

Cyber-Physical Mobility Group

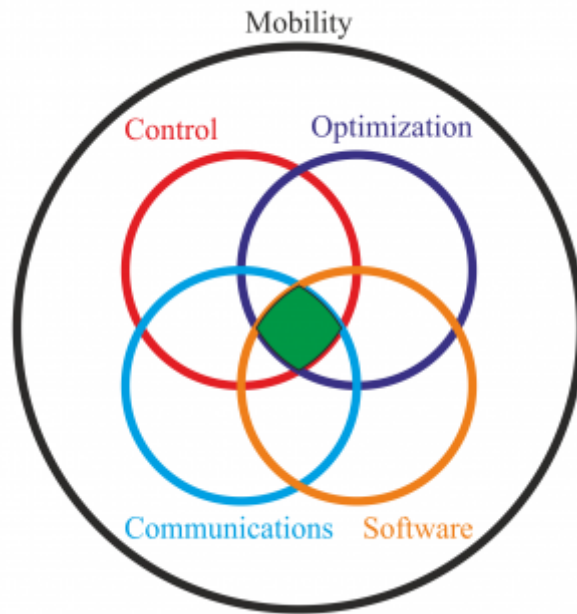
Team

| Member | Position / Project |
|--|---------------------|
| Dr.-Ing. Bassam Alrifaae | Gruppenleiter |
| Alexandru Kampmann, M.Sc. RWTH | UNICARagil |
| Maximilian Kloock, M.Sc. RWTH | AutoKnigge, CPM-Lab |
| mokhtarian | UNICARagil |
| Patrick Scheffe, M. Sc. RWTH | GROKO-Plan, CPM-Lab |



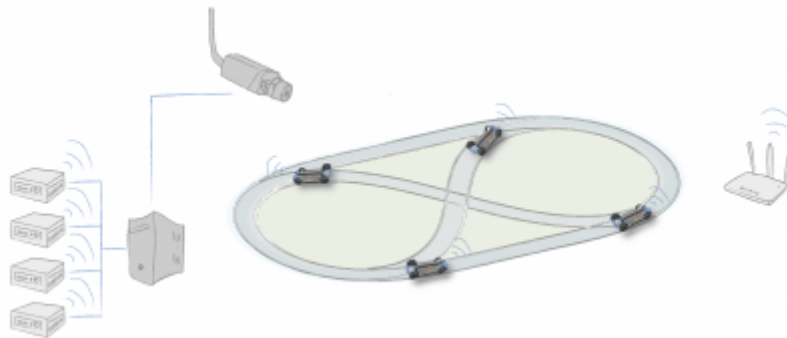
Research

Our research in the field of Cyber-Physical Mobility is located in the interdisciplinary intersection of software engineering, control engineering, mathematical optimization and communication technology. In our applications we deal with autonomous and networked mobility.

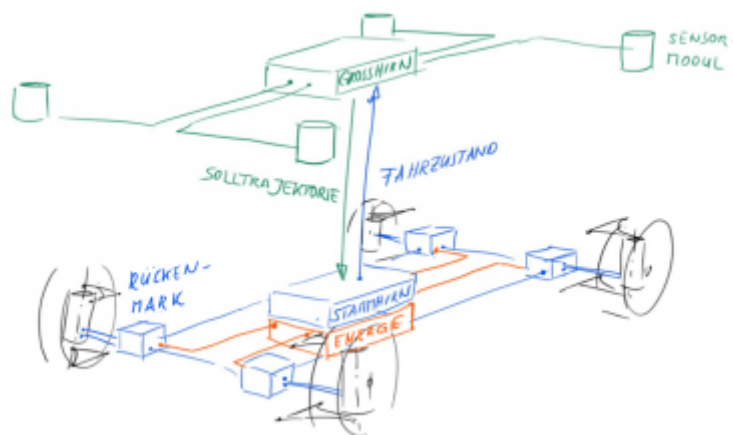


With our research we contribute to the [Future Mobility Center](#). We are also active as a member of the [Profilbereich Mobility & Transport Engineering](#) profile area.

Cyber-Physical Mobility Lab



UNICARagil



CoInCar

The DFG priority program [CoInCar](#) (Cooperatively Interacting Automobiles) is an interdisciplinary cooperation of researchers to provide a holistic system view on cooperative traffic and autonomous vehicles. The Cyber-Physical Mobility Group is working on two subprojects in this priority program, namely [AutoKnigge](#) and [GROKO-Plan](#).

AutoKnigge

The part-project [AutoKnigge](#) (Modeling, Evaluation and Verification of Cooperative Interacting Automobiles), the project partners Institute for Automotive Engineering (ika), Chair of Software Engineering (SE) and the Chair of Embedded Software (i11) research on motion-planning methods for networked vehicles.

Contact person: [Maximilian Kloock, M.Sc. RWTH](#)



Source: <https://blog.degruyter.com/automated-vehicles-towards-zero-accident-future/>

Publications of this project are listed below. Videos can be found here:

<https://youtu.be/XGqI8FrjW6I>

<https://youtu.be/7sq3N8vwuSA>

<https://youtu.be/kboojFK52Fg>

GROKO-Plan

The project GROKO-Plan (graph-based, optimal and cooperative trajectory planning) aims at developing a graph-based planning method for optimal cooperative trajectories for interacting vehicles. Our research includes the theoretical analysis as well as the practical implementation of a distributed cooperative trajectory planning method.

Major challenges of distributed cooperative trajectory planning are (I) dependability of planned trajectories, (II) real-time compliance of the optimizer on board of the vehicles, and (III) a realizable communication effort between vehicles. The first challenge arises since conflict-free trajectories are mandatory. The second challenge is due to high-dimensional non-convex optimization problems, as they occur when many road users have to be taken into account. The third challenge is caused by the thrive for cooperation, i.e. to solve the cooperative optimization problem on one vehicle, parts of the optimization problems of other road users have to be exchanged.

In order to meet these challenges, trim and maneuver primitives are used for cooperative trajectory

planning. This reduces the search space in order to enable real-time optimization. Uncertainty in perception and prediction is considered in robust distributed model predictive control methods.

Contact: [Patrick Scheffe, M. Sc. RWTH](#)

Publications

[KAK+19]

[PDFBIB](#)

Kampmann, A., Alrifaae, B., Kohout, M., Wüstenberg, A., Woopen, T., Nolte, M., Eckstein, L., and Kowalewski, S., "A Dynamic Service-Oriented Software Architecture for Highly Automated Vehicles", in *Proc. 2019 IEEE Intelligent Transportation Systems Conference (ITSC) : [Proceedings]*, 2019, IEEE.

A Dynamic Service-Oriented Software Architecture for Highly Automated Vehicles

Bibtex entry :

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@inproceedings { KAK+19,
  author = { Kampmann, Alexandru and Alrifaae, Bassam and Kohout,
Markus
    and W{"u}stenberg, Andreas and Woopen, Timo and Nolte,
    Marcus and Eckstein, Lutz and Kowalewski, Stefan },
  title = { A Dynamic Service-Oriented Software Architecture for
Highly
    Automated Vehicles },
  booktitle = { 2019 IEEE Intelligent Transportation Systems
Conference
    (ITSC) : [Proceedings] },
  publisher = { IEEE },
  year = { 2019 },
  organization = { 2019 IEEE Intelligent Transportation Systems
Conference -
    ITSC, Auckland (New Zealand), 2019-10-27 - 2019-10-30 },
  doi = { 10.1109/ITSC.2019.8916841 },
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  reportid = { RWTH-2019-11214 },
  cin = { 122810 / 414110 / 120000 },
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[KKM+19]

[PDFBIB](#)

Kloock, M., Kragl, L., Maczijekowski, J., Alrifaae, B., and Kowalewski, S., "Distributed Model Predictive Pose Control of Multiple Nonholonomic Vehicles", in *Proc. 2019 IEEE Intelligent Vehicles Symposium (IV) : [Proceedings]*, [Piscataway, NJ], 2019, IEEE, pp. 1620-1625.

Distributed Model Predictive Pose Control of Multiple Nonholonomic Vehicles

Bibtex entry :

```
@inproceedings { KKM+19,
  author = { Kloock, Maximilian and Kragl, Ludwig and Maczijekowski,
  Janis
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  title = { Distributed Model Predictive Pose Control of Multiple
    Nonholonomic Vehicles },
  booktitle = { 2019 IEEE Intelligent Vehicles Symposium (IV) :
    [Proceedings] },
  publisher = { IEEE },
  pages = { 1620-1625 },
  year = { 2019 },
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  organization = { 2019 IEEE Intelligent Vehicles Symposium (IV),
  Paris
    (France), 2019-06-09 - 2019-06-12 },
  doi = { 10.1109/IVS.2019.8813980 },
  typ = { PUB:(DE-HGF)7 },
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  url = { http://publications.rwth-aachen.de/record/766610 },
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[KNR+19]

[PDFBIB](#)

Keilhoff, D., Niedballa, D., Reuss, H., Buchholz, M., Gies, F., Dietmayer, K., Lauer, M., Stiller, C., Ackermann, S., Winner, H., Kampmann, A., Alrifaae, B., Kowalewski, S., Klein, F., Struth, M. M., Woopen, T., and Eckstein, L., "UNICARagil - New architectures for disruptive vehicle concepts", in *Proc. 19. Internationales Stuttgarter Symposium : Automobil- und Motorentechnik / herausgegeben von Michael Bargende, Hans-Christian Reuss, Andreas Wagner, Jochen Wiedemann*, Wiesbaden, 2019 in Proceedings Springer eBooks, Springer Fachmedien Wiesbaden, pp. 830-842.

UNICARagil - New architectures for disruptive vehicle concepts

Bibtex entry :

```
@inproceedings { KNR+19,
  author = { Keilhoff, Dan and Niedballa, Dennis and Reuss,
  Hans-Christian and Buchholz, Michael and Gies, Fabian and
  Dietmayer, Klaus and Lauer, Martin and Stiller, Christoph
  and Ackermann, Stefan and Winner, Hermann and Kampmann,
  Alexandru and Alrifaae, Bassam and Kowalewski, Stefan and
  Klein, Fabian and Struth, Michael Manfred and Woopen, Timo
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    and Eckstein, Lutz },
    title = { UNICARagil - New architectures for disruptive vehicle
              concepts },
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Automobil- und
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    Hans-Christian Reuss, Andreas Wagner, Jochen Wiedemann },
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Automobil- und
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    doi = { 10.1007/978-3-658-25939-6_65 },
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[KSB+19]

PDFBIB

Kloock, M., Scheffe, P., Botz, L., Maczijewski, J., Alrifaae, B., and Kowalewski, S., "Networked Model Predictive Vehicle Race Control", in *Proc. 2019 IEEE Intelligent Transportation Systems Conference (ITSC) : [Proceedings]*, 2019, IEEE.

Networked Model Predictive Vehicle Race Control

Bibtex entry :

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@inproceedings { KSB+19,
    author = { Kloock, Maximilian and Scheffe, Patrick and Botz, Lukas
and
    Maczijewski, Janis and Alrifaae, Bassam and Kowalewski,
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    organization = { 2019 IEEE Intelligent Transportation Systems
Conference -
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    doi = { 10.1109/ITSC.2019.8917222 },
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}

[KSM+19]

PDFBIB

Kloock, M., Scheffe, P., Marquardt, S., Maczijewski, J., Alrifaae, B., and Kowalewski, S., "Distributed Model Predictive Intersection Control of Multiple Vehicles", in *Proc. 2019 IEEE Intelligent Transportation Systems Conference (ITSC) : [Proceedings]*, 2019, IEEE.

Distributed Model Predictive Intersection Control of Multiple Vehicles

Bibtex entry :

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@inproceedings { KSM+19,
  author = { Kloock, Maximilian and Scheffe, Patrick and Marquardt,
    Sascha and Maczijewski, Janis and Alrifaae, Bassam and
    Kowalewski, Stefan },
  title = { Distributed Model Predictive Intersection Control of
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  booktitle = { 2019 IEEE Intelligent Transportation Systems
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  publisher = { IEEE },
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    ITSC, Auckland (New Zealand), 2019-10-27 - 2019-10-30 },
  doi = { 10.1109/ITSC.2019.8917117 },
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  reportid = { RWTH-2019-11242 },
  cin = { 122810 / 120000 },
}
```

[KWA+19]

PDFBIB

Kampmann, A., Wüstenberg, A., Alrifaae, B., and Kowalewski, S., "A Portable Implementation of the Real-Time Publish-Subscribe Protocol for Microcontrollers in Distributed Robotic Applications", in *Proc. 2019 IEEE Intelligent Transportation Systems Conference (ITSC) : [Proceedings]*, 2019, IEEE.

A Portable Implementation of the Real-Time Publish-Subscribe Protocol for Microcontrollers in Distributed Robotic Applications

Bibtex entry :

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@inproceedings { KWA+19,
  author = { Kampmann, Alexandru and W{"u}stenberg, Andreas and
    Alrifaae, Bassam and Kowalewski, Stefan },
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title = { A Portable Implementation of the Real-Time Publish-
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(ITSC) : [Proceedings] },
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ITSC, Auckland (New Zealand), 2019-10-27 - 2019-10-30 },
doi = { 10.1109/ITSC.2019.8916835 },
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reportid = { RWTH-2019-11216 },
cin = { 122810 / 120000 },
}

```

[VKR+19]

[PDFBIB](#)

Völker, M., Kloock, M., Rabanus, L., Alrifaae, B., and Kowalewski, S., "Verification of Cooperative Vehicle Behavior using Temporal Logic", *IFAC-PapersOnLine*, vol. 52, iss. 8, pp. 99-104, 2019

Verification of Cooperative Vehicle Behavior using Temporal Logic

Bibtex entry :

```

@article { VKR+19,
author = { V{"o"}lker, Marcus and Kloock, Maximilian and Rabanus,
Leon
and Alrifaae, Bassam and Kowalewski, Stefan },
title = { Verification of Cooperative Vehicle Behavior using
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publisher = { Elsevier },
pages = { 99-104 },
volume = { 52 },
number = { 8 },
year = { 2019 },
address = { Frankfurt ; M{"u"}nchen [u.a.] },
issn = { 2405-8963 },
organization = { 10th IFAC Symposium on Intelligent Autonomous
Vehicles,
Gdansk (Poland), 2019-07-03 - 2019-07-05 },
doi = { 10.1016/j.ifacol.2019.08.055 },
typ = { PUB:(DE-HGF)16 },
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url = { http://publications.rwth-aachen.de/record/766778 },
}
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[AM18]

[PDFBIB](#)

Alrifaae, B. and Maczijekowski, J., "Real-time Trajectory optimization for Autonomous Vehicle Racing using Sequential Linearization", in *Proc. 2018 IEEE Intelligent Vehicles Symposium (IV) : 26-30 June 2018 / [sponsored by the IEEE Intelligent Transportation Systems Society (ITSS)]*, Piscataway, NJ, 2018, IEEE.

Real-time Trajectory optimization for Autonomous Vehicle Racing using Sequential Linearization

Bibtex entry :

```
@inproceedings { AM18,
  author = { Alrifaae, Bassam and Maczijekowski, Janis },
  title = { Real-time Trajectory optimization for Autonomous Vehicle
    Racing using Sequential Linearization },
  booktitle = { 2018 IEEE Intelligent Vehicles Symposium (IV) : 26-30
    June
      2018 / [sponsored by the IEEE Intelligent Transportation
        Systems Society (ITSS)] },
  publisher = { IEEE },
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  doi = { 10.1109/IVS.2018.8500634 },
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  url = { http://publications.rwth-aachen.de/record/748563 },
}
```

[GSA+18]

[PDFBIB](#)

Grochowski, M., Schweigler, M., Alrifaae, B., and Kowalewski, S., "A GPS-aided Inertial Navigation System for Vehicular Navigation using a Smartphone", *IFAC-PapersOnLine*, vol. 51, iss. 10, pp. 121-126, 2018

A GPS-aided Inertial Navigation System for Vehicular Navigation using a Smartphone

Bibtex entry :

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@article { GSA+18,
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organization = { 3rd IFAC Conference on Embedded Systems,
Computational
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doi = { 10.1016/j.ifacol.2018.06.247 },
typ = { PUB:(DE-HGF)16 },
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[WLB+18]

[PDFBIB](#)

Woopen, T., Lampe, B., Böddeker, T., Eckstein, L., Kampmann, A., Alrifaae, B., Kowalewski, S., Moormann, D., Stolte, T., Jatzkowski, I., Maurer, M., Möstl, M., Ernst, R., Ackermann, S., Amersbach, C., Winner, H., Püllen, D., Katzenbeisser, S., Leinen, S., Becker, M., Stiller, C., Furmans, K., Bengler, K., Diermeyer, F., Lienkamp, M., Keilhoff, D., Reuss, H., Buchholz, M., Dietmayer, K., Lategahn, H., Siepenkötter, N., Elbs, M., v. Hinüber, E., Dupuis, M., and Hecker, C., "UNICARagil - Disruptive Modular Architectures for Agile, Automated Vehicle Concepts", in *Proc. { 27. Aachener Kolloquium Fahrzeug- und Motorentechnik : October 8th - 10th, 2018 - Eurogress Aachen, Aachen, 2018, Aachener Kolloquium Fahrzeug- und Motorentechnik GbR, pp. 663-694.*

UNICARagil - Disruptive Modular Architectures for Agile, Automated Vehicle Concepts

Bibtex entry :

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@inproceedings { WLB+18,
  author = { Woopen, Timo and Lampe, Bastian and B{"o}ddeker, Torben
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Torben and Jatzkowski, Inga and Maurer, Markus and
M{"o}stl, Mischa and Ernst, Rolf and Ackermann, Stefan and
Amersbach, Christian and Winner, Hermann and P{"u}llen,
Dominik and Katzenbeisser, Stefan and Leinen, Stefan and
Becker, Matthias and Stiller, Christoph and Furmans, Kai and
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Michael and Dietmayer, Klaus and Lategahn, Henning and

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        Siepenk{\o}tter, Norbert and Elbs, Martin and v.
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er%20Partner%20.pdf },
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[AMA17]

[PDFBIB](#)

Alrifaae, B., Maczijekowski, J., and Abel, D., "Sequential Convex Programming MPC for Dynamic Vehicle Collision Avoidance", in *Proc. First Annual IEEE Conference on Control Technology and Applications : Kohala Coast, Hawai'i, August 27-30, 2017 : CCTA 2017 / IEEE, CSS, IEEE Robotics & Automation Society, SICE, Piscataway, NJ, 2017, IEEE*, pp. 2202-2207.

Sequential Convex Programming MPC for Dynamic Vehicle Collision Avoidance

Bibtex entry :

```

@inproceedings { AMA17,
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SICE },
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typ = { PUB:(DE-HGF)7 },
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<https://www.embedded.rwth-aachen.de/doku.php?id=en:forschung:mobility>

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