Structured Model-based Control of Redundant Parallel Robot Kinematics

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1. Introduction

Nowadays, the further development in industrial area is constrained by deficit of powerful machines with adequate dynamics and stiffness. Utilization of parallel robots, especially over-actuated, that are controlled by suitable control algorithms represents promising way to improve dynamics, stiffness, accuracy and productivity of machine tools and their centers. The redundant parallel kinematics can be understood similarly as adequately-actuated structures - movable truss constructions or the movable platform (place of tool or gripper) supported by several links - but they include more actuated links than DOF. This option solves existence of singular positions of adequate structures and furthermore improves stiffness and dynamics. The important and not fully solved issue is their control. This work summarizes two possible ways based on model-based approach: Sliding Mode Control (SMC) and Generalized Predictive Control (GPC).

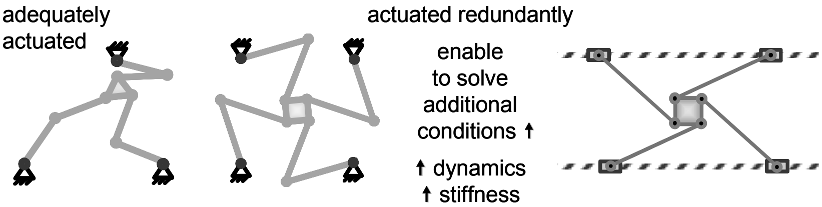

Fig. 1. Parallel kinematics actuated adequately and actuated redundantly.

2. Model - Based Control

There are two levels of the control shown in Fig. 2: local-***1*** and global-***2***. Local (decentralized) level controls each drive independently, without any consideration of mutual relations. The global (centralized) level uses for control design some mathematical model of whole structure; e.g.: model given by set of differential equations. The model-based approach (SMC, GPC) combines feedforward and feedback together. The model represents prior information, which is used for forming the dominant part of control actions. Attached feedback from measurable robot outputs compensates model inaccuracies and certain bounded disturbance. It composes remaining part of designed actions. From view of prediction to future, Sliding Mode Control represents one-step ahead strategy and Generalized Predictive Control represents multi-step strategy. Due to practical reasons, we focus only on discrete cases of mentioned control strategies.

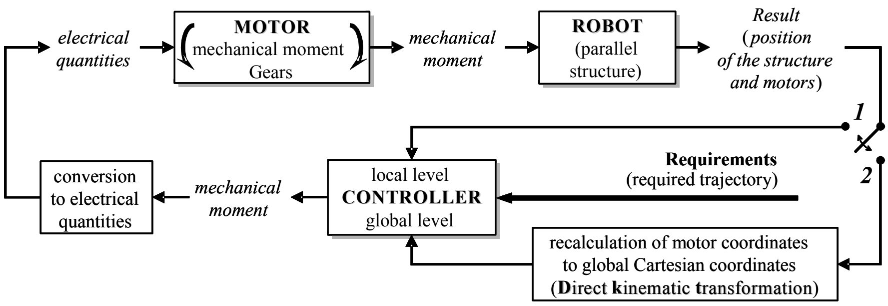

Fig. 2. Conceptual scheme of control.

2.1 Sliding Mode Control

The SMC approach is based on the 'switching' control action and performance of conditions of Lyapunov theorem. The both fundaments generate fast and accurate actuation continuously leading the system to asymptotic stable state approaching to desired position.

2.2 Generalized Predictive Control

The predictive control is a multi-step control based on N – step prediction of outputs inserted to minimization of quadratic cost function e.g. in a form:

$$J_i = \sum_j \left\{ (y_{i+j} - w_{i+j})^T Q_y (y_{i+j} - w_{i+j}) + u_{i+j-1}^T Q_u u_{i+j-1} \right\}, \qquad j = 1, \cdots, N \tag{1}$$

where prediction of outputs y_i is based on mathematical model describing the dynamics of the structure. From the function (1), the suitable control u_i is obtained. In comparison with former SMC strategy, it produces more harmonized control actions. Moreover, this property can be adjusted by suitable choice of penalizations (Q_y, Q_u) and their ratio respectively.

3. Examples and Illustrations

For real experiments, the control scheme (Fig.3) was applied to laboratory prototypes shown in Fig. 4. As real actuators (drives), brush MAXON DC motors were used. The time history of generated requirements on motors i.e. torques on rotors are shown in Fig. 5.

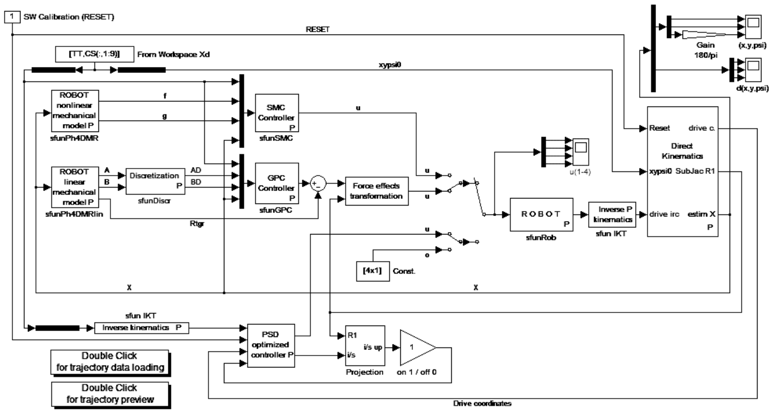

Fig. 3. Structured control circuit including both SMC and GPC strategies enabled via switch.

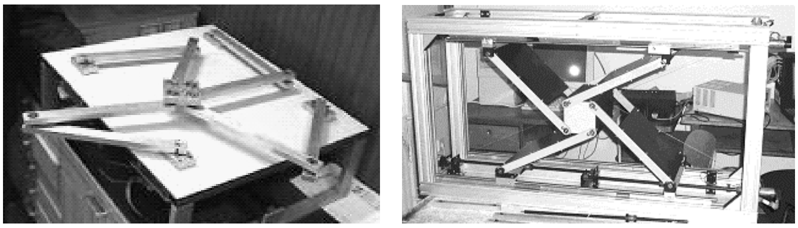

Fig. 4. Two laboratory prototypes of redundant parallel robots, which serve for real experiments verifying the mentioned model-based strategies.

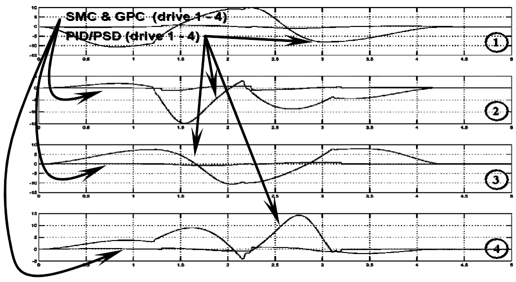

Fig.5. Comparison of model-based control strategies with conventional PID/PSD structures.

Fig. 5 were recorded during the motion along "S- shaped" trajectory. It illustrates the both model-based strategies SMC and GPC in comparison with conventional PID/PSD structures.

4. Conclusions

This work shows two possible ways of control and their comparison. It shows that the classical approaches may be energetically consuming (Fig.5). They should be, in a future, replaced by such strategies e.g. model-based strategies like SMC or GPC, which consider the most of the available information on given controlled object – parallel kinematics (parallel robotic structure).

5. References

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