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SOME PROBLEMS OF THE ROBOT CONTROL BASED ON USING CHANGEABLE STRUCTURES*

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Красимир Георгиев. НЕКОТОРЫЕ ПРОБЛЕМЫ УПРАВЛЕНИЯ РОБОТОВ ПРИ ПОМОЩИ ИЗМЕНЧИВЫХ СТРУКТУР

Обоснована математическая модель динамики антропоморфних роботов. Решение модели можно применить для цели управления. Применение этого подхода расширяет возможности адаптивных управляющих систем роботов.

Krasimir Georgiev. SOME PROBLEMS OF THE ROBOT CONTROL BASED ON USING CHANGEABLE STRUCTURES

For antropomorphic robots a compact system of differential equations is obtained. The solutions are applicable for control purposes. The new approach improves the possibilities of the adaptive robot control systems.

Robot conventional control and structures [1–3] do not consider elasticity and endeffector accuracy. So in this paper an approach to control strategy based on using new structures for compensation of the robot oscillations is proposed.

1. DYNAMICAL MODELLING

Let assume a robot (antropomorphic type) as a system of rigid bodies with

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natural generalized coordinates and additional elasticities in the joints. Then we suppose forces and moments to be applied in the points of the lumped mass model. Starting from the differential equations in the Lagrangian formulation and after linearization, we get for the decuplition motion in a vector matrix form

$$\begin{aligned} &(\boldsymbol{M}_a + \boldsymbol{M}_i)\ddot{\boldsymbol{q}} + \boldsymbol{M}\Delta\ddot{\boldsymbol{q}} + \boldsymbol{B}\dot{\boldsymbol{q}} = \boldsymbol{U}\boldsymbol{Q}, \\ &\boldsymbol{M}_a\Delta\ddot{\boldsymbol{q}} + \boldsymbol{C}\Delta\boldsymbol{q} = -\boldsymbol{M}_a\ddot{\boldsymbol{q}}, \end{aligned} \tag{1}$$

where $\boldsymbol{q} = [q_1, q_2, q_3]^T$ is the column vector of the general coordinates, $\Delta\boldsymbol{q} = [\Delta q_1, \Delta q_2, \Delta q_3]$ — the column vector of the link deformations, $\boldsymbol{M}_a$ — the matrix of the actuators masses, $\boldsymbol{M}_i$ — the diagonal matrix of actuators inertia torques, $\boldsymbol{C}$ — the diagonal matrix of the compliance, $\boldsymbol{C} = \mathrm{diag}[C_1, C_2, C_3]$, $\boldsymbol{Q} = [Q_1, Q_2, Q_3]$ — the column vector of the drive forces and moments, $\boldsymbol{B}$ — the diagonal matrix of the dissipation forces, $\boldsymbol{U}$ — the matrix of the transfer ratio between drives and links.

Solving system (1), we obtain

$$\begin{aligned} \boldsymbol{q} &= (\boldsymbol{M}_a + \boldsymbol{M}_i)^{-1}(\boldsymbol{U}\boldsymbol{Q} - \boldsymbol{B}p\boldsymbol{q} - \boldsymbol{M}_a p^2 \Delta\boldsymbol{q})/p^2, \\ \Delta\boldsymbol{q} &= (-\boldsymbol{C}\Delta\boldsymbol{q} - \boldsymbol{M}_a p^2 \boldsymbol{q})\boldsymbol{M}_a^{-1}/p^2, \end{aligned} \tag{2}$$

where p is a differential operator.

2. ROBOT CONTROL PROBLEMS

By building additional structures in the robot chain we can obtain 'of line' feedback from the robot endeffector and to improve the stability of the robot control.

The adaptive damping module, built in the manipulator, is shown on Fig. 1. The device consists of four micropneumatic valves, elastic springs and special body, fixed on the endeffector of the robotic manipulator.

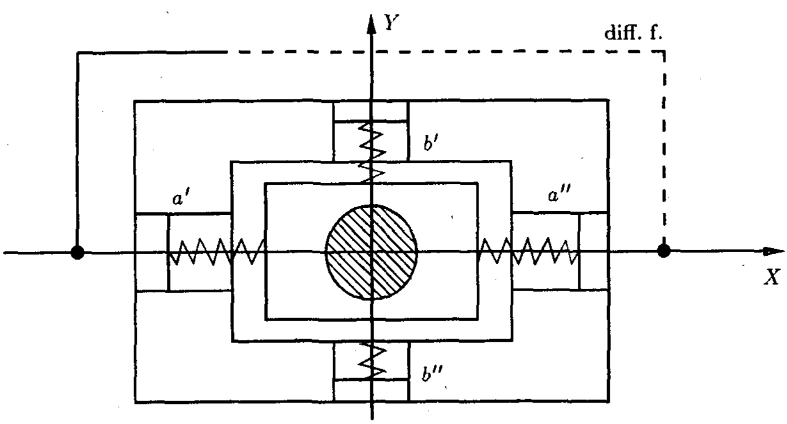

Fig. 1. An adaptive damping module

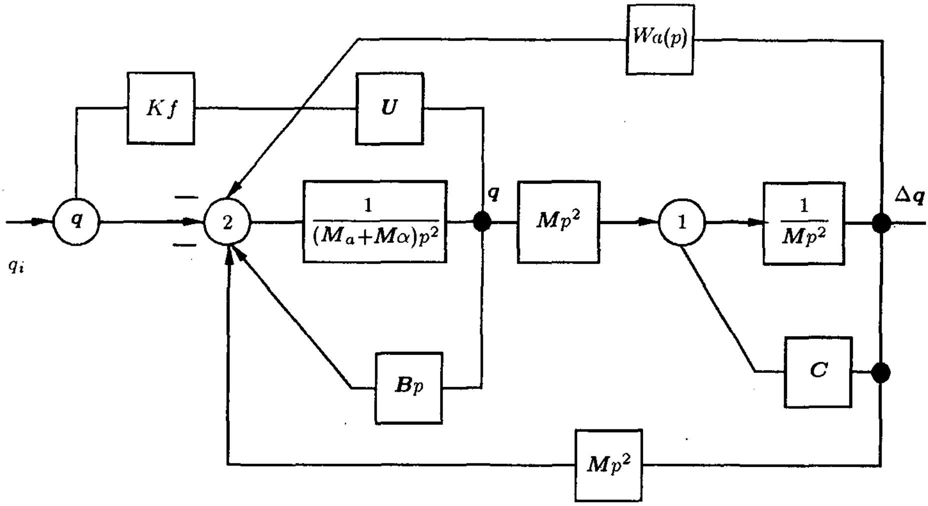

Fig. 2. Closed block diagram with a feedback

The compliance of the damping module is controlable by the action of a pneumatic pressure and servocontrol loop, applying microposition sensors.

Fig. 2 shows the structural block diagram of the mass model with built adaptive module. The chain is of a closed type and we suppose drive forces to be formed by sensor feedback from the endeffector position (Kf is a gain coefficient) and the other local feedbacks in the joints.

The relay action of the adaptive module for damping the robot oscillations consists of threshold increasing of the wrist compliance. In such a manner we can control the compliance matrix $\boldsymbol{C}$ in (2) and the values of the manipulator oscillations 'of line' during the motions.

Therefore we suppose the compliance to be controlled using the following formula:

$$\boldsymbol{C} = \boldsymbol{C}_i(t) + \Delta\boldsymbol{C}, \tag{3}$$

where $\boldsymbol{C}_i(t)$ is the initial adjustable compliance, $\Delta\boldsymbol{C}$ — the controlable threshold value of compliance.

3. SOME RESULTS

For the antropomorphic robots the numerical procedure and examples have been developed using the next data: mass inertia characteristics (two mass model) $M_1 = 16$ kg, $M_2 = 11$ kg (with damping module), $J_1 = J_2 = 10.8$ kg/m, $l_1 = l_2 = 1$ m, $C_1 = 6.10^4$ Nm/rad, $\Delta C = 10.6$ Nm s/rad.

On Fig. 3 the decreasing of the amplitudes of the robot's arm oscillations (with adaptive damping module) on the base of the provided numerical investigation is shown.

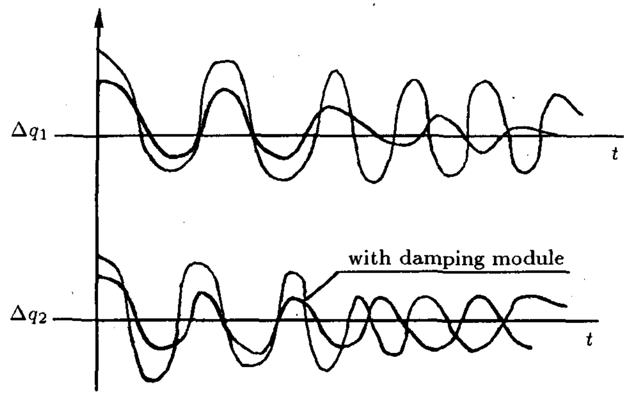

Fig. 3. Manipulator oscillations

This new approach to the robot control leads to the fact that the building of changeable structures (adaptive damping modules) in the robot chain improves the functional capabilities of the adaptive control systems. Applying additional structures in the manipulation robots enables to create a control methodology and to restrict the amplitudes of the robot's arm oscillations.

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