Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute for Control Systems (IRS)

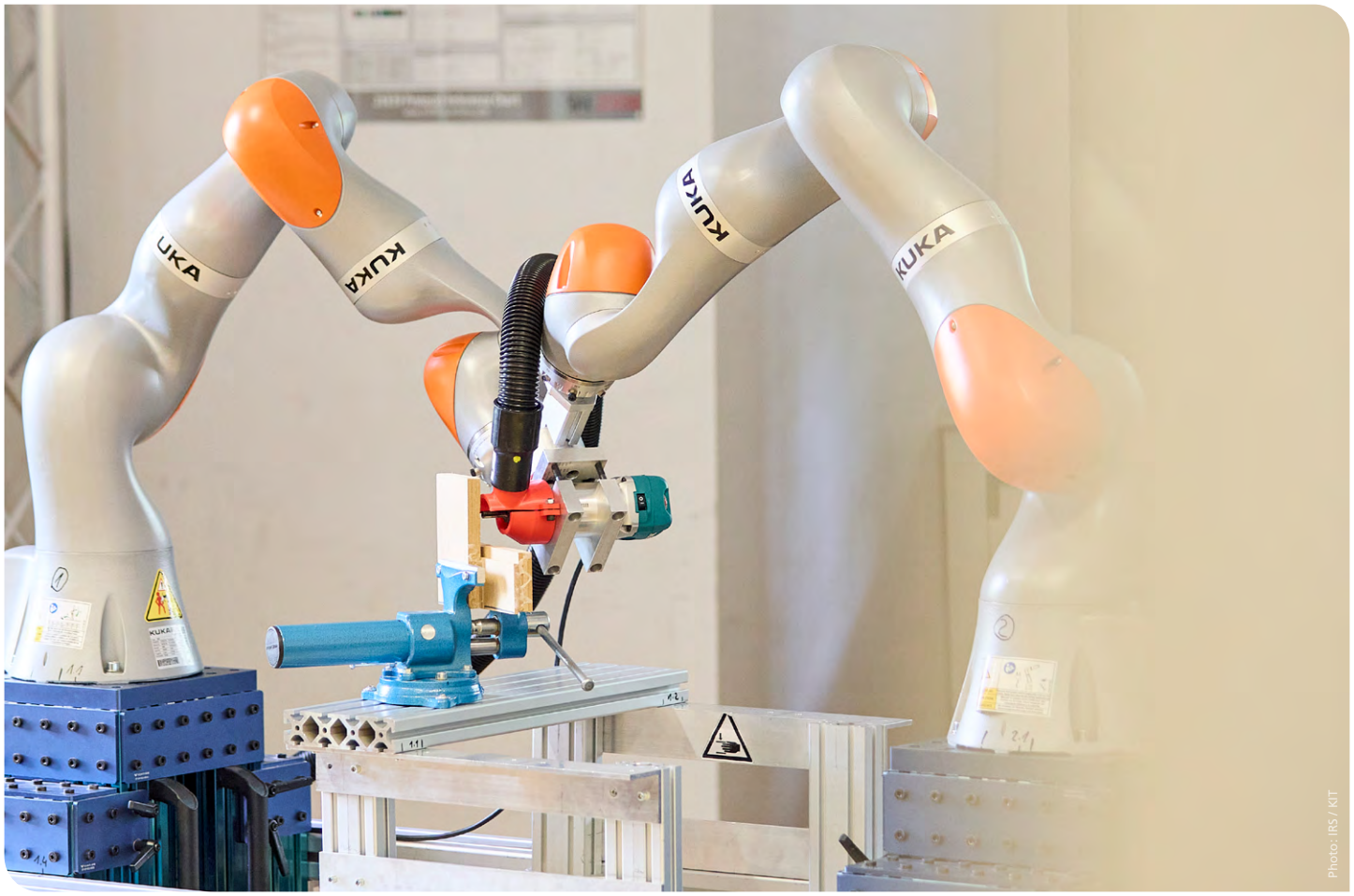
Precise Collaborative Robotics

Smart Collaboration of Industrial Robots Enables Flexible Production

Through collaboration in production, physically coupled industrial robots enable complex manufacturing processes that have only been realized with conventional machine tools so far. However, the low stiffness of the individual robots and difficulties in load distribution between coupled robots still make it challenging to reach high manufacturing precision. The complexity of robot programming presents another challenge. Researchers at KIT's Institute for Control Systems (IRS), in cooperation with the FZI Research Center for Information Technology, have developed a novel control system for milling and bending metal parts by two coupled industrial robots. Via a user interface, operators communicate the task desired to the robot in natural language.

Challenge Faced in Modern Manufacture

Many manufacturing companies face the challenge of producing increasingly customized products in small batches while maintaining high quality. Conventional machine tools reach highest precision, but are expensive and tailored to execute specific tasks for which they were designed. Moreover, their operation requires trained staff. Industrial robots, by comparison, are inexpensive and versatile. Yet, they reach their limits when it comes to complex machining and forming processes. Individual robots alone lack stiffness, causing inaccuracies at high process forces. Safety requirements and lacking concepts for intuitive human-robot collaboration make their use by small- and medium-sized enterprises and craft businesses even more difficult.



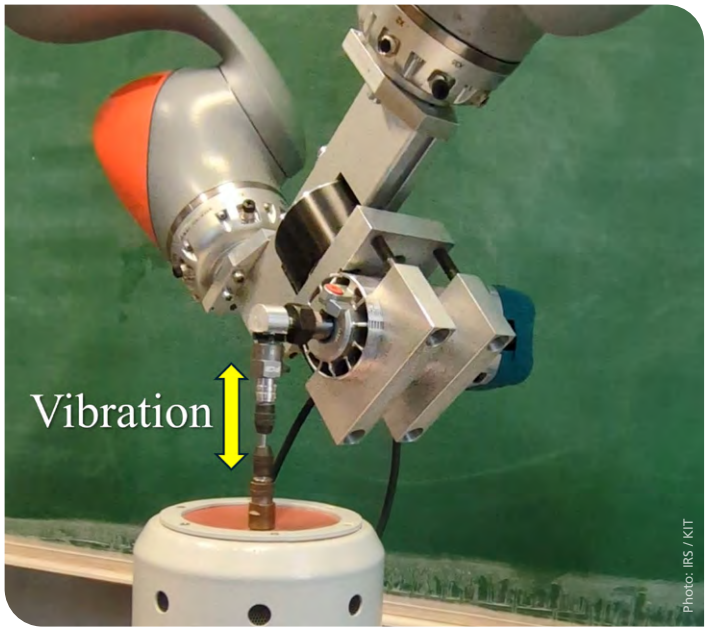
Flexible execution of a highly precise manufacturing task using two collaborative robots.

Collaborative Manipulation with Two Robots

When capabilities of a single robot are insufficient, collaborative manipulation using two or more robots may be a solution. A control system newly developed by researchers from IRS and FZI allows for the use of industrial robots as a real alternative to traditional machine tools. They have coupled two industrial robots to a single system that optimally distributes the forces required for a manufacturing task and controls internal stresses, thereby enabling high manufacturing precision. A demonstrator comprised of two industrial robots bends a workpiece using a tool-changing system and illustrates the motion sequences of milling a workpiece.

Smart Control and Automation Architecture

Both industrial robots are equipped with integrated actuators as well as position and torque sensors in their joints. The researchers have built an automation architecture in which a central processing unit pools all measurement data and computes coordinated control variables that are implemented by decentralized robot controllers. The underlying control concept uses trajectory planning to plan the motion sequences of the robots. The configuration of both robots is determined such that compliance with respect to the process forces is low, thereby maintaining high path accuracy. Model-predictive control guarantees in real time that process forces act on the workpiece in a controlled manner. An integrated task planner converts human commands into tasks that can be understood by the system and sequences the corresponding manufacturing processes. The methods can be transferred to other robot types and larger number of robots, provided that suitable interfaces and sensors are applied.



Evaluation of the stiffness and stability of the system using a vibration test rig over a wide frequency range.

Intuitive Task Planning Using a Language Model

To make the operation of the collaborative robots intuitive and flexible, IRS developed not only control methodologies, but also a user interface based on artificial intelligence (AI). Based on information models of the technical system and text or voice inputs by an operator, including details on the material, bending angle, or milling path, the AI interface can extract task-specific control parameters for the robots and tools. Using the extracted information, the AI system then plans the tasks and executes them autonomously as needed. This allows users without specialized robotics or programming expertise to configure the system and deploy it for various manufacturing steps.

Functional Safety

The researchers aim to make collaborative industrial robots suitable for a wide range of manufacturing processes. This is particularly appealing to companies wishing to apply flexible robot cells instead of specialized machines to handle different components and processes using the same hardware. In the long term, IRS researchers aim to incorporate safety guarantees directly into the control methodology, enabling robots to collaborate more closely with humans without the need for safety enclosures.

Karlsruhe Institute of Technology (KIT)
Institute for Control Systems (IRS) –
Functional Safety Control

Prof. Dr.-Ing. Sören Hohmann
Wilhelm-Jordan-Weg
76131 Karlsruhe, Germany
Email: soeren.hohmann@kit.edu
Phone: +49 721 608-43180
Web: https://www.irs.kit.edu/955.php

Xin Ye
Wilhelm-Jordan-Weg
76131 Karlsruhe, Germany
Email: xin.ye2@kit.edu
Phone: +49 721 9654-181
Web: https://www.irs.kit.edu/People_3320.php

Karlsruhe Institute of Technology (KIT) · President Professor Dr. Jan S. Hesthaven · Kaiserstraße 12 · 76131 Karlsruhe · Germany