Kinematics that Entails Reconfigurable Mechanisms and Robotics

Prof Jian S. Dai

ASME Fellow, IMechE Fellow

Chair Professor in Mechanisms and Robotics

Kinematics and Mechanisms Group

Centre for Robotics Research

King's College London

ASME Mechanisms and Robotics Award

Lifelong Contribution Award Recipient

PROFESSOR JIAN S. DAI

presents

Distinguished Lecture on

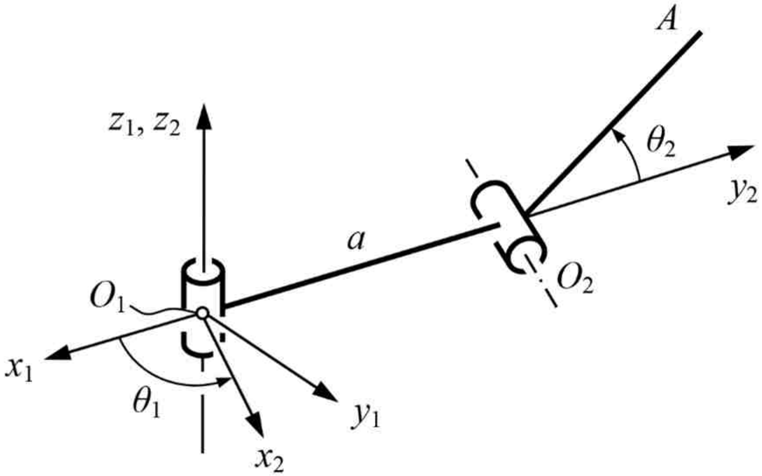
6:00 pm, 3 November, Great Hall,
King's College London

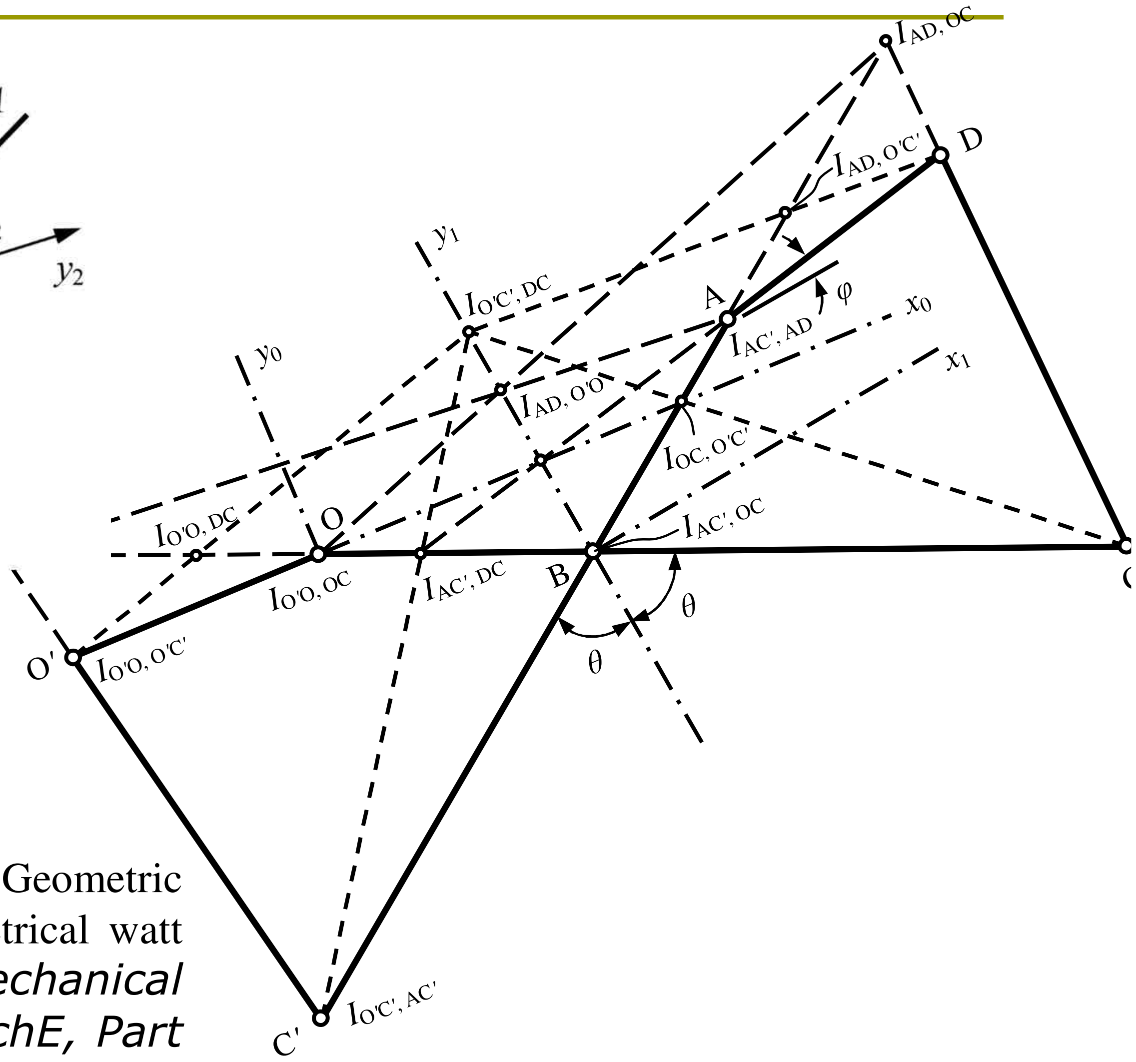
Robots and Mechanisms

What are mechanisms

A Core in Running Machines and Robots That Cannot Be Substituted

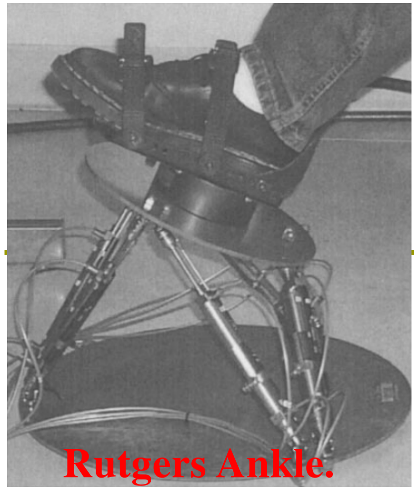
The Patient Handling Robot





Dai, J.S. and Kerr, D.R. (1991) Geometric analysis and optimisation of a symmetrical watt six bar mechanism. *Journal of Mechanical Engineering Science, Proc, IMechE, Part C*, **205**(4): 275-280, 1991.

Ankle Rehabilitation Mechanisms



Rutgers Ankle. Rutgers University, 2001

ARBOT, IIT, 2008

AssistOn-Ankle Ankle Rehab Sabancı University, 2013

Ankle Rehab Parallel Mechanism, King's, 2004

Dai, J.S., Zhao, T. and Nester, C., Sprained ankle physiotherapy based mechanism synthesis and stiffness analysis of rehabilitation robotic devices, Special Issue on Rehabilitation Robotics, *Autonomous Robots*, **16**(2): 207-218, 2004.

Part I

Mechanisms (Linkages)

Body and Skeleton

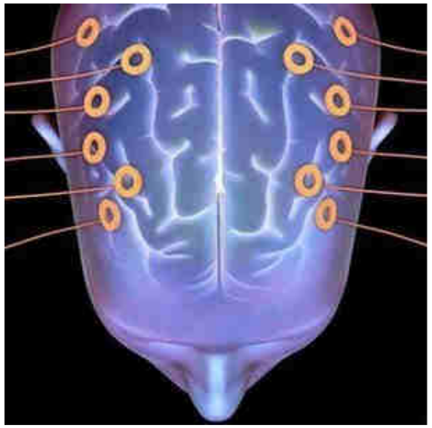
Definition of Robots

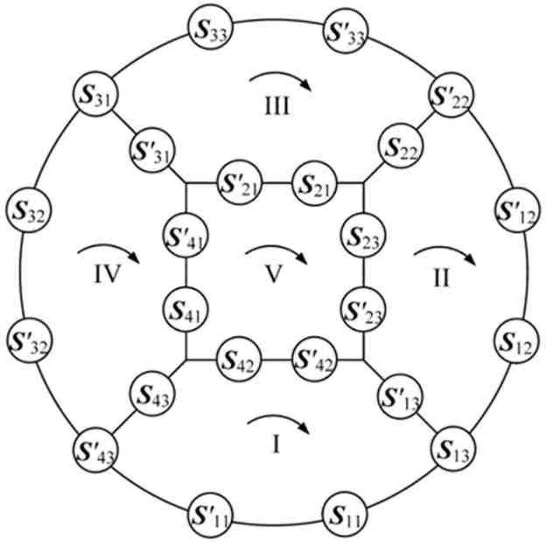
Reprogrammable

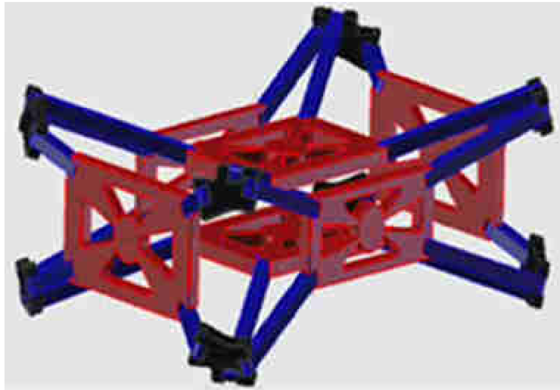
Computers, control, intelligence (Soft)

Machines

mechanisms, reconfigurable, design (Hard)



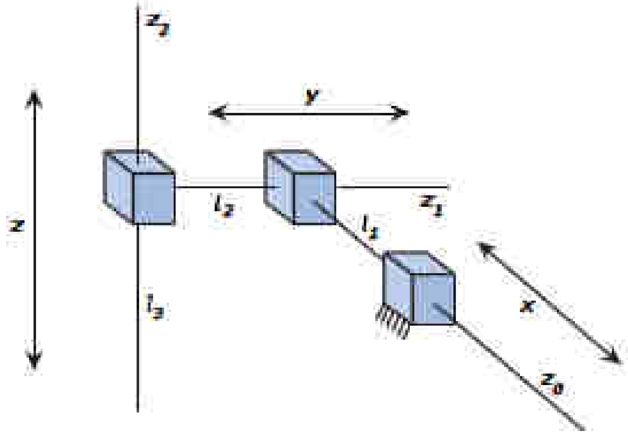




Mathematics, kinematics, dynamics (NMS)

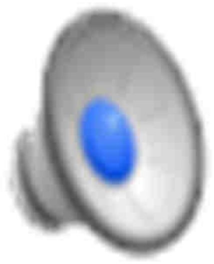
Serial Linkages

Cartesian coordinate robot

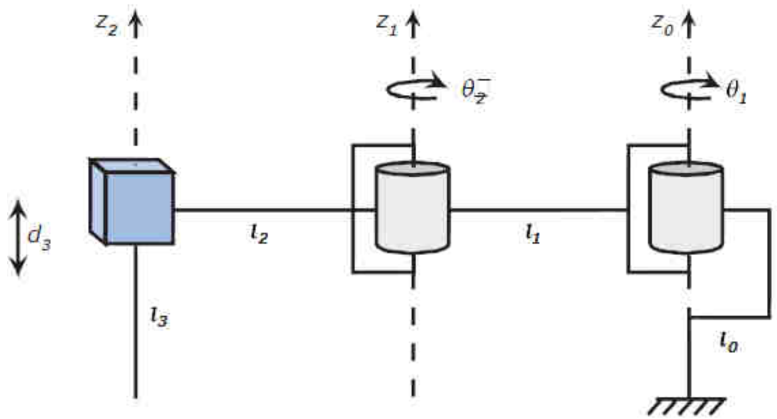


Three prismatic joints

DOF = 3

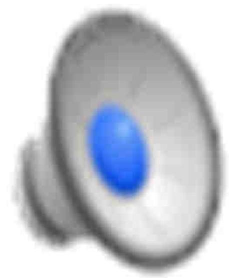


SCARA robot



Two revolute and one prismatic joints

DOF = 3



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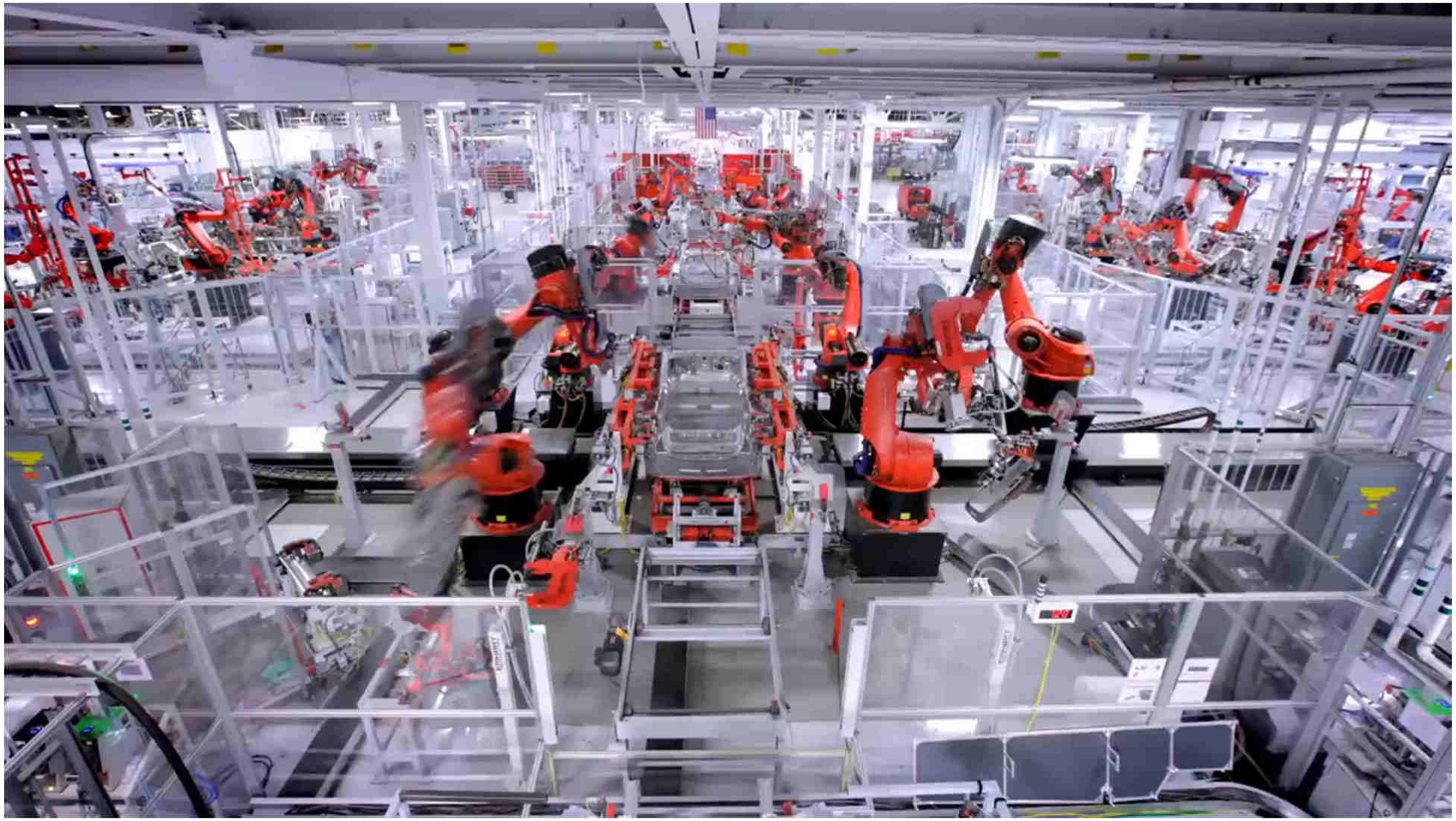
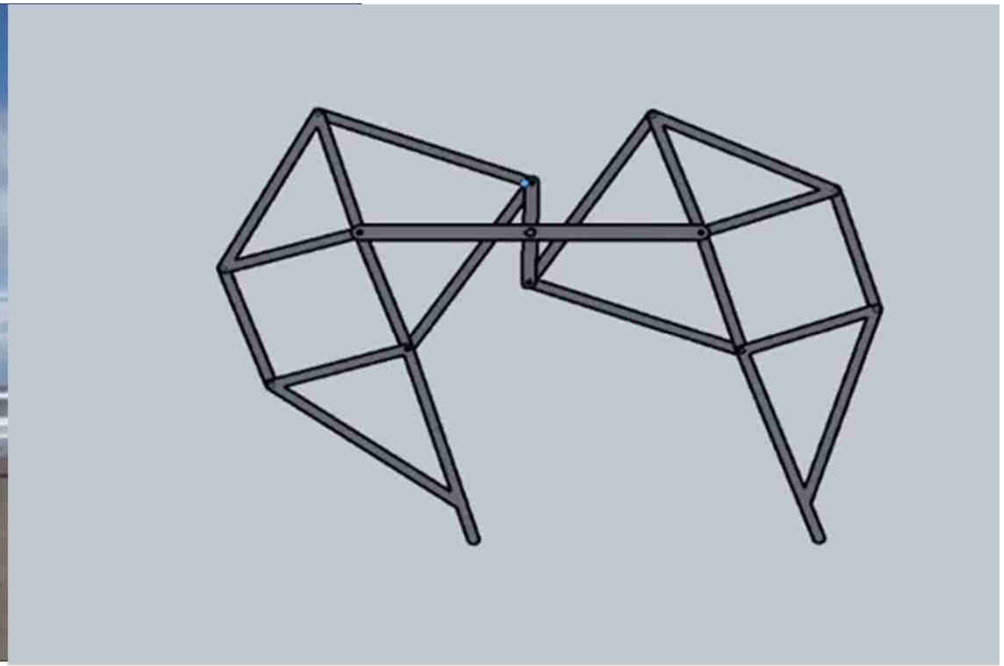
Serial Robots in Automotive Industry（Tesla, US）



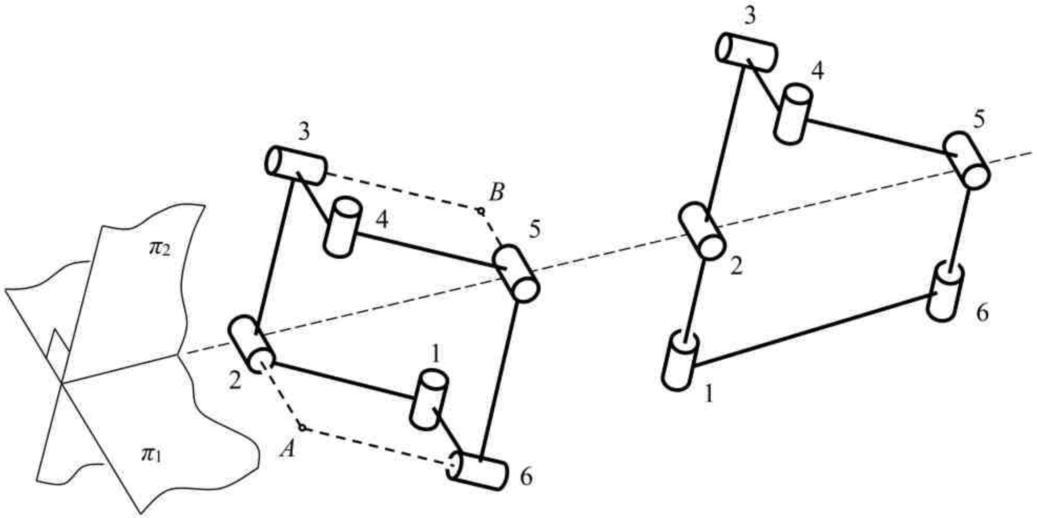
Walking Robot & Its Mechanism

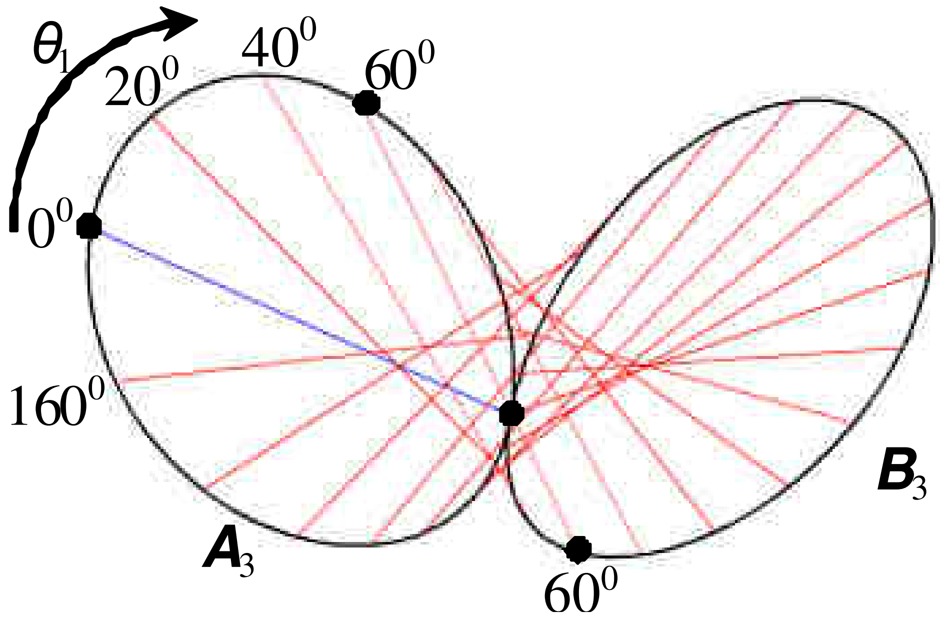


Beach Beast Robot

Theo Jansen Mechanism

Geometry – Mechanisms – Mathematics
Kinematics





Brief Kinematics History and Contemporary Development

Kinematics in Past 200 Years

ELSEVIER

Mechanism and Machine Theory 41 (2006) 41–52

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An historical review of the theoretical development of rigid body displacements from Rodrigues parameters to the finite twist

Jian S. Dai *

Department of Mechanical Engineering, School of Physical Sciences and Engineering, King's College London, University of London, Strand, London WC2R 2LS, UK

Finite Displacement Screws, Screws, Lie Groups and Lie Algebra

	Screws	Finite Screws	Lie Groups	Lie Algebra
1763	Mozzi ISA			
1806	Poinsot Central Axis			
1830		Chasles Motion		
1840			Galois: Group Theory	
1845s		Rodrigues parameters Euler-Rodrigues formula		
		Hamilton quaternions		
		Cayley formula of rotation		
1860-65	Cayley coordinates, Plücker coordinates			
1871-72	Klein reciprocal, Ball reciprocal		Klein Erlangen	
1872-73	Clifford table	Clifford dual quaternion		
1871-76	Ball screw theory			
1880	Killing form			Killing form
1888-93			Lie, Engle: Lie groups	
1900	Ball treaties of screws			
1901	Study dual angles, quaternion groups			

Finite Displacement Screws, Screws, Lie Groups and Lie Algebra

	Screws	Finite Screws	Lie Groups	Lie Algebra
1979	Bottema & Roth: theoretical kinematics			
1984	Phillip: general screw motion			
1990	McCarthy:	introduction to	theoretical kinematics	
1990-1994	Parkin:	finite twist pitch and development		
1994	Murry, Li & Sastry:		Lie group and rigid body motion	
1994-5		Huang: finite screws		
		Dai, H & Kerr:	finite screw representation & operation	
1996	Duffy: planar linkage motion			

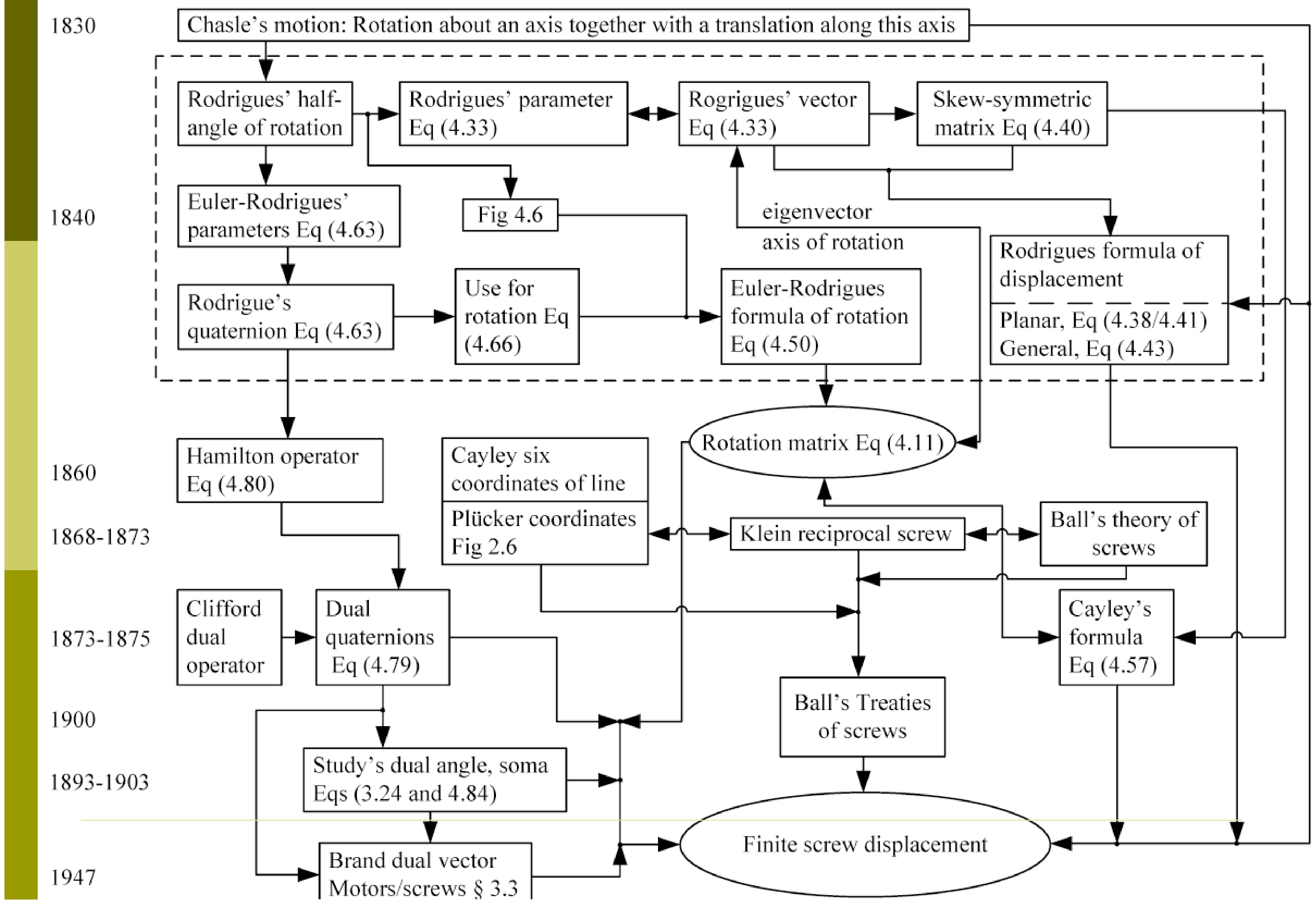
Finite Displacement Screws, Screws, Lie Groups and Lie Algebra

	Screws	Finite Screws	Lie Groups	Lie Algebra
2001	Dai & Rees Jones: screw system relations			screw system relations
2002	Dai & Rees Jones: screw null space			screw null space
2004	Selig: computational mathematics of robotic geometry			
2004	Davidson & Hunt: Robots and screw theory			
2014	Dai: Geometrical Foundation and Screw Algebra for Mechanisms and Robotics			

Dai, J.S., Finite displacement screw operators with embedded Chasles' motion, *Journal of Mechanisms and Robotics*, *Trans. ASME*, **4**(4): 041002, 2012.

Dai, J.S. (2014) Geometrical Foundations and Screw Algebra for Mechanisms and Robotics, Chinese translations, Higher Education Press, Beijing, ISBN: 9787040334838, (translated from Dai, J.S. 2015, Screw Algebra and Kinematic Approaches for Mechanisms and Robotics, to be published by Springer, London)

Relationship of Classical Displacement Operators



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Euler–Rodrigues formula variations, quaternion conjugation and intrinsic connections

CrossMark

Jian S. Dai *

MOE key lab for mechanism theory and equipment
Centre for Robotics Research, School of Natural Sci

Mechanism and Machine Theory 92 (2015) 144–152

Finite Displacement Screw Operators With Embedded Chasles' Motion

Jian S. Dai
Chair of Mechanisms and Robotics
Centre for Advanced Mechanisms and Robotics,
MoE Key Laboratory for Mechanism
Theory and Equipment Design,
School of Mechanical Engineering,

Rigid body displacement can be presented with Chasles' motion by rotating about an axis and translating along the axis. This motion can be implemented by a finite displacement screw operator in the form of either a 3 × 3 dual-number matrix or a 6 × 6 matrix that is executed with rotation and translation as an adjoint action of the Lie group. This paper

Journal of Mechanisms and Robotics NOVEMBER 2012, Vol. 4

Mathematicians' Love of Geometry and Discovery of Mechanisms

Links

Dai, J.S., Huang, Z., Lipkin, H. (2006) Mobility of Overconstrained Parallel Mechanisms, Special Supplement on Spatial Mechanisms and Robot Manipulators, *ASME Journal of Mechanical Design*, **128**(1): 220-229.

Dai, J.S. (2012) Characteristics of the Screw Matrix and Their Effect on Chasles' Motion, *ASME Journal of Mechanisms and Robotics*, **4**(4): 041002.

Mathematicians & Mechanisms

Years	Mathematicians	Contributions	Impacts
1853	Pierre Frédéric Sarrus (France)	Sarrus linkage	world first translating revolute motion into straight line motion, first overconstraint linkage
1875	Franz Reuleaux (TUB)	Kinematics descriptions, kinematics pairs	Describe constraints, machine motion into geometrical surface
1872 & 1876	Siegfried Heinrich Aronold (Germany) Alexander BW Kennedy (UK)	Aronhold & Kennedy theorem	ISA
1897	Raoul Bricard (France)	Six movable six-bar overconstraint linkages, including 3 movable 8-faces, and 3 line, plane symmetric with 3 faces	Movable polyhedra
1903	Geoffrey Bennett (Cambridge)	Bennett linkage	Motion geometry
1931	Myard	Link two Bennett linkages, to form a five-bar plane symmetric overconstraint linkage	

Mathematicians & Mechanisms

years	scholars	contributions	impacts
1942	Paul Schatz (Swiss sculpturer)	Schatz linkage	First used overconstraint linkage
1943	Goldberg	Link a pair of Bennett linkage to form an overconstraint 5-bar linkage	
1954	Altmann	Bricard line symmetric six-bar linkage	
1968	Waldron	Two Bennett linkages to construct a 6-bar overconstraint linkage	Any two 1-DOF linages can share a common axis
1985	Mohamed & Duffy	Use screw algebra to express Gough-Stewart platform	Associating screw algebra to linkages

Geometry that Associates Mathematics with Robotics

10.1098/rspa.2001.0949

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THE ROYAL SOCIETY

Null-space construction using cofactors from a screw-algebra context

By Jian S. Dai[1] and John Rees Jones[2]

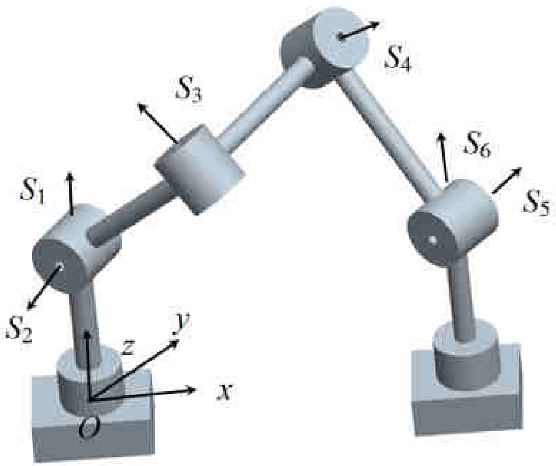
[1] *School of Physical Sciences and Engineering, King's College London, Strand, London WC2R 2LS, UK* (jian.dai@kcl.ac.uk)

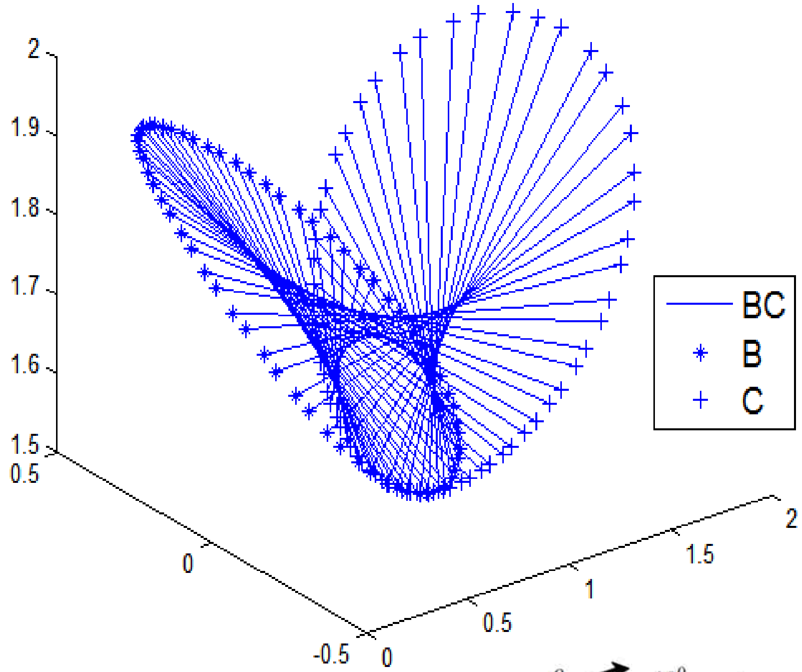
[2] *9 Beaumaris Dr., Thingwall, Heswall, Wirral CH61 7XP, UK* (jreesjones@cs.com)

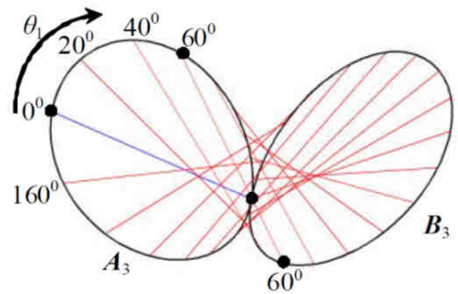
Received 3 May 2001; accepted 26 November 2001; published online —

A representation of a classical mechanism

Ruled surface







$$\boldsymbol{N} = \boldsymbol{N}_\iota \boldsymbol{N}_c = \begin{bmatrix} \boldsymbol{I} & \boldsymbol{0} \\ \iota \boldsymbol{A}_s & \boldsymbol{I} \end{bmatrix} \begin{bmatrix} \boldsymbol{R} & \boldsymbol{0} \\ [\boldsymbol{r}_e \times] \boldsymbol{R} & \boldsymbol{R} \end{bmatrix}$$

Dai, J.S. (2012) Finite displacement screw operators with embedded Chasles' motion. **Trans ASME, Journal of Mechanisms and Robotics**, **4**(4): 041002.

Contemporary Kinematics Study

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Euler–Rodrigues formula variations, quaternion conjugation and intrinsic connections

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Jian S. Dai *

ASME Mechanisms and Robotics Award

—— For Lifelong Contribution to Fundamental Theory, Design and Applications of Mechanisms and Robotics Systems

2015 – Jian S. Dai
2014 - Gregory Chirikjian
2013 - Steven Dubowsky
2012 - Vijay Kumar
2009 - L.L. Howell
2008 - C. Gosselin
2007 - C. W. Wampler, II
2006 - K. Kazerounian
2005 - J. K. Davidson
2004 - J. J. Uicker, Jr.
2002 - K.C. Gupta
2000 - J. Angeles
1998 - A. Midha
1996 - A. T. Yang
1994 - A. Soni
1992 - J. Duffy
1990 - K. J. Waldron
1988 - A. G. Erdman
1986 - K. H. Hunt
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1982 - B. Roth
1980 - G. N. Sandor
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1976 - F. R. E. Crossley
1974 - A. S. Hall, Jr.
1974 - R. S. Hartenberg
1974 - J. E. Shigley

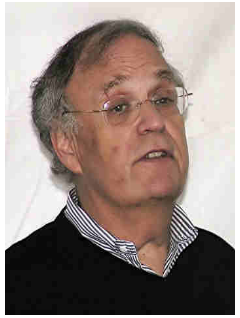
ASME Mechanisms and Robotics Award
—— Lifelong contribution award

2008: Clément Gosselin

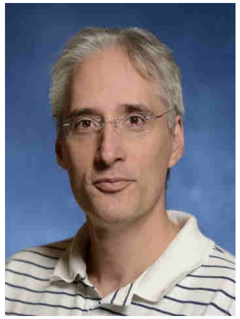
2009: Larry L. Howell

2011: J. Michael McCarthy

2012: Vijay Kumar



2013: Steven Dubowsky



2014: Gregory Chirkjian

2015: Jian S Dai

Journal of Mechanisms and Robotics

Editorial

Jian Dai Awarded the DED Mechanisms and Robotics Award

The Mechanisms and Robotics community would like to acknowledge and honor Jian Sheng Dai, professor at the King's College London, London, UK, and a Fellow of the American Society of Mechanical Engineers (ASME), who received the 2015 ASME DED Mechanisms and Robotics Award at the 39th ASME Mechanisms and Robotics conference held on Aug. 2–5, 2015 in Boston, MA. The Mechanisms and Robotics Award is an honor that is given annually by the ASME Design Engineering Division, to engineers known for a lifelong contribution to the fundamental theory, design and applications of mechanisms and robotic systems. Professor Dai has made a lasting impact on reconfigurable mechanisms through his contributions to theoretical study, mechanism innovation, applications, and societal services and by exploring the screw system relationship for revealing constraint variation that affects mechanism reconfigurability and for establishing a mode of mobility analysis.

Mathematical Problems in Mechanisms and Robotics

Dai, J.S. （2017）Screw Algebra and Kinematic Approaches for Mechanisms and Robotics, *Springer*, London.

Dai, J.S. (2014) Geometrical Foundations and Screw Algebra for Mechanisms and Robotics, (in Chinese), Higher Education Press (HEP), Beijing, ISBN: 9787040334838.

Dai, J.S. (2014) Screw Algebra and Lie Groups and Lie Algebras (in Chinese), Series 42 of Foundations for Modern Mathematics, Higher Education Press (HEP), Beijing, ISBN: 9787040318456.

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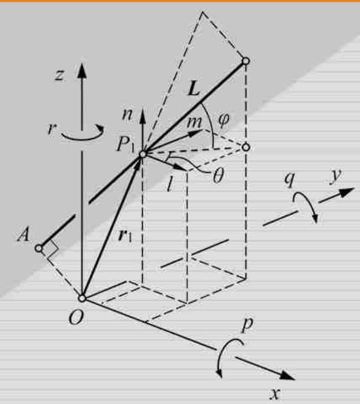

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机构学与机器人学的几何基础与旋量代数

戴建生 著

高等教育出版社 HIGHER EDUCATION PRESS

戴建生，天津大学教授，“长江学者”讲座教授，“千人计划”国家特聘专家；任天津大学先进机构学与机器人学中心主任，伦敦大学国王学院机构学与机器人学首席教授；1982 年毕业于上海交通大学，1984 年获该校硕士学位，1993 年获英国 Salford 大学哲学博士学位。

戴建生教授为 ASME Fellow，IMechE Fellow，长期从事机构学与机器人学基础理论与应用研究，发表国际期刊与会议学术论文 400 余篇，获得多项国内外学术奖励与荣誉，担任多项国际学术组织职务。

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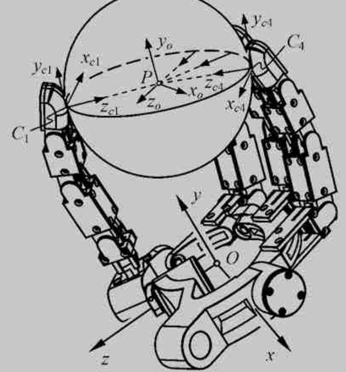
- 深度剖析，全面覆盖，著述空间机构学理论基础与百科全书。



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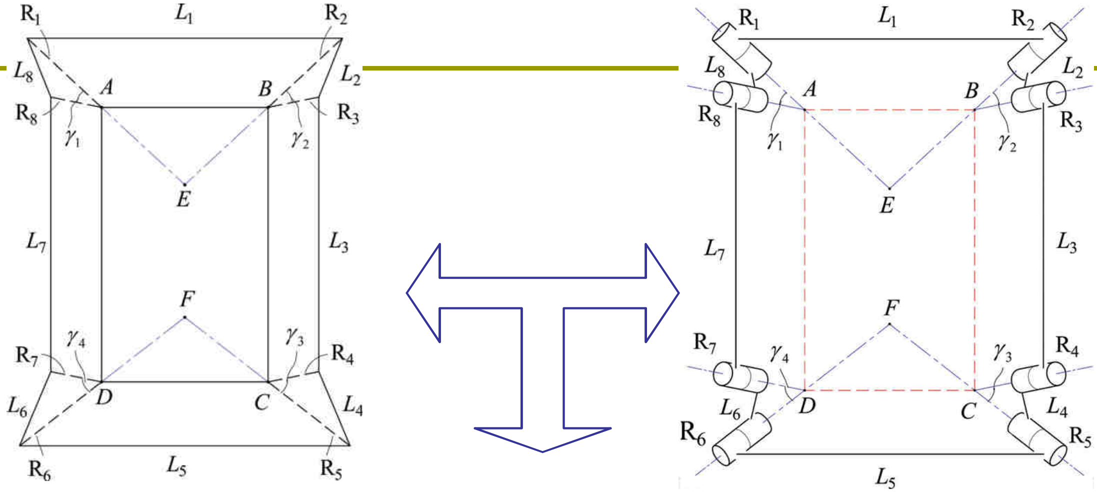
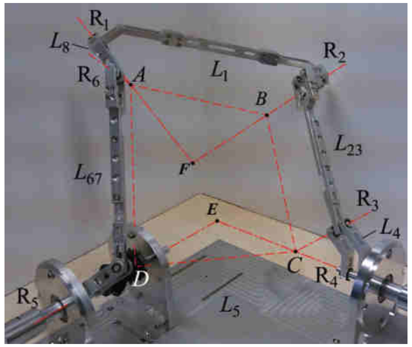
Kinematics Entails Origami Robots

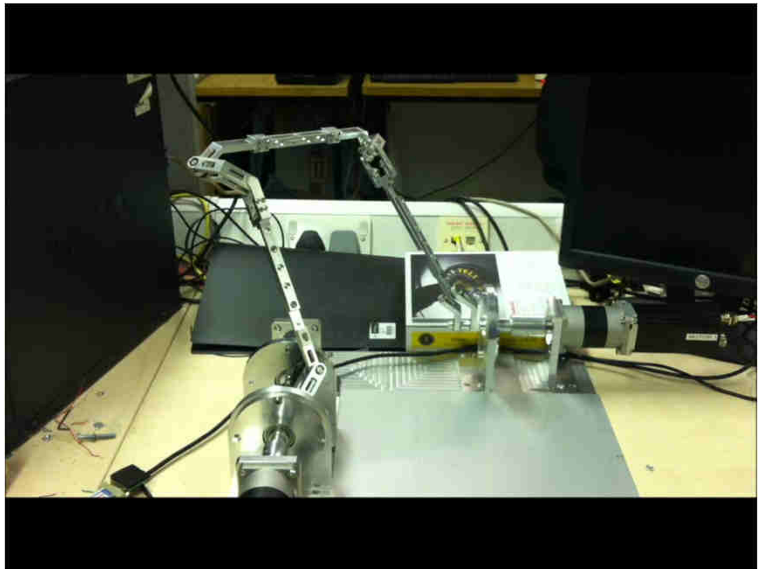
Innovative Robotics

Metamorphic 8R Linkage

Rotating cubes



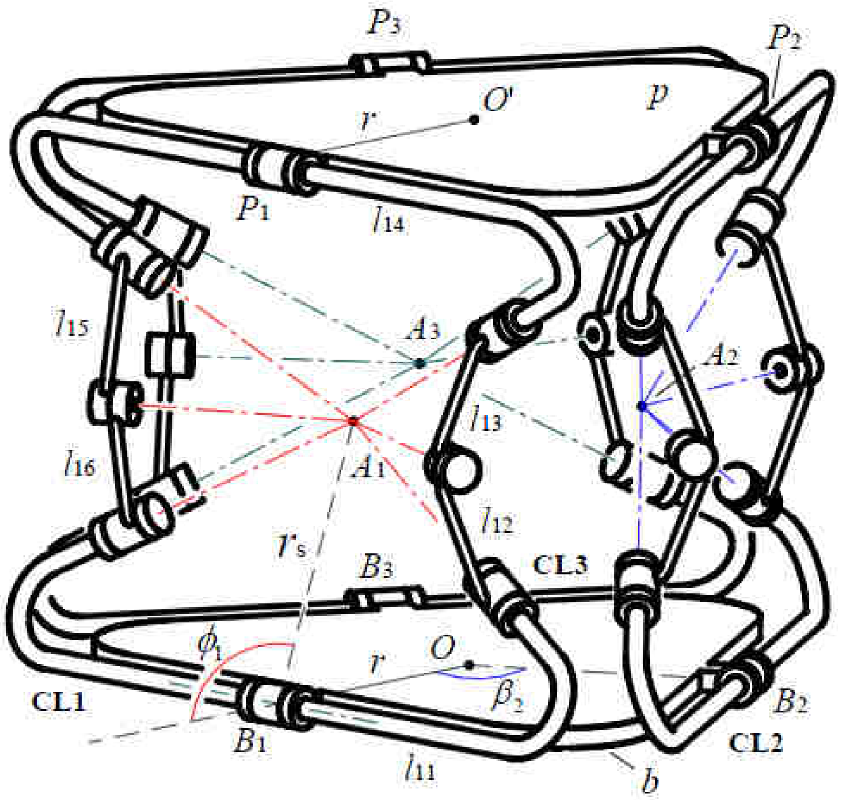




Dai and Rees Jones (1999), Mobility in metamorphic mechanisms of foldable/erectable kinds, *J. Mechanical Design*, **121**(3):375-382.
Zhang, K. and Dai, J.S., Screw-system-variation enabled reconfiguration of the Bennett plano-spherical hybrid linkage and its evolved parallel mechanism, *Journal of Mechanical Design, Trans. ASME*, **137**(7), 2015.

Novel 3-DOF parallel mechanism

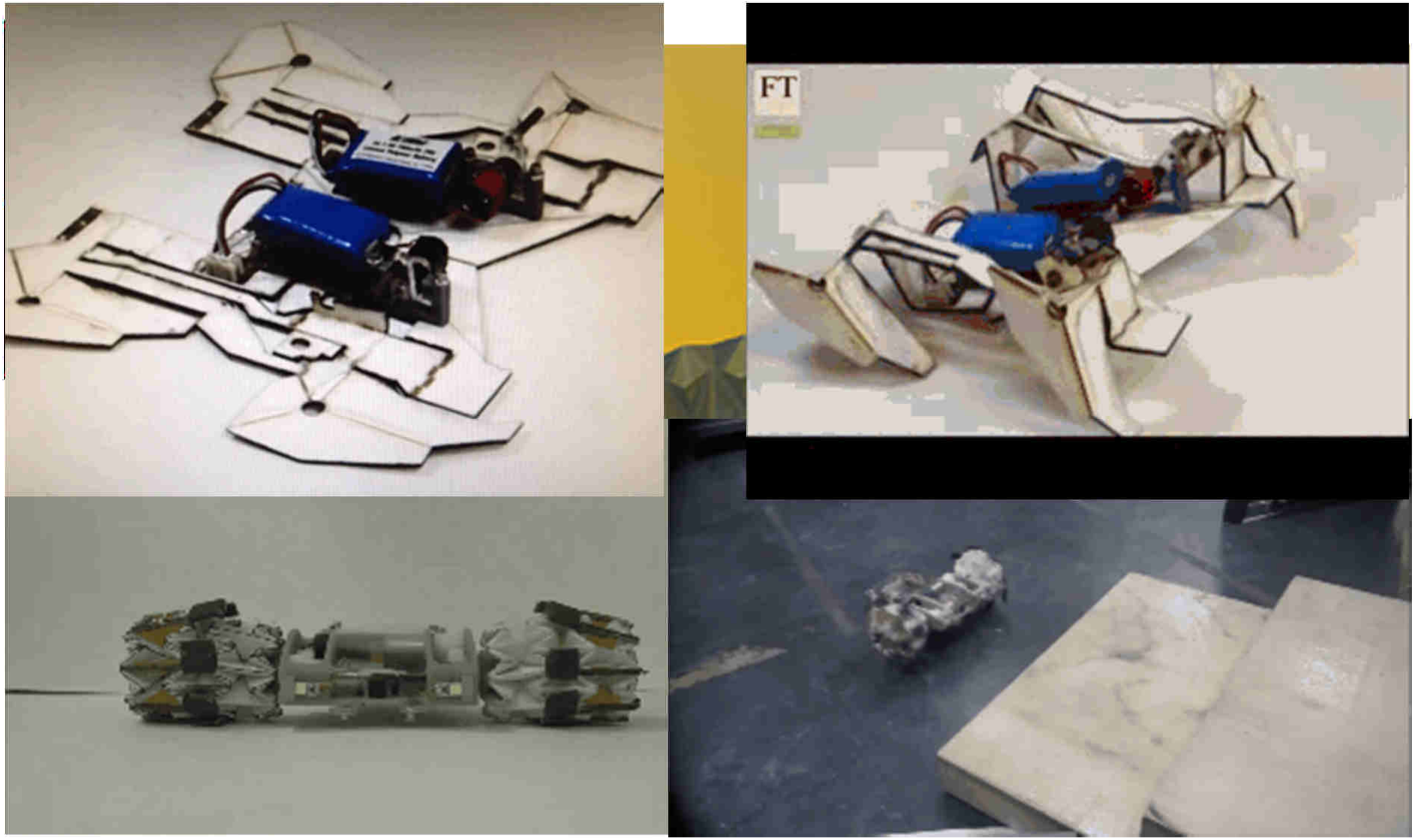
3-Spherical kinematic chain based parallel mechanism



Dai and Rees Jones (1999), Mobility in metamorph l
Design, **121**(3):375-382.

Ketao Zhang, J. S. Dai, Yuefa Fang, 2010, Topology and Constraint Analysis of Phase Change in the Metamorphic Chain and Its Evolved Mechanism, *ASME Transactions*, *Journal of Mechanical Design*, **132**(12), p. 121001-1.

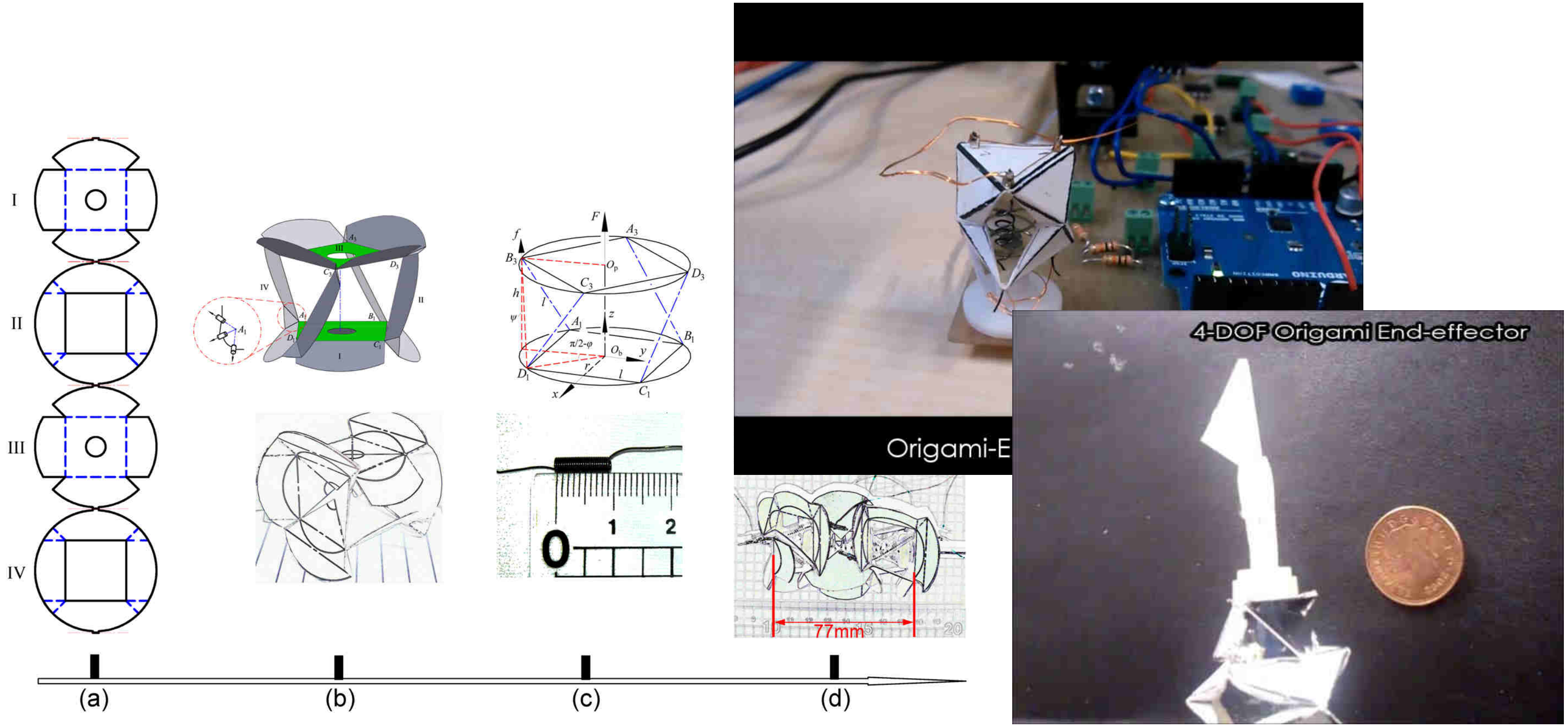
Howard Robots



Origami Robots

Origami Medical Robot

System integration of a milli-scale end-effector

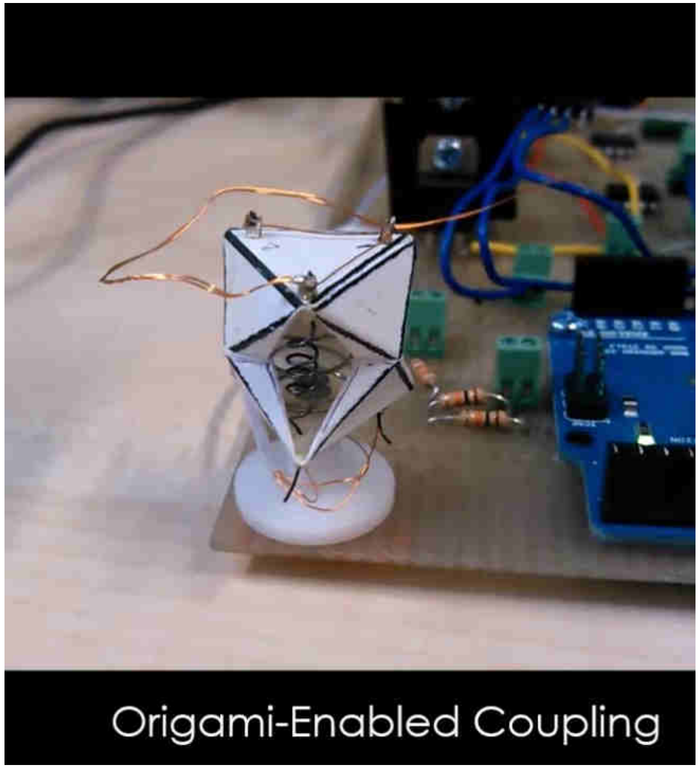


K. Zhang, C. Qiu, J.S. Dai, 2015, Helical Kirigami-Enabled Centimetre-Scale Worm Robot with Shape-Memory-Alloy Actuators, **Trans. ASME J. Mech. Rob.**, 7(2), 021014.

Salerno, Zhang, Menciassi, Dai (2016) A novel 4-DOF Origami grasper with a SMA-actuation system for minimally invasive surgery, *IEEE Trans Rob* (in press), based on Salerno, Zhang, Menciassi, Dai (2014), *2014 IEEE ICRA2014*, Hong Kong.

Origami Medical Devices

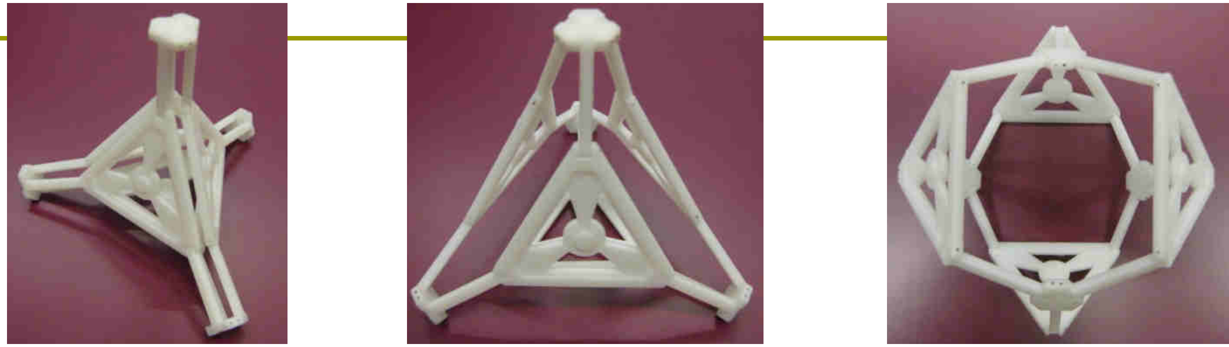
System integration of a milli-scale end-effector



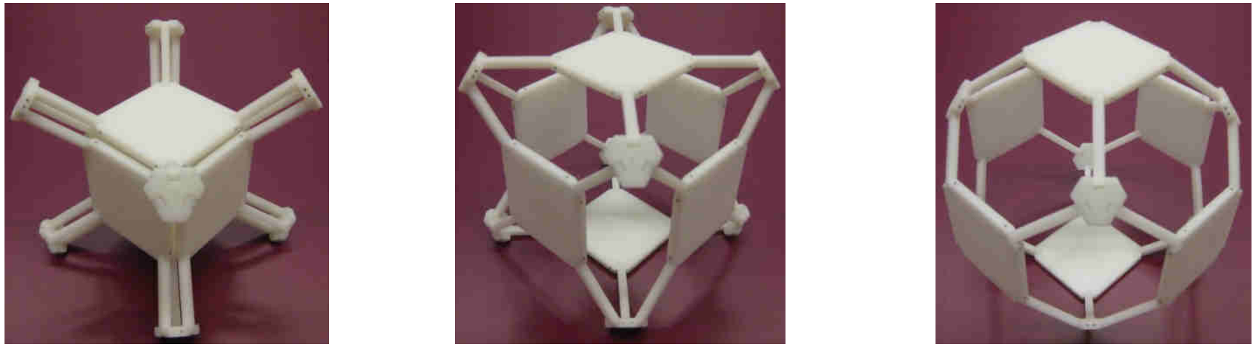
Salerno, Zhang, Menciassi, Dai (2016) A novel 4-DOF Origami grasper with a SMA-actuation system for minimally invasive surgery, *IEEE Trans Rob* (in press), based on Salerno, Zhang, Menciassi, Dai (2014), *2014 IEEE ICRA2014*, Hong Kong.

Zhang, M. Salerno and J.S. Dai, 2014, Origami-Inspired SMA Actuated Constant Velocity Coupling for Dexterous Telesurgical Robot and Self-Morphing Medical Robots, *7th Hamlyn Symposium on Medical Robotics*, Imperial College London, UK, p.30. (Best poster award)

Arts to Deployable



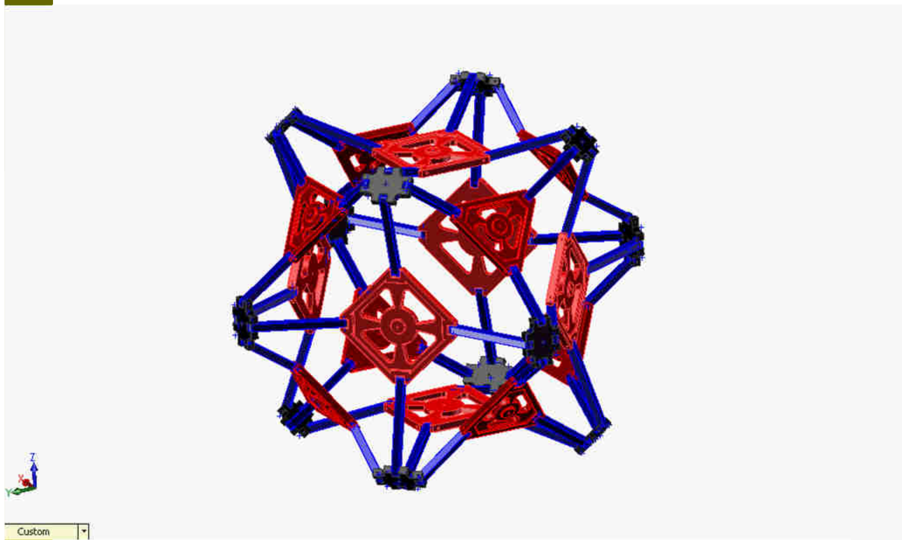
Prototype of a deployable tetrahedral mechanism

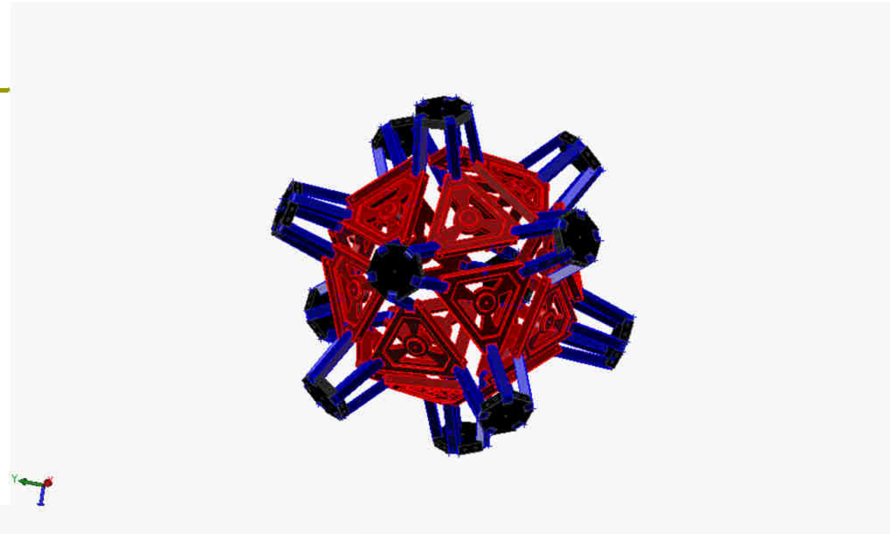


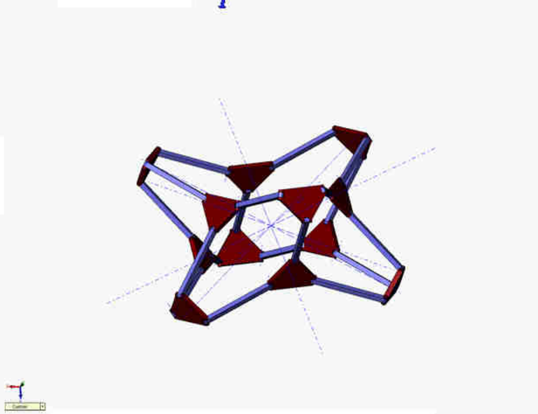
Prototype of a deployable hexahedral mechanism

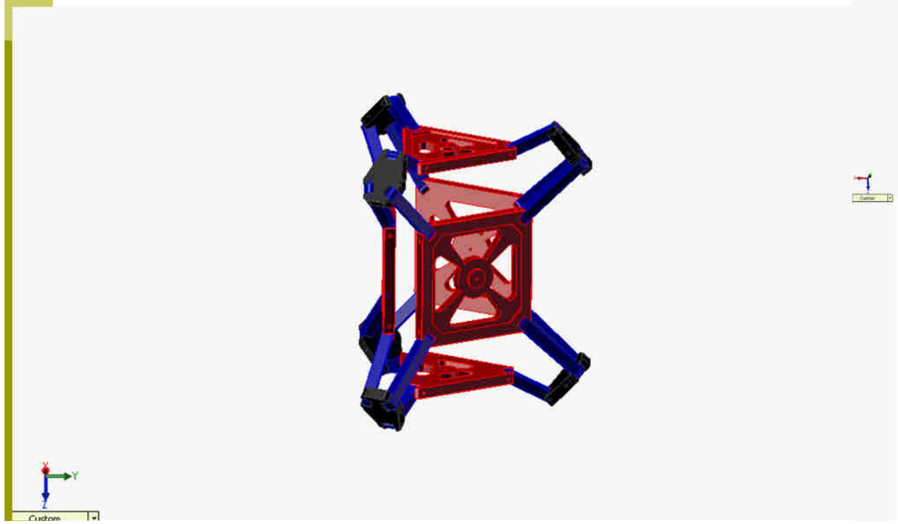
Wei, G., Chen, Y. and Dai, J. S. (2014) Synthesis, mobility and multifurcation of deployable polyhedral mechanisms with radially reciprocating motion, **Journal of Mechanisms and Robotics, Trans. ASME**, **136**(9): 091003.

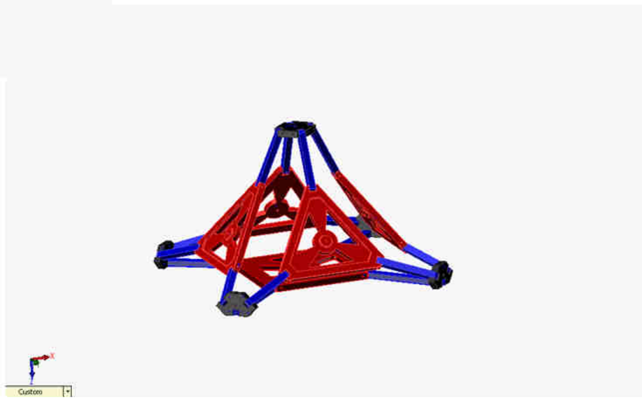
Deployable Platonic Solids









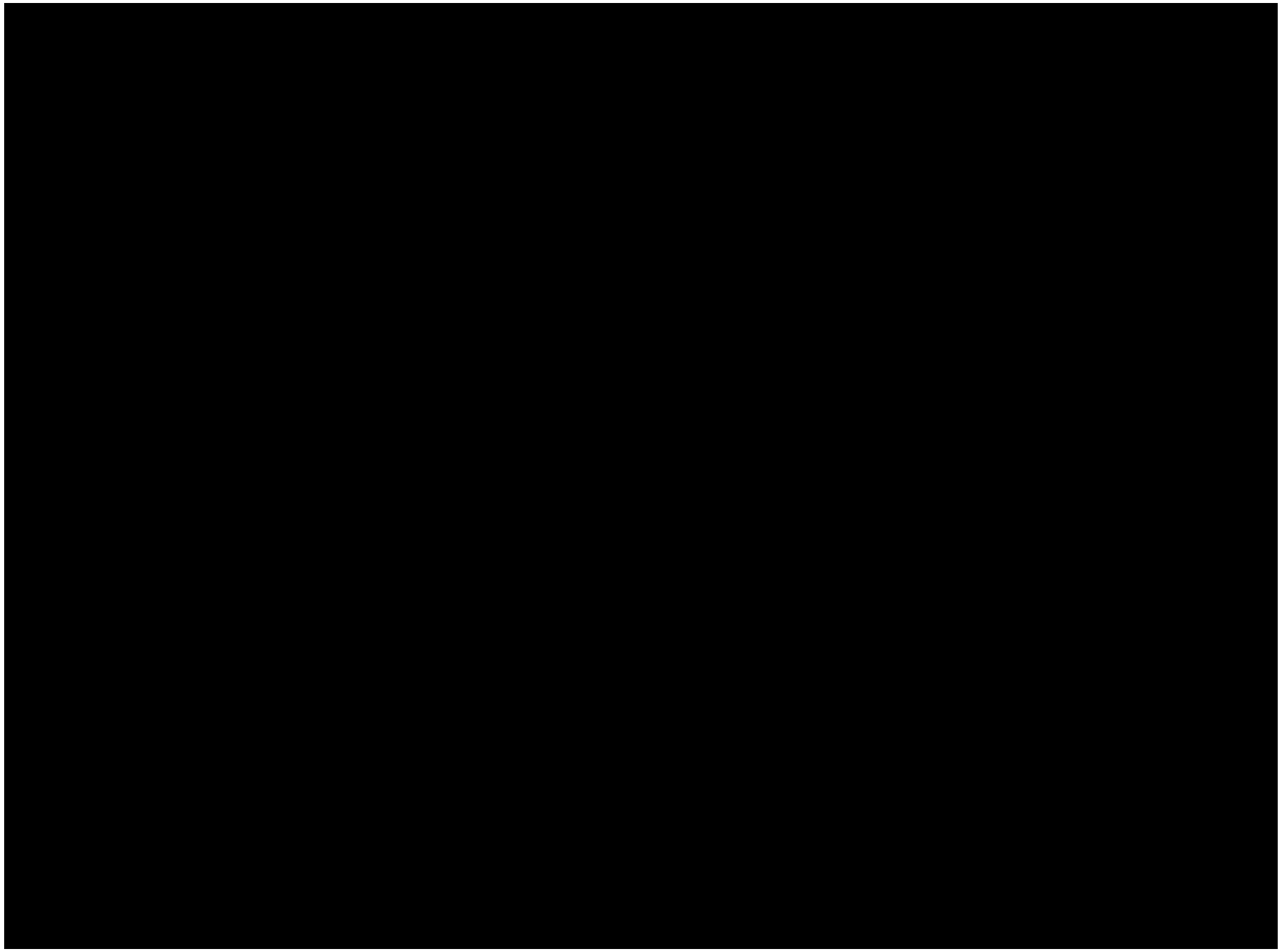


Kinematics Entails Reconfigurable Mechanisms and Robots

Philosophy

Artmimetics
Metamorphosis
Reconfiguration

Reconfigurable Mechanisms and Robots



Metamorphosis

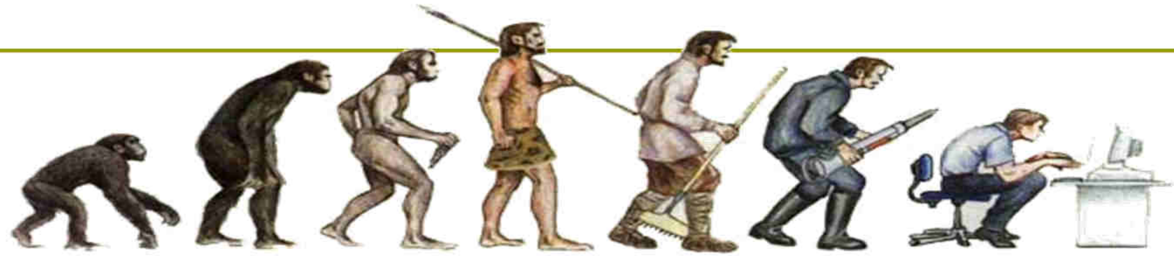
A new way of
mechanism and robot innovation

Dai and Rees Jones (1999), Mobility in metamorphic mechanisms of foldable/erectable kinds, *J. Mechanical Design*, **121**(3):375-382.

Dai and Gogu (2015), Editorial: Morphing, Metamorphosis and Reconfiguration through Constraint Variations and Reconfigurable Joints, *Mechanism and Machine Theory*, **96**(2):213-214 (Special Issue on Reconfigurable Mechanisms).

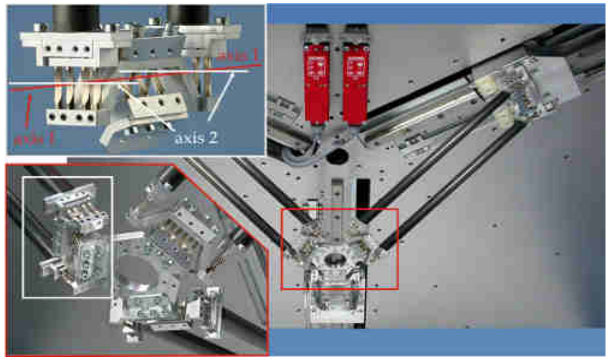
The Creation of Metamorphic Mechanisms: Evolution, Metamorphosis, Self-reconfiguration

Humankind Evolution



Interaction, self-reconfiguration, and reformation with and of the natural environment

Machine Reformation



Step change from simple task oriented machines into complicated task oriented robots

Metamorphic Mechanisms

1998: Dai and RJ revealed metamorphic mechanisms

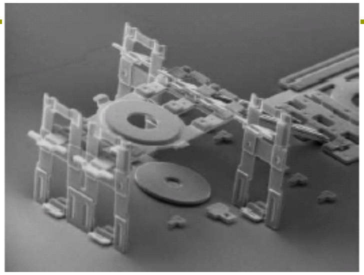
1999: Introduced into China as "变胞机构" with Qixian Zhang, fellow of CAS.

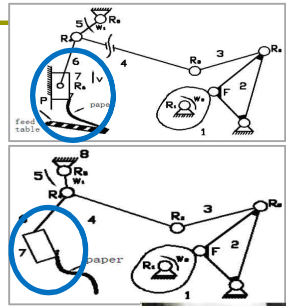
Conventional mechanisms: fixed mobility, fixed topology

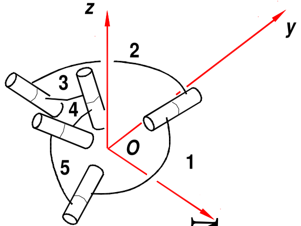
Conventional mechanisms: variable mobility, variable topology

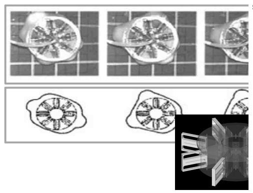
Multi-function machines adapted for multi-task environments (metamorphosis)

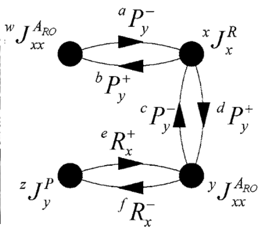
Philosophy of Mechanism Metamorphosis and Development Stages of Metamorphic Mechanisms

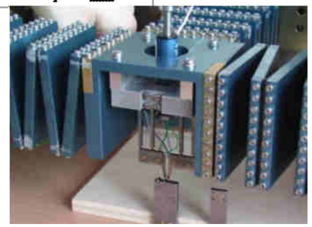


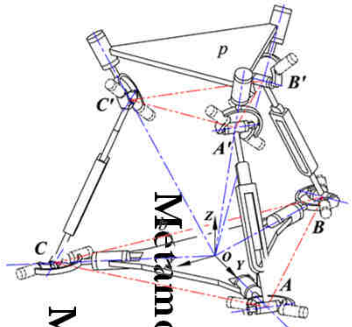












1996 — Automatic reconfigurable packaging system
J. Dai (Unilever)

1998 — Metamorphic mechanisms
J. Dai + J. Rees (DETC)
J. Dai, Q. Zhang

2003 — Metamorphic underwater vehicle
I. M. Chen

2005 — Metamorphic process for compliant mechanism manufacturing
L. Howell (BYU)

2006 — Mechanisms with variable topologies
H. Yan (JMD)

2009 — ReMAR 2009

2010 — Metamorphosis for a sheet transfer system
Shi, Zhang

2011 — Microassembly robot with metamorphic gripper
Giorgio Bozzini

2012 — ReMAR 2012
Metamorphic parallel mechanisms
Zhang, Dai
Gan, Dai

2014 — Metamorphic origami robot
Felton, Tolley

2015 — ReMAR 2015

2016 — Special Issue of MMT on Reconf Mechansms
Dai and Gogu

Historical Review of Metamorphic Mechanisms

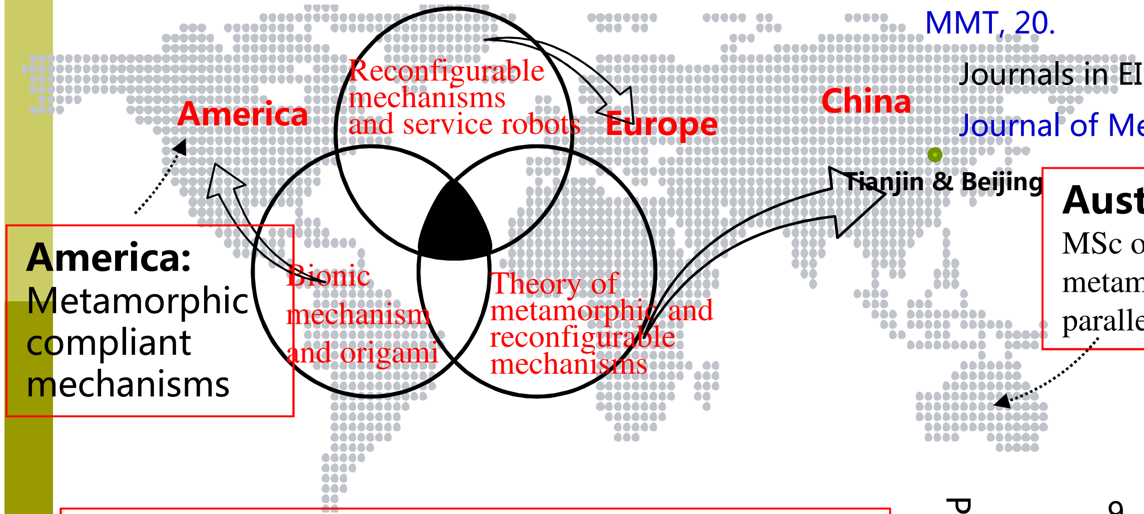
Metamorphosis and Reconfiguration

1. Being extensively researched from being launched in 1998

2. Initiating the IEEE/ASME International Conference on Reconfigurable Mechanisms and Robots

3. Opening an avenue for mechanism research and being a main research field of international journals

Distribution of the research on metamorphic mechanisms throughout the world



- **France and Australia:**

MSc on metamorphic parallel robots

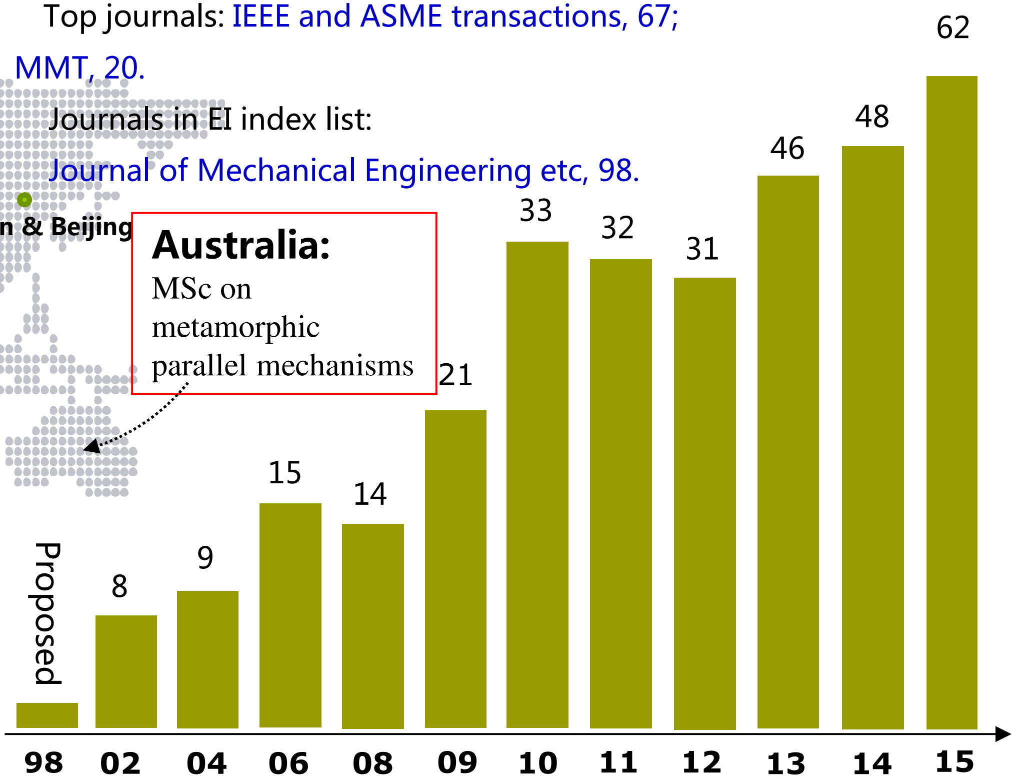
- **Italy:** Metamorphic gripper
- **Europe:** Reconfigurable factory in near future

□ The state-of-the-art in the international research community

Top journals: IEEE and ASME transactions, 67; MMT, 20.

Journals in EI index list:

Journal of Mechanical Engineering etc, 98.



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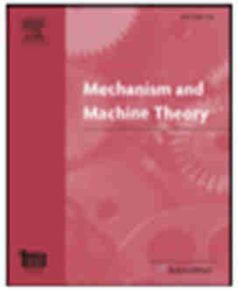

Editorial

Special Issue on Reconfigurable Mechanisms: Morphing, Metamorphosis and Reconfiguration Through Constraint Variations and Reconfigurable Joints

CrossMark

Richness and broadness of the mechanisms world embraces more and more novel mechanisms which constitute a trend of reconfigurable mechanisms.

In their merit of reconfigurability, two typical types of innovative mechanisms as kinematotropic mechanisms and metamorphic mechanisms were explored in the 1990s. In these two types of mechanisms, the former changes mobility without resort to topology change, the latter changes mobility by resort to change of mechanism topology or change of connectivity of mechanism links.

The good coverage and rich materials of the reconfigurable mechanisms and their principle and techniques in reconfiguration in this special issue would provide a useful reference for investigating, developing and analyzing mechanisms with reconfigurability, paving a foundation of further study of reconfigurable mechanisms.

Jian S. Dai

Grigore Gogu

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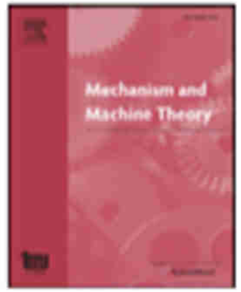


Systematization of morphing in reconfigurable mechanisms

F. Aimedee [a], G. Gogu [a], J.S. Dai [b,*], C. Bouzgarrou [a], N. Bouton [a]

[a] Institut Pascal, UMR 6602 UBP/CNRS/IFMA, Campus des Cézeaux, 63175 Aubière, France
[b] Centre for Robotics Research, King's College London, University of London, Strand, London WC2R 2LS, UK

A R T I C L E I N F O

Available online 11 August 2015

Keywords:
Metamorphic mechanisms
Reconfigurable mechanisms
Reconfigurability
Parallel mechanisms
Morphing
Geometry
Bifurcation
Multi-furcation
Mechanisms
Motions
Review
Systematization

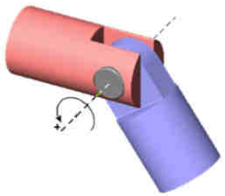
A B S T R A C T

This paper addresses metamorphic and reconfigurable mechanisms based on types of morphing and ways of achieving it through a comprehensive review and a classification of mechanisms in the literature while considering various types of morphing. The morphing process in terms of its topological and geometrical properties is systematically classified. It is found that there are certain ways of achieving reconfigurability through morphing. These include change of relative positions and orientations of links and joints, change of topology and geometry of kinematic chains, change of furcating branches of a mechanism and switch of idle and active joints, subsequently resulting in change of connectivity and mobility. All these ways of morphing are categorized in this paper as topological morphing, geometrical morphing and furcating morphing. The paper hence reveals intrinsic characteristics of the morphing process and presents the relationship between morphing and mechanism and motion types, presenting a rich reference for the study of reconfigurable mechanisms.

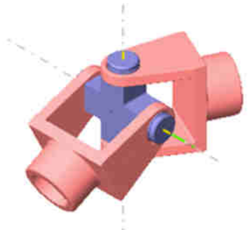
Kinematics Entails Reconfigurable Mechanisms and Robots

Reconfigurable Joints and Robots

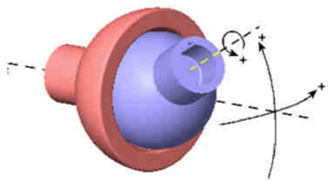
Variable-axis(vA) Joint



R – revolute



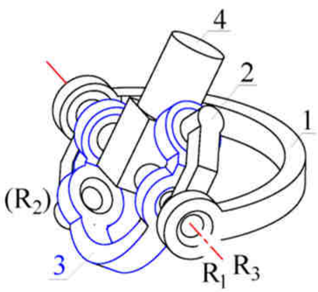
U – universal



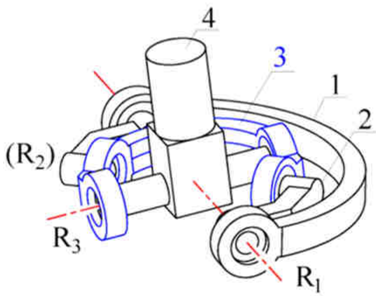
S – spherical

Link | Phase	R	U	S
Link 2	a	a	a
Link 3	i/a	i/a	a

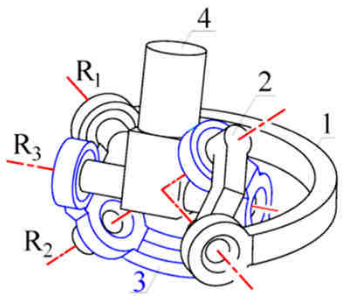
a – active, i – inactive



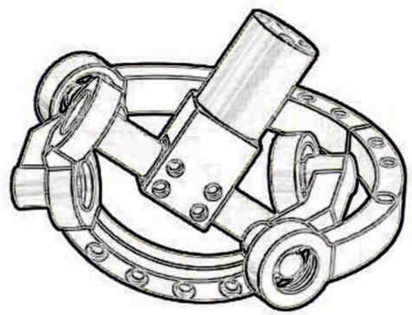
Phase R



Phase U



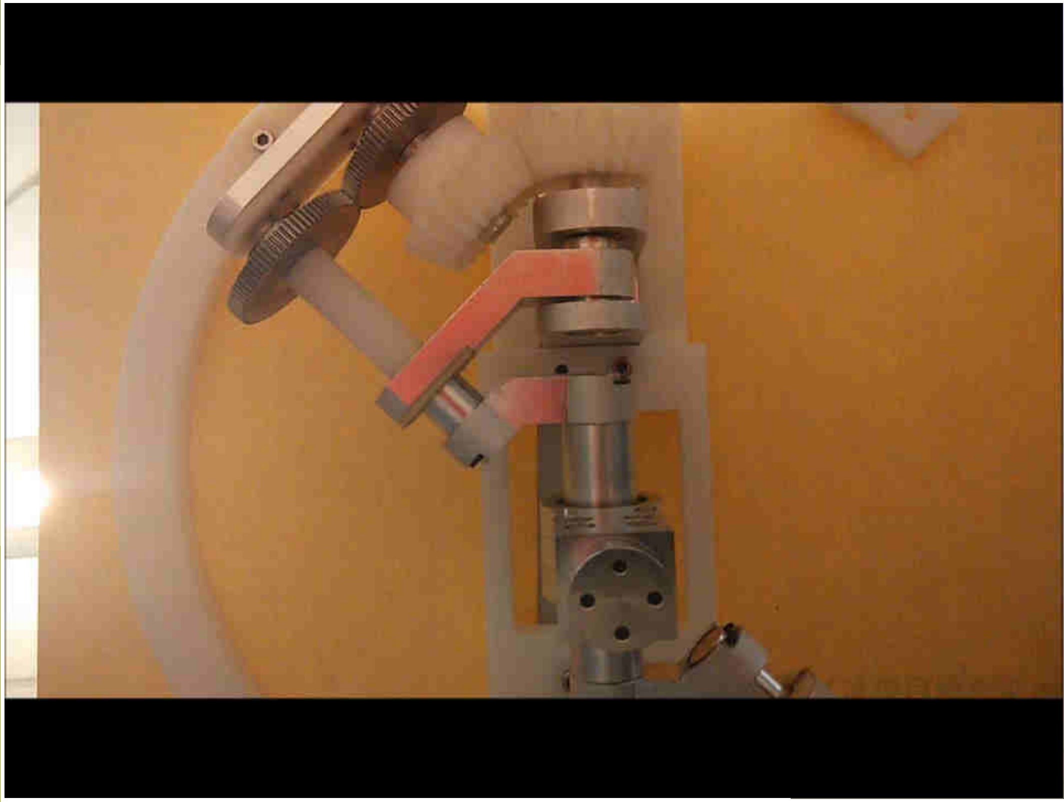
Phase S

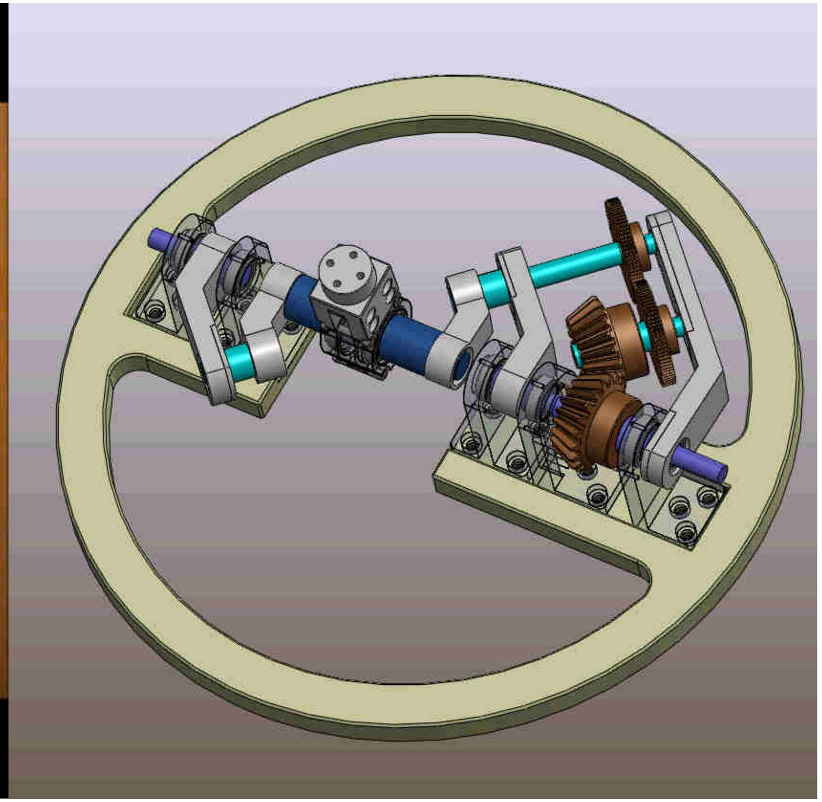


vA joint in phase S

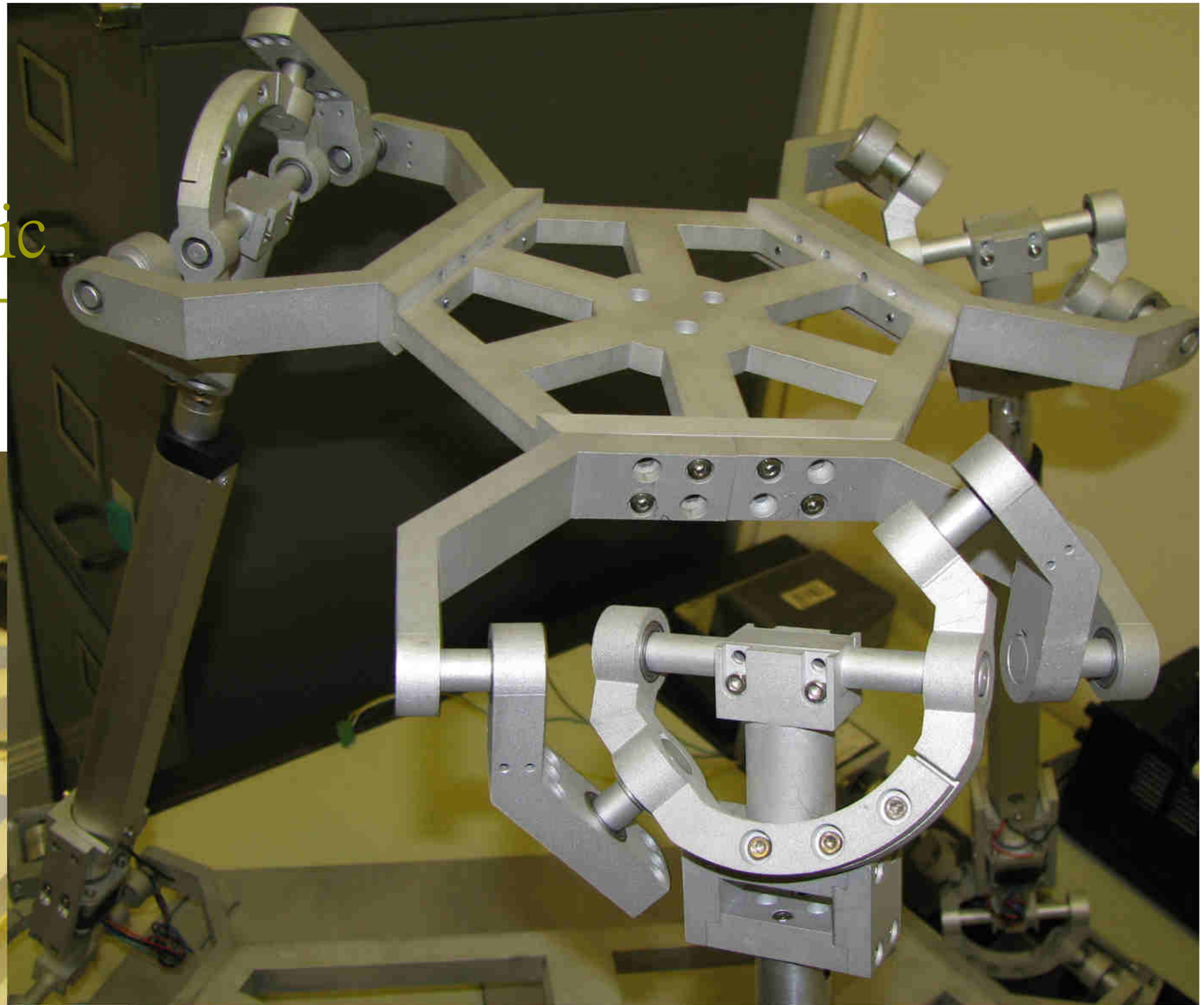
K. Zhang, J.S. Dai, Y. Fang, 2010, Topology and Constraint Analysis of Phase Change in the Metamorphic Chain and Its Evolved Mechanism, *Trans. ASME J. Mech. Des.*, **132**(12), p. 121001-1.

Variable-axis(vA) Joint





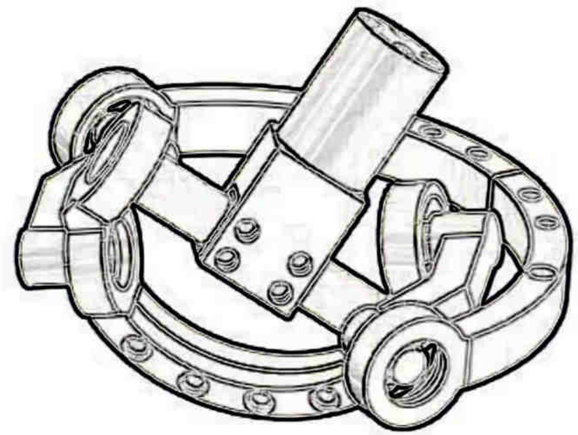
vA joint metamorphic parallel mechanism



Gan, D., Dai, J.S., and Liao, Q, Mobility Change in Two Types of Metamorphic Parallel Mechanisms, *Transactions of the ASME: Journal of Mechanisms and Robotics*, **1**(4), 041007_1-9, 2009.

Parallel Robot

Variable-axis joint and evolved parallel robot



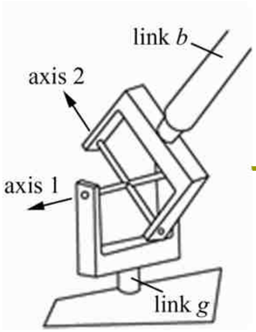
vA 变胞铰链 — 运动等效球副

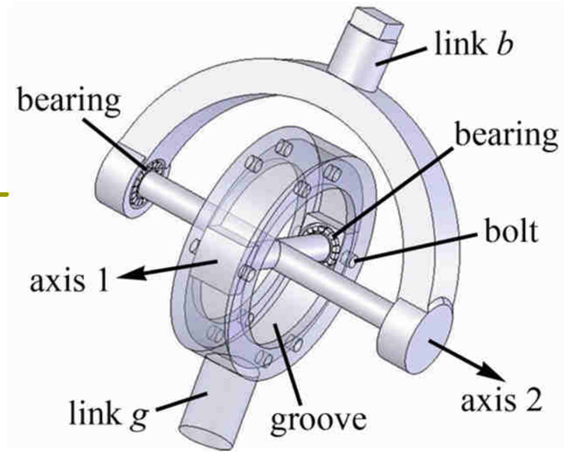
Reconfigurable parallel robot

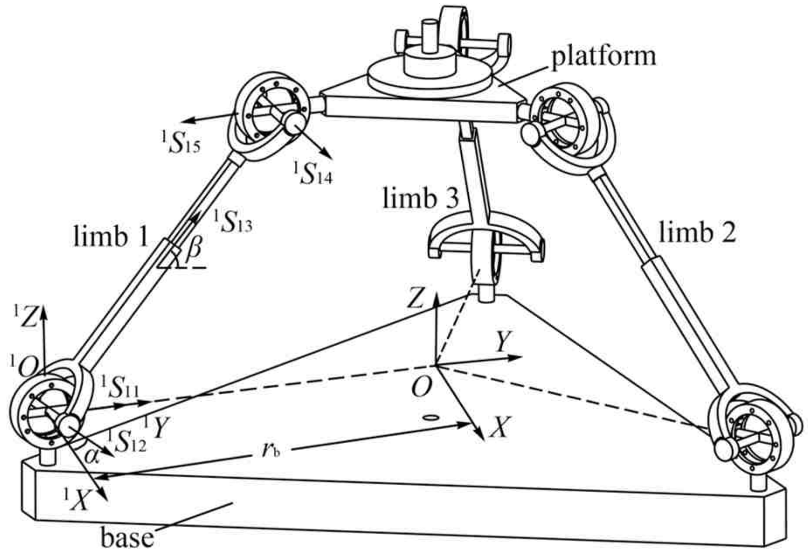
3E

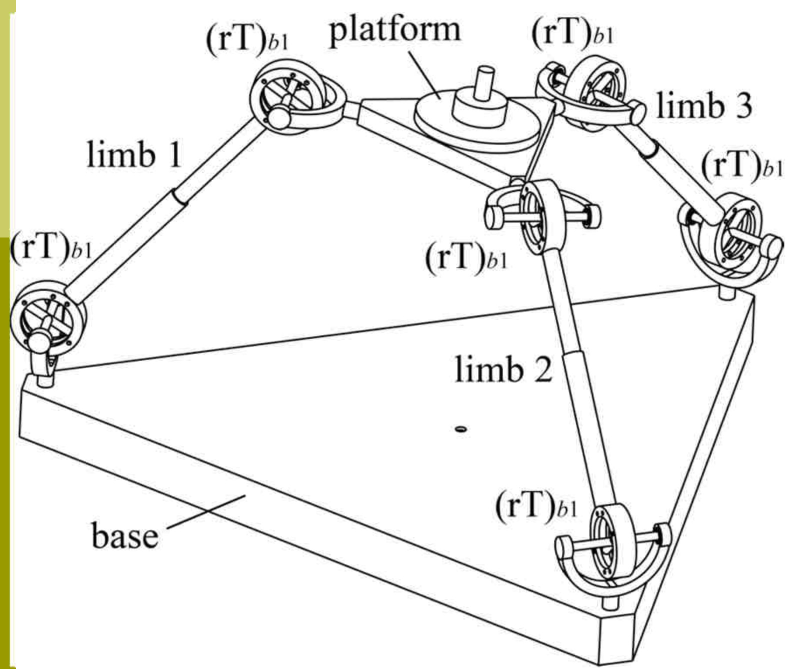
- **Efficiency**
- **Energy-Saving**
- **Economic**

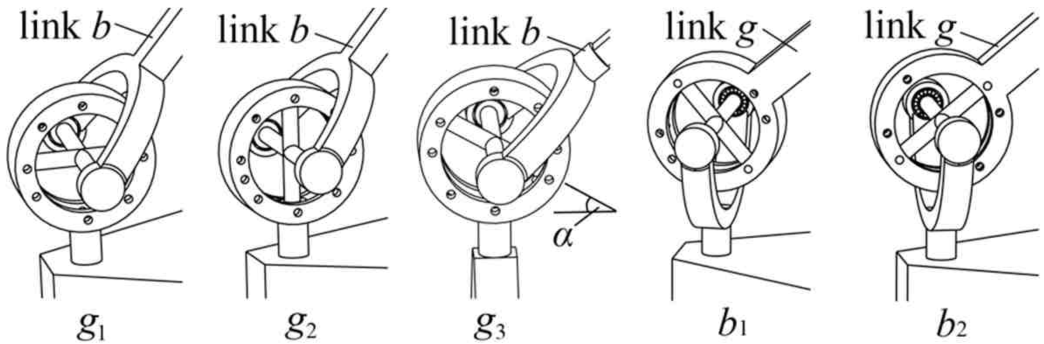
rT joint metamorphic parallel mechanism











Kinematics Entails Reconfigurable Mechanisms and Robots

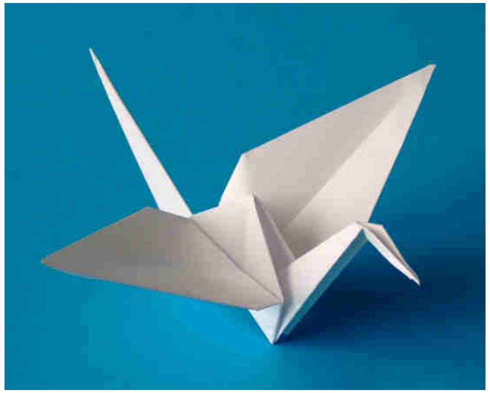
The Metamorphic Hand

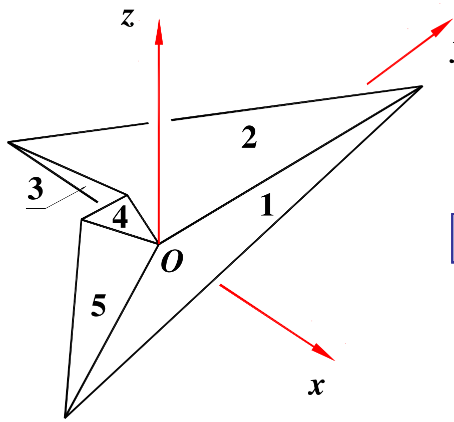
Origami

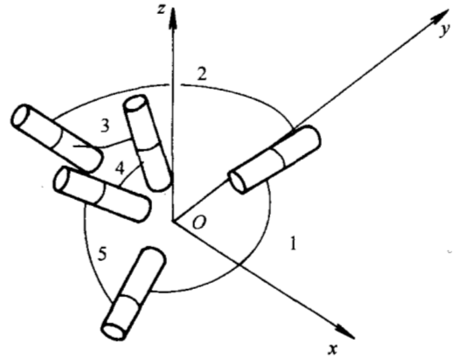
Metamorphosis

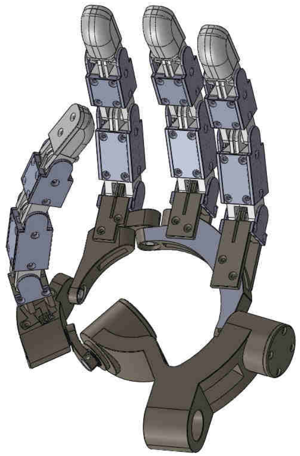
Art、Mathematics、Mechanisms、Robots

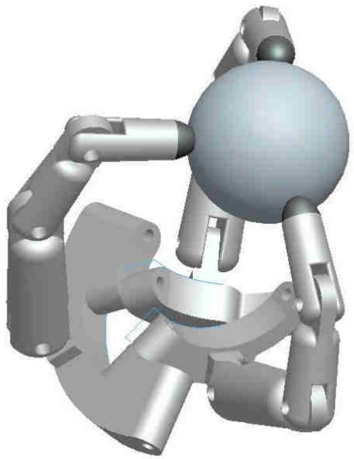
Evolution

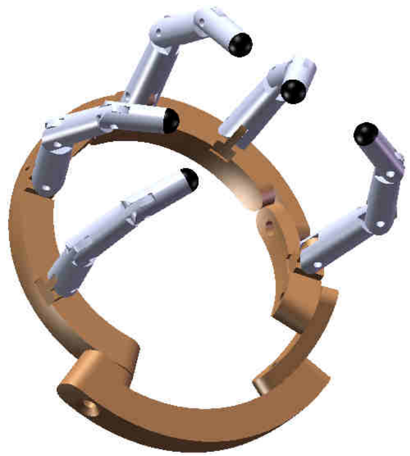








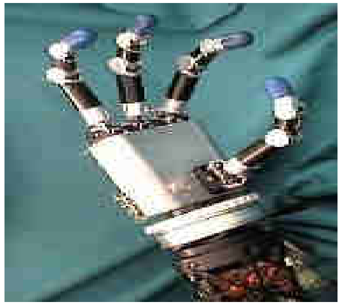


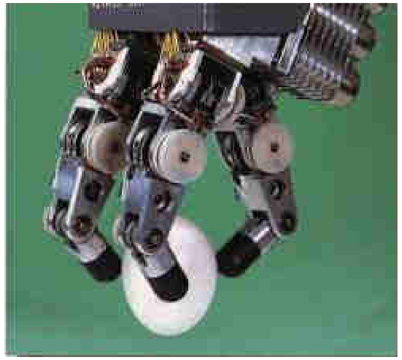


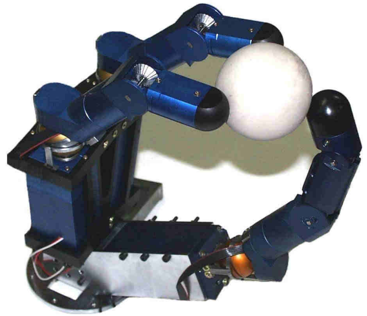
Origami to Robots:

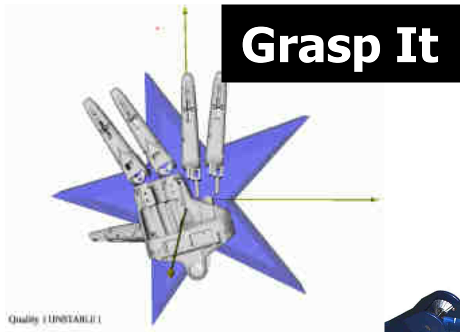
Dai and Rees Jones (1999), Mobility in metamorphic mechanisms of foldable/erectable kinds, *J. Mechanical Design*, **121**(3):375-382.

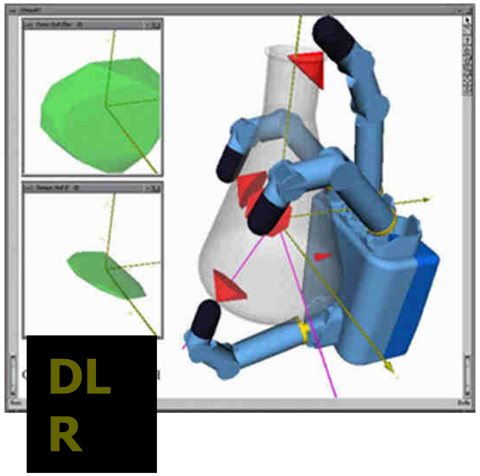
Conventional Robotic Hands

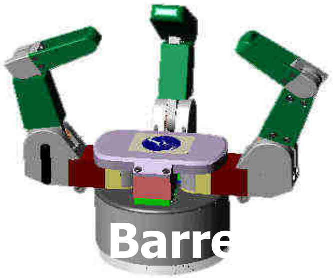


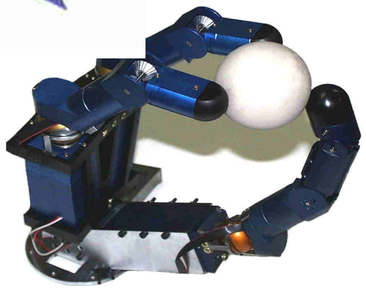










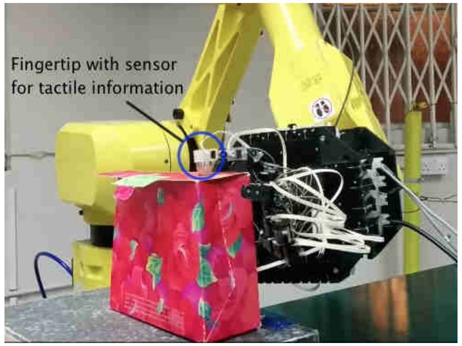


Dai, Wang, Cui (2009), Orientation and workspace of the multifingered metamorphic hand - Metahand, *IEEE Trans Rob*, **25**(4):942-947.
Cui and Dai (2010), A Darboux-frame-based formulation of spin-rolling motion of rigid objects, *IEEE Trans Rob*, **26**(2):383-388.

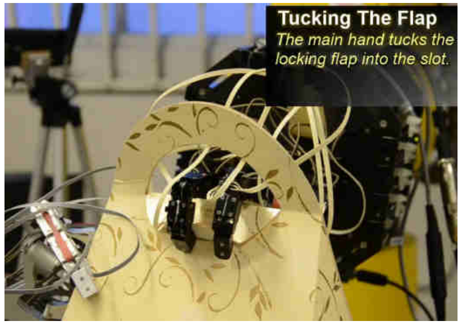
Metamorphic Hand for Dexterous Manipulation

In-hand manipulation

Origami-folding



Folding articulated object



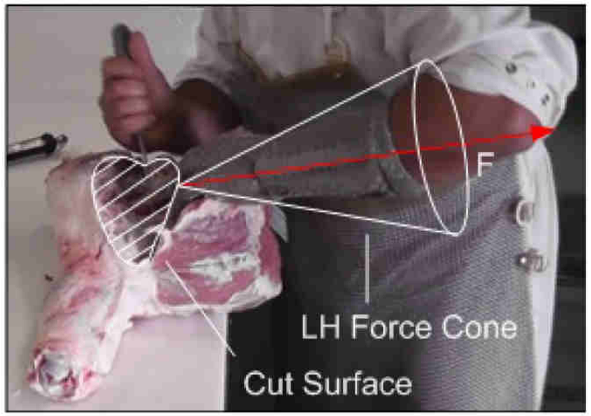
Two-hand cooperation

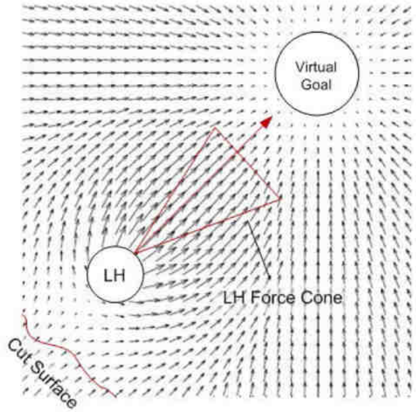
M. Salerno, K. Zhang, J. Paik, J.S. Dai, 2014, Underactuated Robotic Finger with Variable Stiffness, **IEEE Trans. Rob.** (in review)

Human-Robot Coop

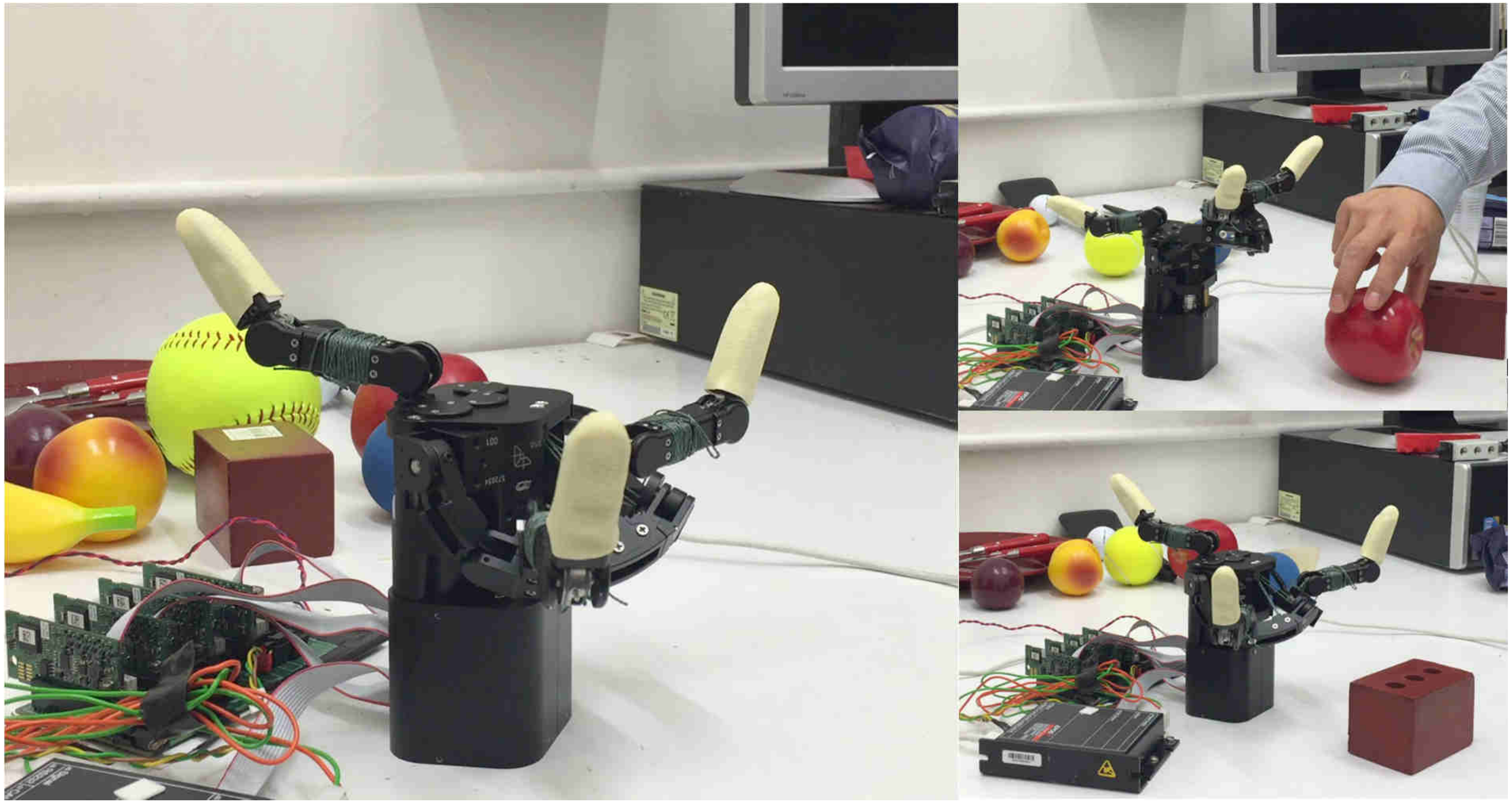
(a) 变胞机械手与Fanuc机械臂相结合进行生产

(b) 变胞机械手与ABB机械臂相结





Hand Testing



Metamorphic Hand

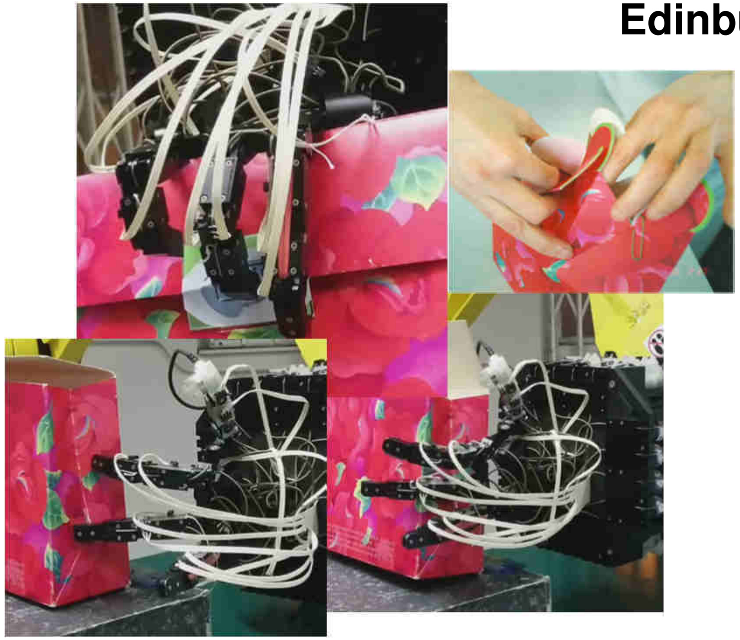
Wei, G., Dai, J. S., Wang, S., and Luo, H., 2011, Kinematic Analysis and Prototype of a Metamorphic Anthropomorphic Hand with a Reconfigurable Palm, International Journal of Humanoid Robotics, **8**(3), pp.459-479.

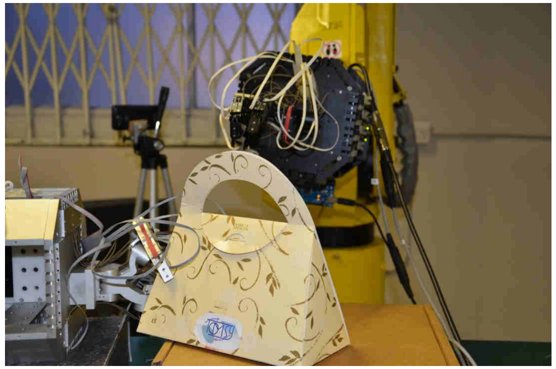
Metamorphic Hand for Dexterous Manipulation

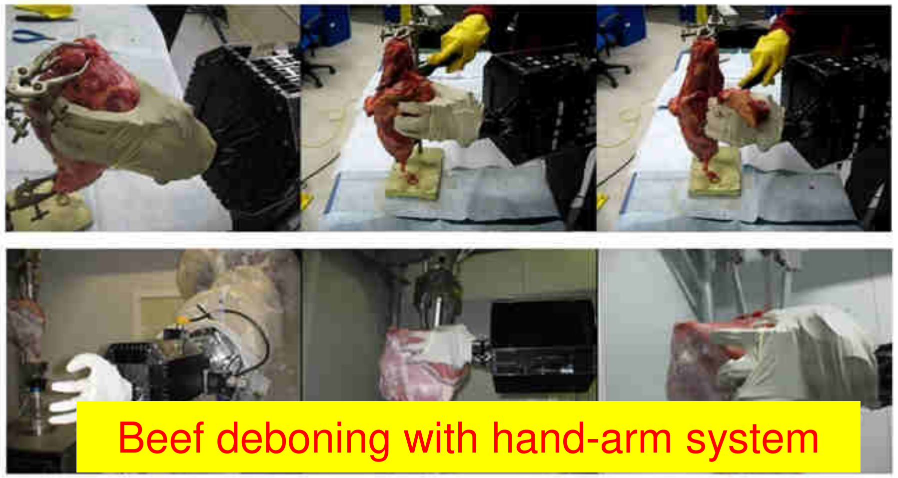
- **Variable palm DOF (5-4)**
- **Highly flexible**
- **High output force**
- **Extended workspace**

TOMSY - Collaborated with **KTH (Sweden), Berlin, Granada (Spain) and Edinburg**

ECORD - Collaborated with **IFMA (France) and Shadow Ltd (UK)**



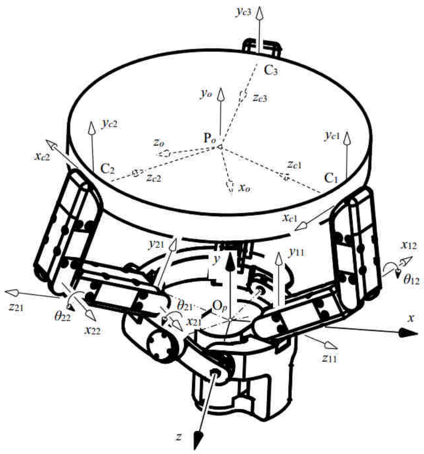


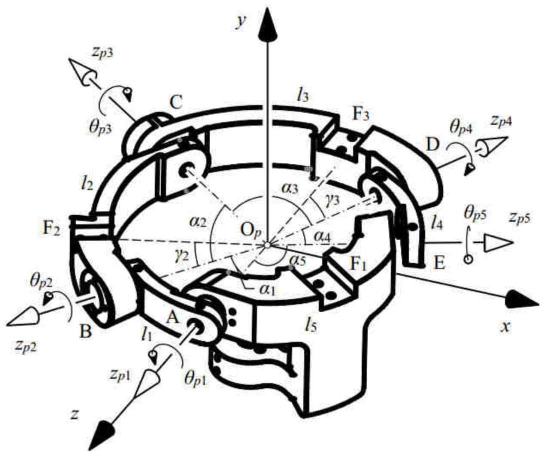


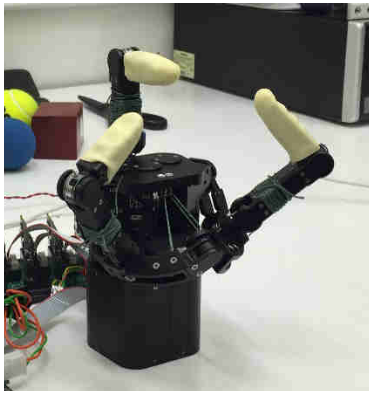
Wei, G., Stephan, F., Aminzadeh, V., Würdemann, H., Walker, R., Dai, J.S. and Gogu, G. (2014) DEXDEB -- Application of DEXtrous Robotic Hands for DEBoning Operation, in ***Gearing Up and Accelerating Cross-Fertilization between Academic and Industrial Robotics Research in Europe***, Rohrbein, F. et al. (Eds), Springer Tracts in Advanced Robotics 94, 217-235.

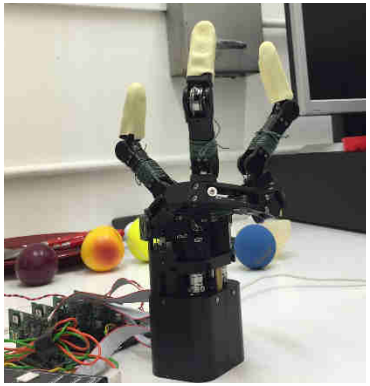
Metamorphic Hand for Education

The Metamorphic Hand









Human-Robot Happy Time

Metamorphic Hand for Education

human-robot interaction

Flexible arm
(King's & Festo)

Metamorphic hand
(King's)

Mobile base
(Festo)

Learning
(TUW & UIBK)

Computer Sci.
TUW (at)
UIBK (at)
ALU-FR (de)

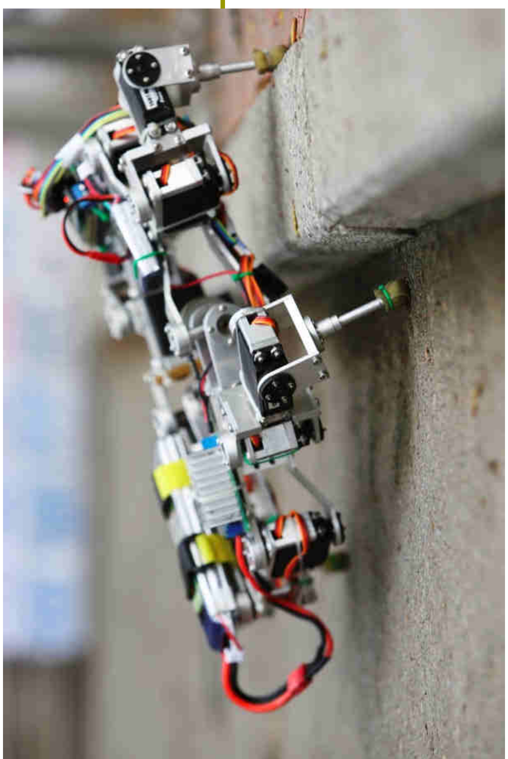
Robotics
King's (uk)
IPA (de)

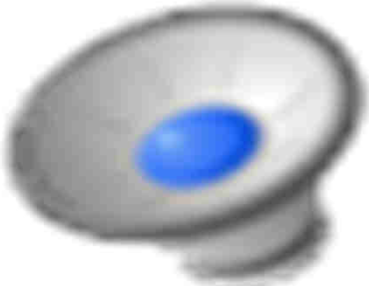
Industry
Festo (de)

End user
UT (nl)
IDMind (pt)
VPI (at)

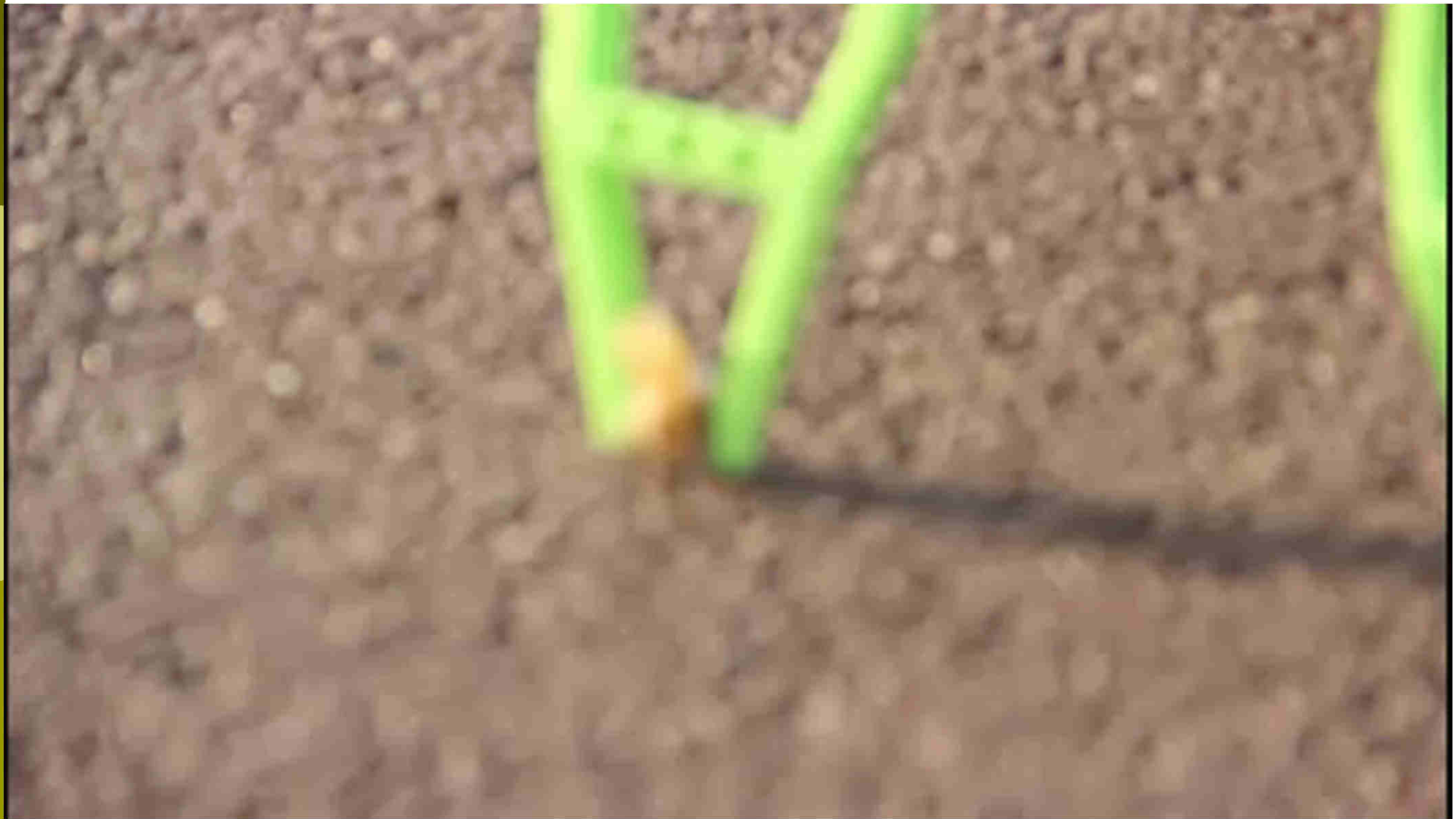
Kinematics Entails Reconfigurable Mechanisms and Robots

The Metamorphic Walker

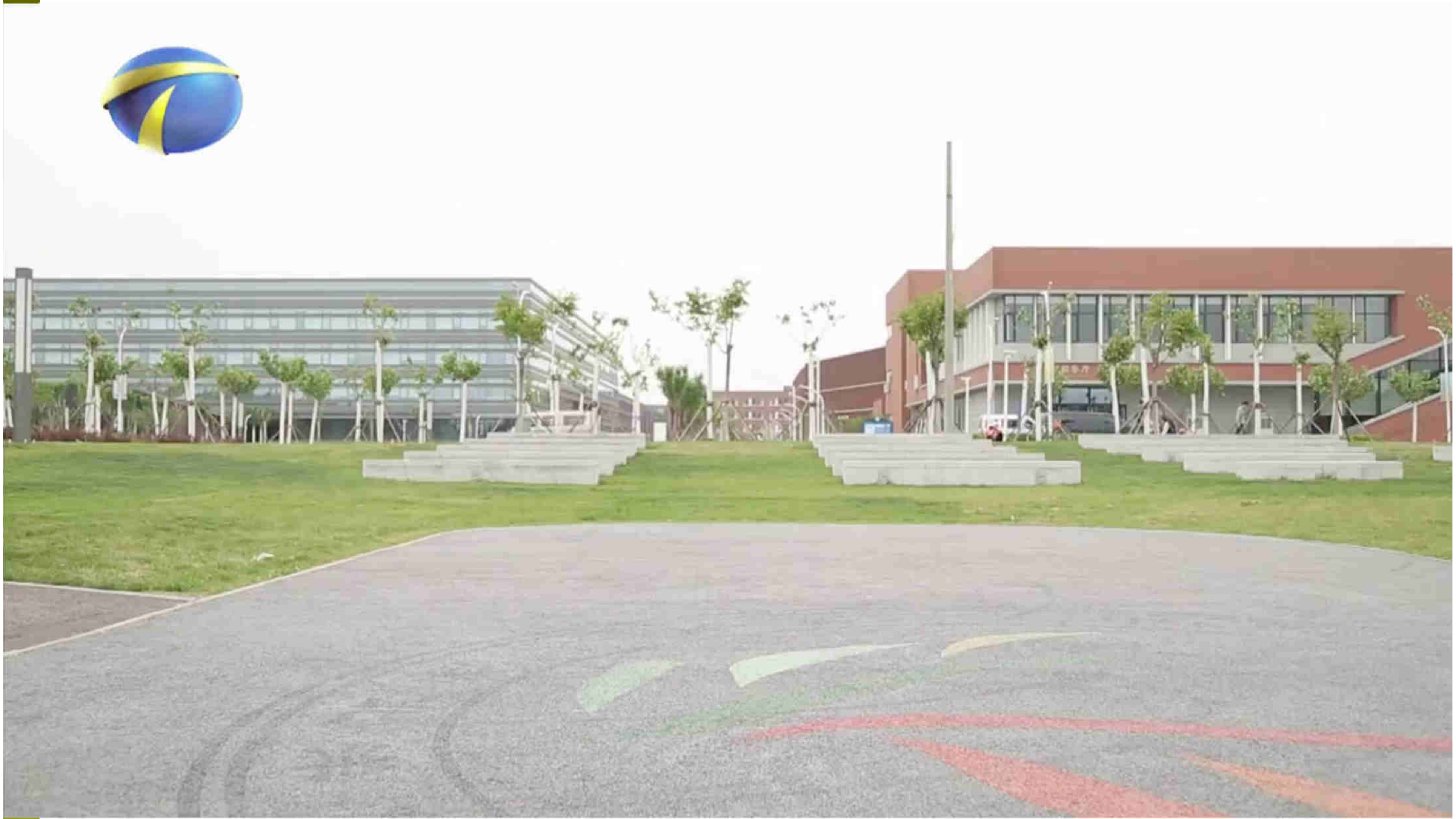




The Metamorphic Walker



The Metamorphic Walker



Kinematics Entails Reconfigurable Mechanisms and Robots

Reconfigurable Production

Reconfigurable Packaging and Reconfigurable Production

Dai and Rees Jones (1999), Mobility in metamorphic mechanisms of foldable/erectable kinds, *J. Mechanical Design*, **121**(3):375-382.

Dai, J.S. and Rees Jones, J., Kinematics and Mobility Analysis of Carton Folds in Packing Manipulation Based on the Mechanism Equivalent, **Journal of Mechanical Engineering Science, Proc, IMechE**, Part C, **216**(10): 959-970, 2002.

Liu, H. and Dai, J.S., An Approach to Carton-Folding Trajectory Planning Using Dual Robotic Fingers. **Robotics and Autonomous Systems**, **42**(1): 47-63, 2003.

Cannella, F. and Dai, J.S., Crease stiffness and panel compliance of carton folds and their integration in modelling, *Journal of Mechanical Engineering Science*, *Proc. IMechE*, **220**(6): 847-855, 2006

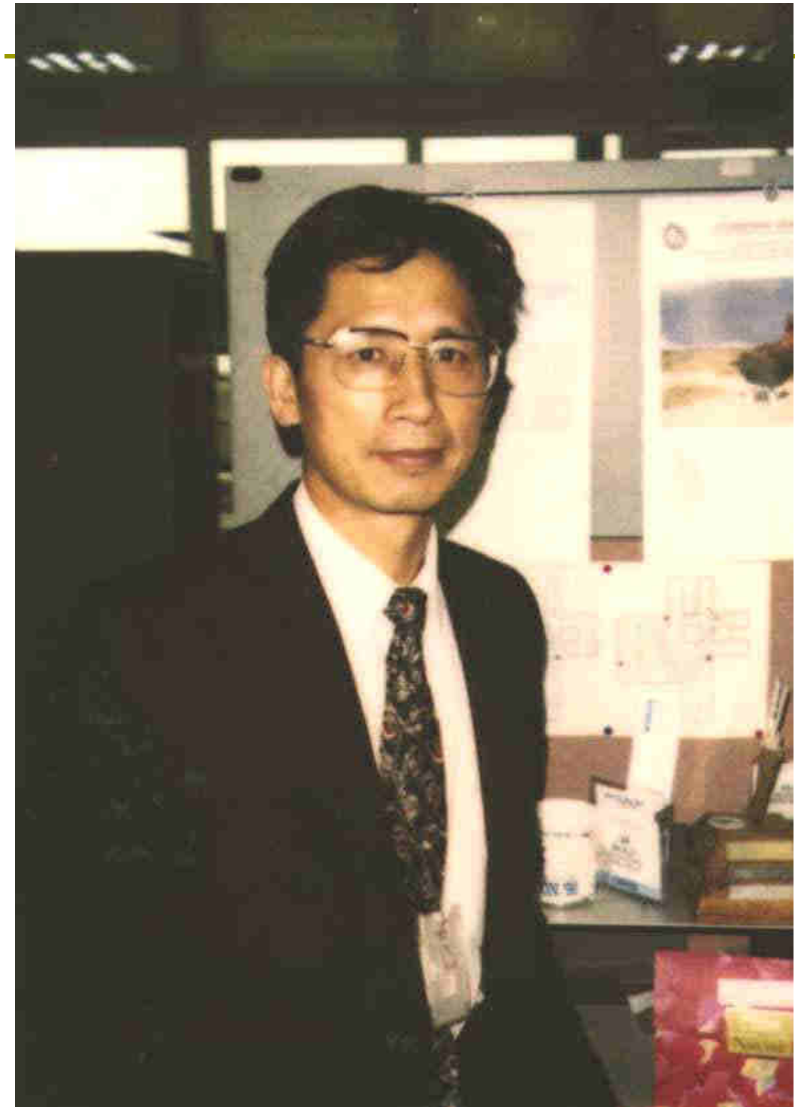
Dai and Caldwell (2010), Origami-based robotic packaging for food industry, *Trends in Food Science and Technology*, **21**(3):153-157.

Manipulation Task Analysis

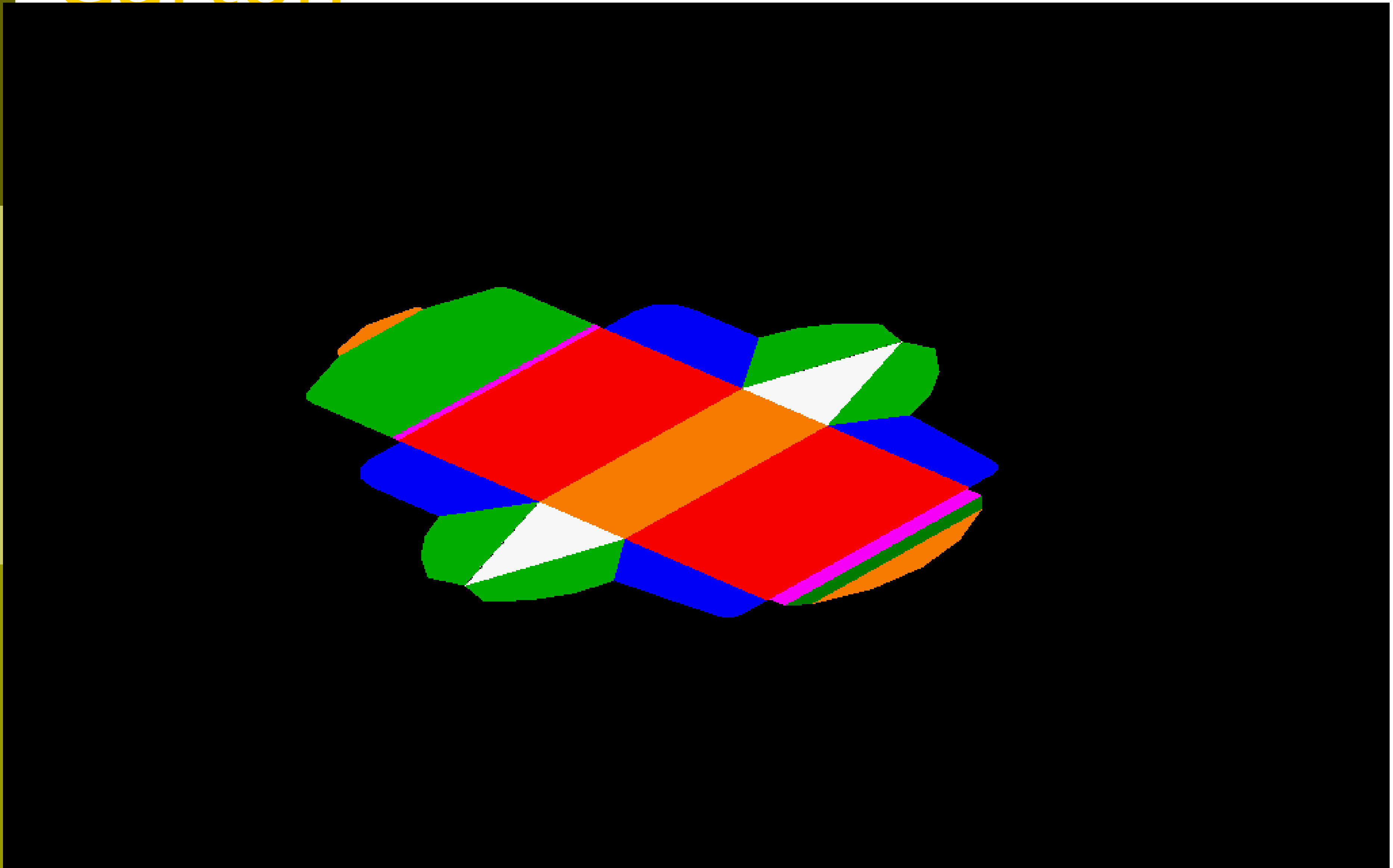
Dai, J.S. and Rees Jones, J., Kinematics and Mobility Analysis of Carton Folds in Packing Manipulation Based on the Mechanism Equivalent, **Journal of Mechanical Engineering Science, Proc, IMechE**, Part C, **216**(10): 959-970, 2002.

Liu, H. and Dai, J.S., An Approach to Carton-Folding Trajectory Planning Using Dual Robotic Fingers. **Robotics and Autonomous Systems**, **42**(1): 47-63, 2003.

Frustrated by the origami cartons

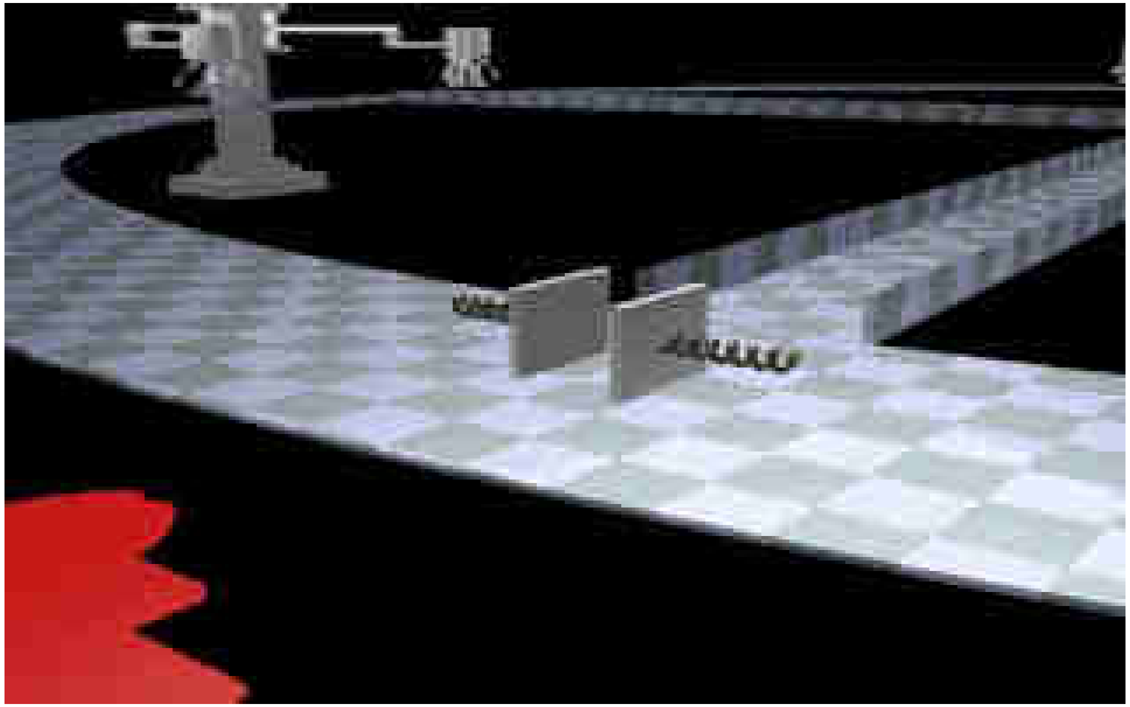


Manipulation: Origami Carton



Dexterous Human Hands

Intelligent Reconfigurable Packaging System



Dai and Caldwell (2010), Origami-based robotic packaging for food industry, ***Trends in Food Science and Technology***, **21**(3):153-157.

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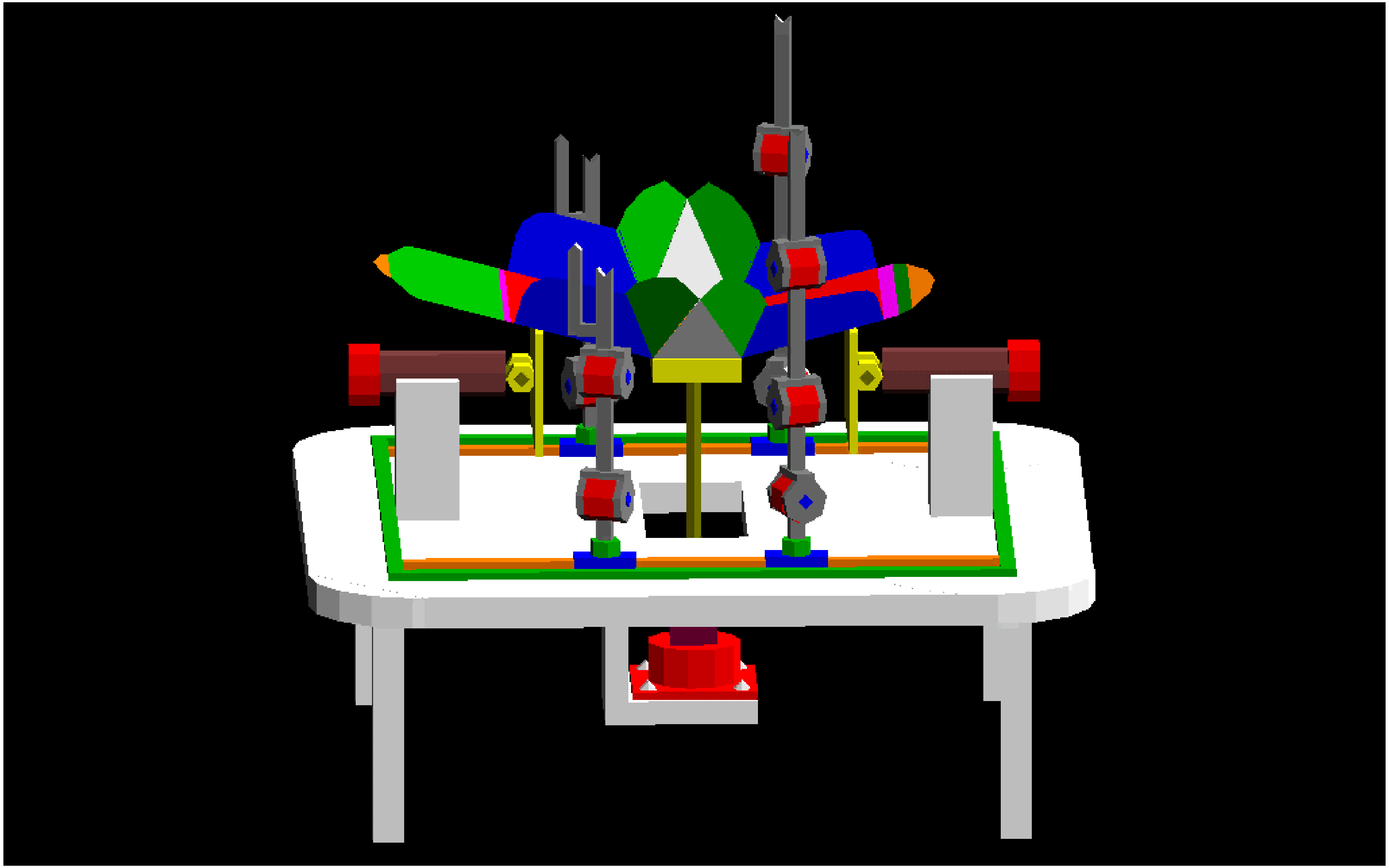


Change-Over

Dubey, V.N., and Dai, J.S., A Packaging Robot for Complex Cartons, **Industrial Robot: An International Journal**, **33**(2): 82-87, 2006.

Reconfigurable Packaging

ARCHAPS

Automatic Reconfigurable Confectionery Handling and Packaging System

King's College London
University of London

University of Bath

Research

ME

Field Packaging

defra
Department for Environment Food and Rural Affairs

EPSRC
Engineering and Physical Sciences Research Council

QUIN → Bendicks → MARKS & SPENCER

Manufacturing **Application** **End user**

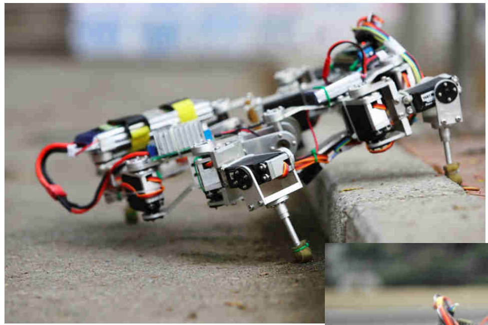
Yao, W. and Dai, J.S. (2008) Dexterous manipulation of origami cartons with robotic fingers based on the interactive configuration space, **Journal of Mechanical Design, Trans. ASME**, **130**(2): 022303.

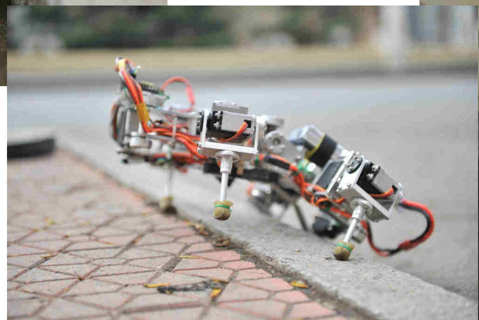
Cannella, F. and Dai, J.S., Crease stiffness and panel compliance of carton folds and their integration in modelling, *Journal of Mechanical Engineering Science*, *Proc. IMechE*, **220**(6): 847-855, 2006

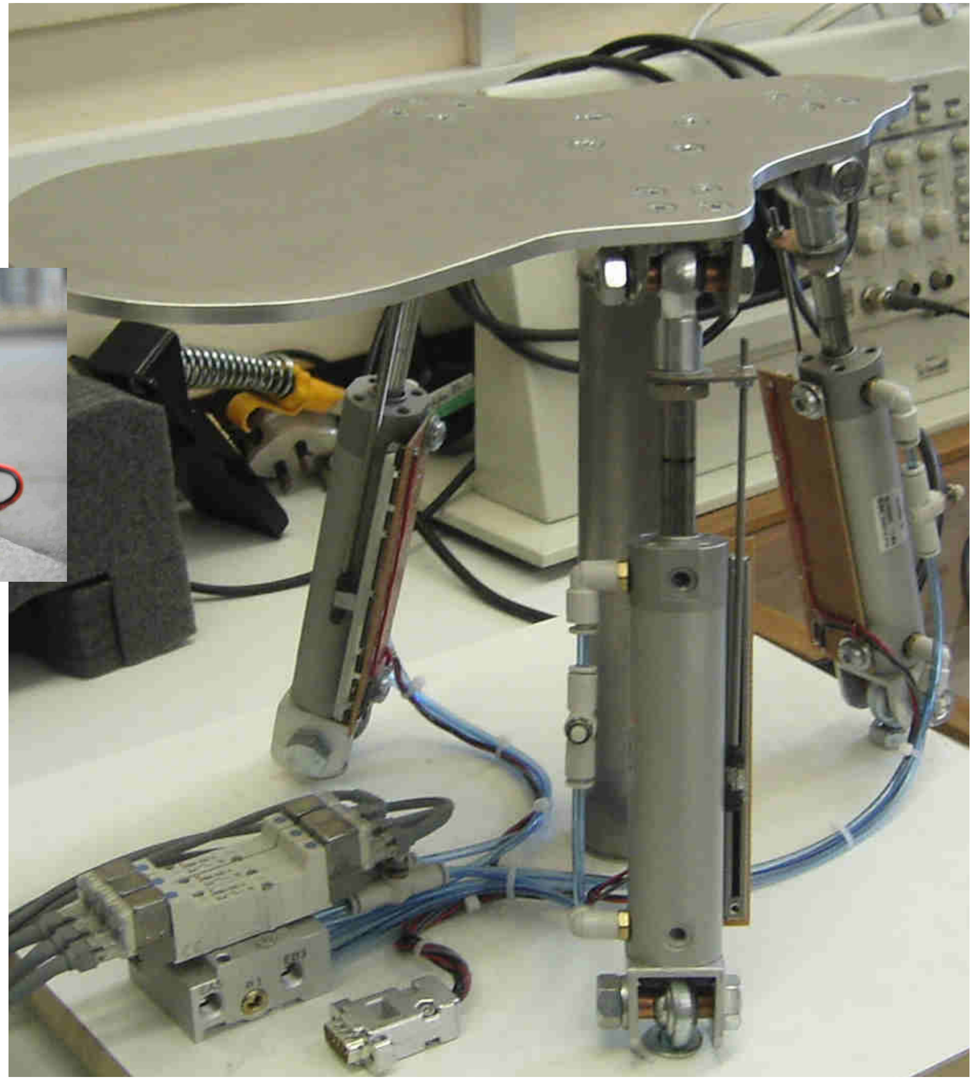

BENDICKS
QUIN
theta

Rehabilitation robot

Medical device based on Stewart platform







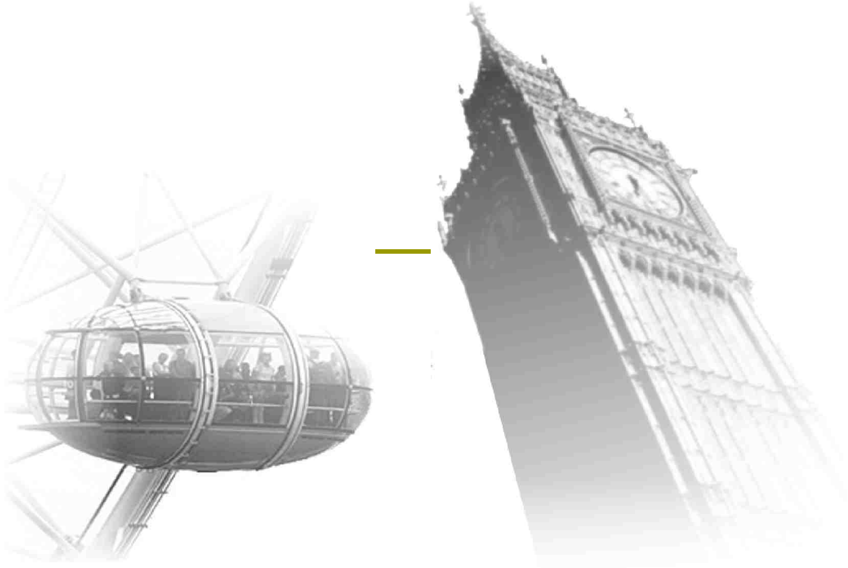
Dai, J.S., Zhao, T. and Nester, C. (2004) Sprained Ankle Physiotherapy Based Mechanism Synthesis and Stiffness Analysis of Rehabilitation Robotic Devices, Special Issue on Rehabilitation Robotics, **Autonomous Robots**, **16**(2): 207-218.

Saglia, J.A., Tsagarakis, N.G., Dai, J.S. and Caldwell (2009) D. G., A high performance redundantly actuated parallel mechanism for ankle rehabilitation, **Int. Journal of Robotics Research**, **28**(9): 1216-1227.

IEEE International Conferences on Reconfigurable Mechanisms and Robots (ReMAR conference series)

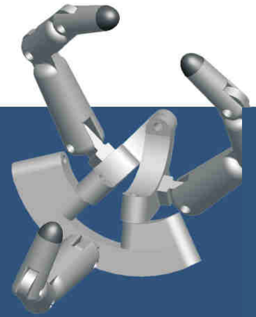
First International Conference on Reconfigurable Mechanisms and Robots (ReMAR)
in 2009 in London


First IEEE/ASME International Conference on
Reconfigurable Mechanisms and Robots
(ReMAR 2009)



Reconfigurable Mechanisms and Robots

Edited by
Jian S Dai, Matteo Zoppi and Xianwen Kong



22-24 June 2009, Londc

This book is the result of the ASME/IFToMM International Conference on Reconfigurable Mechanisms and Robots (ReMAR 2009) held on 22-24 June 2009 at King's College London, London, United Kingdom.

With the development of science and technology and with space exploration, hazardous environment work, and production requirements of small batch, short run and quick change-over, the traditional concept of mechanisms and robot development is facing a challenge in the 21st century to adaptability and reconfigurability. Since 1990s, researchers have been generating new ideas and concepts for new mechanisms, machines and robots of reconfiguration. This has resulted in kinemetatropic linkages, metamorphic mechanisms, and variable topology linkages. The new mechanisms have a property of generating different topological configurations for reconfiguration and for various task requirements.

This book contains 108 selected papers in seven parts which cover the topology, theory and design of reconfigurable mechanisms, their kinematics and dynamics, bio-reconfiguration techniques, origami-inspired reconfigurable mechanisms, and analysis, design and control of reconfigurable robots. The topics also include reconfigurable manufacturing systems. The book explores the new properties in changing mobility and topological structure of the reconfigurable mechanisms and robots and presents their uses in various applications.

COVER DESIGN:
LEI CUI, GUOWU WEI AND HELGE WURDEMANN


ReMAR
2012


Second ASME/IFToMM International Conference on
Reconfigurable Mechanisms and Robots
(ReMAR 2012)
第二届国际可重构机构与可重构机器人大会
ReMAR 2012
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Advances in Reconfigurable Mechanisms and Robots I

Dai · Zoppi · Kong · Eds.

Advances in Reconfigurable Mechanisms and Robots I

Jian S Dai · Matteo Zoppi
Xianwen Kong *Editors*

Advances in Reconfigurable Mechanisms and Robots I

Springer


My road for reconfigurable mechanisms
IEE
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Kenneth J. Waldron
Keynote Speaker


2009
June 2009


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F C
of London

Metamorphic compliant mechanisms

Award ceremony

Thanks to

Current Group Members

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- Dr Evangelos Emmanouil
- Dr Chen Qiu
- Jie Sun
- Xinsheng Zhang
- Peng Chen

Past Group Members

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Dr Jody Saglia (IIT)
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