The Study of the Properties of Independent (decentralized) and Centralized Control of Redundant Parallel Robots

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The fundamental task of parallel robot constructions, especially redundantly actuated, is to provide effective and safe cooperation of all drives - actuators. This paper summarizes the set of the available control approaches adjusted to redundant case: from simple decentralized control (PID (/PSD) controller with reduction of the unproductive part of $I_{ntegeal}/S_{um}$ channels), to the simple centralized control (PID (/PSD) control with redistribution of adequate resultant fictitious force effects to really - used redundant actuators), and one example of the high level control approach (Generalized Predictive Control - GPC).

The parallel robot constructions, in comparison with serial open-loop types, achieve higher stiffness, high load capacity, lower mass inertia etc. These properties, among others, predetermine the robots to the use within more powerful industrial applications performing accurate machining and positioning. This paper discusses and investigates the following approaches of control adjusted to the redundant robots:

- simple decentralized control (the independent PID (/PSD) control with reduction of the unproductive part of I/S channels of the controller),
- simple centralized control (the independent PID (/PSD) control with redistribution of adequate resultant fictitious actuators to the really used redundant drive configuration),
- and one example of the high level control approach (Generalized Predictive Control - (GPC) ensuring the optimal cooperation of all actuators both adequate and redundant).

■ The first approach, the simplest control strategy [1], which can be taken into account, is view on the robots-manipulators, powered by group of the independent systems (drives-actuators), controlled separately, as a set of single-input / single-output systems. The mutual interactions among all actuators due to varying configurations during the robot motion are involved
as disturbance in each system. The graphical representation corresponds with the classical PID/PSD feedback control. However, in case of the parallel robots, mainly redundantly actuated, some problem of the unproductive part of integral/sum control channels must be solved. It does not occur in serial open-loop structures.

Undesirable unproductive part of I/S channels is caused by inaccuracies in mechanism. It means that the drive coordinates designed from independent (Cartesian) coordinates in certain cases cannot be attainable. It causes unpredictable increase of I/S channels, which does not contribute to the motion. Moreover, It leads to instability of the whole robot system. Therefore, some block must be added to the control circuit to reduce this undesired property.

In the ideal situation, the integral/sum part leveled off at certain magnitude, which was integrated during the whole control process. In opposite case, the integration/sum part increases unpredictably. This situation appears from geometrical inaccuracies in parallel construction. To solve the problem the block based on virtual work and projection method is used.

■ The next approach, simple centralized control [1], is based on the control in the independent Cartesian coordinates. The controller designs fictional actuators acting directly to the fix point of the tool. These fictional actuators are consecutively recomputed to the appropriate values. They are expecting from the drives, in order to perform the desired movement.

Utilization of the centralized control has one important advantage. The all-independent Cartesian coordinates within workspace of the robot are always achievable and they do not depend on any recomputation. Thus, there does not occur any unpredictable increase of I/S channels, which can damage the drives.

■ The last approach, high level control, is represented by Generalized Predictive Control algorithm (GPC). The Predictive control [4, 3] is a multi-step control based on local optimization of the quadratic criterion, where the linarized equation or state formula is used (i.e. only the nearest future control signal is evaluated). This approach admits combination of feedback~feedforward parts. As mentioned above, for the quadratic criterion, the nonlinear model must be linearized and converted from continuous to discrete form.

The base of predictive control is the expression (prediction) of new unknown output values from actual topical state. Then, the quadratic criterion is optimized at certain time instant, with use of mentioned prediction. Obtained control can be already used.

Setting of parameters of the controllers of mentioned approaches is not the same task. Number of the parameters is different. For tested parallel robot construction, the decentralized control has three parameters. The second approach, simple centralized control is not so simple for setting, because it generally represents the biggest number of parameters (in our case 12 parameters). The last approach (GPC) is the simplest from the all. Since it represents generally only two parameters (horizon of the prediction and penalization) and their choice is not difficult as in the previous methods. Moreover, the approach achieves the best compliance of the planed trajectory, but it requires linear or linearized dynamic model of the robot.

The simple decentralized control and high level control (GPC) were successfully tested on the real robot application.

References:

[1] SCIAVICCIO, L. – SICILIANO, B.: *Modeling and control of robot manipulators,* McGrwHill Co., 1996

[2] STEJSKAL, V. – VALÁŠEK, M.: *Kinematics and Dynamics of Machinery* Marcel Dekker Inc. 1996

[3] BÖHM, J. – BELDA, K. – VALÁŠEK, M.: *Decetralized and Centralized Control of Redundant Parallel Robot Constructions,* Instituto Superior Técnico 2002 pp. 6.

[4] ORDIS, A. – CLARKE, D.: *A state-space description for GPC controllers,* INT. J. Systems SCI. vol 24, no. 9, 1993, pp. 1727 - 1744.

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