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Concept and exemplary realization of Human Hybrid Robot for supporting manual assembly tasks

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Abstract

Especially for production of unique and small scale series, manual tasks have special significance. The quality hereby depends highly on the employee. In consequence of i.a. the demographic change and the associated increased diversification of the employees skills and abilities, the companies have the challenge to find appropriate staff. Technical systems can be supporting manual tasks to fulfill the production requirements. This paper introduces a new approach (Human Hybrid Robot – HHR) and includes first passive and active implementations. Thereby human and technical elements are combined in a system to take advantage of the individual abilities.

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Keywords: HHR, Human Hybrid Robot, human robot integration, hybrid kinematics, assembly, supporting system, human-robot-cooperation/interaction

1. Introduction

Essential characteristics for increasing the national and international competitiveness of manufacturing companies are represented by the realization of shorter product life cycles, enhancement of the variety or extension of the product functionalities. Against this background, companies challenges have to manage the diminishing quantities and in particular the increasing complexity of products and production. The demographic change and the associated increasing inter-individual variation of abilities and skills are further requirements on the organization of future productions.

In the field of mass production, the automation of production processes is an established approach for i.a. an increasing production rate, an improving quality, a reducing of quality variance and costs as well as to substitute employees or relief routine tasks. Subject of current developments in the field of production technology are for example freely programmable and by sensors expanded automated systems, solutions for asynchronous, dislocated cooperation of human with (semi-) automated and sensor-controlled machines and robots [1, 2], technologies and methods for individualized design of workplaces and systems as well as age-appropriate workforce [3]. Usually the approaches are characterized by a strict spatial or temporal separation of human activities and automated systems.

Especially for the production of unique products or products with small-scale lot size and large-scale lot size with a high diversity of variants, automated solutions are often uneconomical or technological difficult to realize. For future, this induces that several, essential and irreplaceable production tasks are performed manually. On the one hand, the reason can be seen in specific sensomotoric skills and cognitive abilities of humans. On the other hand, it is also essential for the social and economic self-understanding of our society. Equal assumptions apply for sensomotoric activities such as surgery, orthopedics and similar activities in other areas.

Against the outlined background, the employee should be supported appropriate by passive and/or active technical systems.

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This paper introduces a novel concept for a supporting system of assembly tasks which is called Human Hybrid Robot (HHR). First passive and active supporting systems will be illustrating the approach.

2. Idea of the new approach

Due to i.a. an increasing product variety, functionality and complexity advancing demands for the production are expected for the future (see Fig. 1). In addition, the skills and abilities of the employees are decreased by ageing workforce, diversification of qualifications and extent of work. Consequently, the gap between the required and available skills and abilities would be greater than today. The idea of the new approach is to support the employee through technical functionalities.

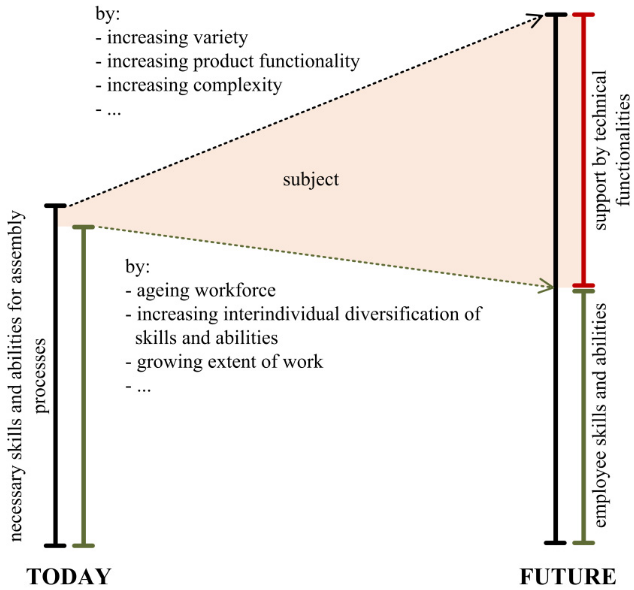


Fig.1: Use of support systems (qualitative illustration)

3. Current approaches

In the field of assembly and handling technology, different approaches exist. Technical solutions are automats, telemanipulators, balancers, manual workplaces, exoskeleton and manipulators based on the concept of human-robot-cooperation.

As illustrated, the demand on production technology and employees increases. The employee is required especially for tasks with small lot sizes (see Fig. 2). For tasks in dangerous environments or inaccessible areas, telemanipulators are applicable [4].Balancer or lifting aids are used for handling tasks with large or heavy components [4]. (Simple) Tasks with many repetitions are typically performed by robots or automats. The approach of human-robot-cooperation can be classified in the intermediate area between free programmable automats and manual workplaces. The main idea of the human-robot-cooperation is to share the work between humans and machines in a common workspace [1]. Technical systems take usually exhausting handling tasks and tasks with many repetitions. The cooperating work of human and machine with one workpiece is currently strictly separated in time or space. A first approach for a spatially and temporally cooperating work is currently explored [5].

Technical systems such as manipulators and balancers protect employees against hazardous substances, support in handling operations and tasks in hard-to-access areas to improve the ergonomics and enable the handling.

In addition, other developments include technologies and methods for individualized design of workplaces and work systems as well as for age equitable employee placements (age-mixed teams, job rotation, etc.) [6].These approaches are also characterized by a strict spatial or temporal separation of the activities of humans and automated systems.

One way for increasing strength and mobility of people are exoskeletons. These systems can support different body parts e.g. hand or upper extremity [7, 8] or the whole body [9]. Classic fields of exoskeletons are agriculture, rehabilitation and military [7, 10, 11].

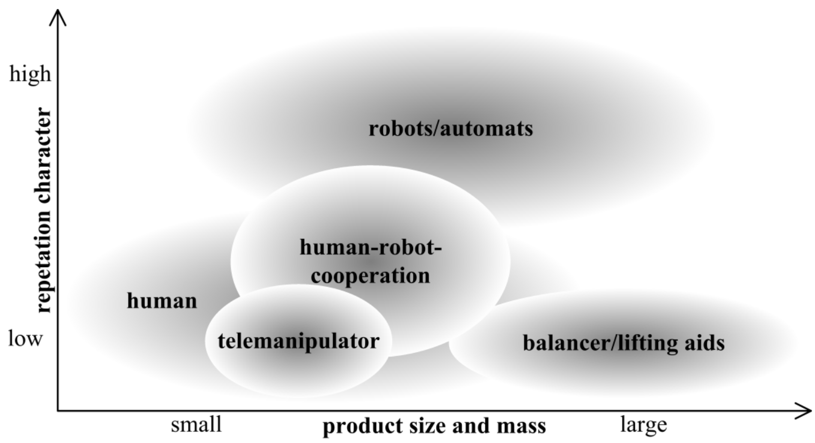


Fig. 2: Qualitative distinction of current approaches

The fulfillment of the requirements for production unique products or products with small-scale lot size and large-scale lot size with a high diversity of variants, current approaches are not satisfactory. Especially in this area, the assembly quality highly depends to the employees. The already developed and usually localized assembly and assistance systems can support the employee or can overtake tasks in some areas.

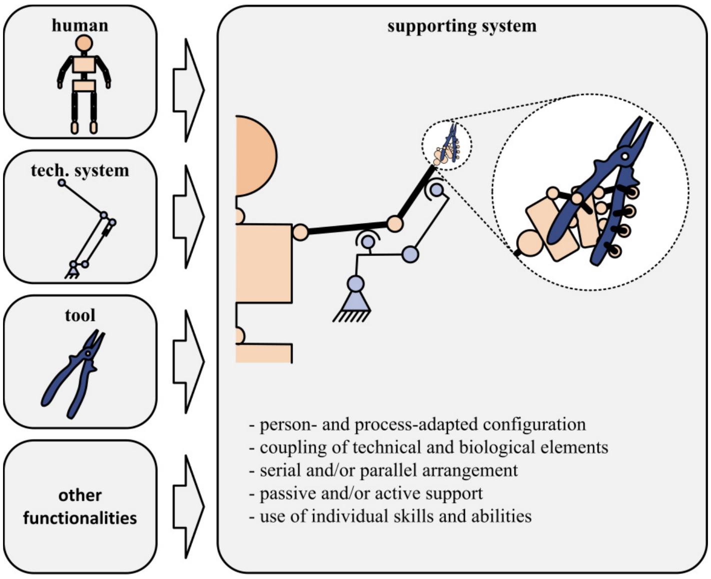


Fig. 3: Approach of the Human Hybrid Robot [12]

4. Concept of Human Hybrid Robot

4.1. Approach

The principle idea of Human Hybrid Robot (HHR) is the person- and process-adapted coupling of human, technical system, tool and other functionalities in a passive and/or active hybrid system (Fig. 3).This hybrid system will enable the employee:

- to perform assembly tasks stress-optimized and
- to supplement those skills and abilities to support identified individual biomechanics, sensomotorics and cognitive limitations.

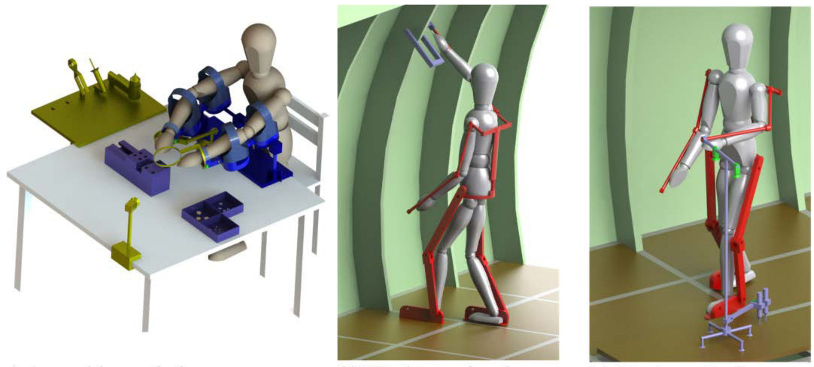
In this way, the gap between the required process skills and abilities as well as the skills and abilities of each employee should be limited.

To support the employee in performing sensomotoric tasks, technical elements will be coupled intelligent with biological physiological conditions. In such a way, the sensomotoric coordination, cognitive functions as well as good sensors of the human and the machine-specific properties (e.g. precision, repeat accuracy, quantitative characterization, force support and execution of activities with many repetitions) are optimal exploited. The coupling of biological and technical elements can be serial and/or parallel. The special compared to approaches from the state of the art consists of the systematic integration of human and machine in a system with a common control system. The target values of the technical system are always given by the human in account to the required work conditions. Result of this strategy is a situation- and context-adaptive system behavior.

The coupling extent of human and technology can be limited to parts of the body, e.g. different extremities, or can be supported the complete body. Different stationary and portable applications are conceivable. Three examples are illustrated in Fig. 4.

One possibility is to support tasks in manual workstations. On the one hand, technical elements can enable a steady and more precise work (e.g. interest in precision engineering). On the other hand, functions for quality assurance can be integrated. The application shows a fix coupling between human and technical elements. Other linkages could be soft and limited. The kind of coupling depends on different aspects, e.g. assembly tasks and support level. As illustrated in [12], hardware support modules lead to a slightly smaller work area. However, the kinematic chain of current technical modules possess enough degrees of freedom to maintain the necessary motion range and motion trajectories as well as a steady arm posture within the work area.

In example two and three, the technical system should be support tasks in non-ergonomic positions. In addition to the



a) Assembly workplace b) Work over head b) Work on the floor

Fig. 4: Exemplary applications

mentioned functionality, the supporting system can increase the endurance by force assistance. Furthermore, serial arranged elements can improve the accessibility of assembly locations, e.g. by an endeffector with power and geometric generating axes.

Beside the identified applications in the field of assembly, other applications such as the support of manual tasks in production, medicine and care are conceivable.

4.2. System configuration

The aim of the new approach is to provide supporting systems which are customized in respect to the employees skills, abilities, body mass and characteristics of the production processes. The flexibility will be achieved by modular system architecture. An ad hoc configuration and reconfiguration can be enabled by a pre-designed construction kit. This contains integrated and interactive hard- and software modules with standardized interfaces. These modules can dispose of multiple functions and have different performance parameters. The development of such a construction kit may be associated to an increased effort (e.g. different kinematics elements and human-machine-interfaces for varying employees). Due to the general validity, a wide use is possible.

The basic of the modules are technical functionalities (Fig. 5).The functions may have different tasks. A main task of the support system is to stabilize the human body or body parts as well as holding tools. The control of technical elements could be realized by different optical and tactile principles. Opportunities therefore are EMG- and force-sensors or the integration of pupillography. Moreover, functionalities for increasing the quality and for observation can be used. Mechanism such as Poka-Yoke can apply for the quality assurance. Further contribution can be realized by functions like process-dependent movement corridors, degrees of freedom and parameters as well as person-dependent operating modes.

The design and configuration of supporting systems according to the approach of Human Hybrid Robot are significant determined by human and assembly process characteristics (Fig. 6). Impacts on this process are for example the body size, the sensomotoric skills and cognitive abilities of the employee as well as the required lot size and the process and product complexity.

The modular system approach yields a complex hard- and software structure, but it leads to a higher flexibility. An appropriate degree of modularization or granularity must be identified and satisfied for the development.

Before operating, the configured system (person- and process-adapted) has to be adjusted to the task/process. This does not occur for every execution, but always after major changes (e.g. adjustment to body size as well as skills and abilities). Moreover, the adjustment effort depends highly to the system solution, thus the effort for active systems are in general greater than for passive systems. The effort can be reduced by pre-designed working modes.

4.3. Objectives and advantages

The passive and/or active support of manual production tasks by parallel and/or serial arranged technical elements should be realizing an innovation which is justified on technical, economic and social benefits. An important contribution therefore is provided by the enablers:

- Support by functionalities: active and passive, control and observation, person- and process-adapted.
- Modularization: modular system design, construction kit, element function mapping, configurability.
- Human-machine-coupling: merging of biological and technical elements, use of individual skills and abilities.

The main objectives and advantages of the new approach are:

- increase of productivity and flexibility due to person and process adapted supporting systems,
- enhancement of the accuracy and integrated quality assurance through supporting functionalities,
- improvement of the staff availability by compensation of individual skills and abilities (e.g. force support),
- decrease the physical load and mental stress due to adapted technical elements,
- increase of employee application field through supporting functions and
- reduction of the learning phase by demonstrating procedure.

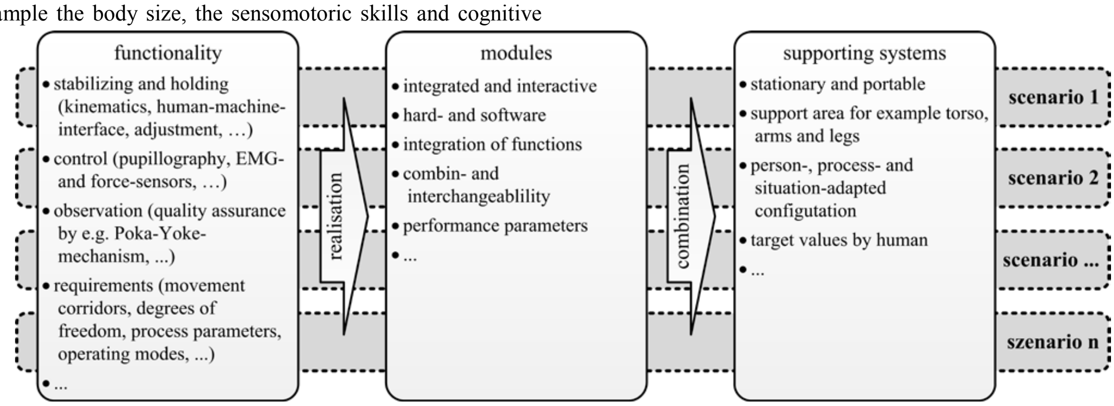


Fig. 5: Development phases

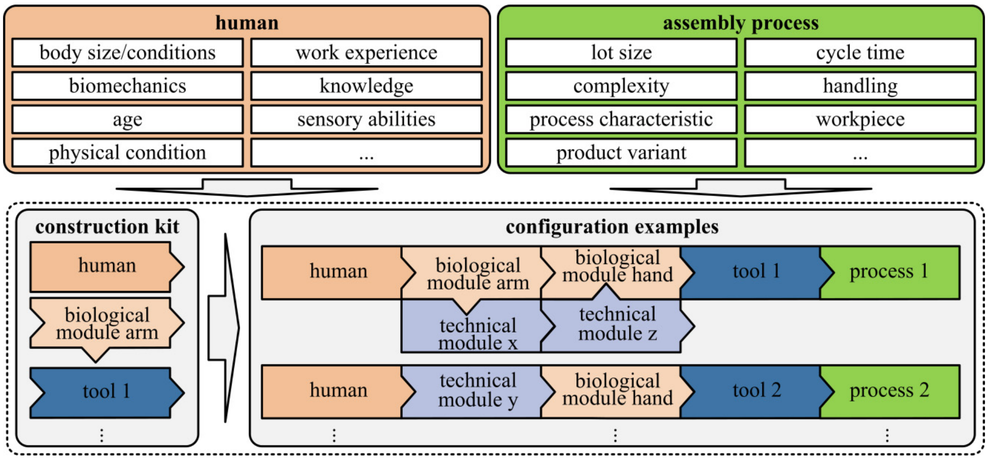


Fig. 6: Person and process customized configuration [12]

5. Exemplary realizations

In the following, first developed hardware modules for supporting systems will be shown. Realizations for passive and active kinematics are illustrated. The modules can be used for stationary applications, e.g. for manual workstations.

A module for passive stabilization and bracing human arms is shown in Fig. 7 a). In this approach, a passive orthosis is used. The orthosis represents the linkage between human arm and guiding mechanism which is mounted on a slide. The kinematic chain of the technical module possess enough degrees of freedom to maintain the necessary motion range and trajectories.

Fig 7 b) illustrates a first active kinematics module. This module consists of robolink® joint modules of igus® inc. and designed human-machine-interfaces. The kinematic chain is composed of four rotatory joints. These are driven through draw-wire technology and stepper motors. The kinematics control is realized by integrated force and angle sensors.

Besides the kind of support (passive and active), the modules shown in Fig. 7 uses different human-machine-interfaces with a various coupling. The coupling intensity for the passive module is higher. As interfaces for the active module, shells are provided. These enable an easy and fast coupling, e.g. for involuntary movements like sneezing and cough.

Further developed hardware modules represent interfaces and a geometric generating tool. The interfaces are suitable for transmission force, torque, information and engine [13]. The geometric generating tool was developed specifically to support the production of optical instruments in medical technology [12]. First software modules are modules for the quality assurance like integrated Poka-Yoke mechanism, movement corridors and workplace monitoring.

6. Summary and outlook

In view of the demand for higher production productivity, higher product quality and the challenges due to the demographic change, new technologies are needed to support manual tasks in production. One approach therefore is the so-called Human Hybrid Robot (HHR) which can be characterized by the intelligent coupling of biological and technical systems. The passive and/or active support of the employee during the execution of his tasks can achieve different benefits, e.g. the optimization of the assembly accuracy, the integration of the quality assurance as well as the improvement of the productivity and availability of the employee.

A supporting system according to the principle of the Human Hybrid Robot can be used for different tasks. Such a system can be designed for example to avoid non-ergonomic working positions and for complex assembly tasks such as handling and assembling micro parts. Medicine and care applications are also conceivable. To maintain the system flexibility, a high modularity is to be considered for the design. The integrated and interactive hard- and software

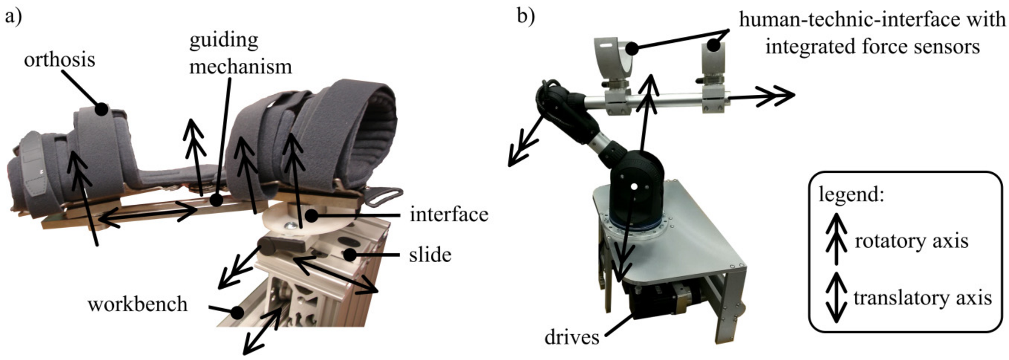


Fig. 7: Exemplary hardware system moduls – a) passive kinematic module b) active kinematic module

system modules can fulfill different functionalities. The degree of modularization or granularity of the modules significantly determine the development effort as well as the functionalities, the handling, the design and the interfaces significantly determine the acceptance of such systems.

Different functionalities for supporting manual assembly tasks are developed on the basis of the presented concept. The identified functionalities have been implemented prototypically in first technical modules. Their feasibility will be shown by further experimental studies. Furthermore, other functionalities and modules will be developed to extend the range of applications for industrial assembly processes. Moreover, social and ethical issues are explored currently, for analyzing the acceptance of such active and passive systems (e.g. coupling extend and linkage), its safety and usability.

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