Lehrstuhl für
Technische Dynamik
Prof. Dr.-Ing. habil. Sigrid Leyendecker

Report
Institute of Applied Dynamics
2025

Friedrich-Alexander-Universität
Technische Fakultät

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Contents

1 Preface

Welcome to a quick overview of the 2025 scientific and teaching activities at the Institute of Applied Dynamics (LTD) at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU). We focus on integrating simulation and optimal control for the dynamics of multibody systems, especially in biomechanics and robotics.
Our main areas of study are:

- **Biomechanics**
- **Motion Capturing**
- **Structure-Preserving Simulation and Optimal Control**
- **Multibody Dynamics and Robotics**

For instance, we simulate heart functions and model how muscles work, combining electrical stimulation with mechanical deformation. We also investigate human movement mechanics, such as grasping, shoulder motions, and walking. Our motion capturing lab plays a crucial role in linking theoretical models with hands-on experiments. This blend allows us to fine-tune control strategies across various scales.
Additionally, we're developing numerical methods for dynamic simulation and optimal control, employing techniques like variational integrators and Lie group methods to address challenges in multibody dynamics, robotics, and fracture mechanics.
A big thank you to our technical, scientific, and administrative staff at LTD, as well as all the students who contributed to making this a successful year at the Institute of Applied Dynamics. We hope you enjoy browsing through our annual report!

2 Team

head of institute
Prof. Dr.-Ing. habil. Sigrid Leyendecker

team assistant
M.A. Ruby Chen

technical staff
M.Sc. Elisa Fleischmann
M.Sc. Markus Lohmayer until 30.09.2025

akademischer Rat
Dr.-Ing. Giuseppe Capobianco, Akad. Rat

postdoc
Dr.-Ing. Xiyu Chen
Dr. rer. nat. Michael Konopik
Dr. Rodrigo Sato Martín de Almagro

scientific staff
M.Sc. Gamal Amer
M.Sc. Birte Coppers
M.Sc. Simon Heinrich
M.Sc. Deepak Balasaheb Jadhav until 31.10.2025
M.Sc. Prateek Prateek
M.Sc. Tan Tran from 01.04.2025
M.Sc. Tengman Wang from 01.02.2025

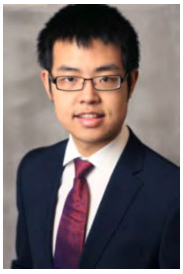
students
Valerie Bartanus
Deven Singh Chauhan
Claudia Cormann
Marie Eberle
Aaron Elias
Vamshidhar Reddy Enugala
Tim Flosbach
Christina Helbing
Matilda Held
Negin Javaheri
Saloni Jethwa
Chen Jiaan
Kaustubh Rajesh Khanvilkar
Tran Lam
Gordon Lanz
Vincent Lehniger
Aaron Linsel
Alexander Müller
Varun Narendra Kumar
Venkatesan Rishyavandhan
Poojary Saurabh
Elisabeth Schmitt
Amit Sharma
Anil Sreeram
Christian Strauß
Shravan B. Sundaresha
Theodore Lemaire Suthan
Tan Tran

Student assistants are mainly active as tutors for young students in basic and advanced lectures at the Bachelor and Master level. Their contribution to high quality teaching is indispensable, thus financial support from various funding sources is gratefully acknowledged.


G. Amer


G. Capobianco


R. Chen


X. Chen

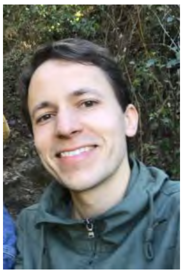

B. Coppers


E. Fleischmann


S. Heinrich


D. Jadhav


M. Konopik


M. Lohmayer


P. Prateek


R.T. Sato


T. Tran


T. Wang


S. Leyendecker

3 Research

3.1 SFB 1483 – EmpkinS

In 2025, the Collaborative Research Center CRC 1483 "Empatho-Kinaesthetic Sensor Technology" (EmpkinS) concluded its first funding period with an on-site review by the Deutsche Forschungsgemeinschaft. In the last four years, the CRC worked on advancing the development of sensor technology and the collection of movement data to better understand human body dynamics. Spearheaded by Prof. Dr.-Ing. Martin Vossiek and Prof. Dr. Björn Eskofier, the project aims to integrate external movement observations with internal biomedical processes to capture and monitor body functions non-invasively.
The subprojects C04 and D01 contributed towards these goals, under the lead of Prof. Dr.-Ing. habil. Sigrid Leyendecker at the Institute of Applied Dynamics and PD. Dr. habil. Anna-Maria Liphardt at the Department of Internal Medicine 3, FAU & Universitätsklinikum Erlangen. Doctoral candidates M.Sc. Simon Heinrich's and M.Sc. Birte Coppers' active research lead to the development of more than ten journal publications. Both subprojects have also fostered substantial collaborations between institutes and universities, as well as other outreach activities. These included research stays at the Queensland University of Technology in Brisbane, Australia and University Jaume I, Castelló de la Plana, Spain, organizing the interdisciplinary hand symposium in Erlangen, or participating in national and international conferences.
Throughout the year, regular meetings have provided platforms for discussion and presentation of progress, allowing researchers to align their efforts and set the stage for future achievements. The insights and data collected paved the way for innovations in sensor technology. For more information on the project's developments, please visit https://www.empkins.de.

Figure 1: Group picture after on-site review in Erlangen.

3.2 FRASCAL – Fracture across Scales

The DFG Research Training Group (RTG) FRASCAL – Fracture across Scales (GRK 2423) leaded by Prof. Dr. Ing. habil. Paul Steinmann and Prof. Dr. Michael Stingl, is a multidisciplinary research initiative where Project P9 is conducted at LTD under the supervision of Prof. Dr.-Ing. habil. Sigrid Leyendecker. Currently the project runs on the third cohort with M.Sc. Prateek Prateek research focusing on variational integrators and peridynamics for dynamic fracture simulations, with emphasis on structure-preserving time integration, nonlocal interaction models, and scalable numerical imple-

mentations.
During the reporting period, ongoing scientific exchange across all FRASCAL projects was actively supported through regular interactions and seminars. Several talks by speakers from within FAU as well as invited external researchers provided valuable opportunities to broaden scientific perspectives, stimulate discussion, and strengthen collaboration across disciplines. Further details related to the project can be found on https://www.frascal.research.fau.eu.

3.3 Computational Biomechanics

In 2025, LTD is pleased to have doctoral researchers M.Sc. Gamal Amer and M.Sc. Tan Tran joining the biomechanics research field. They are currently continuing ongoing work on computational methods, with a primary focus on:

- advancing the material model discovery project, particularly using Constitutive Artificial Neural Networks (CANNs), in collaboration with Prof. Dr.-Ing. Ellen Kuhl's group in FAU and Stanford, to automatically identify material models and parameters for electromechanically coupled materials.

- using multiscale mechanobiological models of bone remodelling to simulate and understand bone loss during mechanical disuse. This project is a collaboration between the FAU under Prof. Dr.-Ing. habil. Sigrid Leyendecker, the UKER under PD Dr. sportwiss. Dr. habil. med. Anna-Maria Liphardt and the QUT in Australia under Prof. Dr.-Ing. habil. Peter Pivonka. A large clinical dataset provided by the ESA is used to enable subject-specific predictions and a robust model validation.

3.4 Lagrangian and Hamiltonian field theories – geometry, discretization, optimal control

The LE 1841/13-1 DFG project *Lagrangian and Hamiltonian Field Theories – Geometry, Discretization, Optimal Control* is a bilateral collaboration with the Instituto de Ciencias Matemáticas (ICMAT) in Madrid, Spain. The principal investigators from LTD are Prof. Dr.-Ing. habil. Sigrid Leyendecker and Dr. Rodrigo T. Sato Martín de Almagro, while Prof. Dr. David Martín de Diego represents ICMAT.
Both institutes are actively collaborating on research related to Lagrangian and Hamiltonian field theories. LTD has welcomed M.Sc. Tengman Wang as a doctoral researcher to the project, and Dr. Oscar Cosserat from the University of Göttingen has also joined the collaboration. The project focuses mainly on developing high-order variational integrators for field theoretical problems on two dimensions.

3.5 Symplectic discretization for optimal control problems in mechanics

The DFG project LE1841/12-1 aims at deriving and characterizing a new approach to solving optimal control problems for mechanical systems. This is a joint project between the LTD and the Numerical Mathematics and Control research group at the Universität Paderborn, with main supervisors Prof. Dr.-Ing. habil. Sigrid Leyendecker and Prof. Dr. Sina ober-Blöbaum, respectively.
Within the second year of the project, on the analytical side, the characterization of the new Lagrangian approach has advanced to include optimal control problems with general second order differential equations as state equations and force-controlled regular Lagrangian systems. In particular their geometric structure has been explored. On the numerical side low-order schemes were developed from the new approach for force-controlled Lagrangian systems that possess 'double-symplecticity'; schemes

that are symplectic w.r.t. the state-adjoint space and symplectic with forcing for the underlying state equations.
Dr. rer. nat. Michael Konopik is focusing on the discrete setting, while Dr. Rodrigo T. Sato Martín de Almagro and Dr. Sofya Maslovskaya are focusing on generalization of the new approach in the continuous setting.

3.6 Scientific reports

The subsequent pages present a brief overview on the current research projects pursued at LTD. These are partly financed by third-party funding German Research Foundation (DFG) in addition by the core support of the university.

Research topics
Automated Constitutive Modeling of Dielectric Elastomer Actuators (DEAs) – Towards Realistic Modeling of Artificial Muscles
Gamal Amer, Denisa Martonová, Sigrid Leyendecker

A differentiable formulation of a set-valued force law approximating planar Coulomb friction
Giuseppe Capobianco, Sigrid Leyendecker

Muscle path modeling for an elbow-shoulder model based on geodesics
Xiyu Chen, Simon Heinrich, Saulo Martelli, Peter Pivonka, Sigrid Leyendecker, Maxence Lavaill

Disease-related changes in forearm muscle activity in inflammatory arthritis
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Robust muscle path modelling based on a local parametrization of geodesics
Simon Heinrich, Xiyu Chen, Saulo Martelli, Peter Pivonka, Sigrid Leyendecker, Maxence Lavaill

Derivation of doubly symplectic numerical schemes for optimal control problems
Michael Konopik, Rodrigo T. Sato Martín de Almagro, Sofya Maslovskaya, Sina Ober-Blöbaum, Sigrid Leyendecker

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Prateek Prateek, Giuseppe Capobianco, Sigrid Leyendecker

Variational integrators for mechanical systems, field theories and optimal control
Rodrigo T. Sato Martín de Almagro, Michael Konopik, Tengman Wang, Oscar Cosserat, David Martín de Diego, Sigrid Leyendecker

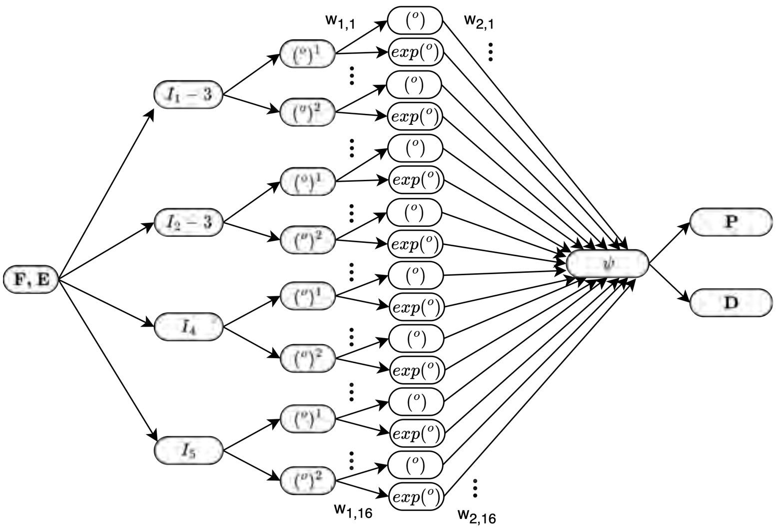
Disuse-related bone loss prediction using a multiscale mechanobiological model of bone remodelling
Tan Tran, Xiyu Chen, Peter Pivonka, Sigrid Leyendecker, Anna-Maria Liphardt

Multisymplectic variational integrators and Runge-Kutta methods in field theories
Tengman Wang, Rodrigo T. Sato Martín de Almagro, Oscar Cosserat, David Martín de Diego, Sigrid Leyendecker

Automated Constitutive Modeling of Dielectric Elastomer Actuators (DEAs) – Towards Realistic Modeling of Artificial Muscles

Gamal Amer, Denisa Martonová[1], Sigrid Leyendecker

Dielectric elastomer actuators (DEAs) are soft, flexible electromechanically coupled materials that undergo large, field-driven deformations and exhibit strong coupling behavior. To accurately capture this behavior without fixing a traditional and rigid closed-form law, we utilize an automated, data-driven approach to learn a polyconvex free-energy function ψ with a constitutive artificial neural network (CANN) that takes as input invariant features of the deformation gradient $\mathbf{F}$ and electric field $\mathbf{E}$ (see Figure 1; cf. CANN ideas in [1] and inelastic extensions in [2]). The network's input, architecture, and output ensure adherence to physical constraints, material objectivity and thermodynamic consistency. The resulting ψ can then be derived to determine first Piola–Kirchhoff stress $\mathbf{P}$ and electric displacement $\mathbf{D}$. The formulation is consistent with nonlinear electroelasticity [3] and can be later deployed in finite-element tools.



mechanical invariants

$I^{\mathrm{m}}(\mathbf{F}) = I^{\mathrm{m}}(I_1 - 3,\, I_2 - 3)$

electric invariants

$I^{\mathrm{e}}(\mathbf{E}) = I^{\mathrm{e}}(I_4)$

coupled invariants

$I^{\mathrm{em}}(\mathbf{F}, \mathbf{E}) = I^{\mathrm{em}}(I_5)$

where

$I_1 = \mathrm{tr}(\mathbf{C}) = \mathbf{C} : \mathbf{I}$
$I_2 = \frac{1}{2}\big(\mathrm{tr}^2(\mathbf{C}) - \mathrm{tr}(\mathbf{C}^2)\big)$
$I_4 = (\mathbf{E} \otimes \mathbf{E}) : \mathbf{I}$
$I_5 = (\mathbf{E} \otimes \mathbf{E}) : \mathbf{C}$

Figure 1: CANN architecture with two hidden layers for isotropic perfectly incompressible DEAs

During training, the network weights $\mathbf{w} = \{w_{i,j}\}$ are identified by minimizing a loss function (1) that combines a mean-squared-error term over all n_{data} samples with an $\mathbf{L}_2$ penalty on the weights. In (1), $\mathbf{F}_i$, $\mathbf{E}_i$ are the i-th measured deformation gradient and electric field, $\hat{\mathbf{P}}_i$, $\hat{\mathbf{D}}_i$ are experimental targets, and $\mathbf{P}$, $\mathbf{D}$ are the model predictions from ψ. Moreover, setting the penalty term $\alpha = 0$ in (1) yields the standard, non-regularized constitutive neural network that solely fits the data, whereas $\alpha > 0$ trades off accuracy against model complexity by shrinking some weights towards zero, thereby simplifying the model and aiding interpretation. The optimization of (1) is carried out with the ADAM first-order gradient method, together with an early-stopping rule that halts training once the prediction error ceases to improve.

$$L(\mathbf{w};\mathbf{F};\mathbf{E}) = \frac{1}{n_{\mathrm{data}}} \sum_{i=1}^{n_{\mathrm{data}}} \Big(\big\|\mathbf{P}(\mathbf{F}_i, \mathbf{E}_i, \mathbf{w}) - \hat{\mathbf{P}}_i\big\|_2^2 + \big\|\mathbf{D}(\mathbf{F}_i, \mathbf{E}_i, \mathbf{w}) - \hat{\mathbf{D}}_i\big\|_2^2 \Big) + \alpha \big\|\mathbf{w}\big\|_2^2 \to \min \qquad (1)$$

$$\text{with} \quad \|\mathbf{w}\|_2^2 = \textstyle\sum_{i=1}^{n_{\mathrm{weights}}} |w_i|^2$$

[1]Institute of Applied Mechanics, FAU, Nürnberg, Germany

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[1] Linka, K., Kuhl, E. (2023). Constitutive Artificial Neural Networks for automated model discovery. *Journal of the Mechanics and Physics of Solids* 163:104864.

[2] Holthusen, C., Keip, M.-A., Stiemer, M. (2024). Inelastic constitutive artificial neural networks. *Computer Methods in Applied Mechanics and Engineering* 422:116856.

[3] Possart, G., Haupt, P., et al. (2006). Coupled electro-elastic modelling at large strains. *Archive of Applied Mechanics* 76:423–444.

A differentiable formulation of a set-valued force law approximating planar Coulomb friction

Giuseppe Capobianco, Sigrid Leyendecker

For many engineering applications, friction is vital for their functionality. E.g. for walking and driving, the friction with the ground is exploited for locomotion. Coulomb friction, with its two phases sliding and sticking, can be described as a set-valued function, see Figure 1. Hence, Coulomb friction is not a function in the "traditional" sense. Moreover, its graph can only be characterized by an equation that involves functions that are merely continuous, but not continuously differentiable. In this project we have devised an approximation of Coulomb friction that can be described using an equation involving continuously differentiable functions and that is still a set-valued friction law, i.e., the approximation still has a sliding and a sticking phase, see 1.

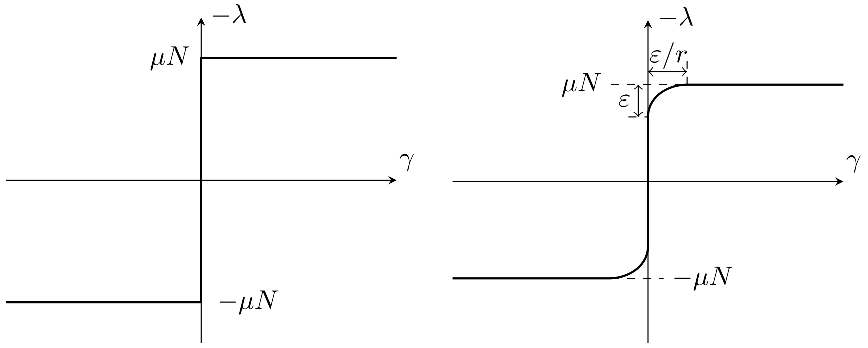

Figure 1: Left: Set-valued Coulomb friction law. Right: Developed approximation of the Coulomb friction law.

The benefit of having a set-valued friction law described by differentiable functions is that it can be used with most solvers for nonlinear optimization problems and therefore paves the way for optimal control applications. In contrast to other approaches, this friction law approximation preserves the switching behavior between the sticking and sliding phases. In fact, most regularizations of Coulomb friction cannot describe the sticking phase at all. As a proof of concept, the developed friction approximation has been applied to the optimal control of a pendulum driven via a frictional clutch, see 2. The

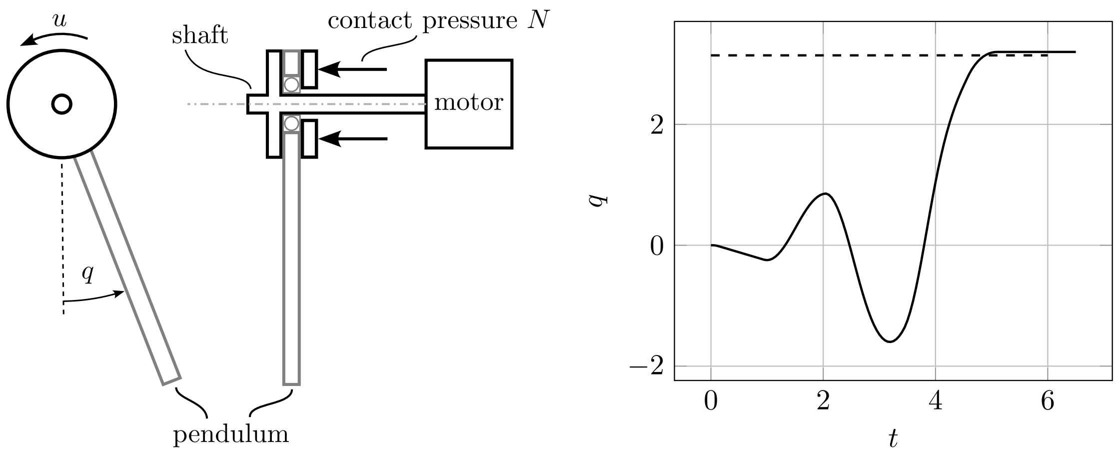

Figure 2: Left: Sketch of a pendulum driven via a frictional clutch. Right: Swing-up trajectory found using optimal control and the developed friction law approximation.

presented results look very promising. Especially, we have not only found that the developed model improves the optimal control result due to more accurate modeling, but we have also experienced that the optimization can be solved more efficiently.

Muscle path modeling for an elbow-shoulder model based on geodesics

Xiyu Chen, Simon Heinrich, Saulo Martelli[12], Peter Pivonka[12], Sigrid Leyendecker, Maxence Lavaill[12]

Accurate and robust estimation of muscle paths is fundamental for computing muscle–tendon lengths, moment arms, and joint torques in musculoskeletal simulations. Early biomechanical models approximated muscles as straight-line segments between origin and insertion points, overlooking the complex interactions between muscles and underlying skeletal geometry. Although computationally efficient, such simplifications fail to capture realistic wrapping and sliding behavior, resulting in notable inaccuracies in moment arm estimation and joint torque prediction, particularly in multi-articular systems. In this study, we employ discrete geodesic Euler–Lagrange equations to model muscle paths with higher biomechanical fidelity. Muscles are represented as massless, frictionless trajectories sliding smoothly over curved bone surfaces. Each path is discretized into K linear segments, $\gamma \in \mathbb{R}^{3(K+1)}$, while surface constraints ensure geometric adherence without penetration or deformation [1, 2]. This framework enables the identification of the shortest feasible muscle path that satisfies the anatomical constraints, offering new insights into mechanobiological modeling.

A key challenge in this process is the sensitivity to the initial guess used in the iterative solver. To enhance convergence reliability across complex joint motions, we developed two strategies. The baseline global parameterization uses the solution from the previous time step. In contrast, a refined local parameterization employs a fixed-body reference frame to better accommodate large relative displacements. We evaluated both strategies using an elbow–shoulder model comprising 11 muscles as shown in the Figure 1, with elbow flexion ranging from 0–150° and shoulder flexion from 0–150°. The results show that global parameterization can lead to discontinuities and muscle "jumping," whereas local parameterization eliminates these issues, yielding smooth muscle-length variations, notably for the Teres Major.

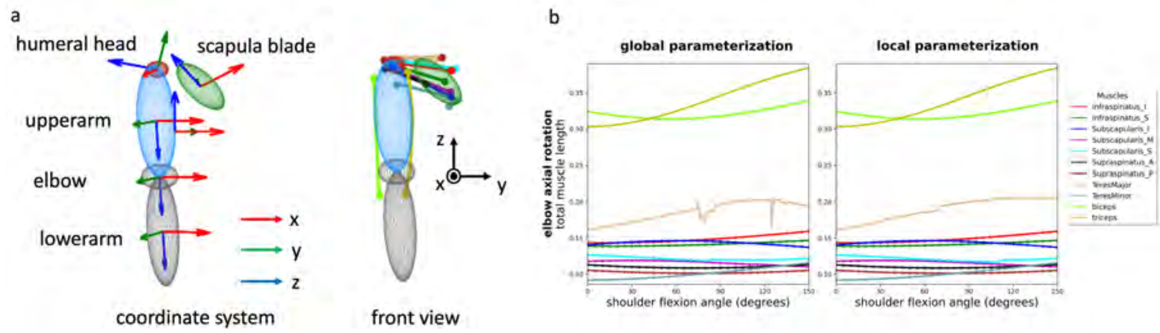

Figure 1: (A) Shoulder–elbow model with five bodies and eleven muscles. Colored frames indicate the local coordinate system for each segment. (B) Total muscle length of the combined shoulder–elbow model during shoulder flexion (0°–150°) with concurrent elbow axial rotation (0°–150°), comparing different local parameterization methods.

References

[1] J. Penner and S. Leyendecker. A discrete mechanics approach for musculoskeletal simulations with muscle wrapping. Multibody System Dynamics 56(3), 267-287, 2022

[2] M. Lavaill, X. Chen, S. Heinrich, P. Pivonka and S. Leyendecker. Muscle path predictions using a discrete geodesic Euler–Lagrange model in constrained optimisation: comparison with OpenSim and experimental data. Multibody Dynamics 65, 621-643, 2025

[1]Mechanical, Medical and Process Engineering, Queensland University of Technology, Brisbane, Queensland, Australia
[2]Centre for Biomedical Technologies, Queensland University of Technology, Brisbane, Queensland, Australia

Disease-related changes in forearm muscle activity in inflammatory arthritis

B. Coppers[1], S. Heinrich, V. Gracia-Ibanez [2], S. Bayat[1], G. Schett[1],S. Leyendecker, A.-M. Liphardt[1]

In rheumatoid arthritis (RA) and psoriatic arthritis (PsA) patients reduced grip strength is present, despite clinical remission [1]. To better understand the underlying muscular changes that contribute to impaired function, we explored surface electromyography (EMG) on forearm muscles. In this analysis, we included 187 participants: Healthy Controls (CON): n=43, 22/21 f/m, age 54±16; RA: n=69, 47/22 f/m, age 53±14; PsA: n=75, 38/37 f/m, age 54±14. Despite clinically low disease activity, female PsA patients showed reduced power grasp strength and significantly lower estimated wavelength for the flexor muscle compared to HC and RA and for the extensor muscle compared to CON. Female RA patients had higher root mean square values compared to PsA and lower grip strength than CON Fig. (1). No significant differences were found in male participants. The higher relative muscle activation observed in female RA patients suggests a better ability to preserve muscle force output. In contrast, female PsA patients exhibit significantly lower strength, indicated by reduced muscle activation, which reflects a diminished capacity to generate force. This work demonstrates the value of EMG-based analysis in identifying subtle changes in muscle function in chronic inflammatory diseases.

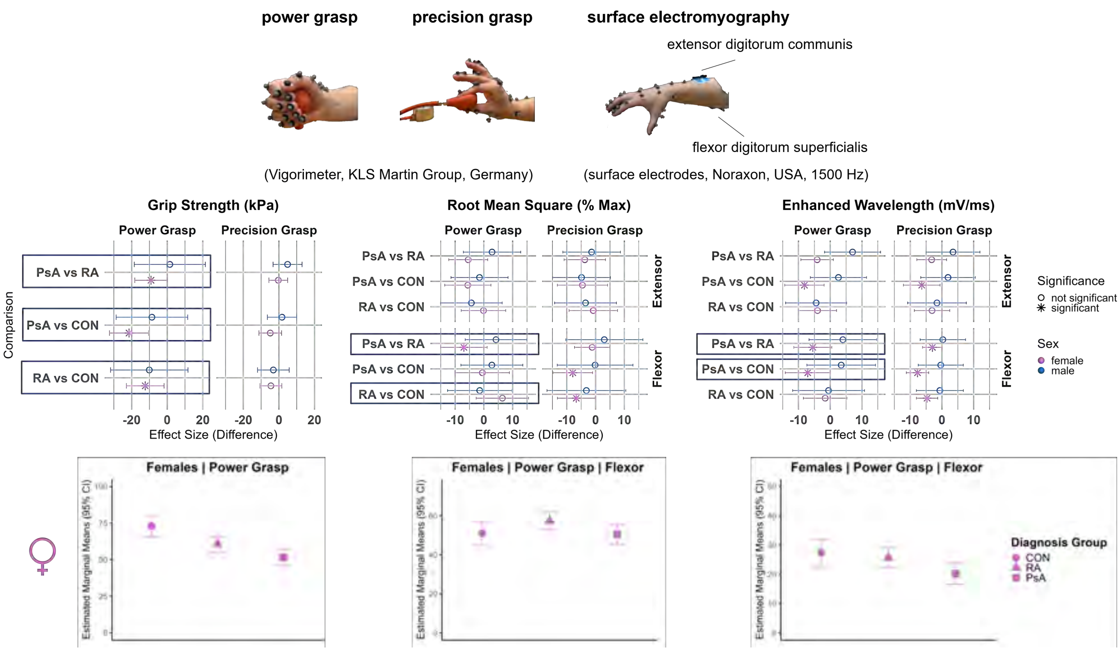

Figure 1: Grip strength tasks and electrode placement (top). Differences in selected muscle parameters between groups (bottom).

Acknowledgments Funding: Deutsche Forschungsgemeinschaft, SFB 1483, Project-ID 442419336, EmpkinS.

References

[1] Coppers, B. et al. *Hand Function Impairments Are More Pronounced in Female RA and PsA Patients and Also Found in Patients without Concurrent Hand Inflammations.* MSSE **57(12)**, 2775-2786 (2025).

[1]Department of Internal Medicine 3, Rheumatology and Immunology, Universitätsklinikum, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

[2]Departamento de Ingenieray Contrucion, University Jaume I, Castello de la Plana, Spain

Robust muscle path modelling based on a local parametrization of geodesics

Simon Heinrich, Xiyu Chen, Saulo Martelli[1,2], Peter Pivonka[1,2], Sigrid Leyendecker, Maxence Lavaill[1,2]

Simulations of musculoskeletal systems are becoming an ever more important part in analyzing and predicting human movement. These simulations require accurate muscle path computations because the force produced by a muscle depends directly on its length and length-change. The muscle path can be modeled as a taut string that wraps over surfaces, like underlying tissue, using geodesic paths [1]. Such a model can be implemented using the geodesic Euler Lagrange equations based on the geodesic Lagrangian $\mathcal{L}_d$ and the Signorini conditions (Eq. 1 and Eq.2). Thereby, $\gamma_k \in \mathbb{R}^3$ is the k-th node of the muscle path in global coordinates, ${}^iq \in \mathbb{R}^{12}$ is the configuration of the i-th wrapping surface, and $\phi({}^iq, \gamma_k)$ and ${}^i\eta_k \in \mathbb{R}$ are the distance function and contact multiplier between the i-th wrapping surface and k-th node.

$$D_1\mathcal{L}_d(\gamma_k, \gamma_{k+1}) + D_2\mathcal{L}_d(\gamma_{k-1}, \gamma_k) - \frac{1}{K}\frac{\partial\phi({}^iq, \gamma_k)}{\partial\gamma_k} = 0 \tag{1}$$

$$\phi({}^iq, \gamma_k) \geq 0 \quad {}^i\eta_k \geq 0 \quad \phi({}^iq, \gamma_k) \cdot {}^i\eta_k = 0 \tag{2}$$

This set of equations and inequalities can be solved using algorithms for nonlinear constrained optimization, where the initial guess is the solution for the previous time-frame. Consider the elbow model from [2], with biceps and triceps discretized into 20 segments each executing a simple spatial movement, which will be discretized into 41 time-frames: An elbow flexion-extension (0° – 100° – 0°) superposed with shoulder abduction-adduction (0° – 145° – 0°), as shown in Figure 1 on the far left. Using the implementation with global muscle node positions γ_k, as introduced in [1], the obtained muscle path is not guaranteed to be physiologically meaningful. As shown As can be seen in Figure 1 on the far right, the triceps wraps between humerus and forearm. This can only be prevented by constructing suitable initial guesses. However, this means that the correct muscle path has to be guessed to some extent. Introducing a local reparametrization of the muscle node positions by means of their relative position with respect to a suitable wrapping surface (here the upper arm wrapping surface) as $\gamma_k({}^i\rho_k, {}^iq)$ (Figure 1 middle left), circumvents the need to construct sophisticated initial guesses. The resulting muscle path (Figure 1 middle right) is anatomically correct over the whole movement. This local reparametrization is furthermore capable to deal with arbitrary complex movement tasks and coarse discretizations in time and space.

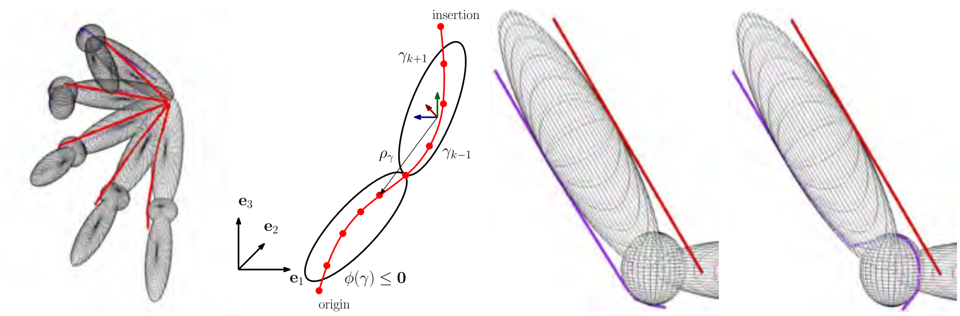

Figure 1: Left: Five poses of the simulated motion with biceps (red) and triceps (purple). Middle-left: sketch of the reparametrized muscle path. Middle-right and right: Close-up of elbow and muscle paths with local and global parametrization on half right and right.

Acknowledgements Deutsche Forschungsgemeinschaft; Grant SFB 1483–Project-ID 442419336

References

[1] J. Penner and S. Leyendecker. A discrete mechanics approach for musculoskeletal simulations with muscle wrapping. Multibody System Dynamics 56, 2022

[2] M. Lavaill et al. Muscle path predictions using a discrete geodesic Euler–Lagrange model in constrained optimisation: comparison with OpenSim and experimental data. Multibody System Dynamics, 65, 2024

[1] Mechanical, Medical and Process Engineering, Queensland University of Technology, Brisbane, Queensland, Australia
[2] Centre for Biomedical Technologies, Queensland University of Technology, Brisbane, Queensland, Australia

Derivation of doubly symplectic numerical schemes for optimal control problems

Michael Konopik, Rodrigo T. Sato Martín de Almagro, Sigrid Leyendecker, Sofya Maslovskaya[1], Sina Ober-Blöbaum[1]

Optimal control of mechanical systems is vital for the design of a variety of systems, including robots, satellites or vehicles. Due to the complexity of the resulting optimality conditions, numerical methods are needed. Recently, we developed a new approach [1], that reformulates the optimal control problem (OCP), with second order differential equations (SODE) dynamical constraints, in the form of a new control Lagrangian.
In [2], we proved that the numerical schemes derived from its discretization preserve the symplectic form of the state-adjoint space where the OCP evolves. Interestingly, if the state dynamics derives from a force-controlled Lagrangian system, the symplecticity of the resulting scheme for the state dynamics is not guaranteed unless the new control Lagrangian is formulated in terms of the underlying Lagrangian system. In [3], we apply the new approach to OCPs of this type, with (q, v_q) the state, (ξ, v_ξ) the adjoints and u the control,

$$\begin{aligned}\tilde{J}[q,\xi,v_q,v_\xi,\mu,\nu,u] &= \phi(q(T),v_q(T)) + \mu(q(0)-q^0) + \nu(v_q(0)-\dot{q}^0)\\ &\quad + D_2L(q(T),v_q(T))\xi(T) - D_2L(q(0),v_q(0))\xi(0) - \int_0^T \tilde{\mathcal{L}}_L^{\mathcal{E}}(q(t),\xi(t),v_q(t),v_\xi(t),u(t))\,dt,\end{aligned}$$

with the new control Lagrangian $\tilde{\mathcal{L}}_L^{\mathcal{E}} : TTQ \oplus_{TQ}^{\kappa} \mathcal{E} \to \mathbb{R}$, $\tilde{\mathcal{L}}_L^{\mathcal{E}} = D_2L(q,v_q)v_\xi + [D_1L(q,v_q) + f_L^{\mathcal{E}}(q,v_q,u)]\xi - C(q,v_q,u)$. The numerical schemes derived from it possess 'double-symplecticity', meaning they result in symplectic schemes both at the state as well as state-adjoint level. This may prove valuable for the numerical solution of OCPs that evolve over long times.

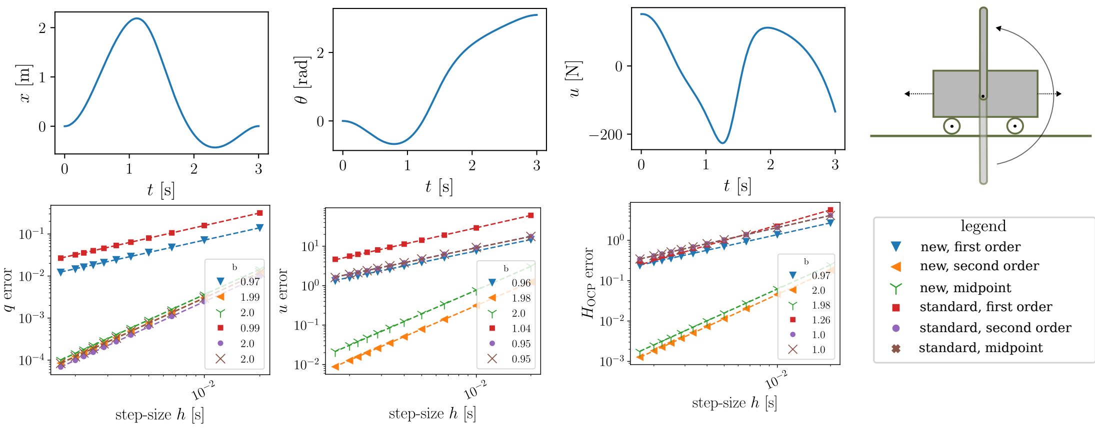

Figure 1: Inversion of a pendulum on a cart with forcing in x-direction (see [3]). Row 1: solution trajectory and control. Row 2: convergence study for different schemes for the new approach and a standard direct approach. More consistent convergence is found for the new approach.

Acknowledgements: This project is funded by the Deutsche Forschungsgemeinschaft (DFG) with the projects: LE 1841/12-1, AOBJ: 692092 and OB 368/5-1, AOBJ: 692093.

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[1] M. Konopik, S. Leyendecker, S. Maslovskaya, S. Ober-Blöbaum, R. T. Sato Martín de Almagro, A new Lagrangian approach to optimal control of second-order system. *Nonlinearity*, 38, 11, 2025.

[2] M. Konopik, S. Leyendecker, S. Maslovskaya, S. Ober-Blöbaum, R. T. Sato Martín de Almagro, Variational Integrators for a new Lagrangian Approach to Control Affine Systems with a Quadratic Lagrange Term. J Nonlinear Sci 36, 11, 2026.

[3] M. Konopik, S. Leyendecker, S. Maslovskaya, S. Ober-Blöbaum, R. T. Sato Martín de Almagro, On the variational discretisation of optimal control problems for unconstrained Lagrangian dynamics. Research-Square: rs-6566751, 2025.

[1] Universität Paderborn (UPB), Numerical Mathematics and Control (NMC)

A variational integrator approach on Bond-Based Peridynamics

Prateek Prateek, Giuseppe Capobianco, Sigrid Leyendecker

Numerical simulation of fracture is extremely challenging, as the spatial derivatives required in classical continuum mechanics (CCM) to solve for the deformation field do not exist near the crack surface and the tip. Peridynamics (PD), a particle-based nonlocal formulation, provides a natural alternative to CCM for modelling and simulating fracture. In CCM, various special techniques such as the extended finite element method (XFEM) or phase-field approaches are commonly employed to handle displacement discontinuities. In contrast, PD inherently overcomes this issue because the material model is formulated in an integro-differential form, where nonlocal interactions occur between material points over a finite distance, as illustrated in 1. Since this interaction between certain points can be present or absent, fracture is an inherent part of the constitutive model itself. Several different types of PD formulations exist, depending on how the interaction force between different points is computed, and we focus on the bond-based (BBPD) formulation, where the equations of motion are given as

$$\rho\,\ddot{\boldsymbol{x}}(t) = \int_{H_x} \boldsymbol{f}\left(\boldsymbol{x}'(t) - \mathbf{x}(t), \boldsymbol{X}' - \boldsymbol{X}\right) dV_{X'} + \mathbf{b}(\boldsymbol{X}, t), \tag{1}$$

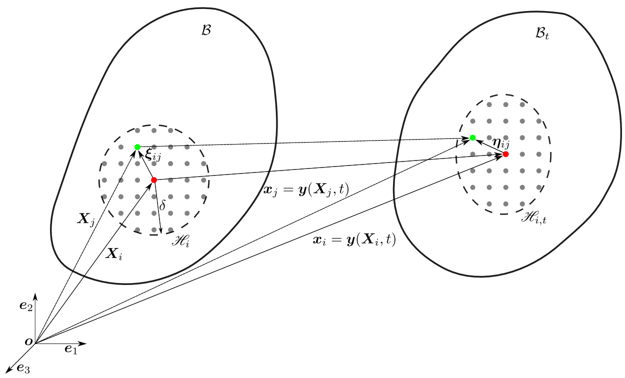

Figure 1: PD body in the reference (left) and actual configuration (right), showing the horizon of point i

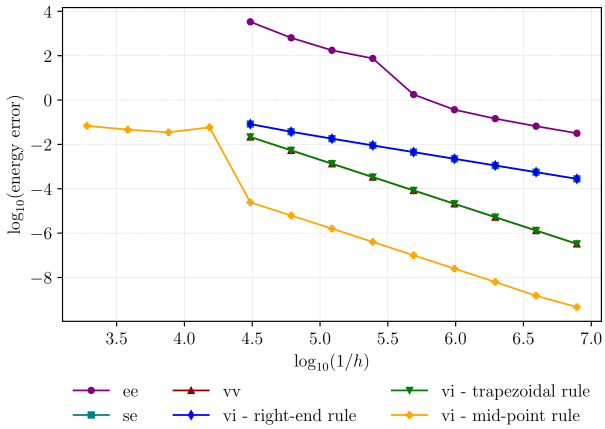

Figure 2: Energy convergence plot for an elastodynamic body simulated using BBPD with prescribed initial displacements

This project aims to develop structure-preserving variational integrators (VI) for fracture simulations based on the PD formulation. Numerical methods that conserve physical properties, such as energy or momentum, while accurately simulating the initiation and propagation of cracks in materials, are constructed. The convergence behaviour of several VIs derived from the bond-based PD model is then investigated for both elastodynamic and fracture simulations. Figure 2 illustrates the energy-convergence behaviour for an elastodynamic test involving a square body subjected to prescribed initial displacements on its top and bottom faces. As shown, the implicit midpoint rule yields the lowest energy error for a given time-step size and exhibits a second-order convergence rate, identical to that of the trapezoidal rule. As expected, the trapezoidal rule matches the performance of the velocity Verlet method, which is widely used in peridynamic simulations. The right-end rule shows a first-order convergence rate and agrees exactly with the symplectic Euler method, while the explicit Euler method fails to produce convergent energy results.

Acknowledgements: This research is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - 377472739/GRK 2423/2-2023.

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Variational integrators for mechanical systems, field theories and optimal control

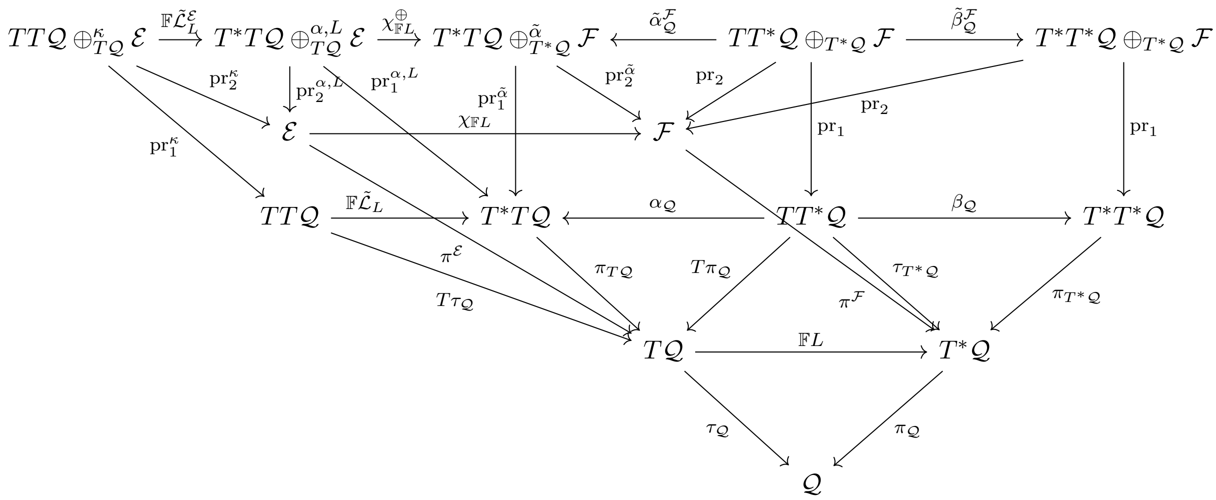
Rodrigo T. Sato Martín de Almagro, Michael Konopik, Tengman Wang, Oscar Cosserat[1], David Martín de Diego[2], Sigrid Leyendecker

Geometric integration involves the numerical solution of differential equations using methods that intend to preserve some or all features or underlying structures that the original problem displays. At our institute, we are interested in variational methods [1, 2]. These are numerical methods tailored to systems derived from a variational principle, e.g. Hamilton's principle of stationary action, and related systems. These systems display important qualitative features that should be present in the results of a simulation, such as conservation laws due to symmetries in the system (Noether's theorem) or compliance with specified constraints.

Applications range from mechanical systems (systems of particles, rigid bodies...) and field theories (finite strain elasticity, perfect fluids, electrodynamics...) to optimal control.

Currently we are focusing on the following topics:

- **New control Lagrangian for force-controlled Lagrangian systems.** We have successfully generalized the approach originally proposed in [5], which transformed particular optimal control problems into Lagrangian problems, to more general optimal control problems of force-controlled Lagrangian systems. Moreover, we have managed to identify the geometry behind the procedure, with Tulczyjew's triple front and center, as well as provided an interpretation in the sense of generating functions of mixed type [6]. Besides this, we have studied the discretization of the new control Lagrangian [7] and proven that the resulting integrators lead to symplectic integration schemes for both the OCP and the underlying forced Lagrangian dynamics [8].



- **Hamilton-Pontryagin variational integrators for field theories.** We apply a discrete version of the Hamilton-Pontryagin principle [9, 10] to construct arbitrary order variational integrators for field theories which are naturally multisymplectic [4, 3], see an example solved in fig. 1.

  This approach makes explicit certain internal constraints present in any field theory. We are also collaborating with David Martín de Diego and Oscar Cosserat to gain a better picture of the geometry behind such discretizations through the concept of discretization maps [11].

[1]Göttingen Mathematisches Institut, Georg-August-Universität Göttingen, Germany
[2]Instituto de Ciencias Matemáticas(ICMAT), Madrid, Spain

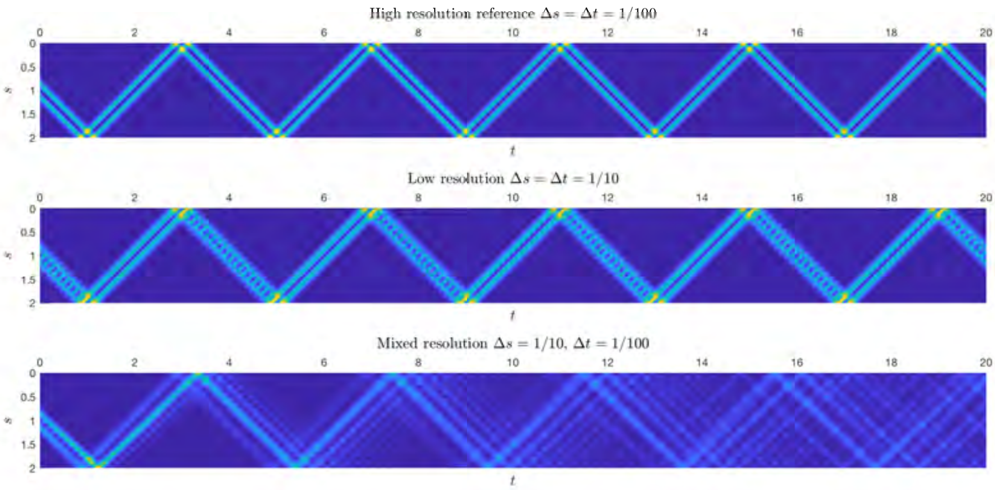


Figure 1: Evolution of the energy density of a Gaussian wave packet using different resolutions for a variational discretization of the linear wave equation. Differences between numerical propagation speed ($\Delta s/\Delta t$) and wave speed lead to dispersion.

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Disuse-related bone loss prediction using a multiscale mechanobiological model of bone remodelling

Tan Tran, Xiyu Chen, Mathilde Lepileur [1], Peter Pivonka [23], Sigrid Leyendecker, Anna-Maria Liphardt [1]

Bone remodelling is a lifelong process involving the removal and formation of bone tissue to maintain the mechanical integrity and provide mineral homeostasis for the skeletal system [1]. Stimuli based on the strain energy density (SED) Ψ_{bm} are driving factors for this process. To link the mechanical loading conditions on the bone tissue level to the dynamical system on the cellular level, we apply a typical multiscale approach depicted in Figure 1. The overall goal of this project is to predict subject-specific responses to disuse and countermeasures and extrapolate our findings to longer duration space flight (e.g. manned Mars mission or living in Moon habitats). We first implemented an existing multiscale mechanobiological model proposed by [1] and made first attempts to fit it to clinical data from a provided ESA bedrest study. Biomechanical parameters of the model were calibrated to account for the average bone loss of the study subjects. The result for an exemplary simulation is shown in Figure 2. We could observe that the behaviour of the calibrated model is consistent with previous studies. The following steps of this project will include statistical analysis and further parameter tuning in order to produce more realistic predictions. Additionally, the usability of different mechanobiological models will be investigated.

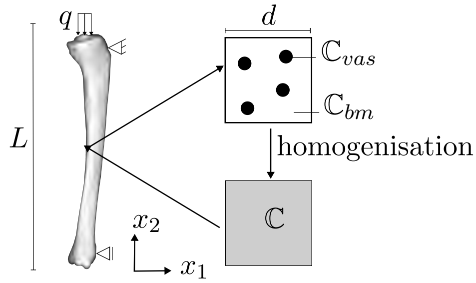

Figure 1: Multiscale model of the tibia: For each macroscopic point, a representative volume element is defined which incorporates the material properties of the bone matrix and vascular pores. An analytical homogenisation scheme is applied to compute the effective macroscopic stiffness.

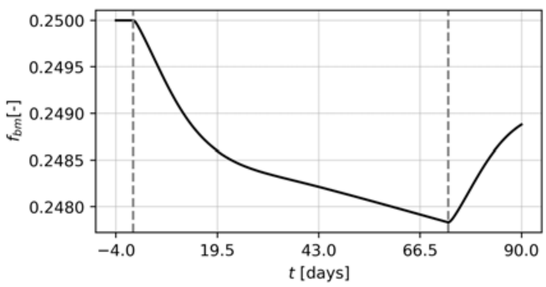

Figure 2: Simulated trabecular bone volume fraction f_{bm} evolution during 4 days of habitual state, followed by 73 days of disuse, followed by 17 days of recovery.

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[1]Department of Internal Medicine 3, Rheumatology and Immunology, Universitätsklinikum, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany
[2]Mechanical, Medical and Process Engineering, Queensland University of Technology, Brisbane, Queensland, Australia
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Multisymplectic variational integrators and Runge-Kutta methods in field theories

Tengman Wang, Rodrigo T. Sato Martín de Almagro, Oscar Cosserat[1], David Martín de Diego[2], Sigrid Leyendecker

The goal is to derive numerical integrators for field theories variationally based on either the correct discrete Lagrangian or discrete Hamilton-Pontryagin action. We also investigate the additional constraints (on both the field variables u^i and the momenta p_i^μ) needed for proper implementation that arise from the use of tensorial grids. Currently, the field theoretical problems are restricted to two dimensions. In the following, the primary focus is on the wave equation with a possibly nonlinear potential function.

Implicit midpoint discretization This low-order method is applied in both space and time. Direct discretization of the wave equation as multisymplectic Hamiltonian PDE in the form $\boldsymbol{M}\partial_t \boldsymbol{z} + \boldsymbol{K}\partial_s \boldsymbol{z} = \nabla S(\boldsymbol{z})$ corresponds to the Preissmann box (PB) scheme [1, 2]. We show that the construction of a discrete Lagrangian based on implicit midpoint rule can deliver an equivalent numerical scheme.

- **Discrete fiber derivatives** These are partial derivatives of the discrete Lagrangian with respect to nodal values of the field on the grid. Corner nodes lead to mixed momenta, whereas midpoint nodes produce "normal" momenta.
- **Midpoint variational integrator vs. PB scheme** From the discrete fiber derivatives derived by differentiation with respect to the corner nodes, we recover the PB scheme by manipulations of $D_k L_d^{i,j}$, $k = 1, 2, 3, 4$. Using the equations from PB scheme, we can also regain the discrete fiber derivatives.

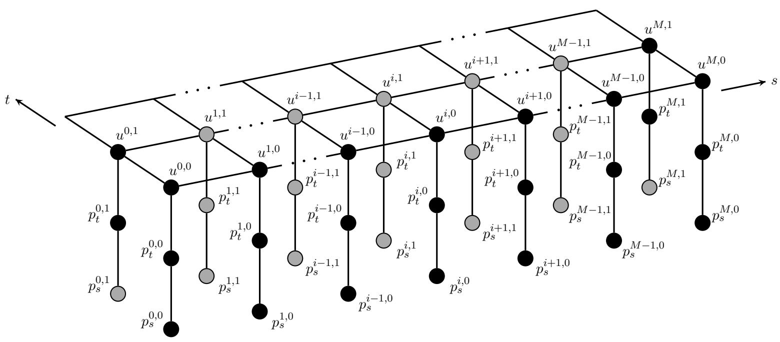

Figure 1: Scheme for nodes at corner.

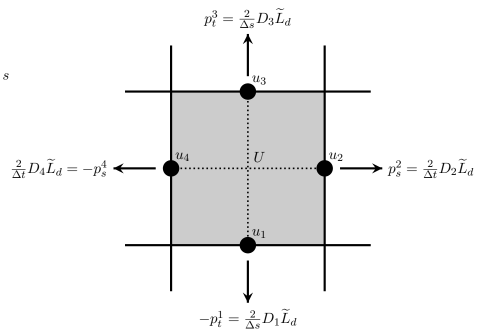

Figure 2: Canonical momenta.

- **Constraints** When working with midpoint nodes on a tensorial grid, a fundamental constraint on the field values materializes: $u_2 + u_4 - u_3 - u_1 = 0$ [2, 3, 4]. To obtain the "tangential" momenta, an auxiliary system of equations as suggested by [2] may be used. However, we discovered that is equivalent to the extension of the previous constraint to the fibres, namely $p_t^2 + p_t^4 - p_t^3 - p_t^1 = 0$ and $p_s^2 + p_s^4 - p_s^3 - p_s^1 = 0$.

High-order methods More than one intermediate stage is required for high-order discretizations. We construct the discrete Hamilton-Pontryagin action in the general case and find that the discrete fiber derivatives correspond to the discrete canonical momenta normal to the edge of each grid element at the collocation points.

Acknowledgements Deutsche Forschungsgemeinschaft; Grant LE 1841/13-1

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4 Activities

4.1 Research stay in Siegen

PhD researchers M.Sc. Prateek Prateek and M.Sc. Deepak Balasaheb Jadhav visited the Chair of Solid Mechanics at the University of Siegen from May 12–23. During their stay, they collaborated closely with M.Sc. Kai Partmann and Prof. Dr. Matthias Thimm on research topics related to fracture simulations using peridynamics and phase-field methods. The visit included in-depth technical discussions on numerical modelling strategies, structure-preserving time integration, and the treatment of dynamic fracture phenomena. The scientific activities were conducted under the guidance of the head of the institute Prof. Dr.-Ing. Kerstin Weinberg and contributed to strengthening the collaboration between the two research groups.

4.2 Summer school at KTH

From 17–22 August 2025 in Stockholm, LTD PhD researcher M.Sc. Gamal Amer attended the KTH summer school Computational Tissue Biomechanics – Making Sense of Data at KTH Royal Institute of Technology as part of his heart project. The one-week program combined lectures by international faculty with supervised labs and FEM/constitutive modeling sessions, concluding with a group multiple-choice assessment (certificate: 2.0 ECTS). Topics included constitutive modeling of soft tissues, vascular and musculoskeletal biomechanics, clinical imaging, and data-driven analysis. This training sharpened his skills in biological tissue characterization and modeling, directly supporting ongoing research in data-driven, physics-informed constitutive modeling.

4.3 Summer school at TU Graz

From 15–19 September 2025 in Graz (Austria), LTD PhD researchers M.Sc. Gamal Amer and M.Sc. Tan Tran attended the 11th Summer School on Physics-Informed Modeling, Simulation and Experiments with Emphasis on the Cardiovascular System at Graz University of Technology. The program delivered state-of-the-art lectures and workshops on cardiovascular biomechanics, including continuum mechanics, constitutive modeling, viscoelasticity, growth and remodeling, scientific machine learning, and clinical translation. Sessions were given by leading experts such as G.A. Holzapfel, R.W. Ogden, A. Quarteroni, D. Nordsletten, and C.J. Cyron, alongside poster sessions and networking events. Attendance provided advanced, heart-focused training that complements the broader tissue biomechanics emphasis of the KTH school.

4.4 GAMM Juniors Fall Meeting

This year's GAMM Juniors Fall Meeting was held at FAU Erlangen-Nürnberg and brought together young researchers for a few inspiring and collaborative days. Organized by Dr. Miguel Angel Moreno-Mateos (LTM, Secretary of the GAMM Juniors) and Dr.-Ing. Giuseppe Capobianco (LTD, President of the GAMM Juniors), the event encouraged lively discussions lead by the GAMM Juniors on new ideas and projects, strengthened connections with the GAMM Board and invited experts, and included engaging social activities in Erlangen and Nürnberg. The scientific program featured presentations by Dr.-Ing. Mischa Blaszczyk, Dr. Emil Løvbak, and Dr.-Ing. Andreas Warkentin, who shared their latest research on topics across computational and applied mechanics, including bone mechanics, stochastic simulations, and multiscale modelling. Their contributions sparked stimulating discussions and constructive feedback within the group. Beyond the formal program, participants enjoyed several social activities, including a visit to the Botanical Garden in Erlangen, a trip to Nürnberg, and shared dinners, providing a relaxed setting for networking and informal exchange.


4.5 Research visits

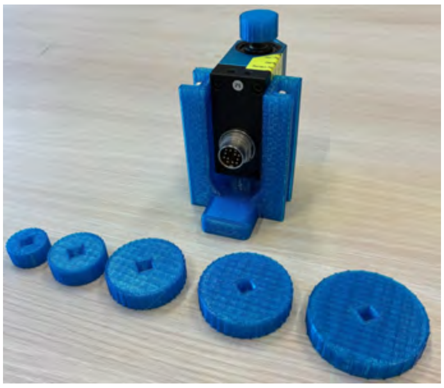
In 2025, LTD was honored to host research visits focused on different project frameworks:

- **Research visit of Prof. Dr. David Martín de Diego from ICMAT and Dr. Oscar Cosserat from Universität Göttingen**
  This visit was hosted by Prof. Dr. Ing. habil. Sigrid Leyendecker and Dr. Rodrigo T. Sato Martín de Almagro as part of the *Lagrangian and Hamiltonian field theories – geometry, discretization, optimal control* project, which is a collaboration with the Instituto de Ciencias Matemáticas (ICMAT) at the Spanish National Research Council in Madrid, Spain. The exchange proved fruitful, particularly through collaboration with project member M.Sc. Tengman Wang. The visit concluded with a seminar by Dr. Oscar Cosserat on Hamiltonian structures of the Timoshenko model and its associated numerical analysis.
- **Research visit of Prof. Dr. Saulo Martelli from QUT**
  Prof. Dr. Saulo Martelli participated in discussions with the biomechanics research group at LTD, and the

Internal Medicine 3 – Rheumatology & Immunology, Uniklinikum Erlangen, focusing on modeling muscle paths for biomechanical simulations in multibody systems. The visit concluded with a presentation by Prof. Martelli on "Bridging Length Scales in Musculoskeletal Biomechanics: Insights and Innovations."

- **Research visit of Prof. Dr.-Ing. habil. Peter Pivonka from QUT**
  This year, Prof.Dr.-Ing. habil. Peter Pivonka, Professor and Chair of Biomedical Engineering and Spinal Disorders and head of the Centre for Biomedical Technologies at QUT, visited LTD to engage in discussions within the biomechanical field. His visit reinforced the partnership and close collaboration between LTD and QUT. The visit concluded successfully with a presentation by Prof. Pivonka on "Recent Advances in Simulating Osteoporosis Drug Treatments: Pathways to Optimize and Utilize Approved Drug Therapies."

- **Research visit of Edison Percy from QUT**
  Edison Percy collaborated with fellow LTD doctoral researcher M.Sc. Simon Heinrich on the Torque Sensor Rig Design Documentation. This project is part of a larger study investigating how arthritis affects hand movement and strength, aiming to design a device that measures the force used when opening jars or bottles – a task many people with arthritis find challenging. The visit successfully culminated in the printing of the first prototype of a torque sensor for measuring these parameters, alongside a seminar presentation by Edison Percy about his work at LTD.



Additionally, in November 2025, Prof. Dr.-Ing. habil. Sigrid Leyendecker had the opportunity to visit QUT, in particular the School of Mechanical, Medical & Process Engineering, for an academic exchange, further enriching collaboration and knowledge sharing.

4.6 Mini Lectures

In 2025, LTD proudly presented two engaging mini lectures on the following topics:

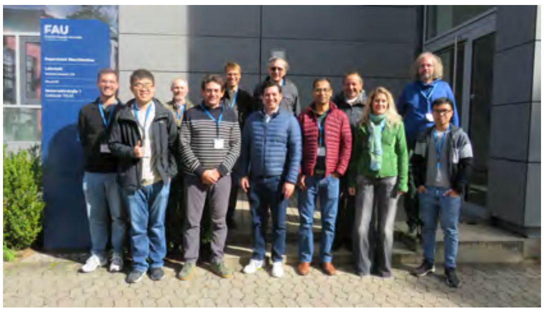
1. Introduction to Port-Hamiltonian Systems: This lecture was conducted by M.Sc. Markus Lohmayer on September 29^{th} as part of advanced topics for doctoral researchers at LTD.
2. Frascal Mini Lecture: Introduction to Numerics: This session took place on October 10^{th} at the Institute of Applied Mechanics, presented by Dr. Rodrigo T. Sato Martín de Almagro and Dr.-Ing. Giuseppe Capobianco as part of the Fracture Across Scales project.

4.7 HWBI Young Scholar Award

The Hand and Wrist Biomechanics International (HWBI) Young Scholar Award is a prize given to outstanding students and early-career researchers in the field of hand and wrist biomechanics, recognizing their excellent work at HWBI symposia. In 2025 the price was awarded to our colleague M.Sc. Birte Coppers, congratulations on this great achievement!

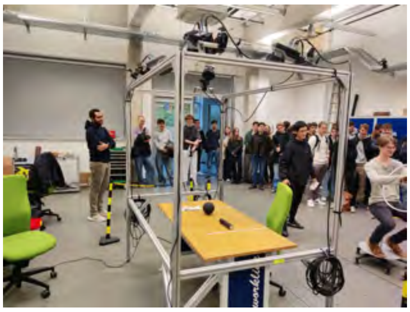
4.8 Annual Symposium of the European Network for Nonsmooth Dynamics

In 2025, the Institute for Applied Dynamics (LTD) hosted the 12^{th} Annual Symposium of the European Network for Nonsmooth Dynamics (ENNSD) from September 30^{th} to October 2^{nd}. The event brought international researchers to Erlangen for a three-day program featuring didactic introductions, scientific talks, moderated open discussions, and round-table sessions. LTD organized the venue logistics and on-site support, providing an accessible setting for deep technical exchange in nonsmooth dynamics. Topics spanned contact and impact dynamics, frictional oscillators, plasticity theory, complementarity and variational-inequality formulations, nonsmooth time-stepping schemes, control and optimization, and applications from various fields, like robotics, granular media and natural hazards.. The symposium strengthened collaborations across the community.



4.9 First semester students welcome visit – Institute & Lab demonstrations

As part of the welcoming visit of the first semester students, "Erstsemester-Einführung", over 50 students visited the LTD on October 10^{th}, 2025 in Erlangen. An introduction of the institute was conducted by fellow PhD colleagues, M.Sc. Gamal Amer, M.Sc. Tengman Wang, M.Sc. Birte Coppers and M.Sc. Prateek Prateek. Ongoing research areas – biomechanics, multibody dynamics, modelling and simulation, and optimal control problems – and typical project workflows were described. The visit concluded with live demonstrations in the Motion Capture Lab, including a motion-capture workflow, conservation-of-angular-momentum with a rotating chair and wheel, a coupled-pendulum demo, and a brief inverted-pendulum overview. The event received positive feedback and will help channel interested students into future projects and theses.

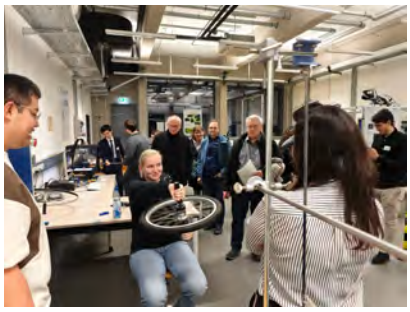

4.10 Long Night of the Sciences "Die Lange Nacht der Wissenschaften" (LNdW)

In 2025, we are pleased to highlight our participation in the Long Night of Sciences (LNdW, #NdW25) on October 25^{th}, 2025. The Friedrich-Alexander-Universität Erlangen-Nürnberg hosted this event, providing a platform for families, students, politicians, and scientists to explore a diverse range of over 450 activities spanning technology, medicine, natural and engineering sciences, humanities, economics, and social sciences. LTD engaged in the LNdW, showcasing captivating experiments in our Motion Capture Laboratory. Attendees had the opportunity to experience "Fascination of dynamics" with:

- Carrera race – an interactive experiment demonstrating optimal control
- angular momentum conservation and Lagrange gyro
- balancing Lego robot on two wheels
- ball balancer, which is a device that uses a control system to keep a ball stable on a flat platform
- motion capture setup – where participants were able to experience motion capturing on their own

A pop-up Mechanics Escape Room was built for the occasion (originally created by SVFS Team, TU-Berlin) that combined a computer-guided storyline with physical puzzles for visitors. The 25-minute game led participants through some challenges on core topics – right-hand rule/reference frames, lever law, tensile testing, beam bending, buckling, and plate vibrations – using 3D-printed components and interactive tasks. The escape room along with several experiments proved particularly appealing to families with children. The atmosphere was vibrant, and we received exceptionally positive feedback, reflecting the success of our engaging and educational contributions to the Long Night of Sciences.





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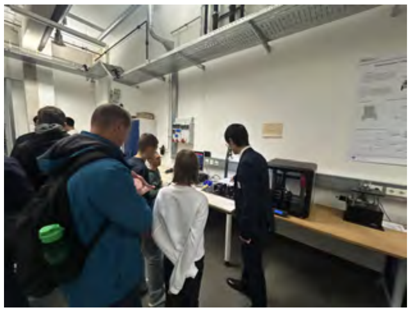


5 Teaching

Winter semester 2025/2026

Dynamik starrer Körper (MB, ME, WING, IP, I, BPT, CE, MT, ACES)

Vorlesung		S. Leyendecker
Übung + Tutorium		G. Capobianco, T. Wang T. Tran, S. Heinrich, G. Amer

Mehrkörperdynamik (MB, ME, WING, TM, CE, BPT, MT, ACES)

Vorlesung		G. Capobianco
Übung		R.T. Sato Martín de Almagro

Praktikum Technische Dynamik – Modellierung, Simulation und Experiment (MB, ME, BPT, WING, ACES)

S. Leyendecker
S. Heinrich, X. Chen, M. Konopik
G. Amer, R.T. Sato Martín de Almagro

Praktikum Matlab (MB, ME, EEI, ACES)

S. Leyendecker
X. Chen, M. Konopik

Summer semester 2025

Statik und Festigkeitslehre (BPT, CE, ME, MWT, MT, MSE, CBI, ET, IPEM, LSE, WING)

Vorlesung		S. Leyendecker
Übung + Tutorium		G. Amer,X. Chen, T. Tran S. Heinrich, D. Jadhav
geprüft	184 + 179 (WS 2024/2025)	

Biomechanik (MT)

Vorlesung + Übung		G. Capobianco
geprüft	31 + 18 (WS 2024/2025)	

Geometric numerical integration (MB, ME, MT, WING, CE, BPT, ACES, DS)

Vorlesung + Übung		R.T. Sato Martín de Almagro
geprüft	4 + 1 (WS 2024/2025)	

Computational Multibody Dynamics (MB, ME, MT, WING, IPEM, ACES)

Vorlesung + Übung		G. Capobianco
geprüft	15 + 1 (WS 2024/2025)	

Praktikum Matlab (MB, ME, EEI, ACES)

Teilnehmer	175	S. Leyendecker D. Jadhav

Winter semester 2024/2025

Dynamik starrer Körper (MB, ME, WING, IP, I, BPT, CE, MT, ACES)		
Vorlesung		S. Leyendecker
Tutorium + Übung		G. Amer,G. Capobianco, X. Chen D. Martonová, P. Prateek
geprüft	237 + 60 (SS 2025)	
Mehrkörperdynamik (MB, ME, WING, TM, BPT, CE, MT, ACES)		
Vorlesung		G. Capobianco
Übung		R.T. Sato Martín de Almagro
geprüft	22 + 2 (SS 2025)	
Praktikum Technische Dynamik – Modellierung, Simulation und Experiment (MB, ME, BPT, WING, ACES)		
Teilnehmer	4	S. Leyendecker X. Chen, P. Prateek D. Holz, R.T. Sato Martín de Almagro
Praktikum Matlab (MB, ME, EEI, ACES)		
Teilnehmer	177	S. Leyendecker G. Capobianco

5.1 Theses

Doctoral theses

- Dr.-Ing. Theresa Wenger
  Variational integrators for multirate systems and holonomically constrained systems
- Dr. rer. biol. hum. Birte Coppers
  Identification of disease-specific biomechanical markers of hand function in inflammatory arthritis
- Dr.-Ing. Markus Lohmayer
  Exergetic Port-Hamiltonian Systems: a compositional, energy-based language for modeling mechanical, electromagnetic, and thermodynamic systems

Master theses

- Amit Sharma
  Asynchronus Variational Integrator for Three-Dimensional Phase Field Model of Dynamic Fracture

Project theses

- Deven Singh
  Comparison of Approaches for Speeding Up Particle-Based Simulations
- Alexander Müller
  Quantitative analysis of the effects of dietary antioxidant intervention on bone loss in bed rest induced disuse
- Vincent Lehniger
  Numerical Optimization of the Upswing of a friction driven Pendulum
- Sreeraam Anil
  Comparison between SLQ and LQR solver for Model Predictive Control

Bachelor theses

- Valerie Bartanus
  Palm arching in inflammatory arthritis patients based on marker based inverse kinematics simulations
- Elisabeth Schmitt
  Einfluss des passiven Gelenkdrehmoments in vorwärtsdynamischen Simulationen von Fingerbewegungen

5.2 Seminar for mechanics

together with the Institute of Applied Mechanics LTM

08.12.2025	Prof. Eran Bouchbinder Department of Chemical and Biological Physics Weizmann Institute of Science, Rehovot, Israel *Topological defects and multi-plane crack interactions in materials failure*
29.09.2025	M.Sc. Markus Lohmayer Institute of Applied Dynamics Friedrich-Alexander-Universität Erlangen-Nürnberg *Introduction to Port-Hamiltonian systems*
18.09.2025	M.Sc. Oscar Cosserat Institute of Mathematics Georg-August-Universität Göttingen *Hamiltonian structures of the Timoshenko model and related numerical analysis*
06.08.2025	Edison Percy Queensland University of Technology (QUT) *Torque Sensor Rig Design Documentation*
30.07.2025	Ms. Charlotte Pollmann Clinical & Sales Development Manager inHEART, Bordeaux, France *How inHEART utilises AI- powered digital twins to guide ventricular tachycardia ablation*
03.07.2025	Prof. Dr.-Ing. habil. Peter Pivonka School of Mechanical, Medical and Process Engineering Queensland University of Technology (QUT) *Recent advances in simulating osteoporosis drug treatments: pathways to optimise and exploit currently approved drug therapies*
22.05.2025	Dr. Xianqiao Wang College of Engineering University of Georgia, USA *Harnessing AI/Data-Empowered Computational Models to Brain Mechanics and Nano-Biomaterial Interface*
19.05.2025	Prof. Dr. Barbara Röhrnbauer School of Engineering Zurich University of Applied Sciences (ZHAW) *Applied and Translational Research in Soft Tissue Biomechanics at ZHAW School of Engineering*
14.05.2025	Dr.-Ing. Rodrigo J. Velasco LS für Autonome Systeme und Mechatronik Friedrich-Alexander-Universität Erlangen-Nürnberg *User-Centered Design of Adaptive and Fault-Tolerant Control Strategies for Elastic Actuators*
31.03.2025	Prof. Dr. Saulo Martelli Queensland University of Technology (QUT) *Bridging Length Scales in Musculoskeletal Biomechanics: Insights and Innovations*

5.3 Biomechanics

The course "Biomechanics", taught by Dr.-Ing. Giuseppe Capobianco, received the second place (2/32) in the student evaluation for the summer semester 2025, with a Learning Quality Index (LQI) of 1.36. This achievement reflects the commitment and passion that our academic staff at LTD brings to all lectures and the institute as a whole. Congratulations!

6 Publications

6.1 Reviewed journal publications

1. H. Lang, R. T. Sato Martín de Almagro, T. Wang, M. Stavole, J. Linn and S. Leyendecker. "A Discrete Mechanics Approach to the Cosserat Rod Theory—Part II: Geometric Insights About Static Equilibria on Vertex and Staggered Grids", *International Journal for Numerical Methods in Engineering*, Vol. 126(23), e70190, DOI 10.1002/nme.70190, 2025.
2. M. Konopik, S. Leyendecker, S. Maslovskaya, S. Ober-Blöbaum and R.T. Sato Martín de Almagro. "Variational Integrators for a new Lagrangian Approach to Control Affine Systems with a Quadratic Lagrange Term", *Journal of Nonlinear Science*, Vol. 36, No. 11, DOI 10.1007/s00332-025-10229-5, 2025.
3. M. Lohmayer, M. Kraus and S. Leyendecker. "Energy-based, geometric, and compositional formulation of fluid and plasma models", *Communications in Nonlinear Science and Numerical Simulation*, Vol. 152(D), 109384, DOI 10.1016/j.cnsns.2025.109384, 2025.
4. D. Martonová, S. Leyendecker, G.A. Holzapfel and E. Kuhl. "Discovering dispersion: How robust is automated model discovery for human myocardial tissue?", *Biomechanics and Modeling in Mechanobiology*, DOI 10.1007/s10237-025-02005-x, 2025.
5. M. Stavole, R. T. Sato Martín de Almagro, V. Dörlich and S. Leyendecker. "On the Determination of Effective Stiffness Properties of Multilayered Axisymmetric Beams Via Analytic and Experimental Approaches", *International Journal of Solids and Structures*, Vol. 317, 113407, DOI 10.1016/j.ijsolstr.2025.113407, 2025.
6. E. Port, B. Coppers, S. Liehr, E. Manger, L. M. Niemic, S. Bayat, D. Simon, F. Fagni, G. Corte, A.C. Bay-Jensen, K. Tascilar, A.J. Hueber, K. Schmidt, V. Schönau, M. Sticherling, S. Heinrich, S. Leyendecker, D. Bohr, G. Schett, A. Kleyer, S. Holm Nielsen and A.M. Liphardt. "Serum Extracellular Matrix Biomarkers in Rheumatoid Arthritis, Psoriatic Arthritisand Psoriasis and their Association with Hand Function", *RMD Open*, Vol. 15, 13656, DOI 10.1038/s41598-025-98395-0, 2025.
7. D. Jadhav, D. Phansalkar, K. Weinberg, M. Ortiz and, S. Leyendecker. "A New Approach to Asynchronous Variational Integrators for a Phase Field Model of Dynamic Fracturea", *International Journal for Numerical Methods in Engineering*, Vol. 126(6), e70025, DOI 10.1002/nme.70025, 2025.
8. B. Coppers, S. Heinrich, S. Bayat, K. Tascilar, A. Kleyer, D. Simon, I. Minopoulou, G. Corte, F. Fagni, V. Schönau, S. Leyendecker, G. Schett and A.M. Liphardt. "Hand Function Impairments Are More Pronounced in Female RA and PsA Patients and also Found in Patients without Concurrent Hand Inflammation", *Medicine & Science in Sports & Exercise*, DOI 10.1249/MSS.0000000000003832, 2025.
9. B. Coppers, S. Heinrich, K. Tascilar, U. Phutane, A. Kleyer, D. Simon, J. Bräunig, J. Penner, M. Vossiek, V. Schönau, S. Bayat, G. Schett, S. Leyendecker and A.M. Liphardt. "Sensor-assessed grasping time as a biomarker of functional impairment in rheumatoid arthritis", *Scientific Reports*, Vol. 15, 6018, DOI 10.1038/s41598-025-90295-7, 2025.
10. M. Lavaill, X. Chen, S. Heinrich, P. Pivonka and, S. Leyendecker. "Muscle path predictions using a discrete geodesic Euler–Lagrange model in constrained optimisation: comparison with OpenSim and experimental data", *Multibody System Dynamics*, DOI 10.1007/s11044-025-10055-3, 2025.
11. E. Celledoni, E. Çokaj, A. Leone, S. Leyendecker, D. Murari, B. Owren, R. Sato Martín de Almagro, and M. Stavole. "Neural networks for the approximation of Euler's elastica", *Computer Methods in Applied Mechanics and Engineering*, Vol. 435, 117584, DOI 0.1016/j.cma.2024.117584, 2025.

6.2 Conferences and proceedings

1. P. Prateek, G. Capobianco and S. Leyendecker. "A discrete mechanics perspective on bond-based peridynamics", *ECCOMAS 18th Thematic Conference on Computational Plasticity (COMPLAS 2025)*, Barcelona, Spain, 02 - 05 September, 2025.
2. D. Jadhav, D. Phansalkar, K. Weinberg, M. Ortiz M and S. Leyendecker. " A spatio-temporally adaptive phase field model of dynamic fracture using an asynchronous variational integrator", *Kolloquium für Mechanik*, RPTU Kaiserslautern, August 20th 2025.
3. S. Leyendecker, M. Konopik, S. Maslovskaya, S. Ober-Blöbaum and R.T. Sato Martín de Almagro. "On the variational discretization of optimal control problems for Lagrangian dynamics", *12th ECCOMAS Thematic Conference on Multibody Dynamics*, Innsbruck, Austria, 13 - 18 July 2025.
4. D. Martonová, M. Peirlinck, G.A. Holzapfel, S. Leyendecker and H. Kuhl."Robust material model discovery for human myocardium", *30th Congress of the European Society of Biomechanics (ESB)*, Zürich, Switzerland, 06 - 09 July 2025.
5. B. Coppers, V. Bartanus, S. Heinrich, S. Bayat, A. Kleyer, I. Minopoulou, D. Simon, G. Corte, F. Fagni , V. Schönau , G. Schett, S. Leyendecker and A.M. Liphardt. "Biomechanical Investigation of Impairments in Palm Arch Mobility in Rheumatoid and Psoriatic Arthritis Patients", *Annals of the Rheumatic Diseases*, poster, Vol. 84, pp. 1275-1276, June 2025.
6. P. Prateek, G. Capobianco and S. Leyendecker. " Variational Integrators with spatial refinement for elastodynamic simulations using Peridynamics", *11th FRASCAL seminar*, Erlangen, June 27th 2025.
7. D. Jadhav, D. Phansalkar, K. Weinberg, M. Ortiz M and S. Leyendecker. " Simulating dynamic phase field fracture using a spatio-temporally adaptive asynchronous variational integrator", *11th FRASCAL seminar*, Erlangen, June 27th 2025.
8. D. Huang, D. Holz and S. Leyendecker. "Optimal control of multibody systems with dielectric elastomer-actuators". *XI International Conference on Coupled Problems in Science and Engineering*, Villasimius, Sardinia, Italy, 25 - 28 May 2025.
9. M. Konopik, S. Leyendecker, S. Maslovskaya, S. Ober-Blöbaum and R.T. Sato Martín de Almagro. "New discrete Lagrangian approach for solving mechanical optimal control problems ". *GAMM Annual Meeting*, Poznań, Poland, 7 - 11 April 2025.
10. T. Wang, T. Thoma and S. Leyendecker. "Simultaneous Inversion for Underactuated Mechanical Systems with Servo-Constraints". *GAMM Annual Meeting*, Poznań, Poland, 7 - 11 April 2025.
11. G. Capobianco and S. Leyendecker. "Optimal control of a pendulum driven via a frictional clutch using a smooth formulation of set-valued friction". *GAMM Annual Meeting*, Poznań, Poland, 7 - 11 April 2025.
12. S. Leyendecker. "Geometric integration of geometrically exact beam dynamics andoptimal control problems". *BIRS – Geometric Mechanics Formulations for Continuum Mechanics*, Banff, Canada, 16 - 21 March 2025.
13. S. Leyendecker. "Geometric integration of geometrically exact beam dynamics andoptimal control problems". *Empkins Annual Meeting*, Erlangen, Germany, March 13th 2025.
14. D. Jadhav. D. Phansalkar, K. Weinberg, M. Ortiz and S. Leyendecker "Computational efficiency of dynamic phase field fracture simulations using a new asynchronous variational integrator", *GAMM PF 25 and Materials/Microstructure modelling: Analytics & Benchmarks*, Karlsruhe, Germany, 12 - 14 February 2025.
15. A.M. Liphardt, S. Leyendecker, P. Pivonka, S. Martelli. "Preventing Disuse-Induced Osteoporosis". *Bavaria-Queensland Research Alliance*, poster, Munich, Germany, February 10th 2025.

6.3 open-source code

1. M. Konopik, S. Leyendecker, S. Maslovskaya, S. Oberr-Blöbaum and, R. T. Sato Martín de Almagro,(2025). “Variational Integrators – Pendulum on a cart” [Repository for the paper ”Variational integrators for a new Lagrangian approach to optimal control affine systems with a quadratic Lagrange term”]. Retrieved from https://github.com/Institute-of-Applied-Dynamics/Pendulum_on_a_cart_variational_integrator_program
2. M. Konopik, S. Leyendecker, S. Maslovskaya, S. Oberr-Blöbaum and, R. T. Sato Martín de Almagro,(2025). “Variational Integrators – Low Thrust” [Repository for the paper ”Variational integrators for a new Lagrangian approach to optimal control affine systems with a quadratic Lagrange term”]. Retrieved from https://github.com/Institute-of-Applied-Dynamics/New_Lagrangian_variational_integrators_for_solving_low_thrust_orbital_transfer

7 Social events

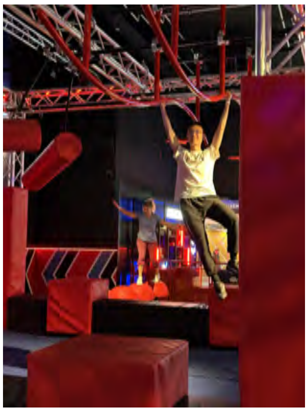
Erlangen beer festival “Bergkirchweih”

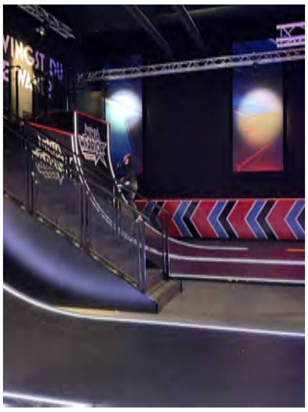
Student summer grill





Summer trip – Ninja Warrior





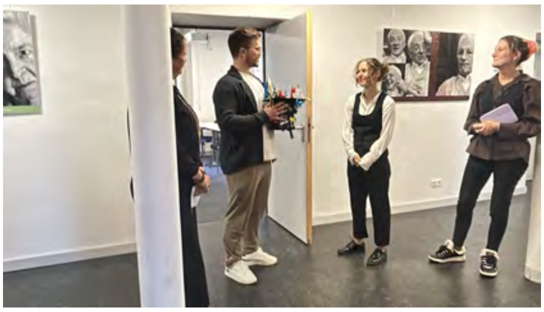
Onboarding lunch of team members

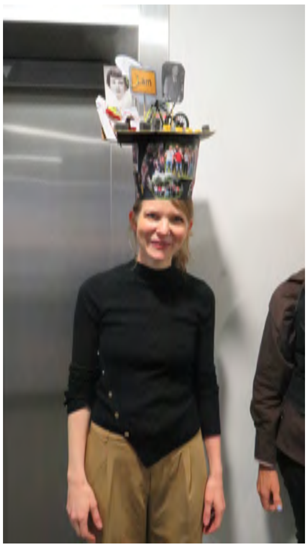
Christmas dinner






Doctoral defenses




Farewell of team members