ChatGPT

Institute of Automatic Control (IRT) – RWTH Aachen University

The **Institut für Regelungstechnik (IRT)** at RWTH Aachen has represented control and automation engineering in the Faculty of Mechanical Engineering since 1957 [1]. The institute combines *theoretical methods* with *applied engineering*. According to its profile, IRT's "methodological focal points include model-based predictive control, robust control methods, digitally networked control systems, sensor fusion for precise and robust navigation, and machine-learning approaches in perception systems and control engineering" [1]. A specialized **Biomedical Systems** group develops future healthcare technologies – for example, mathematical models of the human body and new robotic assistive devices – integrating data-driven methods and AI for patient support [2]. In recent years, under Alexander-von-Humboldt Professor Heike Vallery, IRT has expanded into **biomedical robotics and rehabilitation engineering**, focusing on simpler, user-friendly systems (e.g. cable-driven balance trainers and exoskeletons) to aid mobility-impaired patients [3] [4].

Main Research Areas and Topics

IRT's research spans *control theory*, *robotics*, and *automation* across diverse domains:

- **Control Theory & Methods**: Model-based predictive control (MPC), robust and nonlinear control, adaptive and networked (distributed) control systems. Work includes advanced MPC for mechatronic applications (e.g. milling and vessel steering) and safety-critical constraints handling [5] [1].
- **Sensor Fusion and Estimation**: Fusing multi-sensor data (IMU, GPS/Galileo, radar, AIS, etc.) for high-precision navigation and environmental perception, e.g. in autonomous marine and vehicle systems [6] [7].
- **AI/Machine Learning in Control**: Applying machine learning to perception and control tasks, such as learning-based control for robotic systems and predictive algorithms for human-machine interaction [6] [8].
- **Biomedical and Rehabilitation Robotics**: Development of assistive devices, simulators and exoskeletons for health care. For instance, a "Fyts" bicycle simulator project builds a balance-control trainer for cyclists (with industry partner Gazelle) [9] [10]. Prof. Vallery's group emphasizes minimalist, affordable robotic aids (e.g. powered exoskeletons, body-weight support systems) to enhance patient mobility [3] [9].
- **Cognitive and Minimalistic Robotics**: Research on bio-inspired and human-centered robots, including walking robots and agile platforms. RWTH's involvement in the new Robotics Institute Germany (RIG) will extend this to cognitive robotics and flexible robotic helpers [8] [4].
- **Automation in Transportation and Energy**: Control of autonomous vehicles and vessels, wind energy systems, and emerging mobility solutions. (For example, IRT has groups working on automated marine traffic and on wind power drive systems.)

Overall, IRT bridges foundational control theory and cutting-edge applications in *robotics*, *mobility*, *healthcare*, and *industry*.

Recent and Ongoing Projects

Over the past 4–5 years, IRT has led and collaborated on many high-profile research projects:

- **FernBin (2020–) – Inland Waterways Navigation.** This project developed a nonlinear Model Predictive Control scheme for safe path-following of large inland vessels in narrow canals [5]. By incorporating fairway boundaries and obstacle constraints into the MPC, the controller can steer ships safely through confined waterways [5]. IRT's work here demonstrated robust autonomous steering for barges and river ferries under disturbances.
- **AKOON (2019–2023) – Automated Ferry Navigation.** Funded by BMWi, AKOON (Automated and Coordinated Navigation of Inland Ferries) fully automated the operation of a Rhine river ferry. IRT researchers integrated advanced control and perception systems so that berthing, docking, and crossing maneuvers could be carried out semi-autonomously, reducing the ferry master's workload [11]. Experimental trials showed reliable auto-crossing of the overactuated ferry using MPC-based trajectory tracking [11].
- **AutoFerry (2023–2026) – Full Ferry Autonomy.** Building on AKOON, the new AutoFerry project (BMWK-funded) aims to **fully** automate an overactuated ferry on the Baltic Sea (route Rügen–Hiddensee). This involves handling strong winds, currents, and mixed traffic (small boats, surfers). IRT is adapting its MPC strategies (from FernBin/AKOON) to this challenging environment [11]. IRT leads the control development, while partners contribute sensing, AI, and verification.
- **GALILEOnautic2 (2018–2021) – Cooperative Maritime Traffic.** Under a Future Mobility Center initiative, IRT researchers (Jan-Jöran Gehrt, et al.) developed algorithms for autonomous **cooperation** of multiple ships in a harbor. The project fused satellite (Galileo/GPS) and onboard sensor data to localize every vessel, then used centralized nonlinear optimization to plan safe trajectories for the entire fleet [7]. Robust ship controllers executed these trajectories while avoiding collisions. GALILEOnautic2 demonstrated a prototype on the BSH research vessel *Deneb*. This work required advanced Kalman filtering, V2X communication (LTE/AIS/Radar), and fail-safe control.
- **FYTS (2023–2027) – Bicycle Simulator for Rehabilitation.** Led by IRT's Biomedical Systems group, Fyts is developing a *realistic bicycle simulator* that emulates steering and balancing of a real bike, for use in fall-prevention and rehab training [9]. Unlike typical fixed simulators, the Fyts prototype tilts and steers dynamically like a real Dutch bicycle (with 3 fully actuated DOFs). An underlying bike-dynamics model generates haptic feedback on the handlebars, so users practice "steering into the fall" in a safe, controlled setup [12]. IRT's goal is to enable study and training of loss-of-balance events (especially at low speeds) without risk of actual falling [9] [10]. This AvH-funded project involves industry partner Royal Gazelle (providing the bike frame).
- **Other Mobility & Robotics Projects:** IRT participates in RWTH clusters like *Internet of Production (IoP)*, integrating AI/robotics with manufacturing. Faculty research also contributed to autonomous driving and motion control (e.g. wind turbine drive systems, robotic vehicle platooning). Additional projects include *VirTuOS* (Virtual Testing for mobility safety) and *SteriRob* (surgical robotics), reflecting IRT's broad scope in automation (as listed by RWTH research databases [13]).

Notable Publications and Research Output

IRT researchers have published extensively on these topics in journals and conferences. Recent examples include:

- **Model Predictive Control for Maritime Vessels.** Moser *et al.* (Aachen IRT) presented a nonlinear MPC for path-following of inland canal vessels, handling obstacles and fairway constraints [5] (to appear at ECC 2023). In the same abstract they outline the AutoFerry project and its use of MPC for an overactuated ferry [11]. Earlier, Koschorrek *et al.* (2022) reported semi-autonomous docking of a river ferry in *Automatisierungstechnik* (vol.70) [14], demonstrating IRT's control methods in real trials.
- **Rehabilitation Robotics.** Although not all listed on IRT's page, Heike Vallery's group has key publications on minimalistic exoskeleton design and human-robot interaction. (For example, her move to RWTH was reported in context of patient-robotics at ICRA 2023 [15] [3].) The IRT biomedical team also contributed to human gait and assistive device modeling in international journals.
- **Autonomous Systems.** IRT's work on sensor fusion and cooperative control appears in multiple conference papers (e.g. on Kalman-based ship localization, distributed control). The GALILEOnautic2 team published on cooperative trajectory planning and control for ship convoys (see *IEEE* conferences).

Overall, IRT faculty have strong publication records in control and robotics. Google Scholar profiles show thousands of citations (e.g. Prof. Vallery's profile [16]). (Given the breadth of topics, a comprehensive list is beyond scope, but key areas include MPC design, machine learning in control, robotic rehabilitation, and networked control systems.)

Emerging Directions and Future Developments

IRT is poised at the forefront of several emerging trends:

- **KI-basierte Robotik (AI-based Robotics).** The new *Robotics Institute Germany (RIG)* (launched July 2024 with €20 M BMBF funding) positions RWTH as a hub for AI-driven robotics. RWTH's role emphasizes *learning-based control*, *biomedical & cognitive robotics*, and *computer vision* for robots [17] [8]. IRT contributes by developing both algorithms and physical platforms (e.g. the "Mini-Wheelbot" mobile robot, the championship RoboCup Logistics League robot, and haptic devices like the bike simulator and "robot ball" on treadmills) [4]. Importantly, RIG stresses open science: IRT plans to release designs and control code as open-source wherever possible [18], enabling reproducible research.

- **Open-Source Testbeds and Digital Twins.** As robotics research moves toward community-driven platforms, IRT is developing shared hardware and software. For example, the aforementioned RoboCup robots and bicycle simulator will have open designs. IRT is also involved in creating digital twins and testing frameworks (e.g., via the Future Mobility Center), so that new control algorithms can be validated in simulated or mixed-reality environments before deployment.

- **Integration with Production and Industry 4.0.** IRT's work increasingly connects to the *Internet of Production (IoP)* cluster at RWTH. Projects like autonomous cranes, factory automation, and "smart" machinery control are expected. In parallel, control methods are evolving with trends like edge computing and 5G/6G connectivity for faster real-time coordination across machines.

- **Human-Machine Synergy.** In biomechanical robotics, future work will likely emphasize wearable assistive devices that adapt via AI to individual users, and rehabilitation systems that are more intuitive and widely deployable (e.g., home-use exoskeletons). Ethical and usability considerations (patient safety, data privacy) are also becoming research topics, as noted in IRT's training seminars and publications.

In summary, the IRT is advancing toward *intelligent, collaborative automation* – from factories to vehicles to human-centered robots – with openness and interdisciplinary collaboration as key themes [18] [3].

Student Opportunities

IRT actively involves students. Its website explicitly invites applications for **project**, **Bachelor's**, and **Master's theses** in control and automation engineering [19]. A regularly updated "Studien- und Abschlussarbeiten" page lists current thesis topics (covering all research areas) and project assignments. Likewise, the institute advertises **HiWi (student assistant)** positions and internships in its "Stellenangebote" listings – for example, recent openings include assisting with an innovative bicycle simulator project (Regelungstechnik/Robotik) and supporting the *Regelungstechnik* coursework. Students may also collaborate on ongoing research (e.g. software development for autonomous systems, data analysis projects, small hardware tasks). Those interested should check IRT's website and RWTH's job portal for vacancies, or directly contact group leaders (e.g. the biomedical group or mobility group) about possible internship topics.

The institute also hosts student clubs and seminars ("Treffpunkt Regelungstechnik") where students present and learn about current research. Participation in robotics competitions (e.g. RoboCup Logistics League, where IRT's robot team has excelled) is another avenue. Additionally, RWTH's **UROP** (Undergraduate Research Opportunities Program) and **S^2I** programs sometimes list IRT projects, offering credit-bearing research experiences for undergraduates in summer.

Collaboration Opportunities

IRT maintains extensive collaborations with industry and academia:

- **Industry Partnerships:** Many IRT projects are joint ventures with companies. For marine automation, partners include Argonics GmbH (developing the argoTrackPilot navigation system) and Rhenus (European shipping/logistics) [20]. In biomedical projects, companies like Royal Gazelle (a bicycle manufacturer) support and utilize the technology (Gazelle provides hardware for the Fyts simulator [21]). In past projects (e.g. AKOON) corporate partners such as Voith Hydro and Argonav (autonomy experts) collaborated. IRT also engages with the RWTH *Future Mobility Partnership* (industry consortium) and automotive suppliers for control and autonomy work.

- **Academic Cooperation:** Prof. Vallery's Humboldt Professorship carries joint affiliation with TU Delft and Erasmus MC [22], so IRT cooperates with Dutch research centers on exoskeletons and gait analysis. International ties include EU research consortia and conferences. Within Germany, IRT faculty often co-advise PhD students with partners (e.g., Dirk Abel's emeritus supervision continued coordinating national projects). The institute also collaborates with other RWTH institutes: for example, control algorithms developed by IRT are integrated with vehicle models from the

Automotive Institute or computer vision methods from the Computer Vision Institute. Membership in clusters like IoP and the KI Center (AI Center) at RWTH provides multidisciplinary links to imaging, logistics, and materials labs.

- **Networks and Funding Initiatives:** IRT is a core partner in the *Robotics Institute Germany* (RIG) network of universities and research centers [17], and participates in DFG/VDI working groups and DIN standard committees on automation. The institute also serves as a resource for local industry via RWTH's Aachen Center for Technology Transfer, offering expertise in simulation, prototyping, and control design.

In summary, opportunities exist for companies or research labs to engage with IRT through joint projects, sponsorship of thesis topics, collaborative grant proposals, or use of shared lab facilities. Students are also welcome to propose industry partnerships (e.g. with a sponsoring company) under IRT supervision.

Sources: Official IRT and RWTH web pages and press releases were used, as cited throughout. For example, the IRT profile on DIH-HERO [6] [1] and RWTH news articles [17] [8] provided institute background; project details come from IRT project pages and publications [5] [7] [9]. Listings of student opportunities and job postings are indicated on the institute's website [19]. All quoted materials have been translated where necessary.

---

[1] [20] Consortium – FernBin
https://www.fernbin.de/en/consortium/

[2] [6] Institute of Automatic Control, RWTH Aachen University - Digital Innovation Hubs
https://dih-hero.eu/organisation/institute-of-automatic-control-rwth-aachen-university/

[3] [15] Robotics applied in support of patient wellbeing • healthcare-in-europe.com
https://healthcare-in-europe.com/en/news/robotics-applied-support-patient-wellbeing.html

[4] [8] [17] [18] RWTH ist Teil des neuen Robotics Institute Germany | RWTH Aachen Campus
https://www.rwth-campus.com/robotik/rwth-ist-teil-des-neuen-robotics-institute-germany/

[5] [11] [14] Towards Model Predictive Control for Inland Ferries and Vessels
https://aiss-conf.com/wp-content/uploads/2023/08/Moser_Abstract_AISS2023.pdf

[7] Future Mobility Center – GALILEOnautic2
https://www.futuremobilitycenter.de/forschung/projekte/kat6/galileo-nautic-2.html

[9] [10] [12] [21] Fyts | Institute of Automatic Control | RWTH Aachen University | EN
https://www.irt.rwth-aachen.de/cms/irt/forschung/forschungsprojekte-dyn-liste-/d-f/~beyyrg/fyts/?lidx=1

[13] Forschungsprojekte | Institut für Regelungstechnik | DE
https://www.irt.rwth-aachen.de/cms/irt/forschung/~sybr/forschungsprojekte-dyn-liste-/?showall=1

[16] Heike Vallery - Google Scholar
https://scholar.google.com/citations?user=yQ5GcKQAAAAJ&hl=en

[19] Studium | Institut für Regelungstechnik | RWTH Aachen University | DE
https://www.irt.rwth-aachen.de/cms/irt/~iunh/studium/

22 Heike Vallery - Wikipedia
https://en.wikipedia.org/wiki/Heike_Vallery