University of Stuttgart
Germany
Institute for Control Engineering of Machine Tools
and Manufacturing Units

WE CONTROL THE FUTURE

INNOVATIVELY
INTERDISCIPLINARILY
SCIENTIFICALLY

We are recruiting staff for

HIGH PERFORMANCE AUTOMATION

The Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) of the University of Stuttgart is one of the leading research institutes in the field of control and drive engineering.

The ISW provides a workplace with interesting and technically innovative tasks in various subareas at the highest international level. Our graduates can be found in leading positions in national and international mechanical engineering companies.

For graduates of mechatronics, cybernetics and associated disciplines like informatics, mechanical and electrical engineering ISW provides an excellent environment. As research assistant you develop and work on extremely challenging projects autonomously and with room for development. The focus in those projects is on scientific experience, interdisciplinary expertise, creativity and management skills. The projects cover fundamental research as well as industry-related topics. In addition, there is the opportunity to attain a PhD at one of the most prestigious institutions worldwide in the field of control and drive technologies.

Did we arouse your interest? Then we are looking forward to your application.

Dr.-Ing.
Armin Lechler
Deputy Director
Managing Chief Engineer

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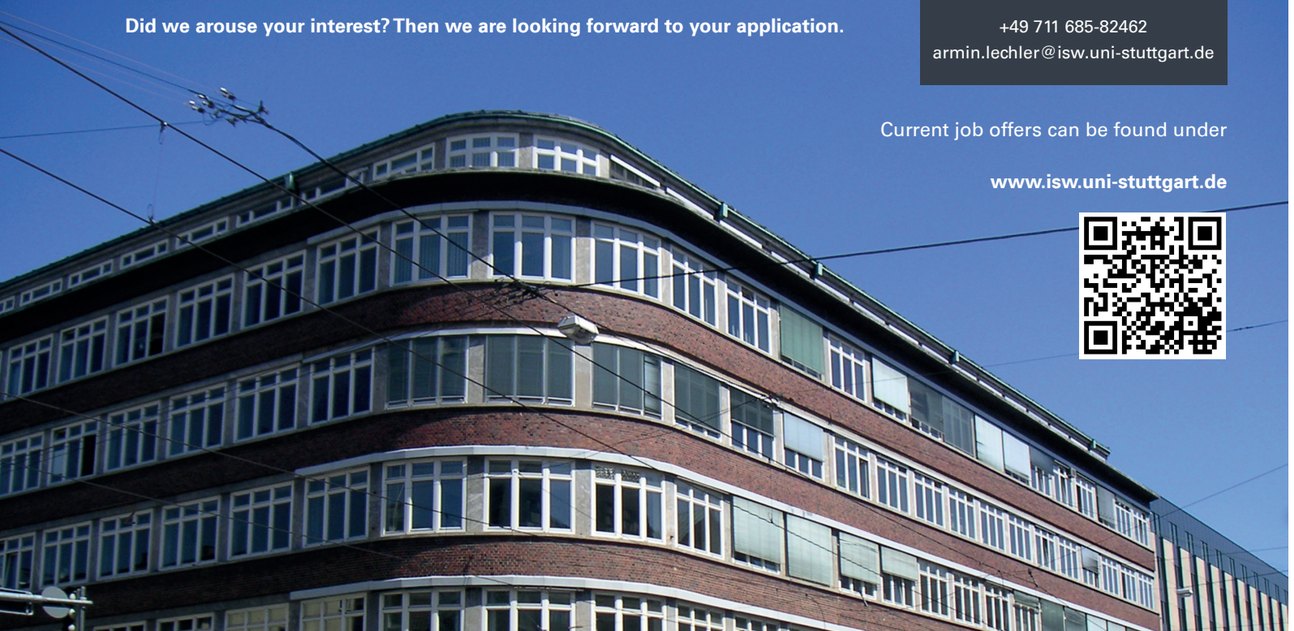
Current job offers can be found under

www.isw.uni-stuttgart.de



Preface

The Institute for Control Engineering of Machine Tools and Manufacturing Units (ISW) of the University of Stuttgart is one of Germany's leading university research facilities in the field of manufacturing automation. For more than 50 years, besides fundamental research activities, also challenging tasks from industry have been developed successfully at ISW.

The core competencies of ISW are still in the areas of industrial control engineering and production IT. This includes research and development activities concerning innovative control and their implementations which range from embedded to cloud-based solutions. The industrial communication starts with the hard real-time field level and extends to machine networking in the cloud. By further developments in simulation and engineering the increasing complexity is manageable.

This brochure gives an overview of the research competencies and the teaching offer, but also the history and the extensive network of the institute. At ISW Industry 4.0 exists for 50 years already!

Numerous international contacts, persistently vivid publication activities, proximity to industry, excellent and sustainable teaching and management of the courses Mechatronics B.Sc. and M.Sc. are the particular strengths of the ISW.

We are looking forward to future challenges.
Get in contact with us!

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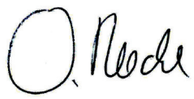


Prof. Dr.-Ing. Oliver Riedel

Milestones

1965
Foundation of the institute on Sept. 1st by Prof. Gottfried Stute

1967-1975
EXAPT, Adaptive Control for 5-axis CNC milling processing

1974-1986
Conception and examination of "Flexible Production Systems" (FFS) and configuration of the first DNC-controlled system

1975-1980
First open modular multiprocessor CNC system (MPST)

1977-1982
Controlled asynchronous drives for machine tool axes

1984-1990
Modular robotics, joints with integrated drive and integrated control

1987-1990
Linear direct drives with digital control based on signal processors

1990-1997
Hardware-independent, modular and open control system (OSACA)

1992-2001
First level parallel kinematics for a CO2 laser processing machine

1994-2001
Acceleration sensors for rotatory and linear movements (Ferraris sensor) for use in highly dynamic drives

1998-2001
Kinematics and control engineering for spatial parallel kinematics

1999-2005
Multimedia machine information system (mumasy)

2000
Founding member and competence center of minimally invasive surgery, MITT

2001
Certification tools and certification authority for SERCOS

since 2002
Adaptronic components for machine tools, adaptive ball screw, oscillation rod

since 2006
Real-time simulation with VIRTUOS

since 2007
Interdisciplinary research center IZST Stuttgart/Tuebingen

since 2010
FPGA technology in drive controls

Pendulum for the German Pavilion at the EXPO in Shanghai

since 2013
Increased dynamics of feed drives via actuator systems

since 2016
Initiative in the field of time-sensitive networking

Presentation of the first multi-axis 3D printer at the SPS Drives in Nuremberg

2002
Special research area SFB 467: Versatile company structures

since 2005
TFB 59: Adaptable systems: reconfigurable machines

since 2007
GSaME, Graduate School of Excellence, excellence cluster SimTech

2008
Energy-efficient production through automation – ECOMATION

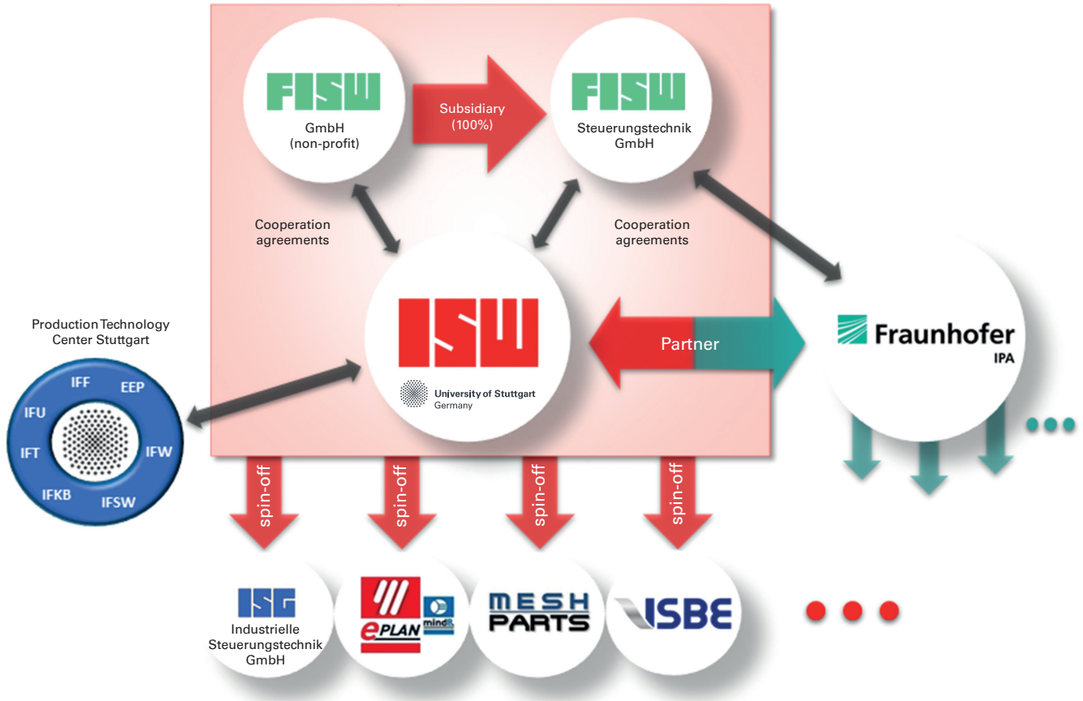
since 2012
Control methods for inductive heating

since 2015
Increased productivity in machining with industrial robots

Cable kinematics at the EXPO in Milano in the German Pavilion

since 2017
International graduate college with New Zealand in the field "Soft Tissue Robotics"

Financing



The ISW is financed for its research work by various research bodies and works in close cooperation with the companies FISW GmbH and FISW Steuerungstechnik Gmbh on industry-oriented developments. The necessary funds for the research assistants and the technical and administrative staff are covered by budgetary resources of the university, publicly funded basic research, cooperative industrial research and direct industrial contracts.

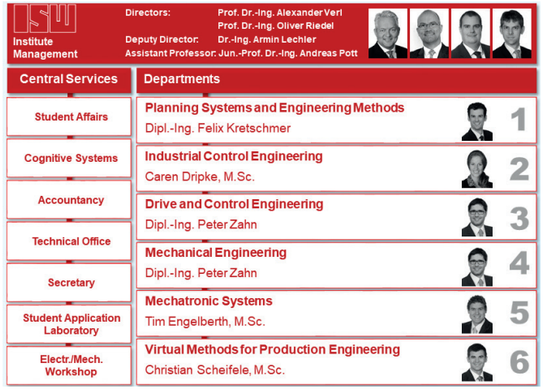
Team

Since November 2016, Prof. Dr.-Ing. Oliver Riedel reinforces the management of the Institute for Control Engineering of Machine Tools and Manufacturing Units together with Prof. Dr.-Ing. Alexander Verl. Dr.-Ing. Armin Lechler continues as Deputy Director of the ISW. Prof. Riedel is holder of the newly established chair **IT for Production** at the University of Stuttgart. The management of the institute is further assisted by Junior Professor Andreas Pott.

The ISW is subdivided into the following six groups with the focus on:

- Planning Systems and Engineering Methods
- Industrial Control Technology
- Drive and Control Engineering
- Machine Technique
- Mechatronic Systems
- Virtual Methods in Production

In each group, the respective research topics and industrial projects are worked on and constantly extended by innovative ideas. Further, the ISW is responsible for the scientific supervision of the Graduate School GSaME for Cluster G at the University of Stuttgart. Central services ensure the success of the institute by assuming administrative tasks in student tutoring, organization of teaching and studying, accounting and secretarial duties. In the technical office events and marketing activities are successfully coordinated. The electrical and mechanical workshops guarantee the fast and reliable implementation of test stands, prototypes and functional patterns.



Teaching at ISW

The institute is integrated into the faculty 7 „Machine Engineering“ of the University of Stuttgart. The research focus of the ISW is the conception and application of control-technological means for automation of machine tools, robots and other production facilities. The emphasis is here on the conception and development of planning systems and engineering methods, real-time-capable simulation of production and material flow systems, the design of new, also cloud-based control architectures and industrial communication, drive, measuring and control technologies. The lecture material derived from this imparts knowledge of the current industrial automation technology, not only related to machine tools and industrial robots.

The ISW works equally in fundamental research and practice-oriented development. The latter is conducted in close cooperation with the industry. This allows students to write exciting theses which are „on the pulse of time“. Besides the deep technical knowledge, they acquire valuable qualifications in project handling, scientific work methods and direct contact to industrial enterprises in the field of automation engineering. Thus, numerous opportunities for a successful career start are provided.

We place particular emphasis on practice-oriented testing of the results; these flow into the lectures, but also into courses and seminars for experienced engineers. Working in industrial projects also offers the possibility to prepare students for their future tasks by gaining personal impressions and contacts.

Do you plan to study abroad for a certain time? We have good connections with research institutions worldwide, and we can support you to experience a successful and efficient stay abroad.

In our diverse range of lectures, internships and seminars you will surely find a suitable one, no matter whether you study machine engineering, mechatronics, technical cybernetics, technology management or medical engineering:

- Control engineering with drive systems
- Control engineering of machine tools and industrial robots
- Applied control engineering in production plants
- Robotic systems – applications in industry and service
- Automation in assembly and handling technology
- Modelling, analysis and design of new robot kinematics
- Planning of robotic systems
- Production Information Technologies
- IT architectures in production
- Control architectures and communication technologies
- Development of scientific software
- Oil hydraulics and pneumatics in control engineering
- Mechatronic systems in medicine
- Bionics

Research

We are doing interdisciplinary research in technologies for production and automation of after tomorrow. The industrial applicability is always in the focus. Our research activities include the following key topics.

PLANNING SYSTEMS AND ENGINEERING METHODS

For increasing the efficiency of the development process the ISW investigates simulation-based and modular engineering methods. Here simulation models are used as communication and validation platforms in order to visualize and verify functions already in early stages of the development process. For facilitating the model creation methods from modular engineering are used that allow the generation and evaluation based on functional primitives within a requirement description. This methodology plans that the models grow along and are finally used for virtual commissioning or in service cases.

In order to cope with the complexity of today's machines and plants, the ISW is developing flexible and 3D-based user interfaces. Here the newest technologies from the gaming industry – like Unity3D or Unreal 4 development environment – are combined with the findings in the area of gamification – the usage of game mechanisms in productive use. The result is an operating concept based on the direct interaction with the virtual image of the machine. For example, cam discs for a transfer press can be programmed with the new concept by direct shifting of the virtual axes – similar to the teach-in method with robots.

Development and projecting methods

- Innovative development and projecting methods (simulation-based, functional, modular, etc.) for manufacturing units
- Optimization of the development process
- Functional consideration of (IT) safety requirements
- Cloud-based system architectures for automation technology

Source: Arena2036

Source: @Mikko Lemola / Fotolia.com

Abb.: WEPA

Planning algorithms

- Camera-based action and path planning (maintenance or welding)
- Model-based process and path planning (casting processes)
- Capability-based scheduling of orders

System analysis and optimization

- Data-driven identification of system (mis)behavior
- System modeling (creation of HiL, process, security models)
- Learning algorithms
- Intuitive operating concepts for complex plants or planning systems

Projects:

- ARENA2036: Versatile production, cell instead of line, new production concepts
- Automatic Maintenance: Action planning, manipulation strategies, autonomous robot
- RobIN 4.0: Data analysis and evaluation, correlation of occurences in the forming process
- MultiCloud: Smart Services, cloud-platform-independent services, new business models
- pICASSO: Control from the cloud, centralized connection, orchestration of instances
- Rent'n'Produce: Safe cloud service for commissioning and control of manufacturing systems
- Vibration suppression: Software module for control, control-based compensation
- HybridCAM: CAM tool for 3D printing, process planning

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Research

INDUSTRIAL CONTROL ENGINEERING

The control and drive technology profits strongly from IT developments. Increasing computation performance due to Multicore, GPU and FPGA systems as well as the cloud technology, miniaturization of hardware components and new software concepts are purposefully used at the ISW for the further development of control and drive systems. Among others, the ISW had a decisive influence on the architecture of current CNC systems and, with the open drive controller platform and testing and certifying solutions for fieldbus and control systems, it has elaborated further innovative solutions and concepts.

Communication technology plays a significant role in machine and plant engineering. Within the initiatives regarding Industry 4.0 and IoT the communication technology became even more important. In this context, the ISW promotes innovations in the fields of real-time-capable and non-real-time-capable as well as wired and wireless communication. In addition to the specification of communication protocols, validation and testing are also in the focus of the research. The ISW is firmly anchored in the Sercos and OPC UA Community.

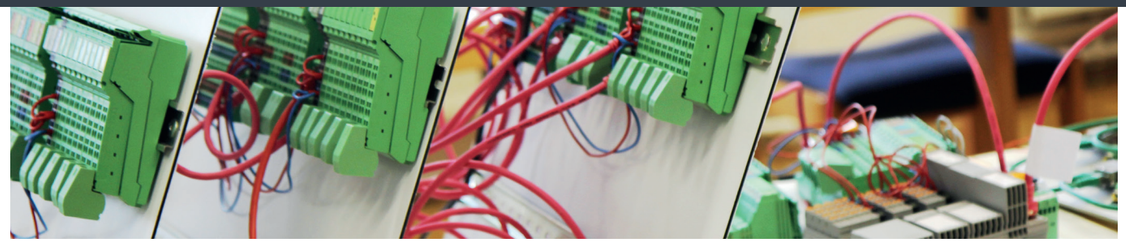
For many years now the ISW works in the area of basic research concerning algorithms for control engineering in machine tool and plant construction. The objectives are to improve the accuracy and surface quality, to reduce the machine and tool stress and to shorten the processing time during workpiece machining. For this purpose the ISW develops new interpolation methods and algorithms for collision-free path planning for machine tools, robots and drive systems. Especially in the field of interpolation methods using clothoids for CNC systems the ISW is the expert.

In the area of user interfaces the ISW examines the modular framework for the HMI development and methods of virtual and augmented reality for use in production. The objective here is the generation of value-added services for the control of production processes.

Control architectures and functions
- NC core functionality
- Real-time-capable and dynamic regrind and interpolation methods using clothoids
- Manufacturer-specific and comprehensive control interfaces
- Cloud-based control engineering
- Distributed interpolation and decentralized systems

Communication technology
- Fieldbus specification and certification (Sercos Competence Center)
- Middleware systems for M2M communication
- LTE- and TSN-based communication

User interface
- Virtual and augmented reality for use in production
- Modular framework for HMI development



Projects:
- EDK: Real-time-capable, synchronous wireless communication for production using LTE
- PANAMA: Parallelization of the NC channel for execution on multicore architectures
- Cornuspline: Real-time-capable and dynamic blending method for controls by means of clothoids
- iWindow: Augmented reality-based value-added services for machine tools
- RetroNet, Cloudplug: Networking of machines and plants in the cloud and service platform
- Conformizer: Model-based, semi-automatic test case generation for inspecting fieldbus devices using certification software
- SeRoNet: Service-oriented backend for service robot solutions
- Evergreen: Modular and dynamically changeable framework for control HMI development
- Devekos: Distributed interpolation and control for multi-component systems

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Research

DRIVE AND CONTROL ENGINEERING

Controlled electric drives play an increasing role in nearly every industry sector. In the area of production engineering, the fast, precise and robust adjustment of position or velocity of machine components is a key challenge. In the area of feed drives, predetermined paths have to be implemented exactly and, at the same time, interferences have to be eliminated. ISW conducts research in this field regarding the implementation of new control methods and structures, which improve preciseness, efficiency or flexibility of drives and enable new applications.

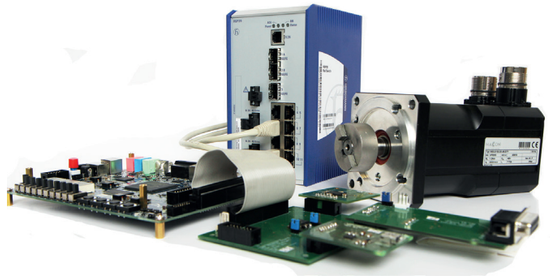
Drive Engineering
- Drives for machine tools and industrial robots
- Control concepts for servo drives and special applications
- Power electronics and converter technology
- Design, system analysis and identification
- Comparative analysis and optimization

Architectural Concepts
- Open control platforms
- Application of FPGA technology
- Recording and processing of sensor data
- Connections to fieldbuses
- Model integration

Machining with Industrial Robots
- Vibration damping
- Examination of pose dependency

Further Subjects
- Control of inductive heating processes

Projects:
- Adaptive PWM: Improving the energy efficiency of drives by demand-oriented switching frequency of the inverters
- MF-Thixo: Continuous measurement of the microstructural condition during inductive heating of components for thixoforging
- SDaR: Drive-based vibration damping of machining robots
- MultiFlex: Optimized distribution of real-time tasks to different computing units
- BaZMod: Universal interface for the application of CPS in machine tools
- Machining with robots: Optimizing the productivity of cutting processes with robots
- Open Automation Platform (OAP): Flexible and FPGA-based real-time platform with open interfaces
- Backlash compensation ZRA: Elimination of the backlash with rack & pinion drives via acceleration feedback
- TSN4Automation: Evaluation of real-time ethernet for use in automation engineering



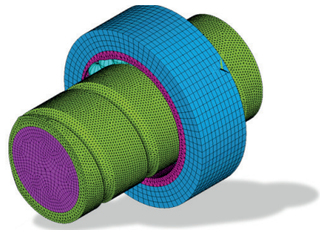
MECHANICAL ENGINEERING

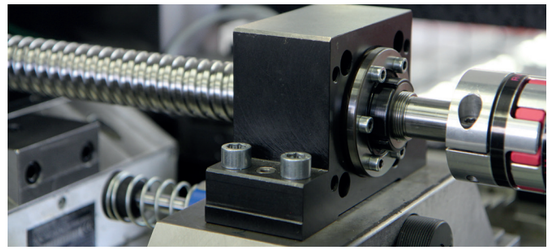
In the field of mechanical engineering the ISW is dealing inter alia with machine dynamics, various feed drive concepts, the individual machine components and novel machine kinematics. Experimental studies of machines and plants are carried out; diverse feed drives like ball screw drives, rack & pinion drives, belt and linear direct drives are also analyzed by measurement. In addition, new possibilities for their design and commissioning are developed. In order to meet current technological requirements, new machine kinematics are developed, designed, constructed and put into operation.

Machine dynamics
- Experimental (modal analysis) and simulative (FEM, MKS) investigations
- Novel concepts for increased dynamics

Feed drives
- Examination of individual components and the overall system
- Design and commissioning
- Numerical optimization (FEM, CACE, MKS)
- Measurements and comparative analyses

Machine components
- Ball screw drives
- Toothed belt drives
- Rack & pinion drives
- Roller bearings
- Elastomer couplings





Projects:
- TopGen: Topologically optimized components with maximum rigidity for additive production processes
- DELVE: Increased dynamics of electrical feed drives via semi-active damping
- Speed controller: Improved dynamics with high mass inertia ratio

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Research

MECHATRONIC SYSTEMS

The research goal is the optimization of the overall system machine tool or production facility in the understanding of a mechatronic system.

Analysis and optimisation of machine behavior
- Examination of the dynamic behavior (experimental modal analysis, FRF)
- Modeling and simulation
- Machine learning methods

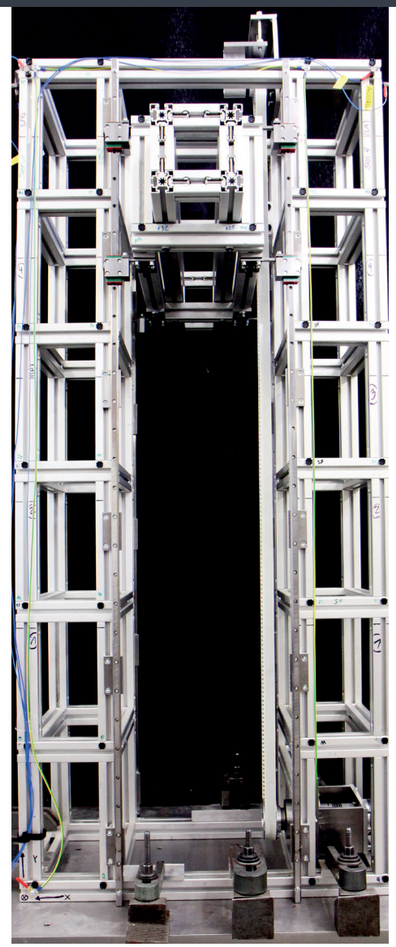
Applied control methods
- Process stability and robustness, vibration reduction
- Diagnosis, increased availability
- Production optimization and resource efficiency

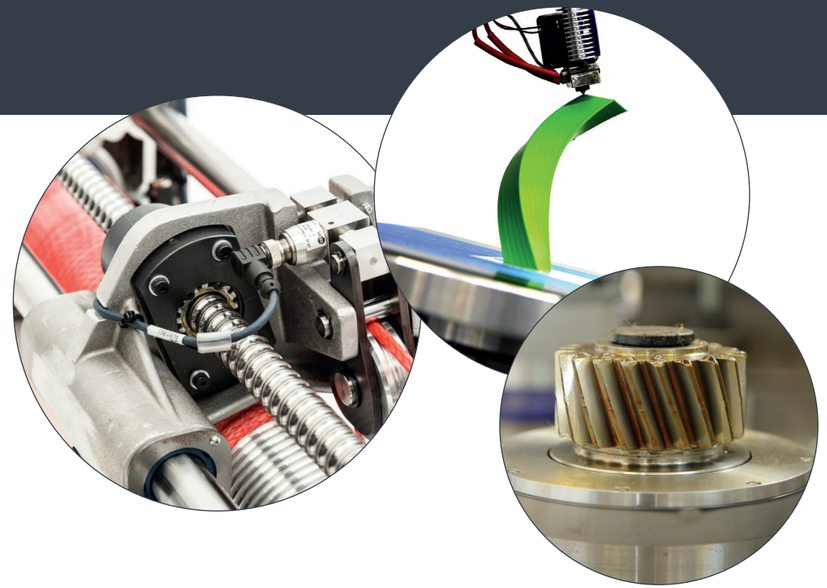
Development of machine concepts
- Reconfigurable and modular machines incl. control engineering
- Special kinematics

Additive Manufacturing
- Control-related optimization of additive manufacturing methods
- Development of kinematics and machine components
- Path planning, control engineering
- Analysis of multi-axis methods
- Commissioning of plants and test realization

Projects:
- Bionic construction: Additive manufacturing of bionic components with composites (concrete, plastic, fibers)
- ZR drives: Electrically braced rack and pinion drives allow the adaptation of the bracing during operation
- Pose identification: Automatic determination of model parameters of large lightweight structures in operation
- FastStorageBWII: Use of power caps in machine tools
- AGTurbo: Modeling and diagnosis of time-varying factors in compressor units
- ForZDM: Waste reduction in multi-stage production systems via process control, inline repair and downstream compensation
- Cable robot: Modeling and simulation of cable robots
- SoftTissue Robotics: Control engineering for handling soft materials using industrial robots

Photo: Ludmilla Parsyak, © Uni Stuttgart ISW





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Research

VIRTUAL METHODS IN PRODUCTION ENGINEERING

The ISW investigates in this area technologies for the digital engineering of the future: During the life cycle of machines and plants there is a need for innovative simulation-based methods and tools, which make the increasing complexity of future production systems manageable, enable optimizations on the virtual image by acceptance Test and support the production during operation.

Virtual commissioning

- Control-oriented Model-in-the-Loop, Software-in-the-Loop and Hardware-in-the-Loop Simulation
- Automated generation of simulation models within the engineering process

Virtual production

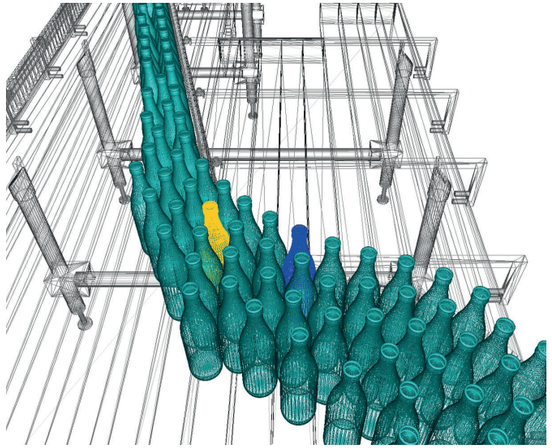
- Digital methods and tools for planning, evaluation and control of production processes and plants
- Process, machine and system simulation in different real-time levels

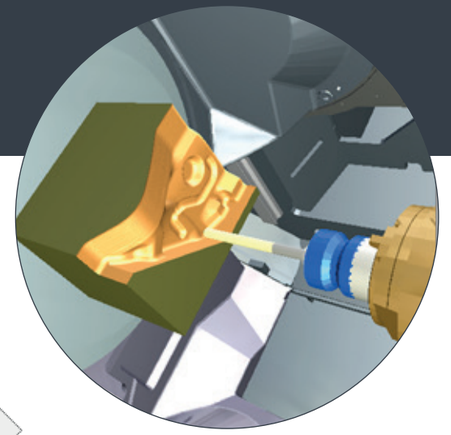
Digital Engineering

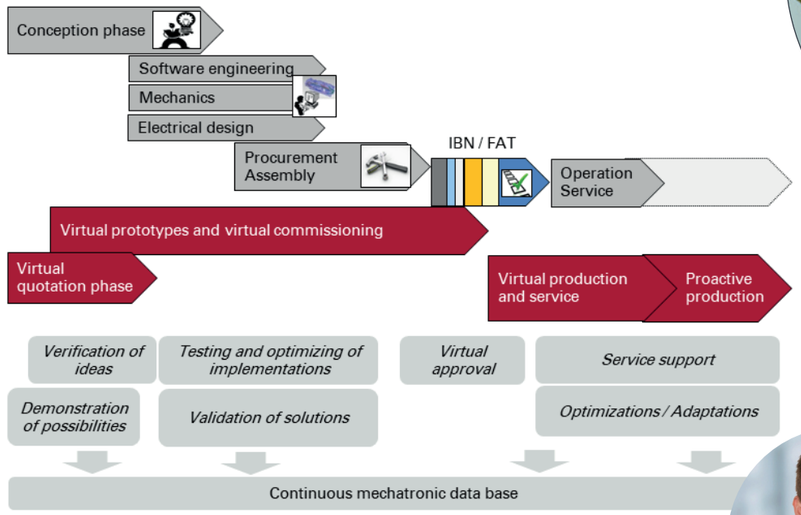
- Simulation-based development, system planning, testing, training, service and operation of production plants
- Modular-based engineering in the context of Industry 4.0 with CPS components

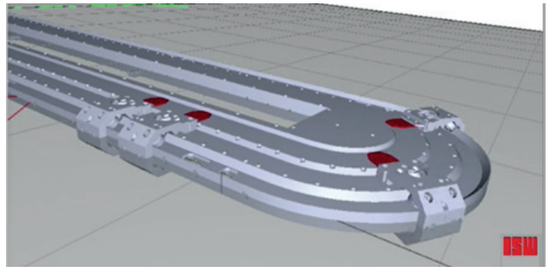
Projects:

- Automatic model generation: Generation of simulation models for the HILS within the engineering process
- CLON-I4.0: Cloud navigation for Industry 4.0
- Online Change: Online change and snapshot for HIL simulators
- SimVar3D: Simulation-based variant generation and automated comparison
- vicosim: Real-time co-simulation, complex control-based HILS
- ViGriff: Virtual commissioning of “Bin picking”
- Virtual control test bench: Test automation, CA VIBN
- Virtual table socker: Student competition at the HIL Simulator









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Services for the Industry

The ISW advises companies on research topics dealt with at the institute and thus helps to ensure the knowledge transfer from fundamental research to the industry. Moreover, companies are being supported in the implementation from prototypes to new products according to their requirements.

Consulting and development:
- Control concepts, architectures and algorithms
- Communication technologies (OPC UA, sercos, ProfiNet, EtherCat, TSN)
- Special machines
- Modeling and simulation
- Module-based engineering
- FPGA solutions
- Machine and component optimization
- Design of drives
- Software architectures
- Technology consulting
- Regulatory processes, parameterizing and methods
- Additive manufacturing
- Positioning accuracy analyses for drive systems
- Security analysis of controls

Training courses and seminars:
- Position Control Seminar
- Stuttgart Innovation Days
- Control Technology Forum
- Industrial Working Group Simulation Technology
- Ethernet-based Communication (OPC UA in control and automation engineering)
- Industrial Working Group
- Hardware-in-the-Loop-Simulation
- Stuttgart Production Academy

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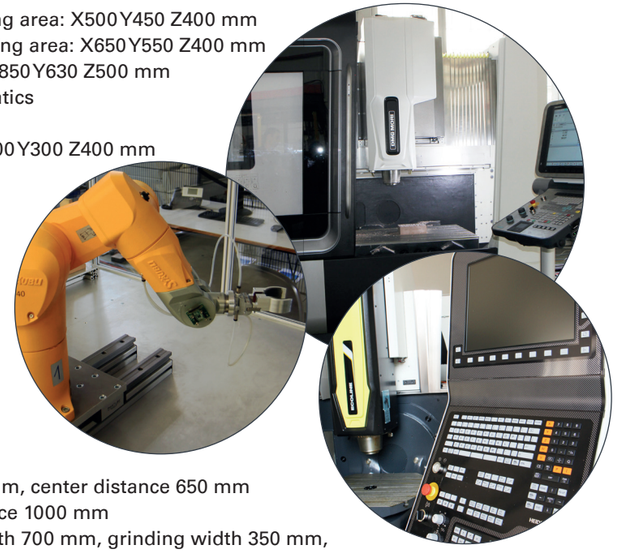
Machinery

The ISW has a versatile machine park

Machine tools:
- Maho MH800E, CNC milling machine, working area: X800 Y450 Z500 mm
- DMG DMC 650V, working area: X650 Y520 Z475 mm
- DMG DMU 50 ecoMill, 5-axis CNC milling machine, working area: X500 Y450 Z400 mm
- Exeron Digma HSC600, 5-axis CNC milling machine, working area: X650 Y550 Z400 mm
- Hermle UWF, 3-axis CNC milling machine, working area: X850 Y630 Z500 mm
- Index V100, vertical CNC turning lathe with parallel kinematics
- 7-axis CNC „Model Milling Machine“
- Deckel FP3A, universal milling machine, working area: X500 Y300 Z400 mm



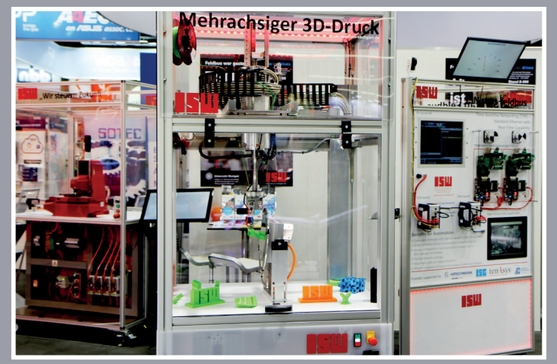
Robots:
- Kuka KR90
- Stäubli TX40, 2 robots
- 7-axis KUKA KR500 robotic processing cell
- Spatial cable robot COPacabana

Workshop machines:
- Band saws
- Bench drills
- Box column drills
- Bench grinders
- Turning machine Weiler Praktikant140, center height 140 mm, center distance 650 mm
- Turning machine VDF, center height 230 mm, center distance 1000 mm
- Horizontal surface grinding machine Blohm, grinding length 700 mm, grinding width 350 mm, grinding height 425 mm

Other equipment:
- Test stand „Ball screw drive“
- Test stand „Rack and pinion drive“
- Test stand „Small machine tool“
- Linapod Parallel Kinematics as 3D printer
- Test facilities for additive manufacturing (various axle configurations)
- Control laboratory
- Drive laboratory
- Student application laboratory

Fairs and Exhibitions

SPS IPC DRIVES



HANNOVER MESSE

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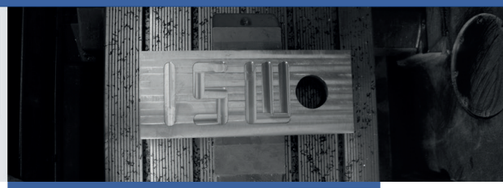

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TRAVEL DIRECTIONS

By car:
From direction Munich or Karlsruhe A8, exit 52b Stuttgart-Degerloch. Follow B27 in direction Stuttgart Zentrum. From Charlottenplatz continue driving on Schlossstraße to Berliner Platz, then turn right into Seidenstraße.

Public transportation:
At **Stuttgart main station** (Stuttgart-Hauptbahnhof, Hbf) take bus 42 (direction Erwin-Schoettle-Platz) to the stop Rosenberg-/Seidenstraße or from Rotebühlplatz/Stadtmitte take tram U24 (direction Hölderlinplatz) or bus 43 (direction Killesberg) to the stop Rosenberg-/Seidenstraße.

From **Stuttgart Airport** (Flughafen/Messe) take the tram S2 (direction Schorndorf) or S3 (direction Backnang) to the stop Rotebühlplatz/Stadtmitte, then the tram U24 (direction Hölderlinplatz) or bus 43 (direction Killesberg) to the stop Rosenberg-/Seidenstraße.

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