Expansion of ergonomics function in medical robotics

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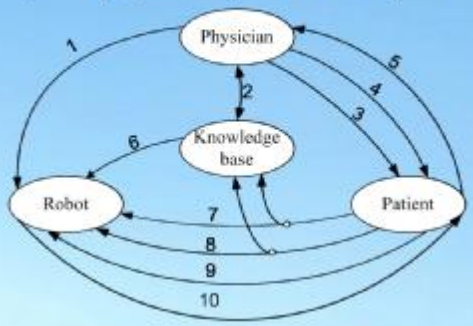
Scheme of interaction between components of system physician- operator, robot, patient



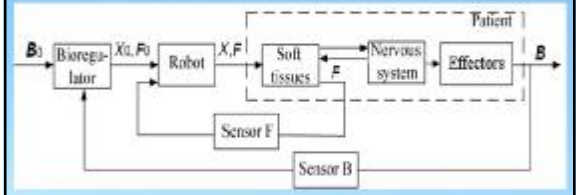
Connections between components and modes

1 – command control from physician for change of modes and procedure parameters, including training mode;
2 – using by physician of the data, received in the previous sessions and knowledge base replenishment (system Medsoft);
3 – psychological influence of physician on the patient;
4 – manual execution of procedure by the physician (solo or with a robot);
5 – signals of subjective patient's state transmitted to physician;
6 – assigned values of forces, movements, velocities for position/force control;
7 – signals of real state of soft tissues for position/force control;
8 – signals of real state of soft tissues for biotechnical control;
9 – signals of individual robot control from patient (Fig. 1). 10 – robot action on patient, 4+10 - mutual performance by physician and robot

Control counters

- automatic position/force control (6+7+10),
- automatic biotechnical control (6+8+10),
- command control (1+2+10),
- manual performing of procedure (4+5),
- mutual performance of procedure by physician and robot (4+10),
- individual robot control from patient (9).
- Some of indicated counters are open loop (3, 6) and others are closed loop (1, 2, 4, 5).

Biotechnical control system



Position/force control

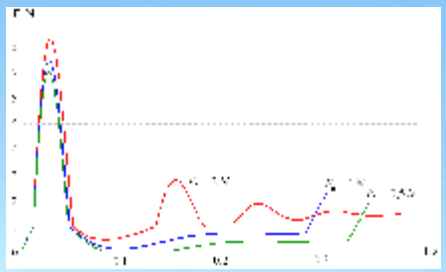
$$X \longrightarrow X_d, \quad F \longrightarrow F_d,$$

$$H(q)\ddot{q} + h(q,\dot{q}) = \phi + J^T(q)F$$

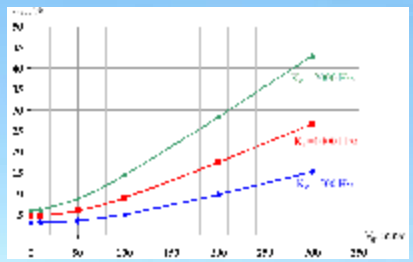
$$M(q)\ddot{q} + L(q,\dot{q}) = -S^T(q)F$$

$$\phi = H(q)M^{-1}(q)\{-L(q,\dot{q}) - S^T(q)(F_d + \frac{1}{T}\int_{t_0}^{t} e(\omega)d(\omega))\} + h(q,\dot{q}) - J^T(q)F$$

Force transients curves at approach speed 100 mm/s



Force error dependencies on approach speed *Vz*

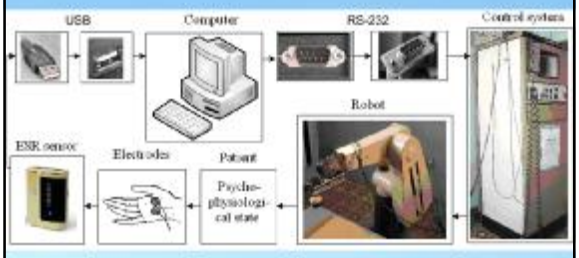


Biotechnical control system goal

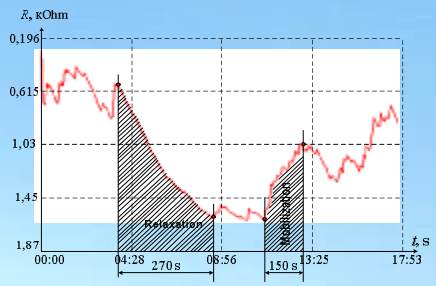
$$\mathbf{B} \xrightarrow{\theta} \mathbf{B}_0,$$

$$\theta = t_1 - t_0$$

Robotic system for restorative medicine

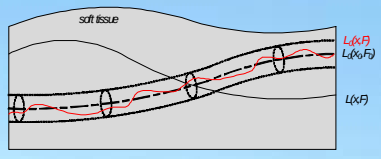


Electric skin resistance in a massage session



Training of force points

$$A = (\mathbf{n}, \mathbf{s}, \mathbf{a}, \mathbf{p}, F, M)^{\mathrm{T}},$$



$$\left\| L_0(X,F) - L_0(X_0,F_0) \right\| < R$$

Compliance and backdrivable robot

Subsystems of individual robot control

Subsystem of mutual performance of procedure by physician and robot

(1+2+3+4+5+6+7+8+9+10)

Security tools

1. Switching-off of drives on signal of the maximum force sensor which is connected to PFC system or abduction of a robot arm on biomedical signals.
2. Check of drives in the beginning of procedures and also the force sensor in programmed control points.
3. Performance of the first movements with the minimum forces.
4. Drives placing not in a robot hand but on a platform that will provide small inertia and easiness of a hand.
5. Soft non-electroconductive covering of robot hand and placing of tactile sensors on wrist and hand of the robot.
6. Use of technical vision system for comparison of the current image of a trajectory of the tool with sample one and virtual planning of procedure.
7. Use of elastic joints and backdrivable manipulators.

Conclusions

1. Ergonomics of medical robotics and especially in restorative medicine robotics has to consider not only dynamics and psychophysiology of physician-operator but also patient also.
2. At extended understanding ergonomics the accounting of patient causes necessary to consider a lot of new subsystems.
3. The appearance of compliance and backdrivable robots, working without enclosure, allows to organize ergonomic interaction human and robot in common work area and to increase efficiency.

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Many thanks for your attention!
Please, your questions.

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