$$T_1 = F_r = F - F_0 - C(q),$$
$$T_2 = -F + C(q) = -F_0 - F_r$$

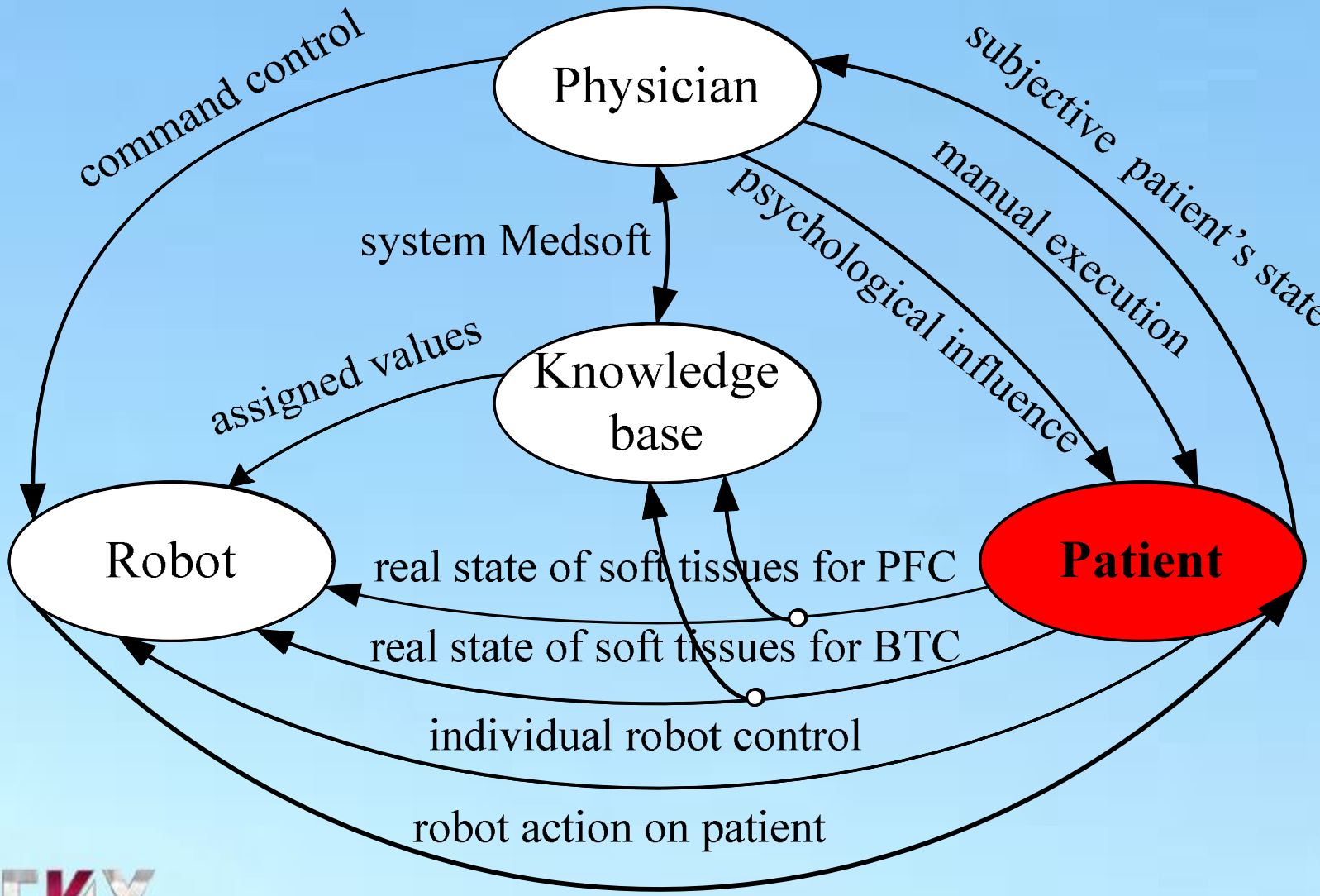


System of training by demonstration in view of soft tissue deforming using measured drive currents



Training by demonstration is a typical problem of the joint control in the general robot work zone

Interaction between components of system physician- operator, robot, patient



Training of Kawasaki FS-003N robot by demonstration with using six-component train sensor

Six-component strain sensor Schunk FTD-Delta SI-330-30 and controller

Conclusions

- The training of separate force points has the benefit no requiring expensive six component strain sensor for force measurement. However it is slow training requiring large number of points.
- The method of training by demonstration of moving in free space is known in industrial robotics for example for spray painting and arc welding.
- The method of training by demonstration with deformation of environment can be used for massage. It is more natural and quick method than the training of separate force points.
- Both methods have significant drawback requiring immobility of the object on which manipulations are performed. This drawback can be excluded by using dynamic position/force control to correct object movements.

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Many thanks for your attention!

Please, your questions.

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