

M. Sc. Program Computational Mechanics

TUM Master's Days

Munich, 26. March 2025



Agenda

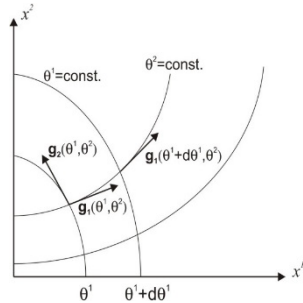
- Key Facts
- Structure and Layout
- Numbers
- Requirements, Application & What to Expect
- Your Questions
- Contacts

Key Facts

Key Facts

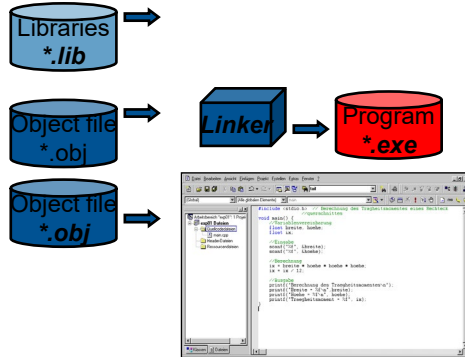
- Founded in 2000, international degree program
- Target group: Bachelor graduates with a focus on mechanical engineering, civil engineering, computer science and applied mathematics
- Interdepartmental consecutive Master of the TUM School of Engineering and Design
- Full time program - 4 semesters with 120 credits in total
- Intake only in the winter semester
- All lectures in English
- Degree: Master of Science (M.Sc)

Study Content



$$\mu u^i|_j + (\lambda + \mu) u^j|_i - \rho \ddot{u}^i = 0$$

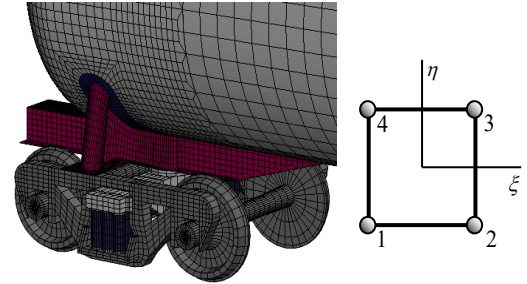
Derivation of differential equations for the description of mechanical systems



Implementation in software

Solution of technical problems using numerical methods

$$\mathbf{K} = \int_{-1}^1 \int_{-1}^1 \mathbf{t} \mathbf{B}^T \cdot \mathbf{C} \cdot \mathbf{B} |J| d\xi d\eta$$



Numerical solution methods

New Chances

- Teaching the necessary skills in the field of simulation of mechanical problems and development of numerical methods
- Interface between classical mechanical or civil engineer, and software development
- Career opportunities in a dynamically developing branch of industry
- Leading position in one of the established engineering professions

Fields of Activity

- Simulation and numerical analysis in classical engineering disciplines
- Software development for the solution of problems in fluid and structural analysis
- Development of new analysis tools
- Relevant in all engineering disciplines

Structure and Layout

Main Chairs in Program Design

Chair of Structural Mechanics

Prof. Dr.-Ing. Gerhard Müller



Chair of Computational Modeling and Simulation

vacant

Professorship for Computational Solid Mechanics

Prof. Dr.-Ing. habil. Fabian Duddeck



Chair of Hydromechanics

Prof. Dr.-Ing. habil. Michael Manhart



Chair of Structural Analysis and Dynamics

Prof. Dr.-Ing. Roland Wüchner

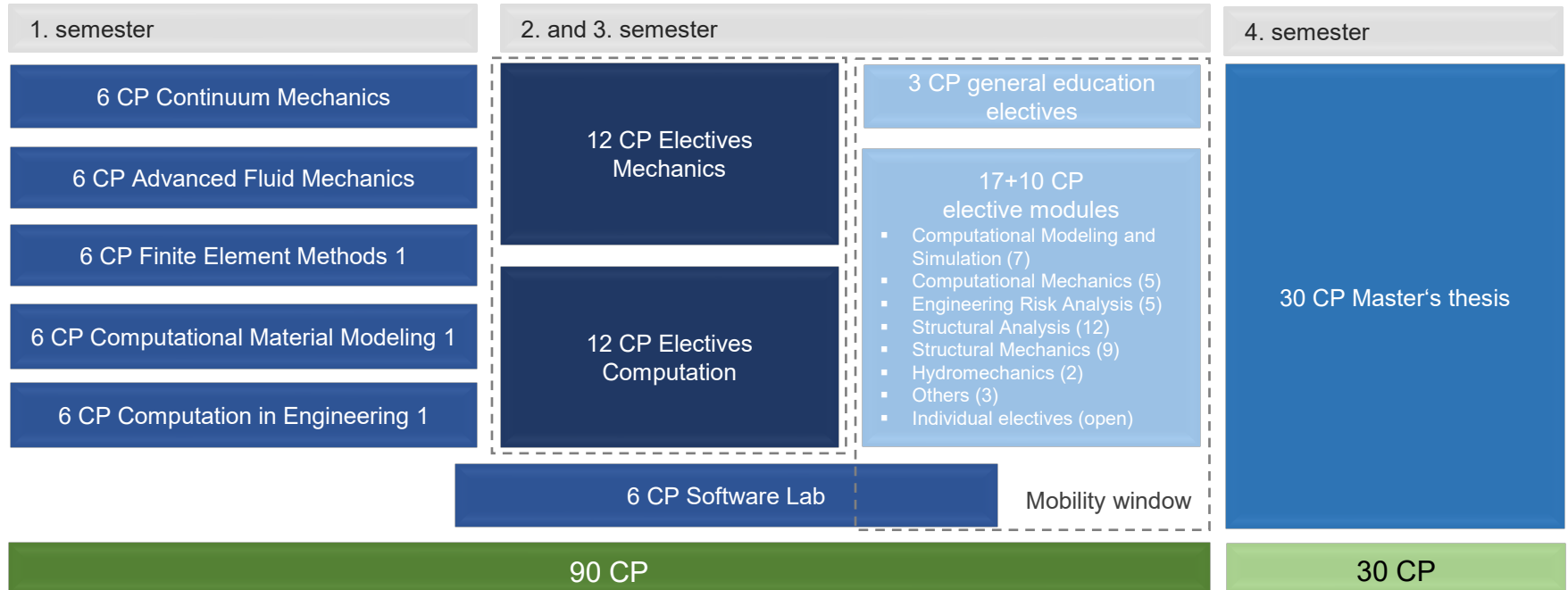


Engineering Risk Analysis Group

PD Dr.-Ing. Iason Papaioannou



Curriculum



→ [Further info and details in wiki](#)

Curriculum (core electives 2./3. semester)

6 CP Computational Fluid Dynamics

6 CP Computational Material Modeling 2

6 CP Structural Dynamics

6 CP Theory of Plates and Shells

12 CP Electives
Mechanics

12 CP Electives
Computation

6 CP Finite Element Method 2

6 CP Optimization

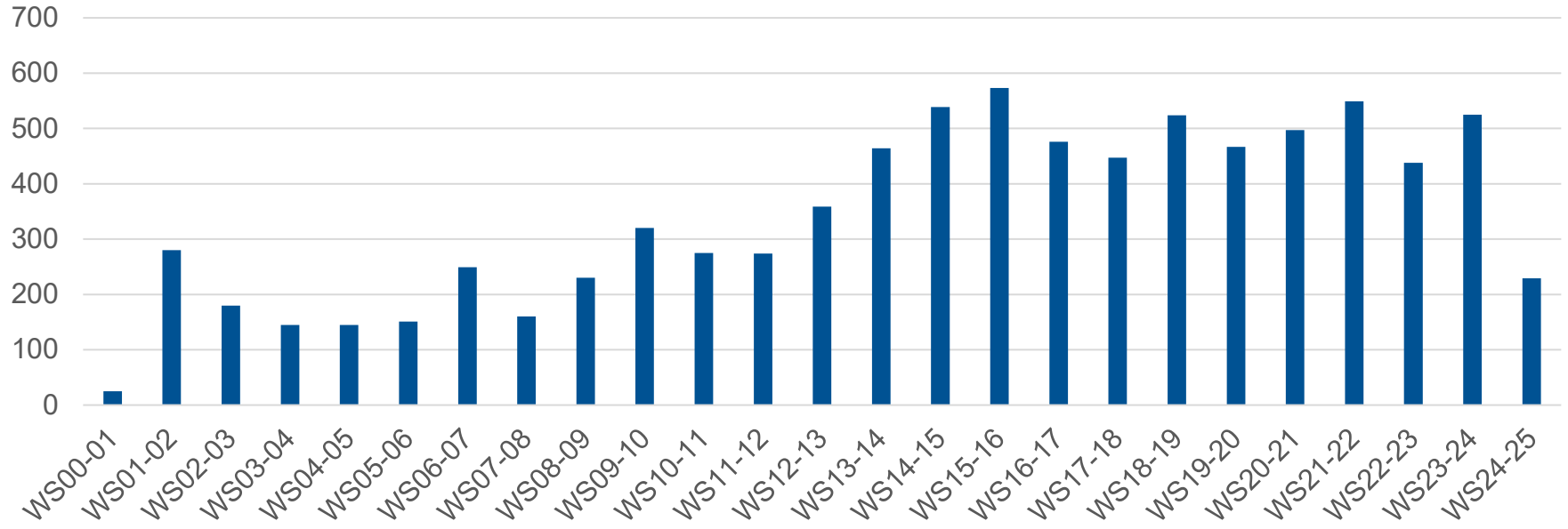
6 CP Functional Analysis &
Computational Linear Algebra

6 CP Artificial Intelligence in
Computational Mechanics

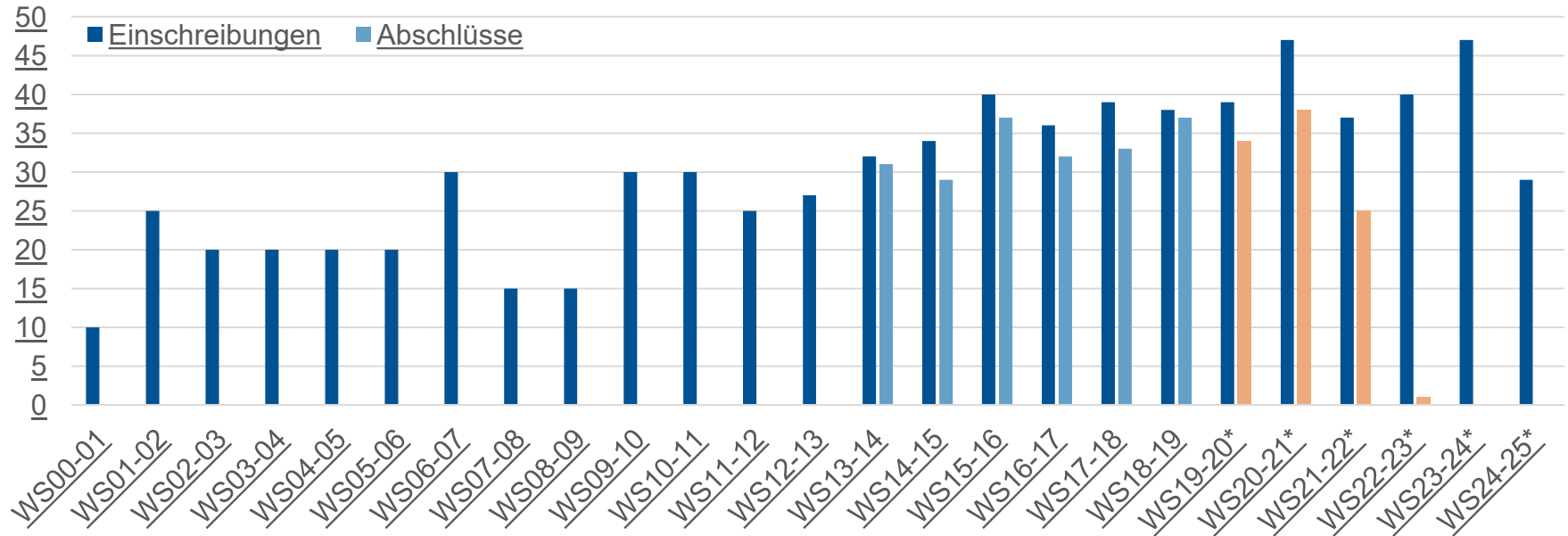
12 CP (2 modules) in
each electives catalogue

Numbers

Applications



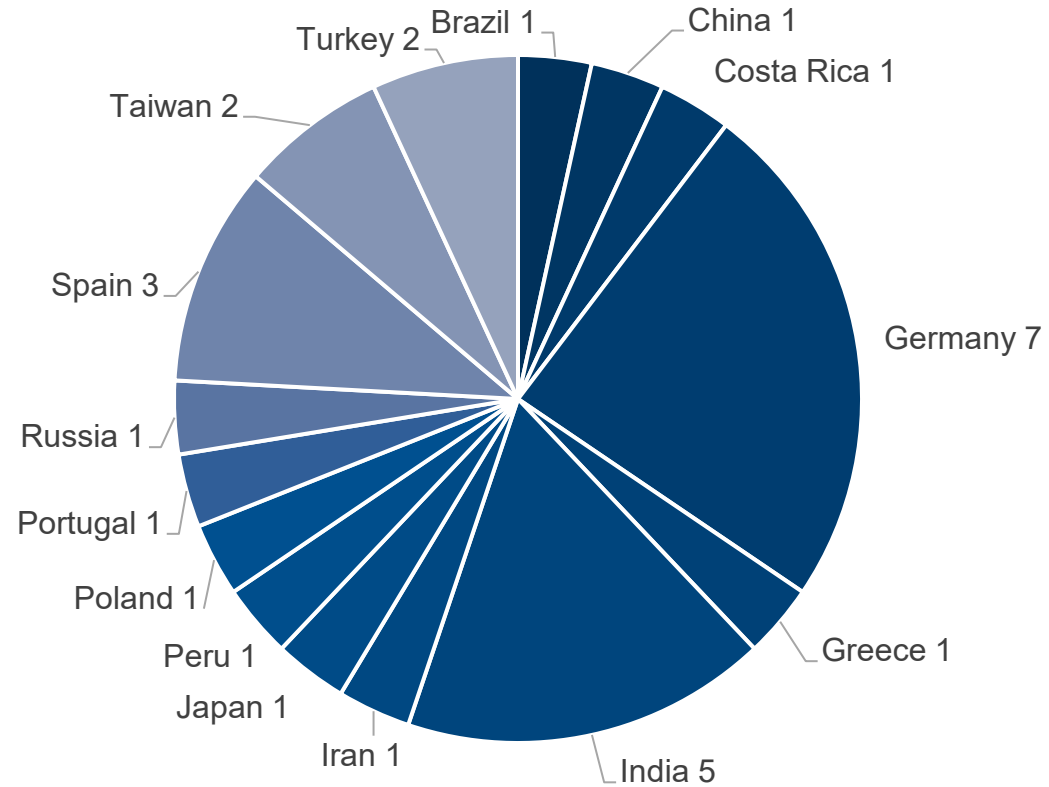
Enrollments and Graduations



*Cohort not completely finished

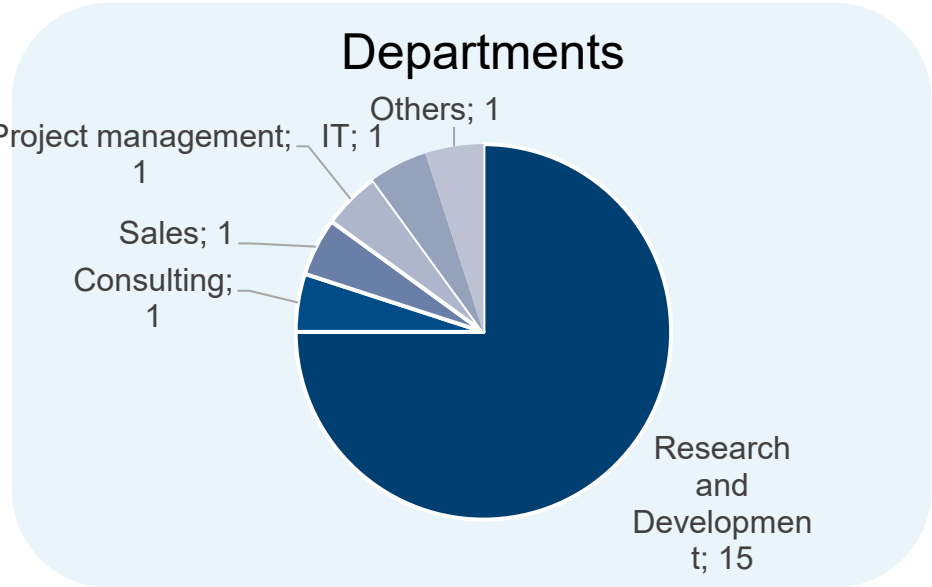
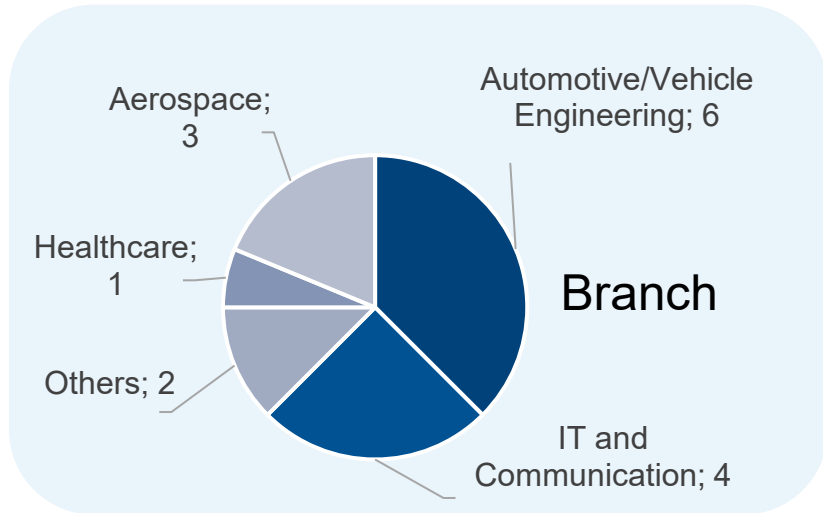
Nationalities I

WS 22/23



Career I

Graduate Poll 2023



Further study-specific areas:

- Structural Analysis
- Software development

Requirements, Application & What to Expect

→ [Further info and details in CoMe-wiki](#)

Requirements

Above average Bachelor's degree

Sound knowledge of mathematics & mechanics (fluid & structural mechanics)

Fundamental knowledge in informatics

English language proficiency

TOEFL (IBT ≥ 88)

IELTS ($\geq 6,5$)

CAE, CPE (A,B,C)

Bachelor's in English

→ Pass Aptitude Assessment

Aptitude Assessment

Two stage procedure

Submission of

Transcript

CV

Letter of Motivation

Essay

Letter of Reference

First stage: assesment of application in first stage: up to 100 points

< 65 points: rejection

≥ 65 points,
< 75 points:

interview

≥ 75 points: admission

Second stage: interview

< 90 points: rejection

≥ 90 points: admission

→ [Further info and details on TUM-webpage](#)



Tuition Fees

No tuition fees for students

from Germany, the EEA (EU + Iceland, Liechtenstein and Norway) and some more

who have acquired their Bachelor's or higher education in the German education system

Tuition fees: 6,000 € per semester

Various scholarships and exemptions

Deadline for Application: 31. May 2024

What to expect

- Interdisciplinary & intercultural teaching and studying
- Onboarding at beginning of studies: welCoMe week & C++ introduction
- Project work: Software Lab
- Care and support in small groups
- Individualizable curricula through "individual electives"
- Part of the Elite Netzwerk Bayern under the umbrella of the Bavarian Graduate School of Computational Engineering

Software Lab

- Implementation of a mechanical/engineering problem into a software solution
- Projects from academic and industrial background
- Simulation of team-oriented and hands-on software development
- Work in small groups (3-4 students)

Software Lab 2021: Stabilization methods for immersed finite element discretization of scalar wave equation

Praveen Kumar Mukala, Francisco Garcia Villanueva, Torsten Schmidt
Philipp Kopp, Tim Burchner

The flowchart illustrates the process from the wave equation to the final results. It starts with the **WAVE EQUATION** $\mu_{tt} - c^2 \nabla \cdot \nabla \mu = f$ in $(0, T) \times \Omega$, where $\Omega \in \mathbb{R}^2$ or \mathbb{R}^3 . This leads to the **WEAK FORM FEM**, which involves physical domain, discretized domain, and nodal basis functions. The next step is **ITERATION FEM**, which includes a linear problem and a weak imposition of Dirichlet BC. This leads to the **STABILIZATION** step, which includes **1. Remedy: FEM Stabilization at $\alpha = 0$** and **2. Ghost Penalty (Jump Stabilization)**. The stabilization process involves interface reconstruction and extension operators. The final step is **RESULTS**, which includes **Time Resolutions** and **Conditioning number for the Mass Matrix**.

Software Lab Project 2021 Implementing Free-Surface Flows using the VOF Method in a Distributed CFD Framework

Group 5 : Arda Şafak, Emre Işık, Mao Watanabe
Supervisor: Christoph Ertl

Introduction

CFD of free-surface flows is an important tool in predicting and analyzing natural disasters such as floods. However, such two-phase flows are usually demanding in computational effort so that parallel computing becomes a must. In this project, we aim to build a multiphase module based on the VOF method upon an existing distributed CFD framework.

Theory

Volume of Fluid (VOF) is an interface-capturing method for two-phase flows, associating phases to volume fractions $f \in [0, 1]$. Then, the interface must be reconstructed from volume fractions.

Implementation



Our implementation is built on a variable density Navier-Stokes solver with extensions.

1. Surface Tension
The surface tension F is the force acting between different fluids. To calculate the force, the Continuum Surface Force (CSF) method is chosen, which allows us to estimate the curvature by using fractions.

2. Advection
Volume fractions must be advected at each time step so that the density and the viscosity can be interpolated by using the volume fraction. Volume fractions in the advection equation are retrieved directly from the reconstructed interface only for the donating region, whose size and location is determined by the local velocity.

3. Reconstruction
Interface reconstruction is performed by the Piecewise Linear Interface Construction (PLIC) method, which approximates the local interface fitting a straight line segment to each grid cell. Estimation of the normal vectors is conducted by the ELVIRA algorithm. All reconstruction and surface tension operators are performed only at the proximity of the interface.

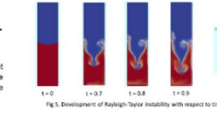
Results and Discussion

Several benchmark cases are tested to validate our solver.

1. Falling drop cases

Falling the drop case is one of the most well-known benchmark cases that is available in the literature. In this case a water droplet is fallen from a height towards the ground by the help of gravitational acceleration. In Figure 5 the slopes of the fallen drop can be seen. Here the blue part represents the water (fraction of 1) while the gray part represents the air. It can be observed from the figure that the shape of the droplet develops into a shape that is expected and we can observe in nature. Additionally, the program implemented enables the formation of smaller droplets depending on the resolution used.

2. Rayleigh-Taylor instability



Rayleigh-Taylor instability is another typical two-phase problem where a denser fluid tries to replace the lighter fluid below under the action of downwards gravity. The case is initialized with a sinusoidal interface profile and in time certain flow fields can be observed as seen in Figure 5. The results are compared with [1] and considered to be reasonable.

Conclusion

In this project, we have managed to implement VOF method on a high-parallelized CFD framework. Future developments to the present work would include optimization of VOF modules for parallel applications and extension to solve for 3D problems.

References

- [1] Kikuchi, Kim, Mizoguchi, A Navier-Stokes Solver for Single- and Two-Phase Flows. MSc Thesis, University of Otsu, Faculty of Mathematics and Natural Sciences, September 2008.
- [2] U. Brackbill, D. B. Kothe, and C. Zang, A continuum method for modeling surface tension, Journal of Computational Physics, 100:335-354, 1992.

Racing-line Optimization using Multibody Models Software Lab Project 2021 Georgios Papageorgiou, Daniel Krivacic, Tianyi Wang Andreas Apostolatos, Steve Miller, Jan van Rensburg

ABSTRACT AND MOTIVATION

The need to design vehicles without using hardware prototypes has led to widespread use of simulation. We explored the use of simulation to identify methods of adapting vehicle design to reduce lap time.

We added new physical designs and control algorithms to an existing Simulink model. Using simulation, we evaluated those designs by comparing them to a baseline. An outlook for next steps is discussed.

OBJECTIVE

Use simulation to evaluate the possible reduction of lap time by modifying design characteristics of the vehicle, control algorithms, and driver behavior

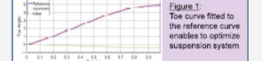
RESULTS

Suspension Design

Figure 2: Suspension and chassis designed for racing integrated into model

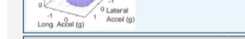


Suspension Tuning

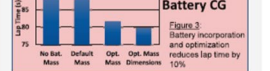


GVV Diagram

Figure 4: GVV diagram generated from model enables evaluation of performance envelope

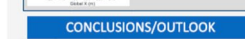


Location of Battery CG

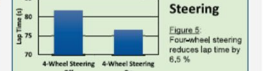


Path Optimization

Figure 6: Path defined by waypoints enables fastest path to be found in simulation



Four-Wheel Steering



CONCLUSIONS/OUTLOOK

- Added new vehicle template and algorithms to library
- Extended use of optimization in evaluating designs

Simscape Vehicle Templates
Set of templates for creating custom vehicle models
https://github.com/mathworks/Simscape_Vehicle_Templates

© Steve Miller (2021), Simscape Vehicle Templates. https://github.com/mathworks/Simscape

Torque Vectoring Algorithm



Your Questions

Related to Career Opportunities

- How useful are the specialization modules like "Biomechanics" for career opportunities and what are experiences with job search?
- What career opportunities are available with this degree? Can it be applied to the energy sector?
- How much it is about programming and what and where I can work afterwards
- What job opportunities do I have?
- Wird es diesen Berufsstand durch den Einsatz von KI weiterhin geben?
- What is the professional scope?

Organization and Teaching

- Are the meetings recorded? The meeting is during my working hours
- How big is the maths part?
- What are the differences between Computational Mechanics and Mechanical Engineering regarding the mandatory/elective courses?
- About the organization in case i want to two M.Sc. in the same time

Aptitude Assessment

- Is the number of ECTS of one's bachelor program (e.g. 210 vs 180 total) taken into account for admission?
- How do I obtain a letter of recommendation if I have not had any contact to professors during my bachelor studies?
- Eligibility criteria for MS in Computational Mecha and other courses at TUM? specific GPA or coursework , Application Procedure.
- What are the some examples of the required modules I need to take as electives as a Bachelor's Mech Eng Student in TUM?
- Habe ich mit einem Hochschulabschluss eine Chance?
- How can I improve my chances to be taken into the Master?

Related to Internships / Exchange / Scholarships

- Is an internship possible within the degree?
- What kinds of incentives are there for exchange programs?
- Scholarship Opportunities

Further Information and Contact



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Links

<https://www.tum.de/en/studies/fees-and-financial-aid/scholarships/tum-scholarships>

<https://www.international.tum.de/en/global/going-abroad/>

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Thank your your interest!

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