Flexibility in Human-Robot Teams

Challenges and Solution Approaches

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***Abstract*— Human-robot teaming attracts an ever-increasing level of attention in academia as well as in industry. Mixed teams promise enhanced productivity and job attractiveness to small and medium enterprises that are not suited for traditional, fenced automation solutions. Yet, coordinated task sharing among heterogeneous partners requires intelligent cobots that are capable of acting flexibly under the influence of process and product variety. This short paper summarizes facets and challenges of flexibility in human-robot teams together with our prior contributions and future research directions.**

Keywords: human-robot teaming, joint task coordination, task modelling, virtual commissioning

I. Motivation and Problem Definition

Partial automation in manufacturing enables enhanced productivity and job attractiveness, *e.g.* due to improved ergonomic conditions [1]. Particularly small and medium-sized enterprises can hardly benefit from traditional automation with statically programmed, fenced robots – setting up respective systems is often too effortful and inflexible when operating robots in unstructured environments, especially when they are strongly influenced by humans. We, therefore, envision an intelligent robot colleague capable of intuitively sharing work with humans in industrial tasks while adapting flexibly to a broad spectrum of product and process variance.

II. Related Work

Related work on human-robot task sharing can be split into static and dynamic approaches. *Static* methods rely on capability indicators assigned to each work item. These indicators quantify the fit of humans or robots to work items. Hence, they enable multi-criteria optimization to minimize makespans and maximize the alignment of task assignment with agent capabilities (*e.g.* [1], [2]). This leads to fixed schedules that humans and robots have to adhere to. By contrast, *dynamic* approaches offer more flexibility by online (re-)planning during joint task execution. Corresponding strategies including our own work (*e.g.* [3], [4]) have mostly focused on robot adaption to human decisions on the ordering of work items – product part variety as a consequence of mass customization, and robustness to human or robot error, changing part feeding locations *etc.* have played a minor role so far. Yet, mixed teams must also reflect these aspects to achieve the full range of flexibility that maximally reduces the hurdle to use robots as team members in production.

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III. Our Approach and Contributions

We are therefore contributing towards solving the below challenges linked to the design of flexible robot co-workers:

Task Modelling: Flexible robot use requires means for end-users to transfer knowledge on joint tasks to the system. Task-level visual programming has recently become broadly available. We have so far investigated the applicability of this paradigm to models for several agents with 'earlier-later'-relations between robot skills. Future work will integrate product variety management by allowing for partly under-specified skill parameters to be grounded at execution time.

Coordination: Once a shared task has been formulated, the division of work must be coordinated online. Our contribution is a heuristic approach that handles partial observability of task progress emerging from a cost-effective yet limited sensor setup. The team can switch between coexistence, cooperative parallel work, and collaboration with physical contact. Configurable state machines control the robot coordination behaviour in terms of action, active perception, and human-robot communication. The approach puts particular emphasis on decoupled work and asynchronous communication, hence keeping robots productive even after human team members have left. Aside from product variety and error handling, advances towards multi-human-multi-robot teams with decentralized coordination capacities are planned.

Benchmarking: Reproducible benchmarks are required for comparable human-robot interaction research. User studies are well established in the field. However, this evaluation method does not scale well to flexible teaming. A comprehensive evaluation of flexible cobots would require extensive numbers of subjects to capture different scenarios. This issue can be overcome by observing dynamic interactions in simulation. To this end, we are working on an approach based on crowd-sourced training data to reproduce indeterministic, yet plausible human behaviour in virtual commissioning.

References

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