TASK-BASED MODULAR CONFIGURATIONS FOR HYBRID AND REDUNDANT PARALLEL ROBOTS

C. Stechert, H.-J. Franke , C. Wrege

Institute of engineering design, Technical University of Braunschweig, Email: stechert@ikt.tu-bs.de

Abstract: Parallel robots provide high stiffness, accelerations and accuracy. They are relatively complex products that are specialized to a specific task. Normally a new robot is designed for every new task. This paper shows an approach that makes it possible to configure parallel robots with the help of a modular system. Thence it is possible to reduce complexity costs and the time to delivery.

Keywords: Control theory, Modular system, Modeling and identification of robotic systems, Computer aided design for robotic systems, parallel robot, hybrid robot.

1. INTRODUCTION

Within the collaborative research center 562 (established by the DFG) concepts for the design and modeling of parallel robots for high operating speeds, accelerations and accuracy are developed. Parallel robots feature relatively small moved masses and high stiffness. In comparison with serial robots parallel robots offer higher dynamics and high accuracy, especially when new and optimized machine elements are used. In some cases hybrid (parallel robots with serial parts of the structure) or redundant kinematics are necessary or useful to solve special tasks (Kuhfuss, 2002; Tsai, 2002; Yang, 2002). This results in relatively complex products. To reduce time and costs of development and production a concept of a modular system was developed and integrated into a development environment. Other existing concepts for modular systems such as (Yang, *et al.*, 2000), (Yoshida, *et al.*, 2002), (Lee, *et al.*, 2002) and (Xu, *et al.*, 2005) cover a different background. Hence results can at most be transfused partially.

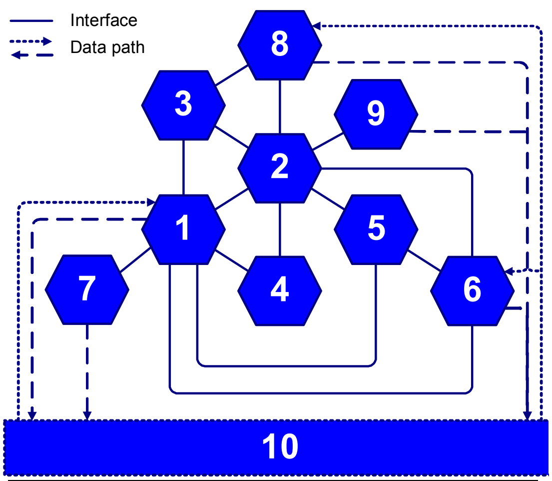
Robots as described above are often produced in relatively small quantities. Therefore a modular system just makes sense when it accompanies the whole product lifecycle. At an early stage of design (in the engineering design department) modules and features are available that allow faster modeling. For offers a robot can be set up of standardized modules. Hence reliable pricing and fast reactions to customer queries are possible (Lux, 2001; Franke, 2005c). The customer can get realistic data of the future robot early to plan the future environment of the robot. The modular system is integrated into a development environment that provides the exchange of data between different simulations. Therefore the modular product can be verified fast and optimized partially. Afterwards data are sent to the robot production line. In the assembly it is put together mostly from standardized components. Hence the margin of error will be very low (Kohlhase, 1997). When the customer changes his production often the robot has to be reconfigured. The known data can then be used to change specific modules to adapt the structure to its new task. Consequently a saving of costs results from the reduction of both design and manufacturing time and the prompt tendering. Furthermore complexity costs can be reduced, because a relatively high extern diversity can be offered, while the intern diversity is kept relatively small (Firchau, 2003).

2. THE MODULAR SYSTEM

To accompany the product lifecycle models of different levels of abstraction and detailing are used. As described by (Franke, *et al.*, 2005a, d, e) for the development of parallel robots different knowledge domains are used. In particular these domains overlap for some steps of the development. Although software became more and more powerful during the last years (e.g. CAD software that integrate logical and mathematical functions), the development of parallel robots still needs an exchange between knowledge-domains, i.e. different software and simulation tools. Hence the robot has to be built up in different levels of abstraction. The developed modular system allows to integrate different levels of abstraction into one concept and therefore to develop a diversity of different structures (Franke, *et al.*, 2005b).

2.1 The abstract structure

The abstract structure scheme . The basis of the further design is an abstract structure scheme (Fig. 1). It contains standardized modules and interfaces between them. By defining a minimum of modules and interfaces the intern diversity and complexity of the product keeps small. But a small number of modules also restricts the possible extern diversity. Therefore the modules and the interfaces have to be defined carefully and delimited exactly from each other.



1	drive
2	joint
3	rod
4	rack
5	working platform
6	tool
7	sensor
8	adaptive components
9	joint integrated sensor
10	control hardware

Fig. 1. Abstract structure scheme for the modular system for hybrid parallel robots.

Just to give one example, module 2 represents a passive joint, which can be e.g. a swivel, a cardan or even a prismatic joint. In parallel structures joints usually connect rods (3), the working platform (5), the rack (4, cp. hexapod structure) and / or the drive (1, cp. triglide structure). For the control of poses (high accuracy, online calibration and monitoring of singularities) sensors are needed (9). When an additional DoF is realized through an auxiliary drive mounted on the rack, the joint is directly connected to the tool (6). Lastly adaptronic components (8) are needed that allow to adjust joint characteristics in process.

The developed structure scheme (Fig. 1) contains 10 modules that allow to realize all already known and planned future structures. Thereby it is irrelevant, whether parallel, hybrid or redundant structures should be made up. A number of exactly defined interfaces exists between modules (shown as connecting lines). That means that every structure can be made up of the structure scheme by arranging modules following the connecting lines. Thereby modules can be used repeatedly, i.e. loops can be repeatedly passed through and connecting lines can be used in both directions. Not every module and interface has to be used for a concrete structure.

The abstract structure-plan. Fig. 6 shows an abstract structure plan for a triglide structure. That is the first level of abstraction. It shows how many modules of what type are used and to which other they are geometrical connected. It gives a first idea of the structure and appearance of the robot to be designed.

2.2 The submodules

The structure scheme is subdivided (Fig. 2). Modules are fractionalized in basic elements and interface elements (geometric interfaces). Each of these submodules own attributes that can be filled with different values. That means that for every submodule a diversity of variants can be generated.

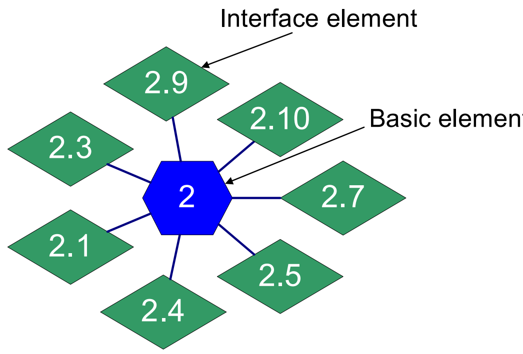


Fig. 2. Division of a module of type “joint” into subelements.

Basic elements. Attributes of a basic element are e.g. mass and moment of inertia. A module can contain several basic elements. For instance a module of type “drive” generally contains basic elements of types “engine”, “clutch” and “gear” and intern interface elements between these basic elements. If submodules are bought-in parts interfaces are generally already standardized and therefore the diversity of variants is already narrowed down. In this case a combination of engine and gear can be seen as one variant of the basic element “drive”.

Geometric interfaces. Geometric interfaces are plug connections for data-exchange (e.g. firewire) or connections between bars and joints (e.g. by a thread) for instance. These interfaces are defined precisely. Construction catalogues of connections were