

8th International Workshop on Computational Kinematics (CK2025)

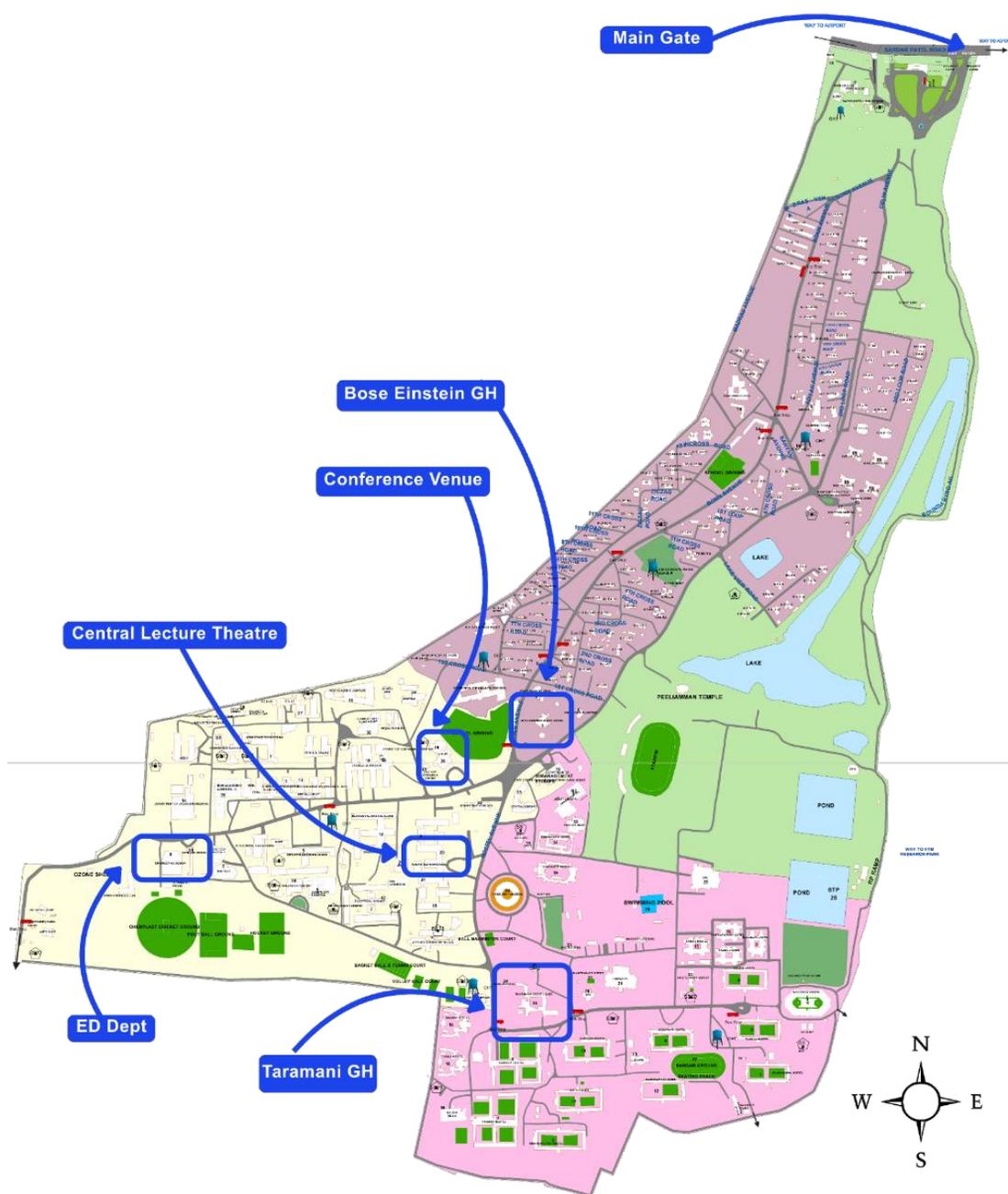
November 25-28, 2025

Indian Institute of Technology Madras,
Chennai, India



Institute Map

Conference Venue Centre for Industrial Consultancy and Sponsored Research (IC&SR)	Accommodation Taramani Guest House
Department Department of Engineering Design, Indian Institute of Technology Madras	



Welcome to CK2025

Dear CK2025 Participant,

On behalf of all the committees of CK2025 and IIT Madras, we extend a warm welcome to all of you! The International Workshop on Computational Kinematics, or “CK”, as it is fondly called, is the flagship event of the IFToMM Technical Committee on Computational Kinematics, which brings together the experts and enthusiasts working in this field every four years. Started in 1993 at Schloss Dagstuhl, the workshop has previously been held at Sophia Antipolis (1995), Seoul (2001), Cassino (2005), Duisburg (2009), Barcelona (2013), and Poitiers (2017). The 2021 session was missed due to the global pandemic. The 8th edition of the workshop is being organised by the Association for Machines and Mechanisms (AMM), the Indian member organisation (MO) of IFToMM, and the Indian Institute of Technology Madras, at Chennai, India.

This edition of CK acquires special significance for two reasons: that the CK tradition is revived after a forced break, and that it has now reached a new destination! By coming to India, CK has visited Asia for the second time in its history of 32 years. It is hoped that this event will promote greater awareness of CK and related topics among the local talent pool and help strengthen the CK community in the future.

The workshop this time is not of the same size as its predecessors, as it received only 33 submissions, despite the global distribution of its authors, spanning over more than 10 countries in Asia, Europe, and North America. After a rigorous round of review, 23 of the original submissions have been selected for presentations in the two-day event. The topics cover theoretical and computational kinematics, analysis and synthesis of mechanisms, serial and parallel robots, applications to flexible manipulators and bio-mechanical problems, among others. Each paper will be presented in a single-session mode, allowing undivided attention and ample scope for discussions. It is hoped that the quality of the papers will provide some compensation for the modest number of papers. In addition, three invited lectures on special topics have been arranged to aid in mutual learning and interactions. Finally, we have an open-ended discussion session, wherein fresh ideas can be presented and discussed informally.

The event was originally meant strictly for in-person participation. However, due to certain unforeseen and unavoidable circumstances, some of the authors have expressed their inability to participate in-person, after their papers were accepted. In such cases, we have arranged for the presentation of their papers electronically via video recording. We hope to meet these friends and colleagues soon at another venue.

On this occasion, we fondly remember our departed friend and colleague, Prof. Iosif Birlescu, from CESTER, Technical University of Cluj-Napoca, who passed away recently at an untimely age. We pray that his soul rests in peace! His paper would be presented remotely by Prof. Calin Vaida, his co-author and colleague.

A large number of people contributed towards the success of the conference. Firstly, we would like to thank all the authors for their contributions to CK2025! The reviewers did a tremendous job by sending in-depth reviews on time. Members of Advisory Committee played an enthusiastic role in helping the conference organisation at different levels. We thank the IFToMM EC and office bearers, the CK TC members, and the AMM EC members for their continuous support. We also thank the administration of IIT Madras for providing the facilities towards the organisation of the event, and supporting the event financially via the CODE Office. Our sincere thanks go to the Department of Engineering Design for its financial support, as well the active participation of the students and faculty of the department in organising this event. It would not have been possible to conduct this event without the tireless efforts of all these volunteers. Finally, we thank Springer Nature for agreeing to publish the proceedings of this event in the book series titled “Mechanisms and Machine Science”.

We look forward to interacting with each of you during the workshop, and we hope that you will find your stay here professionally enriching and personally pleasant!

With best regards,

Prof. Sandipan Bandyopadhyay, IIT Madras, India (Co-Chair)

Prof. Gökbhan Kiper, Izmir Institute of Technology, Türkiye (Co-Chair)



To the attention of:

Participants of the 8th
International Workshop on
Computational Kinematics in
Chennai, India, June 25-28
2025

Nov 17, 2025

Welcome to CK 2025!

Dear participant of CK 2025,

In name of the IFToMM Technical Committee for Computational Kinematics we would like to welcome you to our flagship workshop 'CK' here in Chennai. CK is generally organized every other year, alternating between a standalone workshop as CK 2025 and as a workshop integrated into the IFToMM World Congress, the next one in 2027.

We are very proud that this 8th International Workshop on Computational Kinematics has set foot in India, the 2nd time outside of Europe and a great opportunity to enhance the connection with Indian academics.

We would like to express our sincere gratitude to the general chairs Prof. Sandipan Bandyopadhyay and Prof. Gökhan Kiper and their complete team for all efforts in organizing this workshop. We very much thank all the authors for their valuable contributions and all the reviewers and the CK community for their assistance to ensure the high quality of this workshop.

We wish you a wonderful time here in Chennai with fruitful discussions and fostering friendships. May it be an unforgettable experience!

Sincerely,

Volkert van der Wijk

Volkert van der Wijk - Chair
Marco Carricato – Deputy Chair
Martin Pfurner – Chair Secretariat

Board of the IFToMM Technical Committee for Computational Kinematics



Association for Machines and Mechanisms

Member Organization (MO) of International Federation for the Promotion of
Mechanism and Machine Science (IFToMM)

Society Registration Number: DRB4/SOR/166/2020-2021

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November 19, 2025

Dear Prof. Sandipan Bandyopadhyay and Prof. Gökhan Kiper, General Chairs of CK2025:

It is my great pleasure to write this message for the IFToMM's 8th International Workshop on Computational Kinematics (CK 2025) at IIT Madras. CK is organised every four years, but the 2021 edition could not take place due to the COVID pandemic. I am happy to see that this year, the workshop has been revived, and I thank the organisers for their efforts towards this.

From the perspective of Association of Machines and Mechanisms (AMM), the Indian MO of IFToMM, I am excited to see that this event has come to India for the first time in its history of 32 years. I am confident that this will create greater awareness regarding computational kinematics and allied fields among the Indian researchers and students, and in turn, help in the global growth of this important subject.

The workshop is also important for the participants, as even in the era of Artificial Intelligence (AI), one needs to understand the behaviour of mechanical systems in data-deprived scenarios. Besides, the models and associated computations can create synthetic data for the training of AI algorithms.

I wish Sandipan, Gökhan, and their team the very best for the grand success of the event! On behalf of AMM and fellow Indian participants, I invite our guests from abroad to enjoy the historical beauties of South India blended with its unforgettable cultural aspects.

With best regards,

Prof. Subir K. Saha
President, AMM

Conference Organisation

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Gökhan Kiper (Türkiye)

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Conference Information

Venue	
Registration	IC&SR Corridor (in front of Hall-3)
All Sessions/CK-TC meeting	IC&SR Hall-3
Refreshments/Lunch	Annexe Dining Hall, IC&SR
Cultural programme and conference dinner on 25 th November 2025 at <u>GRT Grand</u> , T. Nagar	

Day 1, 25 November 2025

- 8:30-9:00: Reporting at the reception desk (Ground floor, IC&SR Building)
- 09:00-09:10: Inauguration
- 9:10-10:10: Invited Lecture 1:

Computational Kinematics 1993- ...

Professor Manfred HUSTY

- 10:10-11:30: Technical Session 1 (4 papers)
 - **Change of Kinematic Structures via Snapping Mechanisms**
Martin PFURNER, Daniel HUCZALA
 - **Exact and Approximate Ellipse Synthesis of the Planar 2R Mechanism**
Shashank RAMESH, Mark PLECNIK
 - **On the Classification of Local Extremum Distance Between Two Smooth Planar Curves**
Rama Krishna K.
 - **Synthesis of an Illusory Flapping Wing Mechanism for a Sculpture of Flying Crows**
Volkert van der WIJK
- 11:30-12:00: Interactions over tea/coffee/snacks (Annexe Dining Hall, IC&SR Building)

- 12:00-13:00: Technical Session 2 (3 papers)
 - **Multicriteria Synthesis of Stephenson II Linkage of a Crank Press**
Amandyk TULESHOV, Assylbek JOMARTOV, Moldir KUATOVA
 - **A New Chebyshev Approximation Method for Function Generating 4-Bar Linkage**
Gökhan KIPER
 - **Anisotropic Kinematics of Upright Manuscript Handwriting**
Fırat KARA, Gökhan KIPER
- 13:00-14:30: Lunch break (Annexe Dining Hall, IC&SR Building)
- 14:30-15:30: Invited Lecture 2:

The Expression of Motion - Kinetic Art Sculptures
Dr Volkert van der WIJK
- 15:30-16:00: Interactions over tea/coffee/snacks
- 16:00-17:20: Technical Session 3 (4 papers)
 - **Kinematic and Dynamic Modeling of a Metamorphic Exoskeleton for the Knee Joint**
Hongfei LIU, Yongpeng GUAN, Yuhang ZHU, Yusong XING, Jun WEI
 - **A Tale of Two Motion Problems**
Federico THOMAS, Jaume FRANCH
 - **Common Constraint in the Screw System of a Novel Cubical Kaleidocycle**
Haolin ZHANG, Lizi DENG, Zhao TANG, Jian S. DAI
 - **Transference Principle of Hyper - State on Kinematic Chain with Nilpotent Commutative Algebra**
Daniel CONDURACHE

- 17:30: Gathering in front of IC&SR Main Entrance – travel to GRT Grand by bus
- 18:30-22:00: Cultural programme, followed by conference dinner at GRT Grand
- 23:00: Return to the campus (by bus)

Day 2, 26 November 2025

- 09:00-10.00: Invited Lecture 3:

CK: Revisiting contributions in the past and an outlook for the future

Professor Ashitava GHOSAL

- 10:00-11:20 Technical Session 4 (4 papers)
 - **Computational Assessment of Impact Forces on the Humerus During Boxing Punches: Cross, Hook, and Uppercut**
Avinash S. PRAMOD, Ravichandran G. S., Santhakumar MOHAN, Asokan THONDIYATH
 - **Design of Single-Actuator Driven Upper Limb Shoulder Exoskeleton for Assisted Arm Elevation**
Adithya R. N., Avinash S. PRAMOD, Asokan THONDIYATH
 - **Comparison of Ankle Joint Dynamics During the Stance Phase of Recreational Walking and Running**
S. Edward JERO, Shyam Kumar S., D. Davidson JEBASEELAN, Sukant RAI, P. RAJINIKUMAR, Madhusudan PAL
 - **Optimal Robot Placement for Flexibility in Maxillofacial Surgery**
Ferdaws ENNAIEM, Juan SANDOVAL, Matthias SCHLUND, Med Amine LARIBI
- 11:20-11:50: Interactions over tea/coffee/snacks
- 11:50-13:10 Technical Session 5 (4 papers)

- **Kinematic and Static Analysis of Cable-Driven Spherical X-joints: a new cable-driven spherical 4R linkage**
Vimalesh MURALIDHARAN, Durgesh Haribhau SALUNKHE, Christine CHEVALLEREAU, Philippe WENGER

- **Inverse Kinematics of the 2-RRS-1-RRRR Cable Actuated Mechanism**
Isaac JOHN, Santhakumar MOHAN, Philippe WENGER

- **Forward and Inverse Kinematics of Cable-Driven Continuum Robots**
Soumya Kanti MAHAPATRA, Ashitava GHOSAL

- **Direct Geometrico-Static Problem of Underactuated Cable-Driven Parallel Robots with 3 Cables: Convergence Analysis**
Sara GABALDO, Edoardo IDÁ, Jean Pierre MERLET, Marco CARRICATO

- 13:10-14:10: Lunch break (at the Annexe Dining Hall, IC&SR)

- 14:10-15:30: Technical Session 6 (4 papers)

- **A Semi-Analytical Approach for Computing the Largest Singularity-Free Spheres of a 6-6 Stewart Platform Manipulator for Specified Orientation Workspaces**

Bibekananda PATRA, Sandipan BANDYOPADHYAY

- **Optimal Motion Planning for a Robotic Manipulator using Voxel-Based A* and Redundant IK Solutions**

Joseph JOSHY, Devika Anitha GOPAN, Bijo SEBASTIAN

- **Adaptive Admittance Control for Internal-Force Tracking in Dual-Arm Palm Grasping**

Filippo BRASINA, Roberto DI LEVA, Alessandro DE TONI, Massimiliano Edoardo PETRIOLI, Marco CARRICATO

- **Towards AI-enhanced control: a numerical technique for trajectory smoothing of a parallel robot for pancreatic surgery**

Iosif BIRLESCU, Alexandru PUSCA, Bogdan GHERMAN, Calin VAIDA, Damien CHABLAT, Doina PISLA

- 15:30-16:00: Interactions over tea/coffee/snacks
- 16:00-17:15: Open session – discussions on ongoing research/new problems
- 17:15-17:30: Concluding remarks & closure
- 17:45-18:45: Meeting of the CK Technical Committee

Invited Lecture 1



Prof. Manfred Husty
Unit of Geometry and Surveying,
University of Innsbruck, Austria

Computational Kinematics 1993- ...

The first conference on Computational Kinematics took place at Dagstuhl (Germany) in the autumn of 1993. This event marked the start of a series of conferences that were always in the even years. Therefore, every second time CK conferences were part of the IFToMM world conferences. The CK conferences are the main scientific exchange format of the IFToMM Technical Committee on Computational Kinematics.

In the talk some light will be shed in the foundation of the TC and its historical development over the last 34 years. We will talk about how computational kinematics evolved within the field of theoretical kinematics established in the 19th century. Many different topics were treated and many different computational methods were applied. The new opportunities of software packages like Mathematica, Maple, Singular or McAuley, just to name a few, allowed to solve successfully major problems in the kinematics of mechanisms and robots that were far from classical kinematics. In the kinematics of the 19th century most the time single degree of freedom devices were studied. In computational kinematics multi-degree of freedom systems are dealt with, which yield often systems of multivariate algebraic or functional equations and it turns out that even relatively simple kinematic problems involving multi-parameter systems lead to complicated nonlinear equations. Within computational kinematics different methods- some of them quite old, but now adapted to the new computational environment- are applied to solve these problems. In the talk we will attempt to take a brief look at the 34-year history of computational kinematics, looking into its historical basics, highlighting the most important results, most fruitful methods and maybe look into its possible future.

About the speaker

Professor Husty is retired full professor of geometry of the University of Innsbruck, Austria. He obtained a Master degree from University Graz in 1979 and a PhD from Technical University Graz in 1983. In 1989 he habilitated at Montan University in Leoben, Austria and became associate professor. 1993/94 he spent a successful research year at the Centre of Intelligent Machines, McGill University, Montreal Canada and is elected associate member of the institute since 1994. In 2000 he became full professor of geometry at University Innsbruck and in 2013 he received an honorary doctorate of the Technical

University Cluj-Napoca. Since more than 40 years Husty works on different aspects of kinematics in Euclidean and Non-Euclidean settings. In 1993 he solved the long standing problem of the direct kinematics of Stewart-Gough parallel platforms and later he developed together with Martin Pflurner the fastest algorithm for solving the inverse kinematics of general serial 6-R robots. He published more than 200 papers and wrote or edited 6 books. M. Husty was long time chairmen of IFToMM Austria and the IFToMM TC Computational Kinematics. He received several best paper awards and served on many scientific committees of international conferences. In 2019 he was awarded the “Ehrenkreuzerster Klasse für Wissenschaft und Kunst” (Cross of Honor First Class for Science and Art) of the Republic of Austria.

Invited Lecture 2



Dr. Volkert van der Wijk
Mechanical Engineering,
Delft University of Technology, NL

The Expression of Motion - Kinetic Art Sculptures

Kinetic art works are known as sculptures in motion, with motion often referred to as a fourth dimension of the three-dimensional form. As the form changes in time, it means that the sculpture must not only have a single artistic pose, but a full sequence of artistic poses. In addition, the motion also exhibits a certain behaviour, depending on its kinematics and dynamics. In this talk I will give an overview of my kinetic sculptures and show how I achieve expressive motions through careful design of the kinematics, dynamics, and actuation.

About the speaker

Dr. Volkert van der Wijk is a professional sculptor of Kinetic Art and also a Gentleman Scientist related to Delft University of Technology (NL). He is an expert on the design of dynamically balanced mechanisms and deployable linkages and applies his research to both kinetic sculptures and fast vibrationless moving parallel manipulators. In 2008 he obtained a MSc. Degree (cum laude) in biomechanical engineering at the Delft University of Technology and in 2014 a PhD. Degree (cum laude) at the University of Twente (NL). During 2015-2018 he was a Research Fellow at King's College London (UK) and during 2016-2023 an Assistant Professor at Delft University of Technology. He has published over 80 scientific papers and 4 patents and has received the Wim van der Hoek DSPE Constructor Award 2008 for excellence in mechanical design engineering for his master thesis and the Constructor of Excellence 2017 Award for his kinetic art sculpture Taaie Tiller and for his achievements in scientific research on dynamic balancing. Since 2019 he is the Chair of the international IFToMM technical committee for Computational Kinematics.

Invited Lecture 3



Prof. Ashitava Ghosal,

Professor and Associate Dean at the School of Engineering and Applied Science,

Ahmedabad University, Ahmedabad, India

CK: Revisiting contributions in the past and an outlook for the future

This talk presents a look back at computational kinematics (CK) research, primarily by the speaker and his students, in the last two or more decades, and some thoughts on possible research areas in CK for the future. It is not an attempt at completeness of CK activity in India – there are numerous research efforts and publications by several other well-known researchers in India – and the choice of the topics/areas is purely personal.

The talk is in three parts. In the first part, past effort in use of computer algebra systems, Maple/Mathematica, to obtain singular configurations of a Gough-Stewart platform will be presented. This work was for the analysis and design of a six-axis force-torque sensor with enhanced measurement sensitivity to chosen components of externally acting the force and moment. In a follow-up work, analytical expressions of the singularity manifold of a semi-regular Gough-Stewart platform manipulator were derived, and this has been later used by researchers for path planning while avoiding singularities. In the second part, the focus is on redundancy and motion planning in hyper-redundant serial manipulators in free space and in the presence of obstacles. The work was later extended to the study of kinematics and motion planning of cable driven robots and for design of grippers. In cable driven robots, hyper-redundant robots and in a human arm, the inverse kinematics problem of finding actuations for a desired position and orientation of the end-effector is many-to-one, and one of the key techniques to resolve the redundancy is optimization. As the number of links increases, the computational effort also increases. Recently AI/ML tools have been proposed to “learn” the kinematics and dynamics of redundant systems and once learned, the network can solve the inverse kinematics very quickly. In the last part of this talk, preliminary results obtained from the use of AI/ML tools in robotics and some thoughts on future research on use of AI/ML tools will be discussed.

About the speaker

Ashitava Ghosal is currently a Professor and Associate Dean at the School of Engineering and Applied Science at Ahmedabad University, Ahmedabad. Prior to this, he was the Prof. Satish Dhawan Chair Professor in the Department of Mechanical Engineering with joint appointments at the Centre for Product Design and Manufacturing and at the Robert

Bosch Centre for Cyber Physical Systems, IISc Bangalore. He obtained a PhD from Stanford University, California, a MS and BTech degree from University of Florida, Gainesville and Indian Institute of Technology, Kanpur, India, respectively. His broad research areas are kinematics, dynamics, control and design of robots and other computer controlled mechanical systems.

He has 6 patents, more than 185 publications in archival journals and in national and international conferences. He has guided 18 PhDs and more than 60 master's students. He was elected to the Executive Committee member of IFToMM – an organization of 46 member nations – for two terms (2016-19 & 2019-23). He is an Associate Editor in Elsevier journal Mechanism and Machine Theory and has been an Associate Editor in ASME Journal of Mechanisms and Robotics (2018-24), and ASME Journal of Mechanical Design (2006-12). He was elected as a Fellow of the Indian National Academy of Engineering in 2010.

Professor Ghosal has authored a textbook titled “Robotics: Fundamental Concepts and Analysis” by Oxford University Press which is used in many Universities in India and abroad. He has given invited talks and conducted short term courses on robotics and multi-body dynamics at many institutions in India and abroad. More recently he has created two NPTEL lecture series on Robotics (2021) and Dynamics and Control of Mechanical Systems (2022) which are used by many institutions in India in their academic curriculum. His research has been funded by several national and international funding agencies such as DST, BIRAC, DRDO, General Motors, Robert Bosch Foundation and Solar Energy Research Institute for India and US.

More information is available at:

<https://ahduni.edu.in/academics/schools-centres/school-of-engineering-and-applied-science/people-1/ashitava-ghosal/>

and at <https://mecheng.iisc.ac.in/~asitava>

Technical Session 1 (4 papers)

Change of Kinematic Structures via Snapping Mechanisms

Martin Pfurner and Daniel Huczala

Unit of Geometry and Surveying, University of Innsbruck Technikerstr. 13, Innsbruck 6020, Austria

martin.pfurner@uibk.ac.at, daniel.huczala@uibk.ac.at

Abstract: In this work, a snapping spatial four-bar linkage is utilized to enable changes in the design of a kinematic structure. Such mechanisms possess two distinct assembly configurations and can snap between them through small elastic deformations of the links and joints. This property allows for rapid adaptation of a manipulator to user-specific requirements. A known method for generating a snapping spatial four-bar linkage based on given input is described in detail, applied to generate a snapping mechanism able to perform a change of Denavit-Hartenberg parameters between two adjacent axes, and a 3D-printed prototype is developed to demonstrate the approach using a numerical example.

Exact and Approximate Ellipse Synthesis of the Planar 2R Mechanism

Shashank Ramesh and Mark Plecnik

University of Notre Dame, Indiana, 46556, USA,

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Abstract: Synthesizing mechanism dimensions to achieve the desired velocity ellipses, known as ellipse synthesis, helps in tuning the directional transmission properties of multi-degree-of-freedom mechanisms. A velocity ellipse is a well known visualization of the first-order kinematics of a mechanism. Exact and approximate solutions to ellipse synthesis of a serial planar 2R mechanism are presented in this work. A unique solution for link lengths and the ground pivot to exactly produce a Jacobian matrix at a single Cartesian point is obtained in closed form. When only the orientation and axes lengths of a single velocity ellipse is specified, the solution yields a 2R with the ground pivot lying on an ellipse whose axes are perpendicular to those of the specified velocity ellipse. The 2R can produce only one specified velocity ellipse exactly. For many approximate ellipses, an optimization approach is presented where the residuals of the synthesis equations are minimized assuming the ground pivot is fixed at the origin. The formulation yields a univariate polynomial equation of degree 9 in the 2R link lengths that is invariant to the number of specified ellipses. Consequently, this formulation yields at least one real solution for 2R dimensions that approximately produces the specified velocity ellipses close to the specified points.

On the Classification of Local Extremum Distance Between Two Smooth Planar Curves

Rama Krishna K

Department of Mechanical Engineering, Indian Institute of Technology Delhi, New Delhi- 110 016, India

rkk@mech.iitd.ac.in

Abstract: This paper studies the nature of the local extremal distance between two smooth planar curves. It is shown that the relative location of four points on the common normal line decide the classification of the extremum. Geometric enumeration of various cases deduced from the Hessian matrix of the distance function is presented. A kinematic analogy based on flattened configurations of four-bar linkage is developed for this quick characterization. A potential application of the classification developed, is also discussed.

Synthesis of an Illusory Flapping Wing Mechanism for a Sculpture of Flying Crows

Volkert van der Wijk

Delft University of Technology and Kinetic Art Sculptures,

v.vanderwijk@tudelft.nl

Abstract: This paper presents a design method for a flapping wing mechanism driven by five vertical rods to imitate a flying bird. Two conceptual designs for driving the vertical rods are presented and compared, one based on a set of gearwheels and one based on a crank. Subsequently for the crank design the set of parameter values for an as realistic as possible imitation of the motion of the wings of a crow is derived in two steps, considering the inner wing segments with the body separately from the outer wing segments. It is shown how the resulting kinematic model has been applied successfully for the production of a sculpture of three small flying crows.

Technical Session 2 (3 papers)

Multicriteria Synthesis of Stephenson II Linkage of a Crank Press

Amandyk Tuleshov, Assylbek Jomartov, and Moldir Kuvatova

Joldasbekov Institute of Mechanics and Engineering, 050010 Almaty, Kazakhstan
legsert@mail.ru

Abstract: In industry, crank presses with an actuator based on the crank-slider mechanism are widely used for the production of various mechanical parts. Due to the design features of the crank press actuator, the slider becomes skewed. The skewing of the crank press slider is the main problem in its operation and leads to a decrease in stamping accuracy. To eliminate these problems, the Stephenson II linkage is used as an actuator for the crank press. A multicriteria synthesis based on the Stephenson II linkage is carried out. The reaction forces in its kinematic pairs and the torque on the crank were chosen as the objective optimization functions for the synthesis of the Stephenson II linkage.

A New Chebyshev Approximation Method for Function Generating 4-Bar Linkage

Gökhan Kiper

İzmir Institute of Technology, 35430 Urla, İzmir, Türkiye
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Abstract: In design of function generator linkages one of the well-known methods is the Chebyshev approximation, where the aim is to minimize the maximum structural error between the desired and generated functions. Available methods in the literature try to achieve this optimization task indirectly by either considering the error in a trigonometric function appearing in the input/output relation of the linkage rather than the error in the output itself, or respacing precision points. This chapter presents a new methodology for the application of the Chebyshev alternation theorem for a planar 4-bar function generator linkage, which is simply based on equating the absolute structural error in the output at certain design points and relocating the design points according to the points of extremums of the error function. The proposed formulation can be used as the evaluation step of the iterative Remez algorithm. The presented formulation is illustrated with several numerical examples. The results show that the new method typically converges in a single step, whereas alternative methods such as use of Freudenstein respacing formula converges in several steps for similar amount of precision. The proposed method can be applied for other linkages besides the 4-bar linkage as well.

Anisotropic Kinematics of Upright Manuscript Handwriting

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Abstract: This study presents anisotropic velocity characteristics of upright manuscript handwriting, based on pen-tip velocity components. Data is collected from 30 right-handed adults using an electronic tablet and stylus with a custom Android application. Participants are asked to write the 29 Turkish letters in both uppercase and lowercase, as well as numerals from 0 to 9, each repeated three times, resulting in 174 samples per participant. Each character is stored as a separate CSV file containing pen-tip position coordinates, velocities, timestamp, azimuth, tilt angles and pressure. The horizontal and vertical velocity components are used for analyzed. Results show that writing tends to be faster in the vertical direction, consistent with dominant stroke patterns in the Latin alphabet. These findings confirm the anisotropic nature of manuscript handwriting. The results are planned to be used for the optimal design of a asymmetric manipulator as a supporting equipment for teaching how to write to children.

Technical Session 3 (4 papers)

Kinematic and Dynamic Modeling of a Metamorphic Exoskeleton for the Knee Joint

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Abstract: The knee joint is characterized by variable-axis rotational motion. To enhance the adaptability of rehabilitation exoskeletons to the physiological movements of the knee joint, a metamorphic knee exoskeleton is designed. To address the abrupt changes in constraint equations and the reconstruction of system topology during the metamorphosis process, as well as to clarify the variations in driving force requirements of the exoskeleton before and after metamorphosis, kinematic models for each configuration are established respectively, and a unified dynamic model based on the configuration switching function is developed. First, a simplified mechanism diagram of the knee exoskeleton was established, and its working principle was analyzed. Then, a kinematic model of the exoskeleton was developed using the closed-loop vector method, followed by kinematic simulation. Finally, dynamic analysis was performed via Lagrange equations, providing a theoretical foundation for controlling the metamorphic knee exoskeleton.

A Tale of Two Motion Problems

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Abstract: This paper establishes a formal equivalence between the disk on-sphere motion problem and the terrestrial brachistochrone problem by demonstrating that both are governed by the same differential equation. From a geometric perspective, the underlying problem reduces to interpolating a cusp-free arc of a hypocycloid between two points on a circle. This insight not only reveals a deep connection between seemingly unrelated problems but also offers a unifying framework for their analysis.

Common Constraint in the Screw System of a Novel Cubical Kaleidocycle

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Abstract: This paper presents a novel Cubical Kaleidocycle 8-bar linkage, which originates from the transformation of the Magic Cube. Based on screw theory, the constraint screw system at the bifurcated configuration is analyzed to determine the mobility of the mechanism. A motion branch exhibiting a dual spherical-center configuration is identified through configuration recognition. By integrating the closure equations and screw theory, the motion paths, mobility, and common constraint characteristics of the dual-spherical-center configuration are systematically derived. Furthermore, the geometric conditions of line-plane constraints are investigated to evaluate the stability of the dual-spherical-center mode, providing a new perspective for analyzing similar motion patterns in spatial linkages.

Transference Principle of Hyper - State on Kinematic Chain with Nilpotent Commutative Algebra

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Abstract: This paper presents an extension of the Lie group associated with rigid body displacements and the corresponding Lie algebra for higher-order motion kinematics. It focuses on a three-order commutative nilpotent algebra. She examines the hyper-state, which includes simultaneous the position, velocity vector field, and acceleration vector field of rigid body motions and kinematic chains. By automatically differentiating the nilpotent Lie algebra, the need for additional time-based differentiation is eliminated. The result is expressed by the product of an exponential formula that uniquely determines anybody's hyper-state in a kinematic chain without requiring additional computations.

Technical Session 4 (4 papers)

Computational Assessment of Impact Forces on the Humerus During Boxing Punches: Cross, Hook, and Uppercut

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Abstract: The impact forces on the upper limb of the boxers during punching and defending can cause deformation and fracture to the humerus bone. The humerus, being the most crucial link, is strong and larger compared to the other bones in the upper limb, but continuous cycles of impact forces can cause permanent injury and defects in the bone. The measurement of such impact forces and the effect of cyclic loading on the bone is highly challenging to obtain experimentally on live participants due to the complexity of the measurement technique and the possibility of injuring the participant. This paper presents an upper limb kinematic model for simulating punching motions during cross, hook, and uppercut, based on which the static impact force on the upper limb is computed at the target point. The static forces obtained are further used to understand the cyclic loading effect on the humerus bone model in finite element analysis software for the case of punch delivery and the impact of punch reception during defending in a boxing match.

Design of Single-Actuator Driven Upper Limb Shoulder Exoskeleton for Assisted Arm Elevation

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Abstract: There has been a growing need for assistive devices for everyday activities. However, current exoskeletons are often bulky and expensive. The increased weight and cost are a result of incorporating multiple actuators to mimic the human shoulder motion. A simpler wearable mechanism must be designed to facilitate all possible shoulder motions. This paper presents the design and analysis of a wearable upper-limb exoskeleton to aid in daily life activities that employ a single actuator that facilitates arm elevation. The exoskeleton was designed using mechanism synthesis and static analysis; the necessary reachable workspace and actuator selection were determined using kinematic and dynamic analysis. This study also presents the fabricated exoskeleton.

Comparison of Ankle Joint Dynamics During the Stance Phase of Recreational Walking and Running

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Abstract: Return to sports is a critical phase in an athlete's career following an injury. Continuous assessment of joint biomechanics is important for developing effective treatment strategies during this period. Particularly, knee and ankle movements play crucial roles in sports related tasks. This study aims to compare the biomechanical parameters of ankle joints during walking and running in recreational athletes. For this, motion capture (MoCAP) data from twenty male recreational runners, reported by Qichang Mei et al. 2022, were employed. The data capturing protocol involved recording MoCAP data from each subject before and after a 5k treadmill run. The proposed method consists of preprocessing of the MoCAP data, computing inverse kinematics parameters, joint angles, and inverse dynamics parameters, such as joint reaction forces and moments of the ankle, using the OpenSim open-source musculoskeletal model. The preliminary results were analyzed for the demonstration of variations in the biomechanical parameters during the stance phase of walking and running tasks. It was observed that higher dorsiflexion exists during walking compared to running, with the statistical significance of $p < 0.05$. Finally, significant changes in joint reaction forces and moments ankle were demonstrated across four sessions of walking and running tasks. Notably, the moments during running increased considerably compared to walking. However, no significant changes in the biomechanical parameters of ankle were observed between pre-5k and post-5k run sessions. Future work involves predicting injury risk factors using biomechanical parameters of the knee and ankle joints for a comprehensive assessment of athletes.

Optimal Robot Placement for Flexibility in Maxillofacial Surgery

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Abstract: The success of robotic-assisted maxillofacial surgery hinges on accurate robot placement, as it directly influences the surgeon's dexterity, control, and ultimately, the surgical outcomes. This paper investigates the optimal placement of the KUKA IIWA Med 14 robot, a key component of the robotic platform developed for maxillofacial procedures within the LARA project. The objective is to maximize the robot's effectiveness. To achieve this, an optimization problem is formulated, balancing the need for safe operating conditions with flexibility in patient positioning. The approach ensures that the robot can access a wide range of operating table configurations while avoiding collisions.

Technical Session 5 (4 papers)

Kinematic and Static Analysis of Cable-Driven Spherical X-joints: a new cable-driven spherical 4R linkage

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Abstract: This work presents the spherical X-joint, a novel 4R spherical linkage featuring two pairs of identical links arranged in a crossed configuration. A rigorous kinematic analysis reveals that the mechanism exhibits a unique reflective symmetry and that its full-cycle mobility is theoretically equivalent to pure rolling between identical elliptical cones. This insight enables an unconstrained single-parameter description of the joint's motion that extends the inherent symmetry of the mechanism to the mathematical analysis also. Such a description provides a compact and efficient kinematic and static model for the spherical X-joint. Furthermore, a remote actuation strategy based on antagonistic cables is proposed, and it is analytically proven that the joint exhibits positive coactivation across its workspace. These findings demonstrate the spherical X-joint's strong potential for remote actuation applications, particularly in the design of lightweight, bio-inspired robotic wrists and manipulators.

Inverse Kinematics of the 2-RRS-1-RRRR Cable Actuated Mechanism

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Abstract: This work presents an inverse displacement (ID) formulation of a spatial, cable actuated 2-degree-of-freedom mechanism. The 2-RRS-1-RRRR mechanism studied in this work is derived from the well-known quaternion joint. The system of 13 constraint equations have mixed variables in joint and task spaces, and is solved using polynomial homotopy continuation. Further on, the extraneous solutions are eliminated using the filtering conditions.

Forward and Inverse Kinematics of Cable-Driven Continuum Robots

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Abstract: This paper deals with the forward and inverse kinematics of continuum robots consisting of a flexible backbone with attached disks and actuated by straight and generally routed cables. For forward kinematics, an efficient geometry-based optimization approach is presented with linear complexity in the number of disks. A feed-forward neural network, trained using the data generated from the forward kinematics, is employed for inverse kinematics. In case of straight cable routing, where the inverse kinematics solutions are unique, a standard mean-squared error loss function is used. For general cable routing, with multiple possible solutions, a modified reconstruction-based loss function is introduced, incorporating a separate network to predict forward kinematics. Both models yield accurate predictions, highlighting the effectiveness of the training and the robustness of the proposed approach.

Direct Geometrico-Static Problem of Underactuated Cable-Driven Parallel Robots with 3 Cables: Convergence Analysis

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Abstract: This paper investigates the convergence properties of the Newton method when applied to the direct geometrico-static problem of underactuated cable-driven parallel robots with three cables. The analysis, grounded in the Kantorovich theorem, provides a systematic method to compute the maximum admissible error on cable length measurements that guarantees the problem to converge to a unique solution using the Newton method. Furthermore, the accuracy of the estimated pose is quantified. Simulation results are provided for a representative robot throughout its reachable workspace. The outcomes of this study may support the development of more reliable pose estimation methods for underactuated cable-driven parallel robots.

Technical Session 6 (4 papers)

A Semi-Analytical Approach for Computing the Largest Singularity-Free Spheres of a 6-6 Stewart Platform Manipulator for Specified Orientation Workspaces

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Abstract: This article presents a method for computing the largest singularity-free sphere (SFS) of a 6-6 Stewart-Gough platform manipulator (SGPM) over a specified orientation workspace. For a fixed orientation of the moving platform, the SFS is computed analytically. This process is repeated over a set of samples generated within the orientation workspace, and the smallest among them is designated as the desired SFS for the given orientation workspace. Numerical experiments are performed on four distinct architectures of the SGPM to understand their relative performances w.r.t. SFS volumes over the same orientation workspace. This study demonstrates the potential utility of the proposed computational method both in analysis and design of SGPMs.

Optimal Motion Planning for a Robotic Manipulator using Voxel-Based A* and Redundant IK Solutions

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Abstract: This paper introduces a novel approach towards planning and control of a robotic manipulator within a 3D workspace. The workspace is discretized into a voxel grid, enabling the A* search algorithm to generate collision-free, optimal paths for the start configuration to the goal configuration. While the A* planner operates in 3D task space, the corresponding joint space trajectories are computed using analytical and numerical inverse kinematics methods, with each joint configuration being individually evaluated for collision using a physical engine. A numerical approach is also employed as a fallback when the analytical method fails or yields no valid solution within the workspace. Experimental results demonstrate the effectiveness of this integrated framework, highlighting its applicability for precision tasks in automation and manufacturing environments.

Adaptive Admittance Control for Internal-Force Tracking in Dual-Arm Palm Grasping

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Abstract: This work presents an adaptive admittance control aimed at regulating internal forces in dual-arm robotic manipulation under palm-grasping contact. Traditional admittance controllers, which utilize fixed parameters, often exhibit difficulties in ensuring reliable internal force tracking, particularly during dynamic tasks or when faced with time-varying force references. To address these challenges, this paper adopts an adaptive law that adjusts the damping gain in real time based on the internal-force tracking error. The approach has been experimentally validated using a dual-arm setup that performs high-dynamics 3D and 6D cooperative motions. Results indicate that the proposed method improves force-tracking performance and responsiveness compared to a constant-gain admittance controller even when the choice of parameters is suboptimal.

Towards AI-enhanced control: a numerical technique for trajectory smoothing of a parallel robot for pancreatic surgery

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Abstract: The paper presents a numerical approach for the end-effector trajectory smoothing of a parallel robot designed for minimally invasive pancreatic surgery. The approach is tailored for real-time master-slave control architecture and uses a 3D space mouse for command input for velocity control. The trajectory smoothing is achieved by generating S-curves in the end-effector velocity fields, thus controlling the accelerations, which in turn reduces tissue trauma in the minimally invasive procedures. Real-time control is enabled by segmenting the S curves based on the command inputs from the 3D space mouse. A special case is considered where the acceleration time is constant for all command inputs. Numeric results demonstrate stable transitions (without abrupt changes) in both the end-effector parameter space and in the active joints parameters, thereby validating the proposed approach. Further work aims to test the approach on an experimental model and integrate it into AI-based training modules.

Cultural Programme



Classical Vocal in Carnatic Style

Date: 25/11/2025

Venue: GRT Grand, T. Nagar

Mridangam: Prahalad V

Vocalist: Srividya Vadlamani

Violin: Chetana Sekhar

Vocalist: Supriya Raja

Nearby tourist places

Mahabalipuram

Mahabalipuram, also called Mamallapuram, is a small yet fascinating town in Tamil Nadu which has become one of the top tourist destinations in the recent years. The group of monuments at Mahabalipuram is a collection of 7th- and 8th-century CE religious monuments in the coastal resort town of Mahabalipuram, Tamil Nadu, India and is a UNESCO World Heritage Site. Top places to visit in Mahabalipuram are the Shore temple, the Seashell Museum, the Pancha Rathas, and the light house.

Kanchipuram

Kanchipuram, an ancient city located about 60 kms from IIT Madras, steeped in history dating back to the 2nd century BC, stands as a venerable jewel in the cultural tapestry of southern India. Often referred to as the "Golden City of Temples", Kanchipuram holds paramount significance in the realm of Indian culture. Its rich legacy is a testament to its enduring spiritual and architectural splendor.

Pondicherry

Pondicherry (or Puducherry), a French colonial settlement in India until 1954, is now a Union Territory town bounded by the southeastern Tamil Nadu. Its French legacy is preserved in its French Quarter, with tree-lined streets, mustard-colored colonial villas and boutiques. Some of the popular places to visit in Pondicherry: Sri Aurobindo Ashram, Auroville, Auroville Beach, Promenade Beach, Arulmigu Manakula Vinayagar temple, The Sacred Heart Basilica, Rock Beach, Immaculate Conception Cathedral, Sri Varadaraja Perumal temple, French Colony, Pondy Marina, Paradise Beach, Eglise de Notre-Dame des Anges.



Mahabalipuram



Kanchipuram



Pondicherry

Tourist attractions in Chennai

Chennai is India's southernmost metropolis. It boasts of top notch industries, research labs, and education institutions as well as healthcare. It is also home to a thriving culture of art, music, and timeless traditions. Scan the QR code below to explore some of these tourist attractions.



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