IWBE 2021 QR web Link

IWBE 2021

International Workshop on Bionic Engineering 2021

16-17 September 2021 | Online

Programme & Proceedings

Welcome

Welcome to the 2021 International Workshop on Bionic Engineering (IWBE 2021) and the 4th International Workshop on Biorobotics & Bioengineering.

The IWBE 2021 aims to bring together worldwide researchers and leading scientists to discuss the cutting-edge development in the vigorous field of bionic engineering. This conference will cover the basic science underpinning bionic systems as well as the applied research in a myriad of exciting areas and stimulate discussions and exchange of ideas to better translate nature's inspiration to address grand challenges that we are encountering.

This conference is hosted by the University of Manchester, the International Society of Bionic Engineering (ISBE) and Jilin University.

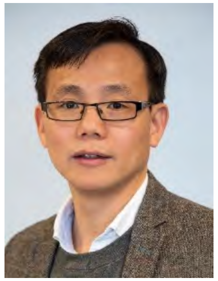
Due to the COVID-19 pandemic, the IWBE 2021 now fully goes virtual to take place on 16-17 September 2021, for the safety of all the delegates. We are fully committed to creating an excellent virtual conference - an online space to meet, network, and exchange knowledge in a safe and accessible manner.

We would like to express our sincerest gratitude to all the invited plenary and keynote speakers, and the authors who submitted the papers. Their high-quality work serves as the foundation for the success of this conference. The conference arranges presentations for all the 73 accepted papers in two parallel sessions, together with 3 plenary and 18 keynote presentations.

We gratefully acknowledge all the sponsors and benefactors for their contributions to this conference. In closing, we hope you will enjoy the invited and technical presentations, online networking, and all the interactive features provided through the online platforms of the IWBE 2021.

Conference Chair

Lei Ren, The University of Manchester

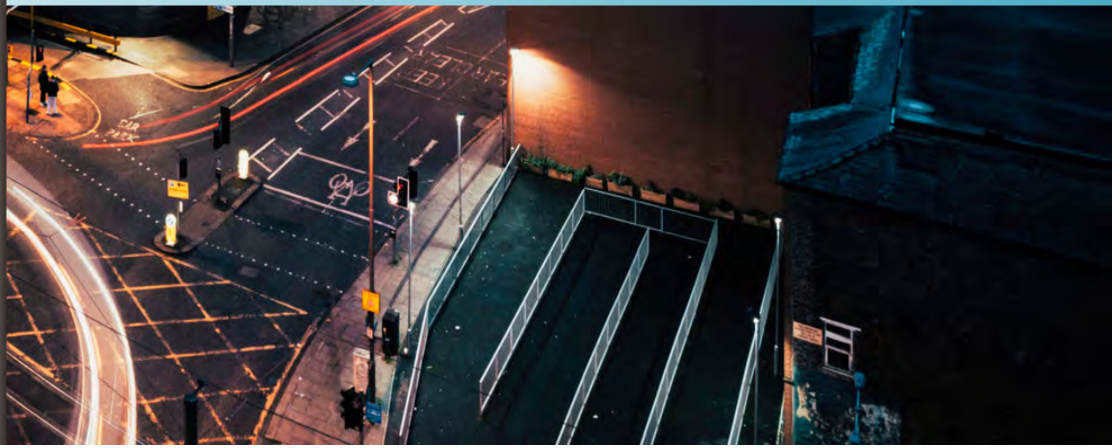


Program Chair

Guowu Wei, University of Salford

International Workshop on Bionic Engineering

Content



Organising Committee

Honorary Chairs

Julian F. V. Vincent	Heriot-Watt University, UK
Luquan Ren	CAS, Jilin University, China

General Chairs

Lei Ren	University of Manchester, UK
Darwin Caldwell	Istituto Italiano di Tecnologia (IIT), Italy
Zhihui Zhang	Jilin University, China

Program Chairs

Guowu Wei	University of Salford, UK
Joe Sweeney	University of Salford, UK
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Conference Sponsors

The University of Manchester

Jilin University

The International Society of Bionic Engineering (ISBE)

University of Salford

International Federation for the Promotion of Mechanism and Machine Science (IFToMM-UK)

Registration Information

Including access to all live streaming talk sessions.

Category	Fee
ISBE Member	Free
Non-Member	Free
Student Member, Non-Member	Free

Conference Secretariat

Lingyun Yan

Email: lingyun.yan@manchester.ac.uk

Hangbing Fan

Email: hangbing.fan@manchester.ac.uk

General Information

Conference Format

This conference will fully go virtual to take place on 16-17 September 2021 via Zoom platform. The IWBE 2021 includes live streaming talks and Q&A sessions, all on an online space to enable all attendees to share, network and interact safely and easily amid the global COVID-19 pandemic.

Topics of interest

Biomimetic surfaces
Biomimetic machinery
Biomimetic materials
Bionic healthcare
Biologically inspired robotics
Life-like sensing, actuation and computation
Biomimetic design methodology

IWBE 2021 Schedule(UK Time)

Thursday 16 September (Day1)

08:00-09:00	Welcome Ceremony Zoom ID: 781 695 8399	
	Plenary Speech Zoom ID: 781 695 8399	
	ROOM1 ZOOM ID: 781 695 8399	ROOM2 ZOOM ID: 425 536 5547
09:05-12:00	Session I: Bionic machinery & bioinspired robotics	Session II: Bioinspired material & bionic healthcare
12:00-13:00	Lunch Break	
13:00-13:45	Plenary Speech Zoom ID: 781 695 8399	
13:50-16:30	Session I: Bionic machinery & bioinspired robotics	Session II: Bioinspired material & bionic healthcare

Friday 17 September (Day2)

08:00-08:45	Plenary Speech Zoom ID: 781 695 8399	
	ROOM1 ZOOM ID: 781 695 8399	ROOM2 ZOOM ID: 425 536 5547
08:50-12:00	Session I: Bionic machinery & bioinspired robotics	Session II: Bioinspired material & bionic healthcare
12:00-13:00	Lunch Break	
13:00-16:20	Session I: Bionic machinery & bioinspired robotics	Session II: Bioinspired material & bionic healthcare
16:20-16:50	Award Ceremony Zoom ID: 781 695 8399	

PS Zoom ID **781 695 8399**, Passcode: **545385**
Zoom ID **425 536 5547**, Passcode: **743792**

IWBE 2021 Programme

Day 1, Thursday 16 September (UK Time)

08:00-08:15 Welcome Ceremony

Zoom ID: 781 695 8399

Chair: Dr. Guowu Wei

08:00-08:05 Prof. Thomas Stegmaier, President of ISBE

08:05-08:10 Prof. Zhihui Zhang, General Secretary of ISBE

08:10-08:15 Prof. Lei Ren, Conference Chair

08:15-09:00 Plenary Speech

Zoom ID: 781 695 8399

08:15-09:00 Manufacturing for Healthcare — Chair: Dr. Guowu Wei

Prof. Mohan Edirisinghe, *OBE, FREng, FEurAcadSci, University College London*

09:00-09:05 Break

09:05-12:00 Session I: Bionic machinery & bioinspired robotics

Zoom ID: 781 695 8399

09:05-10:05 **Keynote Speech** — Chair: Prof. Chaozong Liu

09:05-09:35 Bio-inspired Growing Robots: From Conception to Implementation

Prof. Kaspar Althoefer, *Queen Mary University of London*

09:35-10:05 Biomimetic on Gecko locomotion in Confined Space: From Biology to Engineering

Prof. Zhendong Dai, *Nanjing University of Aeronautics and Astronautics*

10:05-10:10 Break

10:10-11:58 **Oral Presentation** — Chair: Prof. Longjian Xue, Dr. Suqian Ma

10:10-10:22 Design and Analysis of a Novel Bio-Inspired Tracked Wall-Climbing Robot with Flexible Spines

Jian Zhou, Xu Linsen and Liu Jinfu, *Hefei Institutes of Physical Science, CAS*

10:22-10:34 Biohybrid Magnetic Stem Cell Spheroid Microrobots with Rapid Endoluminal Delivery and Imaging

Ben Wang, *Shenzhen University*

10:34-10:46 Bioinspired Engineering Holds Enormous Potential for Mankind: Need for Creating Better Awareness

Pradeep Srivastava, *Scientoons International*

10:46-10:58 An Anthropomorphic Robotic Hand with Human-like Grasping and Manipulation Capabilities by Exploiting the Biomechanical Advantages of the Human Hand

Yiming Zhu, Guowu Wei and Lei Ren, *The University of Manchester*

10:58-11:10 The Development of a Two-finger Dexterous Bionic Hand with Three Grasping Patterns–NWAFU Hand

Xuewei Han and Zhiguo Li, *Northwest A&F university*

11:10-11:22	Elastic Local Buckling Behaviour of Beetle Elytron Plate Xiaoming Zhang, Yong Wang and Meini Su, *The University of Manchester*
11:22-11:34	From Spider-web to Oil-separator Maryam Aliabadi, Thomas Stegmaier, Goetz Gresser, Cigdem Kaya, Yan Liu, Gouyong Wang and Bin Zhan, *DITF*
11:34-11:46	Water Flow Energy Harvesting via Triboelectric Nanogenerator Based on Bionic Structure Zhaoxu Jing, Jiacheng Zhang, Mingkang Zhu, Xinxian Wang, Jianyang Zhu and Tinghai Cheng, *Changchun University of Technology*
11:46-11:58	Fluid-owl Interaction: Experimental Study of the Flow over an Owl Wing David Charland, Roi Gurka and Daneil Weihs, *Coastal Carolina University*
09:05-12:00	**Session II: Bioinspired material & bionic healthcare**
	Room ID: 425 536 5547
09:05-10:05	**Keynote Speech** — Chair: Dr. Helge Wurdemann
09:05-09:35	Reconfigurable Robotic Exoskeleton for Effective Stroke Rehabilitation in Residential Settings Prof. Shane Xie, *University of Leeds*
09:35-10:05	Bioinspired Surface Lubrication Materials and Technologies Prof. Feng Zhou, *Lanzhou Institute of Chemical Physics*
10:05-10:10	Break
10:10-11:58	**Oral Presentation** — Chair: Dr. Wei Yao, Dr. Ce Guo
10:10-10:22	Artificial Superhydrophobic Surfaces and Their Applications Guoyong Wang, Shuai Liu, Wenting Zhou, Ning Sun, Tongyi Zhang and Yan Liu, *Jilin University*
10:22-10:34	Biomimetic Functional Surfaces with Wrinkle Pattern for Tissue Engineering Honghao Hou, *Southern Medical University*
10:34-10:46	Bio-inspired Sensing Principles for Novel Artificial Electronic Skins Xiaodong Wu, *Sichuan University*
10:46-10:58	Bioinspired Surface Design for Strong and Reversible Adhesion Longjian Xue, Zhekun Shi, Di Tan, Quan Liu and Bo Zhu, *Wuhan University*
10:58-11:10	Bio-inspired Water Lubrication Interface & Materials Shuanhong Ma, *Lanzhou Institute of Chemical Physics, CAS*
11:10-11:22	Advanced Bio-inspired Multi-dimensional Structural Materials: Sophisticated Biological Models and Biomimetic Fabrication Strategies Wenda Song, Zhengzhi Mu, Binjie Zhang, Yufei Wang, Zhiyan Zhang, Yujiao Li, Bo Li, Junqiu Zhang, Shichao Niu, Zhiwu Han and Luquan Ren, *Jilin University*
11:22-11:34	Preparation of Bionic Gradient Hardness Surface by Compound Process of Laser Remelting and Nitriding Peng Zhang and Qian Sun, *Jilin University*
11:34-11:46	Study on Surface Residual Stress and Its Effect on thermal Fatigue Properties of Non-uniform Bionic Specimen Prepared by Laser Xiuyun Pang and Hong Zhou, *Jilin University*

11:46-11:58	Bioinspired Surface Design of Microfluidic channels for Microscale Flow Control Shuli Wang and Xu Hou, *Xiamen University*
12:00-13:00	**Lunch break**
13:00-13:45	**Plenary Speech**
	Room ID: 781 695 8399
	Chair: Prof. Shane Xie
13:00-13:45	Cost-effective Robotic Surgery Prof. Brian Davies, *FREng, Imperial College London*
13:45-13:50	Break
13:50-16:30	**Session I:Bionic machinery & bioinspired robotics**
	Room ID: 781 695 8399
13:50-14:50	**Keynote Speech** — Chair: Prof. Zhendong Dai
13:50-14:20	Progress of Biomimetics in Energy Transfer and Storage Prof. Yuying Yan, *University of Nottingham*
14:20-14:50	A Soft Robotics Approach to Understand How the Brain Conditions the Body to Make Realtime Survival in Natural Environments More Efficient Prof. Thrishantha Nanayakkara, *Imperial College London*
14:50-14:55	Break
14:55-16:31	**Oral Presentation** — Chair: Prof. Zhihui Qian, Dr. Aihong Ji
14:55-15:07	A Bio-circular-economy Approach towards a Sustainable Construction Projects Unified Framework: A Case Study in Panama Kimberly Beermann and Miguel Chen Austin, *Universidad Tecnologica de Panama*
15:07-15:19	FE Modelling of Biomimetic Short-Stem Porous Hip Implant for Reducing Stress Shielding & Promoting Osseointegration Seyed Ataollah Naghavi, Jia Hua, Mehran Moazen, Steve Taylor and Chaozong Liu, *University College London*
15:19-15:31	Enzyme-powered Artificial Cell Models Lei Wang, *Harbin Institute of Technology*
15:31-15:43	Inside a Ladybird Coupling: Elastic Setae Store Energy for Elytra Deployment Qiufeng Yuan, Jie Zhang, Yunqiang Yang and Jianing Wu, *China University of Geosciences, Beijing*
15:43-15:55	X-ray Microtomography and Finite Element Analysis for the Study of Plants and Its Implications for Bionics Felipe Luis Palombini, Branca Freitas de Oliveira and Jorge Ernesto de Araujo Mariath, *UFRGS*
15:55-16:07	Biomimetic Passive Cooling August Hammel and Ille C. Gebeshuber, *TU Wien*
16:07-16:19	Structural Bactericide by Biomimetics of the Nanopillars on Cicada Wings Alexander M. Bürger, Richard W. van Nieuwenhoven and Ille C. Gebeshuber, *Vienna University of Technology*

16:19-16:31	The Micromechanics of the Diatom Corethron Criophilum: An Experimental Study Utilizing 3D Printing Kevin Opelt, *TU Wien*

13:50-16:30 Session II: Bioinspired material & bionic healthcare

Room ID: 425 536 5547

13:50-14:50	**Keynote Speech**	Chair: Prof. Qining Wang
13:50-14:20	The Study of Bio-inspired Electromagnetic Fields on Health Enhancement Past, Present and Future Prof. Shujun Zhang, *University of Gloucestershire*	
14:20-14:50	Design of a Bio-inspired Wearable and Adaptive Robotic Hand Glove for Hand Rehabilitation after Stroke Dr. Wei Yao, University of Strathclyde	
14:50-14:55	Break	
14:55-16:31	**Oral Presentation**	Chair: Prof. Chunbao Liu, Prof. Xu Hou
14:55-15:07	Wrinkle Manipulation by Patterned Surface Material Properties for Structural Coloration Yeonghoon Jeong, Jun Gyu Park and Taesung Kim, *Ulsan National Institute of Science and Technology*	
15:07-15:19	Turbulent Drag Reduction on Bioinspired Superhydrophobic Surfaces Xiangting Chang and Haibo Huang, *University of Science and Technology of China*	
15:19-15:31	Drop Bouncing on Superhydrophobic Surfaces Yahua Liu, *Dalian University of Technology*	
15:31-15:43	Near-infrared Light Accurately Controllable Superhydrophobic Surface Yanlong Shao, Jie Zhao, Zhihui Zhang and Luquan Ren, *Jilin University*	
15:43-15:55	Study on the Bionic Electric Actuation of Liquid Metal Column in Confining Channels Liang Shuting; *Chongqing University of Arts and Sciences*	
15:55-16:07	The Impact of Principles Biomimicry for Sustainable Building Materials Abdulfattah Yahya, *Cairo University*	
16:07-16:19	High-Performance Ionic Polymer-Metal Composites: towards Large-Deformation and Fast-Response Artificial Muscles Suqian Ma, Yunhong Liang, Lei Ren and Luquan Ren, *Jilin University*	
16:19-16:31	Artificial Fingerprint-textured Liquid Crystalline Polymeric Coatings and Their Applications Wei Feng, *Max Planck Institute for Intelligent Systems*	

Day 2, Friday 17 September (UK Time)

08:00-08:45 Plenary Speech

Room ID: 781 695 8399

Chair: Prof. Nikos Tsagarakis

08:00-08:45	Exoskeletons for Industrial (Occupational) Application: Preventing Work-related Musculoskeletal Disorders (MSD) and Increasing Efficiency Professor Darwin Caldwell, *FREng, IIT*
08:45-08:50	Break

08:50-12:00 Session I:Bionic machinery & bioinspired robotics

Room ID: 781 695 8399

08:50-10:20	**Keynote Speech**	Chair: Prof. Shujun Zhang
08:50-09:20	Compliant and Ergonomic Design Principles for Enhanced Performance Robots and Wearable Systems Prof. Nikos Tsagarakis, *Istituto Italiano di Tecnologia (IIT)*	
09:20-09:50	Soft Wearable Robotic Hands: Actuation, Sensing and Human-in-the-loop Control Prof. Guoying Gu, *Shanghai Jiaotong University*	
09:50-10:20	Human-Centered Wearable Robots for Broader Applications Prof. Qining Wang, *Beijing University*	
10:20-10:25	Break	
10:25-12:01	**Oral Presentation**	Chair: Prof. Thrishantha Nanayakkara, Dr Yahua Liu
10:25-10:37	A Linkage-spring-tendon-integrated Compliant Modular Anthropomorphic Robotic Hand: MCR-Hand Haosen Yang, Guowu Wei and Lei Ren, *The University of Manchester*	
10:37-10:49	Six Biological Models for Bionic Design of High Strength and Tough Structures Tao Lin, Guangming Chen, Ce Guo and Ning Dai, *Nanjing University of Aeronautics and Astronautics*	
10:49-11:01	Hollow Mandibles: Structural Adaptation to High-speed Strike in the Trap-jaw Ant Odontomachus Monticola Zixin Wang, Yunqiang Yang and Jianing Wu, *China University of Geosciences, Beijing*	
10:01-11:13	Numerical Bionic Fish Schooling Based on Deep Reinforcement Learning Huiyang Yu, Bo Liu, Haibo Huang and Xi-Yun Lu, *University of Science and Technology of China*	
11:13-11:25	Essential Role of Longitudinal Segmental Spacing in Nectar Capture Bo Wang, Yunqiang Yang and Jianing Wu, *China University of Geosciences*	
11:25-11:37	An Active 3-DoF Soft Joint for Soft Robot Movement Guangming Chen, Shi Ding, Shuang Zheng, Long Qiao and Aihong Ji, *Nanjing University of Aeronautics and Astronautics*	
11:37-11:49	Inflatable Bioinspired Robots for Space Joseph Ashby, Samuel Rosset and Iain Anderson, *University of Auckland*	

11:49-12:01	Design of Bionic Grasping Robot Zhengguang Liu and Zhiguo Li, *Northwest A&F University*	

08:50-12:00 Session II: Bioinspired material & bionic healthcare

Room ID: 425 536 5547

08:50-10:20	**Keynote Speech**	Chair: Prof. Laurence Kenney
08:50-09:20	Osteochondral Scaffold Innovation toward Early Treatment of Osteoarthritis: Going Biomimetic Prof. Chaozong Liu, *University College London*	
09:20-09:50	3D Bioprinting of Human Skeletal Tissues Dr. Marco Domingos, The University of Manchester	
09:50-10:20	Influence of Prednisolone and Alendronate on the de novo Mineralization of Zebrafish Caudal Fin *Dr. Riaz Akhtar, University of Liverpool*	
10:20-10:25	Break	
10:25-11:55	**Oral Presentation**	Chair: Dr. Riaz Aktar, Dr. Kunyang Wang
10:25-10:37	Rapid, Energy-saving Bioinspired Soft Switching Valve Based on Snapping Membrane Actuator Fangzhou Zhao, Yingjie Wang, Chunbao Liu, Luquan Ren and Lei Ren, *Jilin University*	
10:37-10:49	Human Tactile Sensing and Sensorimotor Mechanism: From Input Afferent Tactile Signals to the Output Motor Control and Its Applications on Robotics Yuyang Wei, Lei Ren and Guowu Wei, *The University of Manchester*	
10:49-11:01	Construction of High-performance Nacre-inspired Metal-ceramic Composites via Ice Templating and Melt Infiltration Ping Shen, Zhijie Hu and Likai Yang, *Jilin University*	
11:01-11:13	Research on Bionic Erosion Resistance Mechanism of Surface Ripple Morphology Xuwen Zhao, Yan Zhangand Tianqi Wang, *Tianjin University of Science and Technology*	
11:13-11:25	Electrochemistry-Induced Improvements of Interfacial Adhesion of Hydrogels Lidong Zhang, *East China Normal University*	
11:25-11:37	Articular Cartilage Inspired Hydrogel with Good Mechanical and Lubricating Performance Pan Jiang and Xiaolong Wang, *Lanzhou Institute of Chemical Physics, CAS*	
11:37-11:49	Bioinspired Color-Changeable Organogel Tactile Sensor with Excellent Overall Performance Yafeng Liu, *Tsinghua University*	
11:49-12:01	A Bio-inspired Tactile Sensor and Its Processing Algorithm for Spike Signals Longhui Qin, *Southeast University*	
12:01-12:13	Hair Receptors on a Honey Bee Tongue are Sensitive Tactile Sensors Caiying Liao, Jianing Wu and Zhigang Wu, *Sun Yat-Sen University*	
12:13-12:25	3D Printed Template-Assisted Bioinspired Microfibers Rui Shi and Liqiu Wang, *University of Hong Kong*	

12:25-13:00 Lunch break

13:00-16:20 Session I:Bionic machinery & bioinspired robotics

Room ID: 781 695 8399

13:00-14:00	**Keynote Speech**	Chair: Dr. Marco Domingos
13:00-13:30	Soft Robotics for Healthcare Dr. Helge Wurdemann, *University College London*	
13:30-14:00	Myoelectric Upper Limb Prostheses – the Promise and the Reality Prof. Laurence Kenney, University of Salford	
14:00-14:05	Break	
14:05-16:05	**Oral Presentation**	Chair: Prof. Rong Song, Dr. Lidong Zhang
14:05-14:17	Heterogeneous wettability surfaces for liquid manipulation and materials patterning Huizeng Li, Yanlin Song, *Institute of Chemistry Chinese Academy of Sciences*	
14:17:14:29	Bio-inspired Liquid Gating Technology Xu Hou, *Xiamen University*	
14:29-14:41	Simulation of Single-leg Adaptive Control Based on Position Impedance Haofeng Deng, Liucun Zhu, Jiyue Wang, Mingyou Chen and Hongwei Wu, *Beibu Gulf University*	
14:41-14:53	Contact Force Control of a Crocodile Moving across Different Substrates Liang Yingqi, Wei Jiangkun and Wu Jianing, *Sun Yat-Sen University*	
14:53-15:05	Uncover Motion Geometry and Timing of Human Arm Control Xiaofeng Xiong, *University of Southern Denmark*	
15:05-15:17	An Anthropometric Study for the Anthropomorphic Design of Tomato-harvesting Robots Zhiguo Li, *Northwest A&F University*	
15:17-15:29	Toward Yaw Stability of Bionic Propulsion in Flow Field Guanwen Chen, Yuhan Li and Yong Zhong, *South China University of Technology*	
15:29:15:41	Slide Mode Control of Robot Single-leg Foot Force and Joint Angle Yongyong Zhao, Jinghua Wang and Guohua Cao, *Changchun University of Science and Technology*	
15:41-15:53	Crashworthiness Optimisation of a Multicellular Thin-walled Tube with Triangular Cells Chengxing Yang and Shuguang Yao, *Central South University*	
15:53-16:05	Root Systems Research for Biomimetic Design of Foundations and Coastal Engineering Petra Gruber, Thibaut Houette and Elena Stachew, Transarch	
16:05-16:17	Development of Expandable Drill for Landfill Aeration Y. Kim, D.-G. Lee, Y. Jung, Y. D. Jung, J. Lee, S. H. Lee, and Wan-Doo Kim* Korea Institute of Machinery & Materials	
16:17-16:20	Break	

13:00-16:20	Session II: Bioinspired material & bionic healthcare
	Room ID: 425 536 5547

13:00-14:00 **Keynote Speech** Chair: Prof. Feng Zhou

13:00-13:30 The Rise of Bionic Robots in the Optimisation of Personalised Clinical Procedures

Prof. Rui Loureiro, *University College London*

13:30-14:00 Bionic and Adaptive FES control for Ankle Rehabilitation

Prof. Rong Song, *Sun Yat-sen University*

14:00-14:05 Break

14:05-16:05 **Oral Presentation** Chair: Dr. Xiaofeng Xiong, Dr. Qian Zhao

14:05-14:17 A Two-Step Carbon Fiber Modification for Enhanced Fibrous Composites Inspired by Hook-Groove Interlock Structure of Raptor's Flying Feathers

Zhengzhi Mu and Yufei Wang, *Jilin University*

14:17:14:29 Biomimetic Foam Core Sandwich Composites with High Mechanical Performance Inspired by Hierarchical Structure of Bubo bubo Feather Shaft

Zhiyan Zhang and Zhengzhi Mu, *Jilin University*

14:29-14:41 Pufferfish-inspired Testing of Bionic Surface Drag Reduction Performance

Guizhong Tian, Dongliang Fan, Xiaoming Feng and Yaosheng Zhang, *Jiangsu University of Science and Technology*

14:41-14:53 Water-Based Robust Transparent Superamphiphobic Coatings for Resistance to Condensation, Frosting, Icing, and Fouling

Wancheng Gu, Xinquan Yu and Youfa Zhang, *Southeast University*

14:53-15:05 A Bio-Inspired Interleaf for Enhanced Interlaminar Fracture Toughness of Carbon Fibre Reinforced Polymers

Wenda Song, Zhengzhi Mu, Yufei Wang, Zhiyan Zhang, Yujiao Li, Binjie Zhang, Bo Li, Junqiu Zhang, Shichao Niu, Zhiwu Han and Luquan Ren, *Jilin University*

15:05-15:17 Robust Superhydrophobic Surface by Plasma Coating

Sandipan Bera, Seonju Yeo, Seungchul Park and Hyuneui Lim, *Korea Institute of Machinery and Materials*

15:17-15:29 Bio-inspired Smart Surface with Anisotropic Friction for Controllable Locomotion

Zhongying Ji and Xiaolong Wang, *Lanzhou Institute of Chemical Physics, CAS*

15:29-15:41 Integrated Real-time Polarization Sensor for Autonomous Navigation

Chuanlong Guan, Ze Liu, Zhemin Yin and Jinkui Chu, *Dalian University of Technology*

15:41-15:53 Anti-moisture active carbon mediated by ZIF-8 shell

Yanzheng Ji, Xuan Jiao and Youfa Zhang, *Southeast University*

15:53-16:05 Influence of Prednisolone and Alendronate on the de novo Mineralization of Zebrafish Caudal Fin

Fabio Rocha Bohns, Yann-Rong Shih, Yung-Jen Chuang, Po-Yu Chen, Riaz Akhtar, *National Tsing Hua University*

16:05-16:20 Break

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16:20-16:50	Award Ceremony
	Room ID: 781 695 8399

Six awards as follows will be presented at the end of the IWBE 2021 conference. Each of the award winners will be given a certificate together with a £100 prize that are provided by the International Society of Bionic Engineering (ISBE) and Jilin University.

- Best Paper in Bionic Robotics
- Best Paper in Bionic Materials
- Best Paper in Bionic Healthcare
- Best Presentation in Bionic Robotics
- Best Presentation in Bionic Materials
- Best Presentation in Bionic Healthcare

Award Committee:
Prof. Chaozong Liu (Chair), Prof. Zhihui Qian, Dr. Guowu Wei, Dr. Helge Wurdemann, Dr Wei Yao

Proceedings

Plenary Speakers

Prof. Darwin Caldwell

FREng, IIT

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Exoskeletons for Industrial (Occupational) Application: Preventing Work-related Musculoskeletal Disorders (MSD) and Increasing Efficiency

Abstract

Industrial workers are often required to manually handle quite heavy materials. This activity can significantly load the lumbar spine and carries a high risk of physical injury. Of the EU working population, over 30% must perform some form of Manual Material Handling (MMH), 63% have work that involves repetitive movements and 46% are exposed to awkward body postures. As a result, every year more than 40% of workers suffer from lower back or neck/shoulder pain. These work-related injuries have a severe impact on the worker's quality of life and increase the costs sustained by industry.

Exoskeletons are personal assistive technologies (wearable devices) that provide a level of additional mechanical power or endurance to the human body. In so doing, they reduce the biomechanical load, allowing users to perform tasks that they might otherwise find too physically demanding. Early research on exoskeletons was driven by the military who were looking to provide their personnel with enhanced power and endurance. Medical practitioners, particularly those working in rehabilitation (e.g. post-stroke) were quick to see the potential of exoskeletal systems and were early adopters.

Each of these areas still remain active users of exoskeletons, but recent trends have identified the prevention of injury rather than increasing power or the restoration of motions, as one of the greatest potential uses of exoskeletons. Manufacturing, and related industries such as automotive, assembly/disassembly, construction, logistics, aviation, and healthcare are now starting to see the opportunities for various forms of exoskeletons and assistive devices.

This presentation will explore the development of exoskeletons, the factors influencing their design and operation, and the potential uses, benefits and challenges afforded by the use of occupational (industrial) exoskeletons.

IWBE 2021

Biography

Prof. Darwin Caldwell is Founding Director of the Italian Institute of Technology (IIT) in Genoa, Italy, where he is also the Director of the Dept. of Advanced Robotics. Caldwell pioneered the development of core technologies in compliant actuation, Soft and Human Friendly Robotics and the creation of 'softer', safer robots, drawing on developments in materials, mechanisms, sensing, actuation and software. These developments have been fundamental to applications in exoskeletons/force augmentation, humanoids, quadrupeds and medical robotics.

Key robots developed in/by his group have included: iCub, a child-sized humanoid robot capable of crawling, grasping objects, and interacting with people; COMAN, a compliant humanoid robot designed to safely interact with people; WALK-MAN, a 1.85m tall, 120kg humanoid that competed in the DARPA Robotics Challenge; the HyQ series (HyQ, HyQ2Max, HyQ-Real) of high performance hydraulic quadrupedal robots; and the Centauro, a "human-robot symbiotic system capable of robust locomotion and dexterous manipulation in the rough terrain and disasters" (e.g. earthquake, nuclear, chemical).

Prof. Caldwell is or has been an Honorary professor at the University of Manchester, University of Sheffield, King's College London, and the University of Bangor in the UK, and Tianjin University and SAAT in China. He has published over 600 papers, and has received over 50 awards/nominations at international conferences and events. In 2015 he was elected a Fellow of the Royal Academy of Engineering.

IWBE 2021

Prof. Brian Davies

FREng, Imperial College London

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Cost-effective Robotic Surgery

Abstract

Professor Davies will discuss his personal experiences of surgery developing cost-effective robotic systems and suggest some of the ways that these can be made more effective. In addition he will cover some of the mistakes that he's made and suggest improvements and how the whole area has developed over the years. He will discuss his experience in setting up the Acrobot company Ltd and its development that led to a number of patients benefiting from the system before the Company was sold. He will also go into some detail about the Signature Robot Ltd, a company which he started in 2018, and the need for companies to protect their intellectual property using patents and trademarks and the resulting problems.

Biography

Professor Brian Davies is an Emeritus Professor of Medical Robotics at Imperial College London. He has been at Imperial College since 1984 and started the whole activity of robotic surgery with the world-first clinical application of a robot for prostate surgery in 1991. He founded the spin off company ACROBOT in 1999 which was very successful in performing a number of uni-condylar knee surgeries, and was sold to Stanmore Implants Worldwide in 2010. He is also the Founder and Managing Director of Signature Robot Ltd. Signature Robot is a company concerned with minimally invasive low-cost surgery using a small cooperative robot. The robot is currently being applied to minimally invasive unicondylar knee surgery, although it can also be applied to a range of small and low cost surgeries, such as trauma surgery and spine surgery for pedicle screw implants.

He has published over 250 papers on medical robotics and was the founder of the Mechatronics in Medicine section at Imperial College London, which is currently led by Professor Ferdinando Rodriguez.

Prof. Mohan Edirisinghe

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Manufacturing for Healthcare

Abstract

If the Covid-19 pandemic taught us one lesson that would be about preparedness to manufacture for healthcare. It was clear that, worldwide, we had not considered this area adequately to respond immediately and very effectively. This lecture will highlight this experience.

Inventing novel scalable methods for making fine bubbles/vesicles, particles/capsules and fibres of the micro-nano scale is an essential part of modern advanced science and engineering which underpins public healthcare. These structures play a crucial part in key areas like biomedical engineering which is of a very high utilitarian value and public demand. Microbubbles are very effective drug delivery agents and are also crucial contrast agents in ultrasound imaging. While bubbles contain air, vesicles usually enclose liquid. Particles and capsules are extensively used in modern therapeutic delivery. Fibres, in the form of scaffolds, filters and patches are used in advanced applications such as tissue engineering, microbial screening and chronic wound healing bandage strategies. However, the quest to make these structures reproducibly with high productivity and process control is still elusive and is a hot research topic as scale-up possibilities and actual industrial manufacturing in addition to new scientific, engineering and technological innovations are crucial factors. The **Biomaterials Processing & Forming Laboratory**, Edirisinghe Lab, (www.edirisinghelab.com), has been at the forefront of this research internationally and this lecture will illustrate how these novel making developments are currently taking place at great urgency and pace. Our research has led to many inventions and spin-offs and has already won 25 high impact international journal front covers.

Microbubble generation using microfluidics and electrohydrodynamics and their combination has led to a new medical frontier (1), and we are the inventors of the combined method. We have also invented new electrohydodynamic devices which can make 4-layered particles and fibres (2) and these are paving the way to a new generation of therapeutics, for example to combat urinary tract infections in a new way (www.atocap.co.uk). The device can also be carried in a mobile point-of-care application unit, which was invented very recently. We have also invented a new fibre manufacturing method called pressurised gyration (3,4) which has allowed doped-manufacturing of nano-micro scale polymeric fibres with a high yield and this has revolutionized fibre-mesh generation for making antimicrobial filtration mats, tissue engineering constructs and wound healing/drug delivery patches. Our research has also paved new ways of utilising new materials such as graphene and its derivatives in biomedical engineering (5).

Many more exciting developments are in progress in collaboration with USA, China, Europe and Asia to further exploit these new and challenging novel manufacturing technologies especially in biotechnology (6) and core-sheath structure generation to enhance biomedical applications (7) and this talk will also briefly indicate the exciting progress we are making in these areas, include using the core-sheath functional/structural feature in anti-Covid19 face mask manufacture (8,9).

Biography

Professor Mohan Edirisinghe holds the established Bonfield Chair of Biomaterials in the Department of Mechanical Engineering at University College London (UCL) and has served as a University of London professor for over 20 years. He was appointed to this UCL chair in December 2005 and prior to this he was Professor of Materials at Queen Mary University of London. He has actively pursued advanced materials processing, forming and manufacturing research, for over 25 years publishing over 500 journal papers with a H-index of 66 and over 15,000 citations (Source: Google Scholar, May 2021). In addition, his research has led to many inventions and patents and he has also delivered over a 100 keynote/invited lectures at many different international conferences and meetings worldwide, particularly in the USA (major recent meetings include: TMS, MS&T and MRS). He has supervised over 250 researchers, graduating 100 doctoral students (41 to date at UCL), and has been awarded grants to the value of over £25 million, with 43 UK Research Council grants including two Platform Grants which have given him the opportunity to adventurously explore novel avenues of forming and manufacture of advanced materials for application in key areas such as healthcare. His research has won many prizes including the Royal Society Brian Mercer (Innovation) Feasibility Award an unprecedented three times (2005, 2009 and 2013), the 2010 Materials Science Venture Prize and the 2012 Presidents Prize of the UK Biomaterials Society to recognise outstanding contributions to the biomaterials field. In 2015 he was elected as a Fellow of The Royal Academy of Engineering in the UK. In 2017 he was the recipient of The Royal Academy of Engineering Armourers & Brasiers prize for excellence in Materials Engineering and the Premier IOM3 Chapman Medal for his distinguished research in the field of biomedical materials. In 2020, he was elected as a Fellow of The European Academy of Sciences. In the Queens New Year Honours 2021 he was appointed OBE for his services to Biomedical Engineering.

Keynote Speakers

Dr. Riaz Akhtar

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Influence of Prednisolone and Alendronate on the de novo Mineralization of Zebrafish Caudal Fin

Abstract

Dysregulated balance between bone resorption and formation mediates the onset and progression of osteoporosis. The administration of prednisolone is known to induce osteoporosis, whereas alendronate is commonly used to reverse the process. However, the assessment of the effects of such medicines on the nanostructure of bone remodelling and mechanical properties remains a major technical challenge. In this paper, a number of analytical approaches are applied to evaluate the compositional, morphological, and mechanical properties of regenerative zebrafish caudal fin bony rays affected by prednisolone and alendronate. Adult wild-type AB strain zebrafish were first exposed to 125µM of prednisolone for 14 days to develop glucocorticoid-induced osteoporosis. Fish fins were then amputated and let to regenerate for 21 days in tank water containing 30µM of alendronate or no alendronate. The lepidotrichia in the proximal and distal regions were evaluated separately using confocal microscope, scanning electron microscope, electron-dispersive spectroscopy, Raman spectroscopy, atomic force microscopy, and a nanoindenter. As expected, prednisolone led to significant osteoporotic phenotypes. A decrease of Ca/P ratio was observed in the osteoporotic subjects (1.46 ± 0.04) as compared to the controls (1.74 ± 0.10). Subsequent treatment of alendronate overmineralized the bony rays during regeneration. Enhanced phosphate deposition was detected in the proximal part with alendronate treatment. Moreover, prednisolone attenuated the reduced elastic modulus and hardness levels (5.60 ± 5.04 GPa and 0.12 ± 0.17 GPa, respectively), whereas alendronate recovered them to the pre-amputation condition (8.68 ± 8.74 GPa and 0.34 ± 0.47 GPa, respectively). As an emerging model of osteoporosis, regrowth of zebrafish caudal fin was shown to be a reliable assay system to investigate the various effects of medicines in the de novo mineralization process.

Biography

Dr Riaz Akhtar is a Senior Lecturer in the School of Engineering, and the Programme Director for the MSc in Biomedical Engineering at University of Liverpool. His research largely focusses on structure-property relationships in ageing and diseased soft tissues at the nano- and micron- level. His work spans a number of biomaterials and tissues including hydrogels, cardiovascular tissues, ocular tissues and skin.

Riaz Akhtar graduated from UMIST in 2003 with a First Class M.Eng. (Hons) degree in Biomedical Materials Science with Industrial Experience. In 2007, he completed a Ph.D. degree at The University of Manchester on the micromechanical behavior of bone. Following this, he undertook a postdoctoral position investigating the micromechanical properties of soft tissue. In 2008, Riaz was awarded a British Heart Foundation Advanced Training fellowship investigating vascular stiffening and diabetes. He joined the University of Liverpool in October 2011 as a lecturer in Biomedical Engineering and was later promoted to Senior Lecturer.

IWBE 2021

Prof. Kaspar Althoefer

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Bio-inspired Growing Robots: From Conception to Implementation

Abstract

Recent years have seen a considerable surge of interest in tip-growing robots. Taking inspiration from how plants grow, this new type of robotic structure is capable of extending from the tip. A number of different approaches have been proposed and studied by roboticists around the world. Solutions include robots that are equipped with rapid prototyping technology to continuously "3D-print" a new tip on top of the current one. Other robots incorporate the eversion principle whereby a sleeve like structure, usually actuated by air, folds inside-out at the tip. These new robots are particularly suited to advance into otherwise inaccessible spaces, e.g., into the abdominal cavity of a patient during minimally invasive surgery, into a collapsed building as part of a search and rescue mission or into a nuclear plant for nuclear waste decommissioning. Since they are only expanding at the tip, they achieve a virtually frictionless forward motion keeping the disturbance of the environment to a minimum. This talk will present recent advances in the field of growing robots and discuss the challenges that need to be overcome to create practical robotic systems that are fit for purpose.

Biography

Professor Althoefer is an experienced roboticist leading competitively funded research on soft robotics, intelligent micro-sensing systems and interaction dynamics modelling with applications in minimally invasive surgery, assistive technologies and human-robot interaction at Queen Mary University of London. He acquired in excess of £6.5M as Principal Investigator from national/international funding bodies and successfully completed 22 PhD projects. Professor Althoefer's research team, currently comprising 10 postdoctoral research associates and PhD students, is involved in funded collaborative research with leading London hospitals, European research organisations and international companies creating novel robot-assisted solutions for nuclear waste decommissioning, cardiac catheterisation, foetal ultrasound monitoring, tissue diagnosis using miniaturised sensors and ergonomically-optimised human-robot interaction in the manufacturing sector. Over the last decade, the team has built a large portfolio of projects in application-oriented research for the healthcare sector and a wide range of industries with funding from organisations such as EPSRC, European Commission (including coordination of two EU-projects), Wellcome Trust and UK-based charities, exceeding £30M and producing more than 450 peer-reviewed papers.

Prof. Zhendong Dai

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Biomimetic on Gecko Locomotion: From Biology to Engineering

Abstract

Gecko has been studied for many years for their excellent moving abilities on various circumstances, including any inclines, confined spaces. Here we reported our studies on the gecko's locomotion behaviors and techniques during climbing through or in confined spaces. Results were summarized as follow: 1) the speed was heavily restricted when width of aisle (W)/width of brain (w) , Pw=W/w<0.9, and height of aisle (H) to the height of brain (h), Ph=H/h<0.9. 2) Gecko smartly optimized the foot trajectory to retract the legs and reduce the step pitch to avoid the leg extended out when move in width confined spaces. 3) Geckos developed a new method to overcome the difficult to move in height confined space by extending the legs and drive the body by adhere on the substrate even on floor. 4) We have developed bio-inspired a gecko mimicking robot to move in both width and height confined spaces. This robot has be found many possible applications of structure health detecting in narrow

Biography

Zhendong Dai, Professor, Nanjing University of Aeronautics and Astronautics (NUAA).

He obtained his education degrees in NUAA in 1983, 1986 and 1999 respectively. He has charged two NSFC key projects, key international cooperation projects, and several projects from MOST. He interests in the research of biomimetic, including animal locomotion stimulation, dynamics and reaction force, adhesive materials, and gecko mimicking robots.

Dr. Marco Domingos

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3D Bioprinting of Human Skeletal Tissues

Abstract

Nature in general, and lower vertebrates in particular, have evolved to grow and regenerate tissues and organs through complex self-assembling mechanisms using cells and other biomolecules as building blocks. Unfortunately, our bodies do not display this capacity, and although some organs (e.g. liver) can regenerate to a reasonable extent, most of human tissues resort to fibrosis and scar tissue formation upon trauma or disease. The emergence of 3D Bioprinting technologies has enabled us to overcome some of these limitations and develop artificial implants suitable for clinical restoration of human tissue and organ function [1]. Operating in a layer-by-layer form, 3D Bioprinting allows for the automated fabrication of 3D tissue analogues with complex functional and structural organization through the precise spatial positioning of multiple materials and cells [2]. Although our ability to create biological constructs with increasing complexity has been significantly improved with the introduction of these additive manufacturing technologies in the field of tissue engineering and regenerative medicine, the reality is that many of the cellular and molecular mechanisms underpinning human tissue regeneration and disease remain unclear. In this talk I will describe some of the most recent work done in our group to emulate human tissues and organs using advanced biofabrication systems in combination with polymeric hydrogels and stem cell technology. In particular, I will attempt to demonstrate how different fabrication strategies (i.e. top-down, bottom-up and hybrid) can be used to build 3D models with tuneable properties (i.e. physical, chemical, biological) and effectively employed in interrogating biological processes associated with the regeneration of (1) bone (2) cartilage and (3) intervertebral disc. Finally, I will discuss some of the major challenges and opportunities in the field of biofabrication towards the development of personalized therapies.

Biography

Marco Domingos is a Senior Lecturer/Associate Professor in the Department of Mechanical, Aerospace, and Civil Engineering at the University of Manchester (UK). He graduated in Mechanical Engineering (2006) from the Polytechnic Institute of Leiria (Portugal) and holds a Ph.D. (2013) cum laude in Mechanical Engineering from the University of Girona (Spain). He was elected fellow of the Higher Education Academy (UK) in 2016 and fellow of the Institution of Mechanical Engineers (FIMechE, UK) in 2017. He is also visiting Professor at the Centre for Rapid and Sustainable Product Development (CDRSP, Portugal) and at The University of Naples, Federico II (Naples, Italy). Since 2019, he is a principal investigator at the Henry Royce Institute (Manchester) with research interests in advanced biomaterials and biofabrication for regenerative medicine. He served as reviewer for several international funding bodies including Wellcome (UK), CINECA (IT) and Polish National Science Foundation (PL). He has authored or co-authored more than 50 scientific publications, including articles in peer-reviewed international journals, books and book chapters obtaining over 2600 citations (H index: 22)

Prof. Guoying Gu

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Soft Wearable Robotic Hands: Actuation, Sensing and Human-in-the-loop Control

Abstract

Human hands are skilled, versatile, and compliant for our intricate interaction with the world. Over generations, our hands have evolved unique musculoskeletal mechanisms integrating the muscular, skeletal, and neural systems. For almost a century, inventors and scientists have created numerous myoelectric hand prosthesis such as hook-like devices, multi-finger hands and anthropopathic hands. The success of bionic hand prosthesis, however, introduces the huge mechanism complexity and cost by integrating numbers of motors, transmission gears, tendons, connectors, electronic boards, and controllers, usually with years of development for each prototype. In this talk, I will present our recent development on a class of lightweight, low-cost soft wearable robotic hands and their applications as prostheses.

Biography

Prof. Guoying Gu is a professor of School of Mechanical Engineering, Shanghai Jiao Tong University, China. He was a Humboldt Fellow with University of Oldenburg (Germany). He was a Visiting Scholar at Massachusetts Institute of Technology (USA), National University of Singapore (Singapore) and Concordia University (Canada). His research interests include soft robotics, bioinspired and wearable robots, smart materials sensing, actuation, and motion control. He is the author or co-author of over 100 publications, which have appeared in Nature Biomedical Engineering, Science Robotics, Science Advances, National Science Review, Advanced Materials, Advanced Functional Materials, IEEE Trans., etc., as book chapters and in conference proceedings.

Prof. Gu received the National Science Fund for Distinguished Young Scholars. Now he serves as Associate Editor of IEEE Transactions on Robotics and IEEE Robotics and Automation Letters. He has also served for several journals as Editorial Board Member, Topic Editor, or Guest Editor, and several international conferences/symposiums as Chair, Co-Chair, Associate Editor or Program Committee Member.

Prof. Laurence Kenney

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Myoelectric Upper Limb Prostheses – the Promise and the Reality

Abstract

The first myoelectric prosthesis was demonstrated in the 1940s and clinical devices have been in use from the 1960s. Despite the vast number of research studies to improve myoelectric prostheses, a recent study suggested around 40-50% of patients report abandoning their device, a figure which has changed little over recent decades. The talk will provide an overview of research in Salford attempting to understand some of the factors which may contribute to the high levels of patient dissatisfaction. The talk will discuss the importance of the socket design in determining the reliability with which devices can be controlled, and introduce tools with which to better understand the users interactions with their prosthesis in their everyday lives.

Biography

Laurence Kenney originally trained in Mechanical Engineering. Since the late 1990s his research has focused on the design of devices to assist limb function, together with novel tools with which to evaluate them. He has published over 70 journal papers, is a past Associate Editor of Prosthetics and Orthotics International and chaired the 2019 TIPS upper limb prosthetics conference, TIPS.

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Prof. Chaozong Liu

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Osteochondral Scaffold Innovation Toward Early Treatment of Osteoarthritis: Going Biomimetic

Abstract

Osteochondral defects (OCDs), typically derived by repetitive trauma within the joint may alter the architecture or composition of the bone. Traumatic OCDs affect both the cartilage and the bone. If untreated, OCDs will lead to the development of osteoarthritis where a joint replacement is used in an end-stage treatment [1]. In 2018, there were 231282 replacements performed in England and Wales including 108902 hip procedures and 112382 knee procedures predominantly for osteoarthritis (93%) Stopping or delaying progression of OCDs would have significant impact in human health care.

The treatment of osteochondral defects has become a major concern in Orthopaedics because predominantly these defects do not heal spontaneously which make the joints susceptible to "early onset" secondary osteoarthritis [2]. Tissue engineering approaches have emerged for the repair of cartilage defects and damages to the subchondral bones and have shown potential in restoring joint's function [3]. To achieve satisfactorily regenerate the bone and the native hyaline cartilage, the osteochondral scaffold needs to recapitulate the physiological environment of the native osteochondral tissue with respect to its gradient structure, compositions and mechanical property.

To this end, we have invented a novel a multi-layered osteochondral scaffold system which works with the body's natural mechanisms to bear the load of the joint, while encouraging the regeneration of cartilage and bone tissue. This novel scaffold incorporates both organic and inorganic material to make it customizable to each patient, a quality which, scaled-up, would be an impressive advance for precision medicine, improving outcomes and the longevity of replacement joints and reducing the costs and risk factors of the knee and hip surgeries.

The in vivo sheep study has observed that gross morphological appearance of regenerated cartilage was superior in osteochondral scaffold group compared to the control group. Collagen 2 and Safranin-O stainings confirmed formation of a hyaline-like cartilage. The pQCT examination revealed that the BV/TV ratio in the surrounding subchondral bone was significantly higher (p=0.01) in the osteochondral scaffold group (~40%) than that in the control group (~15%). The bone-scaffold contact analysis revealed the bone-implant contact achieved 61%.

The sheep condyle model studies have demonstrated that the osteochondral scaffold achieved a stable mechanical fixation when implanted into the osteochondral defect of the joints, the bone grew into the Titanium matrix and formed strong support to the overlying cartilage regeneration, which led to the improved cartilage fill and healthy growth as revealed by histological examinations.

This novel osteochondral scaffold technology is designed to repair and regenerate cartilage damage at an early enough stage to stop or slow down the progression of osteoarthritis. It is suitable for patients who have experienced trauma to a joint, caused by a sports injury, fall or car accident. By finding an effective way to treat patients at an early stage of cartilage damage we could delay or avoid the need for a total joint replacement. This can reduce the financial burden to healthcare providers and the patients themselves. The beneficiaries reflect the value chain from the patient, through the clinician, the hospital and healthcare providers, to the industrial generators of the underpinning technology and materials.

Biography

Chaozong Liu is a Professor of Orthopaedic Engineering, the programme leader of MSc in Musculoskeletal Science, and the group leader of UCL Orthopaedic Bioengineering Research Group within the Division of Surgery & Interventional Science University College London， in associate with the Royal National Orthopaedic Hospital.

Professor Liu's current research is directed toward the biomaterials processing and development of enhanced medical devices for treating musculoskeletal disorders, tissue repair and regeneration. This is a growing area of interest at UCL Surgical & Interventional Science. His research in this area is supported by Versus Arthritis UK, Innovate UK, Horizon2020, NIHR, EPSRC. and Rosetrees Trusts, and from Fitzpatrick Referrals Ltd. He has developed a new osteochondral scaffold technology that is likely to have a strong potential in regeneration of bone and cartilage for early intervention of osteoarthritis. A glimpse of how this scaffold performs has been given, with promising results, by Professor Noel Fitzpatrick of the Channel 4 TV series Supervet, where it was implanted in a pet dog shoulder to treat a large osteochondral defect. His achievement in early treatment of osteoarthritis has recently been highlighted in Arthritis Toady (Nov 2017). The recent awards from Innovate UK-MoST and EU HORIZON2020 have significantly boosted his research in this field. The Versus Arthritis UK treatment sub-committee deemed the osteochondral scaffold "an exciting technology with the potential to provide a novel intervention for a large number of patients and potentially provide good value for money for the health services" (dated 24 Oct 2017), and awarded grant for first in man clinical trials which has started 01 October 2019 in the Royal National Orthopaedic Hospital.

Prof. Rui Loureiro

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The Rise of Bionic Robots in the Optimisation of Personalised Clinical Procedures

Abstract

For over two decades there has been a growing interest and activity to explore the use of robots in rehabilitation, where the model is to incorporate robotic assistance designed to enhance recovery following injury. In this model it is expected that the robot will be made available possibly during the patient's hospital stay or in the months that follow. This talk will look at new ways of using robots and games for clinical training and will demonstrate how strategies that aim to 'trick' the brain can have a positive impact on the recovery of cognitive and physical injuries and in reducing pain.

Biography

Prof Rui Loureiro is a Full Professor at UCL and Head of the UCL Institute of Orthopaedics and Musculoskeletal Science and of Aspire's Centre for Rehabilitation Engineering and Assistive Technology (CREATe) at UCL. He is a member of the strategic board of the UCL Institute of Healthcare Engineering and he is PI at the Wellcome-EPSRC Centre for Interventional and Surgical Sciences (WEISS) where he leads the development of musculoskeletal surgical innovations. He is the founding president of the International Consortium on Rehabilitation Robotics (since 2018). He specialises in advanced robotics and human interactive systems for surgery and rehabilitation. He has pioneered work in stroke rehabilitation and movement disorders and has a wealth of experience with both the design of rehabilitation technologies and clinical assessment and translation of such aids to clinical practice, and on the development of immersive simulators for surgical planning and training.

Before joining UCL in the Spring 2014, he was a senior lecturer at Middlesex University (2010-2014) and enjoyed research appointments at the University of Reading (2000-2010), Royal Berkshire Hospital NHS Foundation Trust (2006-2010), and engineering consultancies at Synectic Design LTD (1998-2000). In 2004, he received the Top 10 Britain's Young Engineer award from Rolls-Royce and Science Engineering and Technology (SET) for Britain and in 2006, the Siemens Automation & Drives award from the Institute of Measurement & Control for outstanding academic achievement. He is associated with several professional organisations, has applied for five patents, raised over £22m in research and commercial grants and his work has been highly cited.

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Prof. Thrishantha Nanayakkara

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A Soft Robotics Approach to Understand How the Brain Conditions the Body to Make Realtime Survival in Natural Environments More Efficient

Abstract

Recent experiments using human participants and validation using soft robotic counterparts show that it is efficient to condition the physical mechanics of the body to solve realtime control and perception problems. In terms of efficient perception, passive dynamics of the body can be conditioned to reduce the variability of task related random variables. In terms of control too, such conditioning of mechanics can help to use contraction regions for realtime convergence to steady states. In this talk, I will show some examples to suggest that the brain takes a selective approach when it wants to intervene in dynamic tasks to make then more efficient and stable. I will take examples from soft tissue palpation, object recognition, and locomotion to show some recent results from my lab.

Biography

Prof. Thrishantha Nanayakkara is the director of the Morphlab, Dyson School of Design Engineering, Imperial College London. He is also the present chair of the Imperial Robotics Forum consisting of 44 Robotics Principal Investigators, and one of the three directors of the UK RAS Strategic task group for soft robotics. His research interests are in taking a soft robotics approach to understand the nature of the shared computation between the nervous system and the physical body of biological beings. He has published more than 150 peer reviewed papers in flagship robotics journals and conferences. He is in the editorial board of Scientific Reports in Nature Publishing Group, IEEE ICRA, IROS, RAL, Frontiers Mechatronics, and Journal of Robotics and mechatronics. For more details, please visit: https://www.imperial.ac.uk/morph-lab

Prof. Rong Song

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Bionic and Adaptive FES control for Ankle Rehabilitation

Abstract

Functional electrical stimulation (FES) is commonly used for individuals with neuromuscular impairments to generate muscle contractions and correct drop foot. Both joint torque and stiffness play important roles in maintaining stable posture and resisting external disturbance. However, most previous studies only focused on the modulation of joint torque using FES while ignoring the joint stiffness. A model that can simultaneously modulate both ankle torque and stiffness induced by FES was investigated in this study. Moreover, an iterative learning control to adaptively adjust the output intensity of the functional electrical stimulation according to the gait performance was proposed and verified on patients after stroke.

Biography

Professor Song has been working on rehabilitation robotics, biomedical signal processing and related areas for many years. Based on the support of general program of National Natural Science Foundation of China, key program of Science and Technology Planning Project of Guangdong Province etc., he has authored/coauthered over 50 SCI papers in rehabilitation engineering and robotics. He also has applied for over 40 patents of invention (over 20 authorized). Professor Song is currently the member of the Technical Committee on Rehabilitation Engineering in Chinese society of Biomedical Engineering, director of Guangdong Provincial Engineering and Technology Center of Advanced and Portable Medical Devices, and IEEE senior member.

Prof. Nikos Tsagarakis

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Compliant and Ergonomic Design Principles for Enhanced Performance Robots and Wearable Systems.

Abstract

The talk will provide an overview of the robot mechatronic developments within the Humanoid and Human Mechatronics Lab at IIT, introducing the design and control approaches adopted in the development of a series of robotic systems from mobile legged robots to wearable assistive and tracking devices for the upper and lower limbs. Such robotic systems will include CENTAURO and COMAN+ legged robots and the IT-Knee and Exo-Muscle assistive devices. The details on the compliant actuation, ergonomic design and control principles adopted in these robotic platforms will be introduced and how these principles can eventually enhance the physical and ergonomic performance of these systems will be discussed. In particularly the improvements attained in terms of physical strength and resilience, motion economy of the legged robots as well as reduction of constraints and parasitic forces generated by the wearable devices will be presented.

Biography

Professor Nikos Tsagarakis is Tenured Senior Scientist and Principal Investigator of the Humanoid & Human Centred Mechatronics (HHCM) Research Line, a leading research laboratory at IIT with strong expertise in robot design, modelling and control, and in the development of new mechatronics components (actuation and sensing). HHCM is the home laboratory where the compliant humanoids COMAN and WALK-MAN and the CENTAURO hybrid wheeled-legged quadrupedal manipulation platform were developed. Nikos Tsagarakis was the coordinator of EU project WALKMAN and has served as principal investigator for several EU projects in the past including VIACTORS, SAPHARI, AMARSI, WEARHAP and most recently for CogiMON, CENTAURO and EUROBENCH. He is an author or co-author of over 350 papers in research journals and at international conferences and holds 16 patents. He has received the Best Jubilee Video Award at IROS (2012), the 2009 PE Publishing Award from the Journal of Systems and Control Engineering and prizes for Best Paper at IEEE ICAR (2003) and the Best Student Paper Award at IEEE Robio (2013). He was also a finalist for Best Entertainment Robots and Systems - 20th Anniversary Award at IROS (2007) and finalist for the Best Manipulation paper at IEEE ICRA (2012), the Best Conference Paper at Humanoids (2012), the Best Student Papers at IEEE Robio (2013) and ICINCO (2014), Best Interactive Paper finalist at IEEE Humanoids (2016).

Best Interactive Paper at IEEE Humanoids (2017), Best Conference Paper Finalist at IEEE ROBIO (2019), Best Paper Award IEEE/ASME AIM (2021) and Best Paper Finalist at IEEE Humanoids (2021) He has been in the Program Committee of over 60 international conferences including IEEE ICRA, IROS, RSS, HUMANOIDS BIOROB and ICAR. Nikos Tsagarakis was Technical Editor of IEEE/ASME Transactions on Mechatronics (2012-2015) and from 2014 served on the Editorial Board of the IEEE Robotics and Automation Letters.He is currently a Senior Editor of IEEE/ASME Transactions on Mechatronics. He has been involved in the following projects and activities: EU Project CONCERT (2021- 2024) Role: Project Coordinator, EU Project SOPHIA (2020- 2023) Role: IIT Co-applicant, IIT & Kilometro Rosso JOiiNT LAB (2020-2024), EU Project EUROBENCH (2018-2022) Role: IIT Principal Investigator, EU Project CENTAURO (2015-2019) Role: IIT Principal Investigator, EU Project CogiMon (2015-2019) Role: IIT Principal Investigator, EU Project WALK-MAN (2013-2017) Role: Project Coordinator, EU Project SAPHARI (2011-2015) Role: IIT Principal Investigator, EU Project AMARSI (2010-2014) Role: IIT Principal Investigaror, EU Project VIACTORS (2009-2012) Role: IIT Principal Investigator, EU Project ROBOTCUB (2004-2009).

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Prof. Qining Wang

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Human-Centered Wearable Robots for Broader Applications

Abstract

The rise in life expectancy combined with falling birth rates, will accelerate the ageing of this population. On the other hand, robotic applications have rapidly expanded from classical industrial applications with repetitive tasks to applications with close human-robot interaction. While initially conceived for human motion augmentation purposes, wearable powered robots have been gradually proposed as a technological aid for motion rehabilitation and assistance, and functional substitution in patients suffering from motor disorders. In this talk, the state-of-the-art of wearable robotics, especially lower-limb prostheses and exoskeletons will be introduced. Then the recent progress in this area of my lab will be shown. Finally, we will show recent progress on the new area of underwater applications. To date, all the exoskeletons have been studied to assist human motions on land. However, regardless of the exoskeletons being rigid or soft, an exoskeleton for underwater motion assistance has not been realized thus far. This talk will discuss the challenges of using exoskeletons for underwater applications. And recent breakthrough of an underwater soft exoskeleton from my lab will be introduced in detail.

Biography

Qining Wang received the Ph.D. degree in Dynamics and Control from Peking University, Beijing, China, in 2009. He is currently a Tenured Full Professor with the College of Engineering, Peking University, and serves as the Deputy Dean of the College of Engineering, Peking University, China. He has authored/coauthored more than 190 scientific papers in international journals and refereed conference proceedings. His research interests include wearable robotics and human-machine interfaces. He serves as an Advisor of the IEEE-RAS Technical Committee on Wearable Robotics. He was an Associate Editor for the IEEE Robotics and Automation Magazine from 2016 to 2018, and a Technical Editor for the IEEE/ASME Transactions on Mechatronics from 2017 to 2020. He has been an Associate Editor for Robotica since 2018, and an Associate Editor for the IEEE Transactions Medical Robotics and Bionics since 2018. He received Xiongyoulun Outstanding Youth Award in 2018.

Dr. Helge Wurdemann

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Soft Robotics for Healthcare

Abstract

Departing from traditional types of robots, which are based on an arrangement of rigid link elements connected via joints, soft material robots are made of fundamentally different structures. With the increased interest in the use of soft materials for the creation of highly dexterous robots, soft material robotics has established itself as an important research topic within soft robotics. This talk will present a number of soft material robots with applications in healthcare, industrial settings and autonomous driving. Examples include miniaturised soft, stiffness-controllable manipulators for minimally invasive surgery and large-scale structures that guide drivers when changing between different levels of autonomy in highly automated vehicles. Scalability, stiffness controllability and modelling are challenging topics in the field of soft robotics that will be discussed along with innovative opportunities for future systems.

Biography

Helge Wurdemann is a roboticist and Associate Professor of Robotics leading research on soft haptics and robotics at UCL Mechanical Engineering. He is also Co-Director of the Intelligent Mobility at UCL (IM@UCL, www.im-ucl.com) lab, a full-size driving simulator. His Soft Haptics group (www.softhaptics.website) focuses on the hardware design and application of soft material robotic systems that have the ability to change their shape and stiffness on demand bridging the gap between traditional rigid and entirely soft robots. Dr Wurdemann creates and embeds innovative stiffness-controllable mechanisms as well as combine advanced Artificial Intelligence with control strategies in robotic prototypes emerging from his lab.

Dr Wurdemann has authored/co-authored more than 100 peer-reviewed papers. The majority of his journal papers are in the top journals of the field, including top transactions and journals of the IEEE and ASME and proceedings of the leading national learned societies in the field, IMechE and IET. He has published his research findings in refereed conference papers in the proceedings of leading conferences in his field. He currently is Associate Editor for prestigious robotics conferences (ICRA and IROS) and serves as Associate VP within the IEEE Robotics & Automation Society Conference Activities Board and as member of the IET Robotics and Mechatronics TPN Executive Board. He is Co-General Chair of the IEEE International Conference on Robotics and Automation 2023, the premium robotics conference, which will be hosted for the first time in the UK.

Prof. Shane Xie

University of Leeds, UK

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Reconfigurable Robotic Exoskeleton for Effective Stroke Rehabilitation in Residential Settings

Abstract

Stroke and neurological diseases have significant impact on our society, this talk will discuss the key societal challenges, robotic technologies for delivering effective rehabilitation and opportunities for the healthcare industry. The keynote will cover the recent development of robotics for stroke rehabilitation, the research gaps and the need for new technologies in neuroscience, robotics and artificial intelligence. The talk will introduce a EPSRC-funded project on intelligent reconfigurable exoskeletons tailored to meet patients' needs, deliver effective diagnosis and personalised treatment, and monitored remotely by rehabilitation therapists. The talk will also briefly introduce the Leeds Centre for Assistive/Rehabilitation Robotics and our work on ankle robot, gait exoskeleton, gait upper limb bilateral robot, neuromuscular and brain computer interfaces. The focus is on the technologies for those whose strength and coordination have been affected by amputation, stroke, spinal cord injury, cerebral palsy and ageing.

Biography

Prof Shane (Sheng Q) Xie, Ph.D., FIPENZ, is the Chair of Robotics and Autonomous Systems and Director of the Rehabilitation Robotics Lab at the University of Leeds, and he was the Director of the Rehabilitation and Medical Robotics Centre at the University of Auckland, New Zealand (NZ, 2002-2016). He has >28 years of research experience in healthcare robotics and exoskeletons. He has published > 400 refereed papers and 8 books in rehabilitation exoskeleton design and control, neuromuscular modelling, and advanced human-robot interaction. He has supervised >15 postdocs, 62 PhDs and 80 MEs in his team with funding of >£27M from five countries since 2003. His team has invented three award-winning rehabilitation exoskeletons. He is an expert in control of exoskeletons, i.e. impedance control, adaptive control, sliding mode control, and iterative learning control strategies. He has received many distinguished awards including the New Zealand Science Challenge Award, the David Bensted Fellowship Award, and the AMP Invention Award. He is an elected Fellow of the Institute of Professional Engineers of New Zealand and the Technical Editor for IEEE/ASME Transaction on Mechatronics.

Prof. Yuying Yan

University of Nottingham

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Progress of Biomimetics in Energy Transfer and Storage

Abstract

Living things have been continued to evolve under the pressure of survival and show structures with certain functions. They provide inspirations for humans to cope with challenges that they face today. In this presentation, our recent progresses of the work inspired by nature or biological entities are introduced. This includes the energy transfer and storage involving using composite phase change materials with hierarchical porous structures for energy storage. Such biomimetic structures, inspired by natural plants, help avoid the leakage of phase change materials in the porous and improve overall performance of heat transfer. In addition, a recent progress in terms of the application of the radiative cooling coating inspired by human skin wrinkles is reported. This work provides a novel strategy for designing, fabrication, and application of high-performance radiative cooling materials.

Biography

Yuying Yan, who obtained PhD in Mechanical Engineering from City University of London in 1996, is Professor of Thermofluids Engineering in Faculty of Engineering at University of Nottingham, UK. His research covers wide range area of fluid flow and heat transfer including heat transfer enhancement, phase changes, nanofluids and nature inspired solutions for energy efficiency, as well as energy storage and thermal management (for gas turbines, electrical & electronics and automotive engineering).

Dr. Wei Yao

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Design of a Bio-inspired Wearable and Adaptive Robotic Hand Glove for Hand Rehabilitation after Stroke

Abstract

Stroke is increasingly becoming a more regular part of everyday life. The recovery of use of patient's hand is inferior to those of other joints. A wearable and adaptive hand glove system has been designed that would utilise the patient's own skeleton as the frame to operate from. Inspiration was drawn from looking at nature, for how best an object can be secured in place whilst at remaining rigid in its placement, best illustrated by an octopus, an animal that suction based grippers on its tentacles that allow it to tightly grip an object and subsequently move with it. The concept for this component was that a glove would provide a good fitting base by suction cups that matches the shape of the hand and to provide a stable base for the actuator to function in a consistent manner. If the suction cups were fixed in place against the skin it would provide the firmest base for the vacuum generation to be performed. This design has the possibility of providing one to each patient, allowing them to exercise their hand throughout their daily life.

Biography

Dr Wei Yao is a senior lecturer in Medical Robotics in the department of Biomedical Engineering, The University of Strathclyde, Glasgow, UK. Previously, he was a Postdoc Research Fellow at King's College London for a project of developing an MRI-compatible steerable robotic catheter system for cardiac catheterization. Before he moved to King's College, he worked for two years in the Department of Surgery and Cancer at Imperial College London, carrying on research into robotics for minimally invasive surgery. C. His research focuses on developing a number of cutting-edge and multi-discipline robotic technologies by integrating mechatronics, sensing, control, medical imaging and robotic navigation for the next generation of surgery and rehabilitation.

Prof. Shujun Zhang

University of Gloucestershire

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The Study of Bio-inspired Electromagnetic Fields on Health Enhancement Past, Present and Future

Abstract

It is believed that the health of our body is totally dependent on the health of our cells. The cell is the basic structural, functional and biological unit of all known living organisms. Cells consist of cytoplasm enclosed within a membrane. The membrane pulses at a certain frequency with certain magnitudes. More cell pulse activity there is, the more active, energetic and healthier cells are. Human and other animals live in an earth environment of extremely low natural frequencies (ELF).The earth produces these both high in the atmosphere (Schumann (7.83Hz)) as well as on and below the planet's surface (Geomagnetic (10 Hz)). Schumann and Geomagnetic frequencies are vital to the wellbeing of all living things. It is believed that if we are in an environment with bio-inspired electromagnetic signals generated by mimicking natural earth and body cells frequencies (ELF's), then our cells will be more energetic and active, providing greater health. Time-varying pulsed electromagnetic fields (PEMF) are the signals that induce electric fields in the body's conductive tissue through inductive coupling, thereby producing eddy currents. PEMF are typically applied at extremely low frequencies between 5 and 300 Hz, but can also feature short wave frequencies, for example, 27 MHz. The potential of electromagnetic fields (EMFs), especially bio-inspired EMFs (Bio-EMFs), for disease treatment and health enhancement has been actively pursued over the recent decades.

This paper will first review the advancement of the PEMF study in the areas of (1) cell pulsations and pulsed electromagnetic fields, (2) their bio-inspirations for health enhancement, (3) development devices, (4) health enhancements, (5) health condition treatment. Then, the discussion will be placed on the problems associated existing study and our view of the future research.

Biography

Prof. Shujun Zhang is a professor of School of Computing and Engineering, University of Gloucestershire, UK. He is Tang Auqing Lecturing Professor, Key Laboratory of Bionics Engineering, Jilin University, China. His research interests include bio-computing, bionics engineering, bio-inspired assistive robots, the electromagnetic systems for health enhancement inspired by cell pulsations, 3D computation, big data and datamining, bio-inspired smart algorithms and smart system design and development.

He is the author or co-author of I have published a total of more than 150 papers which appears on more than 15 international renowned journals such as Journal of Bionics Engineering, Journal of Mechanical Engineering Science (IMechE Journals), Robotica, Polymer Engineering and Science, Journal of Sensors, Mathematical Biosciences and Engineering, Emerging Science Journal, Applied Bionics and Biomechanics, Science China, Technological Science, International Journal of Advanced Manufacturing Technology, Rapid Production, Mathematics and Computer in Simulations, etc., as book chapters and in conference proceedings.

Prof. Zhang has received About 40 funded projects have been carried out, including the funds from EPSRC, EU, NSFC, UK Science Ministry, UK Technology Strategy Boards, South Korea Government and Industrial partners.

He is the founding member of Journal of Bionics Engineering and The International Society of Bionics Engineering. He is currently serving for several journals as Editorial Board Member or Guest Editor, and several international conferences/symposiums as Program Committee Member or session chair. He has given more than 10 invited keynote speakers.

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Prof. Feng Zhou

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Bioinspired Surface Lubrication Materials and Technologies

Abstract

Inspired by the extraordinary hydration mechanism, unique biochemical structure feature and the adaptive load-bearing/stress dissipation route of natural articular cartilage, a series of novel soft matters lubrication materials have been designed. These novel materials exhibit high load-bearing, low friction and excellent wear-resistance properties, as well as remarkable lubrication performance of cartilage. eg. One kind of novel archetype of cartilage-mimicking bilayer material by robustly entangling thick hydrophilic polyelectrolyte brushes into the subsurface of a stiff hydrogel sub-strate is developed. This kind of cartilage-inspired lubrication material is capable of attaining low friction coefficients (order 0.01) under heavily loaded conditions (order 10 MPa contact pressure) in water environment, a performance incredibly close to that of natural articular cartilage. Furthermore, some novel methods for decorating these high-performance soft matters lubrication materials onto the surface of materials are developed, for which exhibit huge application potential in the fields of lubricious biomedical devices, anti-fog, and antifouling etc. Meanwhile, the optimal mechanical modulus, strong interface bonding and rich surface hydration are three key factors to design robustly lubricious coatings materials. Finally, a series of functional lubrication products&technologies are developed.

Biography

Feng Zhou is a Full Professor in Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, China, and head of the State Key Laboratory of Solid Lubrication. He gained his PhD in 2004 and spent three years (2005–2008) in the Department of Chemistry, University of Cambridge as a Research Associate. He has published more than 400 journal papers, which have received more than 20000 citations and have a high-index of 80. His research interests include bioinspired tribology, biomimic surfaces/interfaces of soft matter, drag-reduction, anti-biofouling, and boundary lubrication. He has obtained more than 80 authorized patents, most of the technologies have successfully applied to the design of new products in the fields defense, industry, medical and ecological environment. He has gained a number of awards including the ‘‘Outstanding Youth Award’’ of the International Society of Bionic Engineering, 2013, and National Award for Natural Sciences (Second Class), 2015. He serves as an Editorial Board Member of Tribology International, Friction, Journal Fiber Bioengineering and Informatics, Coatings etc.

IWBE 2021

Abstract ID No.01

Artificial Superhydrophobic Surfaces and Their Applications

Guoyong Wang, Shuai Liu, Wenting Zhou, Ning Sun, Tong-Yi Zhang, Yan Liu
Jilin University

Abstract

Superhydrophobic surfaces have attracted great interest because of their potential applications in various areas, such as self-cleaning, antisticky, anticorrosion, oil-water separation and microfluidic devices. Solid surfaces with switchable wettability between superhydrophobicity and superhydrophilicity are of great importance due to their numerous industrial applications. Here, we built up a hierarchical copper structure combining micro- and nanogaps/pores on copper substrate by etching and electrodeposition. The surface could be hydrophobized with thiol-modified fluorocarbons, after which it showed a water contact angle as high as 165° ± 2° . This surface could also regain the superhydrophilicity with a zero water contact angel after annealing at 200 ° C for 10 min to desorb the low surface energy monolayer of thiol-modified fluorocarbons and reform a CuO layer again on the surface. Repeating the process of adsorption/desorption of the monolayer by modification and annealing, it was successful to fulfill the wettability cycling between superhydrophobicity and superhydrophilicity on the copper surface. On the basis of this study, we obtained a suitable surface roughness on the copper matrix by using chemical etching and electrodeposition. The pristine superhydrophilic CuO surface spontaneously transited to be superhydrophobic after exposed in air at room temperature for about 3 weeks. The wettability change is attributed to the adsorption of oxygen molecules on the topmost layer according to the surface chemical analysis. The adsorbed oxygen molecules could be removed by dipping the sample into l-Ascorbic acid solution for 10 s, leading to the recovery of the pristine superhydrophilicity. Thus the copper surface can be converted from superhydrophilic to superhydrophobic for several times without surfactant modification.

In the application of superhydrophobic surface, we found that those surfaces is limited by the fragility of nanoscale asperities. Combining chemical etching and anodization, microscale pits and nanoscale pores, instead of the micro and nano protrusions on traditional superhydrophobic surfaces mimicking Lutos leaves, were fabricated on commercially pure aluminum surfaces. After modified by FDTS, the surfaces were superhydrophobic and self-cleaning. The ultrahigh hardness and electrochemical stability of Al2O3 coating endowed the surface excellent mechanical durability and good corrosion resistance.

In addition, traditional oil−water separation materials have to own ultrahigh or ultralow surface energy. Thus, they can only be wetted by one of the two, oil or water. Our experiment here demonstrates that the wettability in oil−water mixtures can be tuned by oil and water initially. Hierarchical voids are built on commercial copper foams with the help of hydrothermally synthesized titanium dioxide nanorods. The foams can be easily wetted by both oil and water. The water prewetted foams are superhydrophilic and superoleophobic under oil−water mixtures, meanwhile the oil prewetted foams are superoleophilic and superhydrophobic. Many kinds of water−oil mixtures were separated by two foams, prewetted by corresponding oil or water, respectively, combining a straight tee in a high flux, high efficiency, and continuous mode. This research indicates that oil−water mixtures can be separated more eco-friendly and at lower cost.

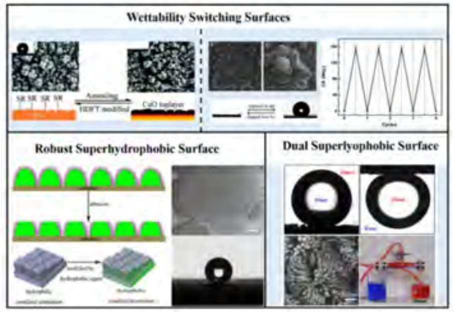

Figure 1: Artificial superhydrophobic surfaces and their applications [1-4]

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Abstract ID No.02

Biohybrid Magnetic Stem Cell Spheroid Microrobots with Rapid Endoluminal Delivery and Imaging

Ben Wang
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Abstract

High-precision delivery of microrobots at the whole-body scale is of considerable importance for efforts towards targeted therapeutic intervention. However, vision-based control of microrobots, to deep and narrow space inside body, remains a challenge. Here we report a soft and resilient magnetic cell microrobot with high biocompatibility that can interface with the human body and adapt to the complex surroundings while navigating inside body. We achieve the time-efficient delivery of soft microrobots using an integrated platform called endoscopy-assisted magnetic actuation with dual imaging system (EMADIS). EMADIS enables the rapid deployment across multiple organ/tissue barriers at the whole-body scale and high-precision delivery of soft and biohybrid microrobots in real-time to those tiny regions with depth up to meter scale through natural orifice, that are commonly inaccessible and even invisible by conventional endoscope and medical robots. The precise delivery of magnetic stem cell spheroid microrobots (MSCSMs) by the EMADIS transesophageal into the bile duct with a total distance of approximately 100 centimeters can be completed within 8 minutes. The integration strategy offers a full-clinical imaging technique-based therapeutic/intervention system, which broadens the accessibility of hitherto hard-to-access regions, by means of soft microrobots.

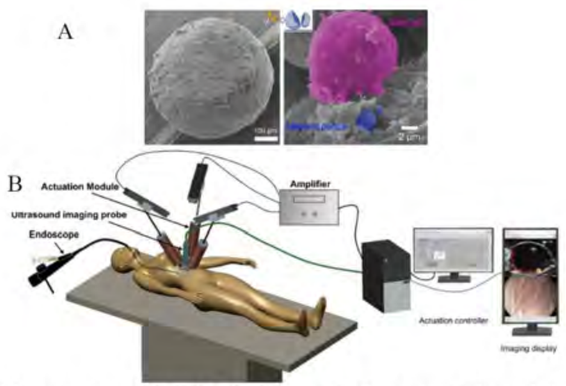

Figure 1: (a) SEM images of an MSCSM. (b) Schematic of the micro-robotic delivery by EMADIS.

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Abstract ID No.03

The Impact of Principles Biomimicry for Sustainable Building Materials

Abdulfattah Yahya
Cairo University

Abstract

Sustainable development is development that fit the requirements of the present without reducing the ability of future generations to meet their own needs. The research paper is exposed to the study of different types of new materials, recycled and used in several different Majallat and functions of the buildings designed through simulating nature and knowledge of the needs of the individual, and also display models of buildings has been the use of sustainable interfaces using starter simulate nature. This paper is a comprehensive study of some of the principles of biomimicry, new materials that may help in the practice of designing and building a more sustainable ways, are expected to use these principles in all parts of the building to get the best results come from nature.

1- Introduction:
Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. These principles of green buildings are key elements in developing design practices for more ecological built environments

2- Research Methodology
The research starts with a brief theoretical review of Biomimicry Research and More application of new materials (Function and technics), whenever they take advantage of the chances of sustainability and the Save energy in buildings..

Conclusions
The concept of Biomimicry is an important underlying principle of a new method of design thinking. It is not a new style of architecture, rather it is a methodology based on ecological principles. Although society pays for the hidden costs of negligent design through the externality costs of energy production, natural resource depletion, the destruction of habitat ecosystems, the pollution of air, water and soil, and higher health risks caused by the toxic materials and poorly ventilated buildings, it is not the responsibility of society to change the practices of architects. That obligation rests on the design and construction profession. As the designers of the buildings we live and work in, we have the duty and opportunity to lead humanity towards a more sustainable lifestyle. Fundamentally, the client, architect and builder need to make a decision together to contribute to move towards environmental accountability.
The building must react with the surrounding environment, according to the concept of sustainability. Through the balanced interaction with natural resources like the sun, the wind, the topography of the land, building materials available, adapted to the social values, customs and traditions of society.

Abstract ID No.04

Numerical Bionic Fish Schooling Based on Deep Reinforcement Learning

H. Yu, B. Liu, H. Huang, X.-Y. Lu
University of Science and Technology of China

Abstract

Fish schooling and their spontaneously formed stable formations are intriguing. The mechanism beneath the phenomena is invaluable for the bionic design of the autonomous underwater vehicle (AUV). In this work, a numerical study of collective behaviours of two and multiple self-propelled foils swimming is presented. Deep reinforcement learning (DRL) is applied to characterize the intelligence of fish. We explored whether stable formations emerge spontaneously under the driven of two different strategies. One strategy is that only the following fish gets hydrodynamic advantages. The other is that all individuals in the group take advantages of the flow-mediated interaction. Under the two strategies, collective stable configurations with different characteristics, i.e., the staggered-following, tandem following, phalanx and compact modes emerge. They are consistent with the results in the literature. The hydrodynamic mechanism of the above stable and high-efficiency collective travelling modes is analysed by the vortex-body interaction and thrust. We also found that the time sequence feature and hydrodynamic information in the DRL are essential to improve the performance of collective swimming. Our research can reasonably explain the controversial issue observed in the relevant experiments. The study may be helpful for the design of bionic fish.

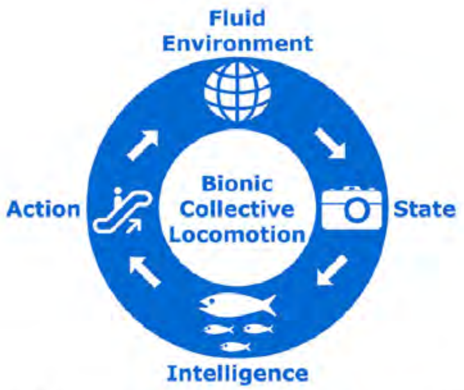

Figure 1: Bionic collective locomotion based on the deep reinforcement learning and the local flow environment.

Abstract ID No.05

Elastic Local Buckling Behavior of Beetle Elytron Plate

Xiaoming Zhang, Yong Wang and Meini Su
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Abstract

Beetle elytron plate (BEP) is a biomimetic sandwich structure inspired by the internal architecture of beetle elytra and characterized by trabeculae in the core. This type of structure has been shown to possess superior mechanical properties to conventional sandwich plates; however, there are no studies that evaluate its structural bending resistance. This paper develops an analytical method to calculate the key component of bending resistance of BEPs: the elastic local buckling load of the compression skin. It assumes that the compression skin of BEPs is simply supported by the trabecular core. After eliminating local buckling in the edges of the compression skin outside the trabeculae, two buckling zones, depending on the ratio (η) of trabecular radius to the distance between two adjacent trabeculae, are identified. At low η values (η ≤0.25), elastic buckling occurs in the space of the compression skin surrounded by four adjacent trabeculae. Beyond the critical value of η (η>0.25), buckling occurs in the compression skin enclosed by individual trabecula. Guided by finite element simulation results, this paper identifies a new suite of deformation shape functions and derives local elastic buckling load for the compression skin according to the principle of minimal total potential energy. Afterward, a convenient quadratic polynomial regression equation is proposed to modify the elastic buckling coefficient of the compression skin of equivalent conventional grid honeycomb sandwich plates, with the maximum difference between analytical calculation results and finite element simulation results being about 7%.

Abstract ID No.06

Bio-inspired Liquid Gating Technology

Xu Hou
Xiamen University

Abstract

Nature provides a huge range of biological materials with various smart functions over millions of years of evolution, and serves as a big source of inspiration for bio-inspired materials. Ion channels existed in living organisms play a significant role in maintaining balanced physiological conditions and serve as "smart" gates to ensure selective ionic transport. Inspired by ion channels, various smart artificial nanochannel systems have been developed. Pore and channels are everywhere on different scales, ranging from biological ion channels to large oil pipelines. The problems with such channels center on energy saving, anti-block, anti-fouling and anti-corrosion. Currently, we are focusing on the development of bio-inspired liquid-based gating system, which is a smart gating membrane. The reconfigurable fluid gate is able to reconcile the competing demands of responsive control, complex multiphase selectivity, and clogging prevention in a single integrated mechanism. For each transport substance, the gating threshold can be rationally tuned over a wide pressure range. This system allows gas-liquid sorting in a microfluidic flow and separates a three-phase air-water-oil mixture with an antifouling behavior. This bio-inspired system could be used in a variety of pore structures, material chemistries, and micro/macroscale systems, providing opportunities for complex sorting in fuel, environmental, microfluidics, biomedical, 3D-printing, and other applications.

IWBE 2021

Abstract ID No.07

Construction of High-performance Nacre-inspired Metalceramic Composites via Ice Templating and Melt Infiltration

Ping Shen, Zhijie Hu, Likai Yang
Jilin University

Abstract

Inspired by fantastic "brick-and-mortar" structure and fabulous properties exhibited in nacres [1], we synthesized a series of nacre-like metal ceramic composites using a combined ice-templating and melt-infiltration technique. The morphologies and structures of the composites can be tailored by changing some intrinsic and extrinsic factors during freezing of ceramic slurry and subsequent metal infiltration. Several strategies were proposed to facilitate the penetration of molten metal into porous ceramic architectures based on the wetting principle, and the defects were greatly reduced, thus substantially improving the mechanical properties of the resultant composites. Through in-situ observation of crack extension, we preliminarily revealed the fracture behavior and toughening mechanisms of the biomimetic composites. This research provides a simple, economical and scalable way to prepare the nacre-inspired high-performance structural materials.

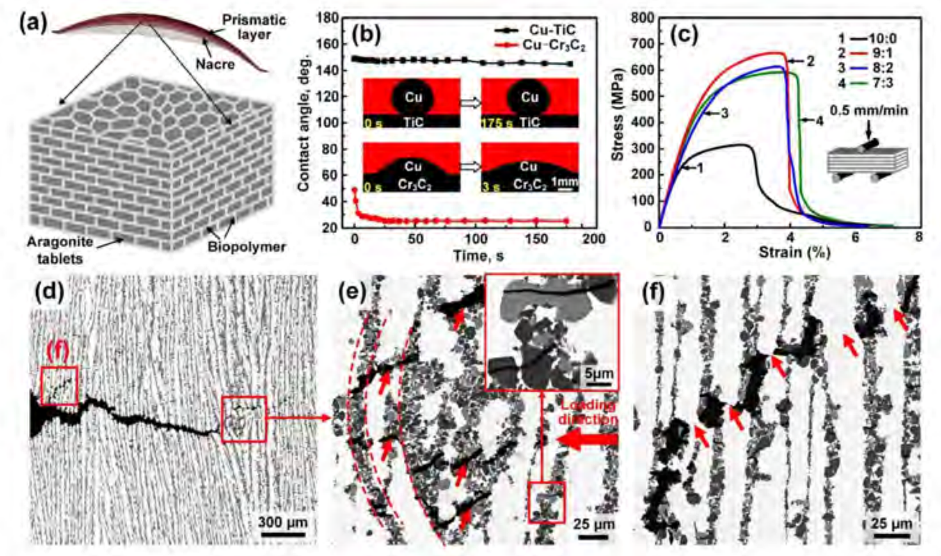

Fig.1 Schematic of the hierarchical "brick and mortar" structure in nacre (a); the high-temperature wettability of the metal-ceramic systems (b); the mechanical performances (c), crack-propagation mode (d) and toughening mechanisms (e-f) of the synthetic nacre-like metal-ceramic composites

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IWBE 2021

Abstract ID No.08

Research on Bionic Erosion Resistance Mechanism of Surface Ripple Morphology

Yan Zhang, Xuwen Zhao, Tianqi Wang
Tianjin University of Science and Technology

Abstract

Under the conditions of gas-solid and liquid-solid two-phase flow, the target surface often forms the regular corrugated morphology. This morphology does not appear accidentally, it is widely present in the natural environment that is eroded by the gas-solid and liquid-solid two-phase flow. For example, such regular ripples can be found on the surface of sand dunes that have been eroded by wind and sand or on the surface of tidal flats that have been washed by solid particles carried by water. Research on the formation process of erosion ripples has found that the formation of ripples has four stages: incubation period, acceleration period, deceleration period and stable period. In the stable period, the removal of the wave peak material and the plastic flow rate on the surface of the material basically reach a dynamic balance, and the erosion rate at this time is maintained at a relatively low dynamic stable stage.

Based on the characteristics of low erosion and wear rate in the stable period, quartz sand particles are used as abrasives, and the erosion test of 1060 pure aluminum plate is carried out using gas-solid two-phase erosion test equipment. The height and width data of erosion ripples formed under different pressure and angle of attack test conditions are obtained. By combining the round, triangular, and rectangular corrugated cross-sectional shapes, the corrugated shape factors were combined and designed by the orthogonal test method, and 9 bionic samples were obtained. The erosion and wear test was carried out at an impact angle of 40°, a pressure of 0.4 Mpa, and an erosion distance of 70 mm. Using the range analysis method, the bionic corrugated sample with a corrugation width of 0.5 mm, a corrugation height of 0.6 mm, and a round cross-sectional shape has the best erosion resistance. Using Fluent fluid simulation software, the effect of the surface topography of the bionic sample on the velocity vector of the near-wall airflow and the pressure on the wall is simulated and analyzed. The simulation analysis shows that the corrugated topography will interfere with the trajectory of the erosion particles, thereby changing the erosion rate. The surface eddy current of the corrugated sample can reduce the pressure on the surface of the sample, and effectively reduce the erosion weight loss. In this study, the steady-state corrugated morphology bionics was applied to the study of erosion and wear, which provided a new idea for the study of passive erosion resistance of parts.

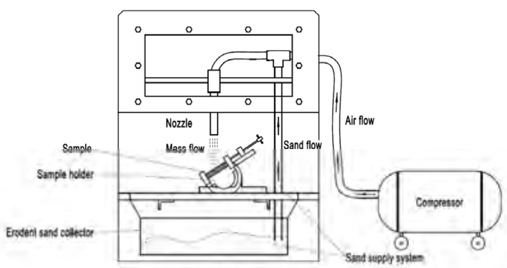

Fig. 1: Schematic diagram of erosion test

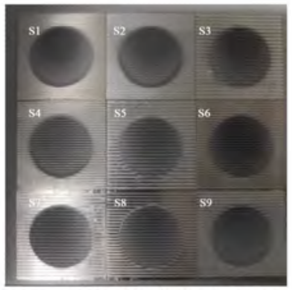

Fig.2 Surface morphologies of the different samples after erosion test.

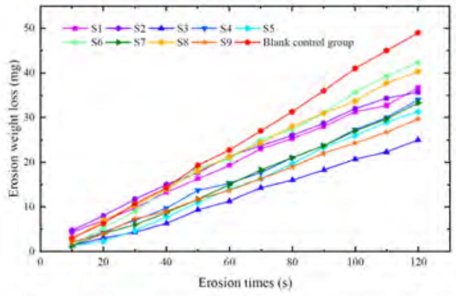

Fig. 3 Erosion weight loss curves of the samples with different surface morphologies

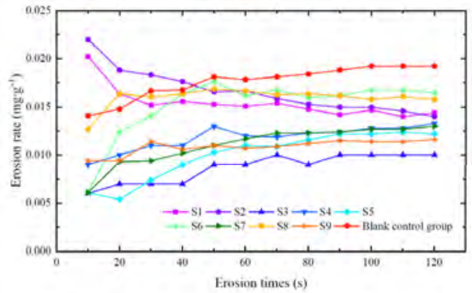

Fig. 4 Erosion rate curves of the samples with different surface morphologies

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IWBE 2021

Abstract ID No.09

Green Printing Technology for Manufacturing of Functional Devices

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Abstract

Based on the droplet drying process on the surfaces of different wettabilities, controllable nanoparticles assembling and stereo structures patterning could be achieved. [1] Through controlling the droplet spinning motion and movement of the vapor-solid-liquid three phase contact lines [2], the basic units (dot, line, plane and stereo structures) via the printing technology can be precisely controlled. Significantly, we achieved the silver nanoparticles assembled conductive patterns with single nanoparticle resolution.[3]. Our further work on assembling metal nanomaterials or graphene via printing process, patterned various linear or curved 1D/2D structures on diverse substrates.[4] The desirable conductive patterns contribute the remarkable application on sensitive electronical skin[4a], transparent touch screen[4b,c], multi-layer circuits[4d], ultra-integrated complex circuits[4e] and soft actuators[4f]. Moreover, stereo structures can be prepared through manipulating the solidsolid interface, which contributes to a versatile additive manufacture procedure. [5] This achievement on printed electronics and additive manufacture are benefited from the fundamental researches on interfacial wettability manipulation, morphology control of drying droplets, as well as functional nanomaterial fabrication, which constructs the theoretical and technical system of Green Printing Technology.

Abstract ID No.10

Bioinspired Surface Design for Strong and Reversible Adhesion

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Abstract

In nature, several animal groups, like insects, arachnids, tree frogs, and lizards use reversible adhesions for their locomotion. Comprehensive studies have suggested two highly specialized structures, which are smooth pads and fibrillar pads, rather than the surface chemistry of the foot surface contribute mainly to the strong adhesion of those animals. Both structures could be considered as the pillar array. Based on this concept, hierarchical micro- & nano-pillar arrays with various substructures have been developed. The incorporation of nanopillars and nanoparticles into the microstructures has the ability to regulate the stress distribution at the separating interface. The stress maximum is shifted towards the central part of the contact interface, which results in a strong adhesion. The incorporation of stimuli-responsive material, like graphene, into the polymeric matrix, could regulate the mechanical property of the adhesive. The adhesion could thus be regulated by the external stimulus.

IWBE 2021

Abstract ID No.11

Bioinspired Surface Design of Microfluidic channels for Microscale Flow Control

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Abstract

Microfluidic devices are miniaturized fluid handling systems, regulating small amount of fluids travelling through networks consisting of tiny channels with diameter typically ranging from tens to hundreds of micrometers. Nowadays, microfluidics have shown various applications in biology, chemistry, medicine, and energy-related applications due to the remarkable properties including high-efficient mass-heat transfer, reduced sample volume, short analysis time, high-throughput, and portability, etc [1]. The performances of the microfluidic systems depend on precise and systematic manipulation of the fluid flow in the microchannels, which is usually realized by microfluidic elements including pumps, valves, mixers, separators, etc. In addition, fluidic flow behaviours in microfluidics are also dominated by the interfaces created between the fluids and the inner surface walls of microchannels [2]. Microchannel inner surface designs, including the surface chemical modification, and the construction of micro-/nanostructures, are good examples of manipulating those interfaces between liquids and surfaces through tuning the chemical and physical properties of the inner walls of microchannel. Inspired by biological surfaces with superwettability and anisotropic wettability, various bioinspired surfaces with specific wettability have been developed, which pave a potential way for controlling the microscale flow behaviour in microfluidic channels. Inspired from anisotropic rice leaf structures, we prepared bioinspired anisotropic wetting surfaces with chemical patterns or micro-nanostrutures, and realized the microscale flow control in microchannels by utilizing the bioinspired surfaces as one of the microfluidic channel surfaces [3,4]. In recent years, a weave of researches focusing on the ideas of using liquids as dynamic surface materials are identified, and the unique characteristics endowed with liquid-liquid interfaces have revealed the interesting phenomena can extend the scope of interfacial interactions determining microscale flow behaviours [5,6]. Inspired from the structure of the liquid linings in gastrointestinal tract, we designed a bioinspired microfluidic system that consists of an interconnected porous matrix partially infiltrated with a functional liquid and a microchannel constructed inside, which enables the formation and instantaneous recovery of stable liquid–liquid interfaces that sustain a wide range of pressures and prevent channel contamination [7]. These liquid surface design of microchannels expand the basic scientific issues of the traditional membranes from the solid−liquid/gas interface to the solid−liquid−liquid/gas interface and bring more possibilities for the applications of microfluidic systems.

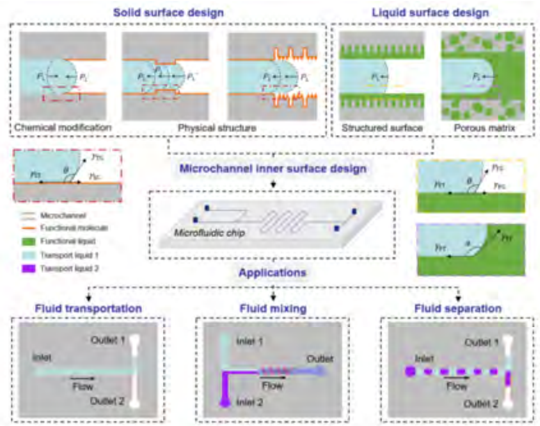

Figure 1: Inner surface designs of microfluidic channels for microscale flow control [2]

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Abstract ID No.12

Advanced Bio-inspired Multi-dimensional Structural Materials: Sophisticated Biological Models and Biomimetic Fabrication Strategies

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Abstract

Rising structural performance requirements in engineering are driving research and development of stronger, stiffer, and lighter materials. Unfortunately, most traditional artificial materials are unable to meet the needs of modern industrial and technological development. However, multifarious biologies in the Nature are far ahead in using structural materials. Natural structural materials are composed of a fairly limited selection at ambient temperature. They usually consist of hard and soft phases arranged in a complex hierarchy with characteristic dimensions ranging from nanoscale to macroscale. The resulting materials usually show nearly perfect combination of strength and toughness integrating with lightweight characteristics. This is exactly what the engineering materials yearn for. In this work, different biological materials were into the following types of structural elements: 1D fibrous structures, 2D layered structures, 3D cellular structures and heterogeneous interface structures. This work is anticipated to inspire the innovative design and deep understanding of the existing artificial composites. Taking fiber-reinforced composites as an example, it consists of a reinforcing phase, a matrix phase, and an interface, which are similar to those of biological materials. For each structural element, the structural composition and mechanical properties of typical organisms were well described. Additionally, fabrication approaches of biomimetic structural materials and their development trend were summarized.

Abstract ID No.13

From Spider-web to Oil-separator

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Abstract

Facing the increasing oily wastewater problem in the world, it is necessary to develop materials for efficient oil-water separation, especially for industrial processes with droplets smaller than 20 µm. For most existing separation methods, the limitations are by high energy consumption, complicated processes, long processing time and high costs. The bionic development of fiber-based materials has led to tremendous improvements in the performance of technical textiles in various industrial processes. The living nature, e. g. desert beetle backs, cactus spines and spider web capturing silk offer some astonishing archetypes with interesting functions regarding droplet coalescence and separation. In this project we are developing fiber-based spindle-knotted structures for the collection of dispersed micron-sized oil droplets in water, inspired by the collection of similar-sized water droplets on the spider web capturing silk in nature. For the first time, we can demonstrate a very comprehensive theoretical model describing the principles of directed droplet transport along the bioinspired structured models. Applying 3D printing for bioinspired conical models and showing the agreement between the theoretical and experimental results, the theoretical model has been evaluated.

Based on the predictions of the theoretical model, the design and fabrication of fibrous material have been carried out using the electrospinning method. Performing the corresponding oil-water separation experiments, the coalescence of the micron-oil droplets on the fibers and the separation of an ultra-high efficiency of 99 % were seen.

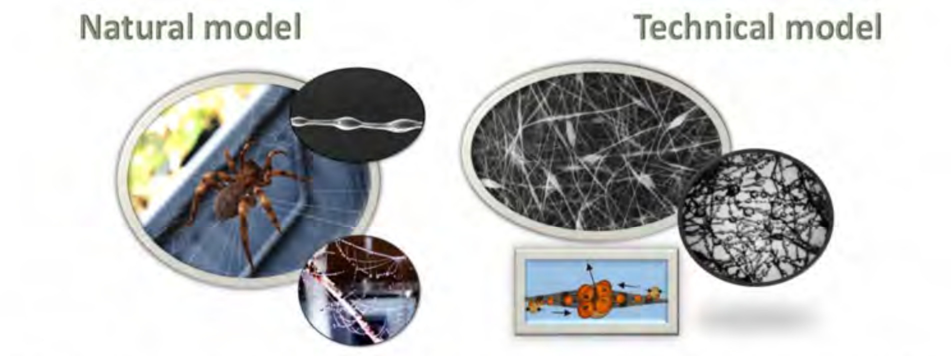

Figure 1: Natural model: Spider web capturing silk with water collection capability. Technical model: Electrospun spindle-knotted structured fibers with underwater micron-oil droplets collection capability.

Abstract ID No.14

Preparation of Bionic Gradient Hardness Surface by Compound Process of Laser Remelting and Nitriding

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Abstract

Bionic gradient harness surface can be applied on a variety of working parts. In previous, the surface was prepared by adjusting the hardness after laser remelting and processing route to achieve performance changes. In this paper, a combination of laser remelting and nitriding was used to prepare a gradient hardness surface with higher hardness and controllability. The results show that the laser pretreatment can refine the steel grains to provide more diffusion channels and shorten the diffusion path for subsequent nitriding. It promotes the infiltration of more nitrogen elements under the same conditions. The highest H13 surface hardness processed by this method can reach 1280HV, which is higher than the surface hardness (around 1100HV) processed by traditional nitriding and the surface hardness (around 680HV) processed by laser remelting. In this compound process, the laser remelting depth and harness are no longer the goal of parameter optimization. The degree of grain refinement is the focus instead. By adjusting the laser parameters to control the grain size, it is possible to prepare a high gradient hardness bionic surface after nitriding the traditional die steel.

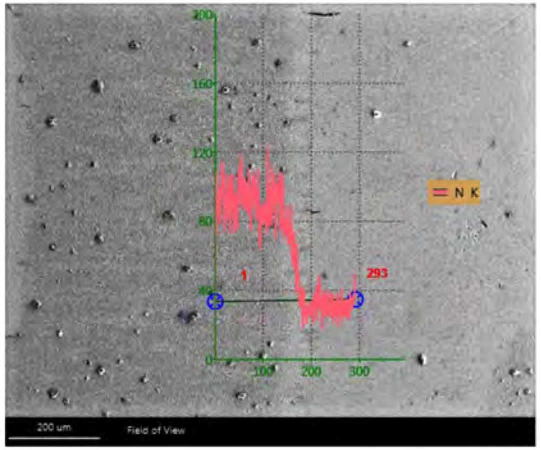

Fig.1 Effect of laser remelting pretreatment on Nitrogen content distribution (Left half area: Laser rememting pretreatment+ Nitriding; Right half area: Common nitriding)

IWBE 2021

Abstract ID No.15

Study on Surface Rsidual Stress and Its Effect on Thermal Fatigue Properties of Non-uniform Bionic Specimen Prepared by Laser

Xiuyun,Pang, Hong Zhou
Jilin University

Abstract

Thermal fatigue cracks are the most common failure forms of hot work tools and the its initiation is closely related to the surface stress distribution..In this paper, an X-ray residual stress analyzer was used to measure the changes of the surface residual stress on the surface of the laser bionic hot-working H13 steel and common heat-treated molds during the thermal fatigue process. The results show that among the laser parameters, the pulse width has the greatest influence on the distribution of surface stress. In the direction of the optimal laser processing depth, the maximum compressive stress appears in the middle part of the melting zone, and the stress decreases with the increase of the depth. With the increase of thermal fatigue cycles, the compressive stress is released gradually, and then the tensile stress is accumulated till its exceed the yield limit and cracks are initiated. The rest of the specimens produce cracks more quickly because of no release of compressive stress. The crack initiation can be slow down by adjusting the laser parameters to create the surface residual compressive stress so that prolong the thermal fatigue life.

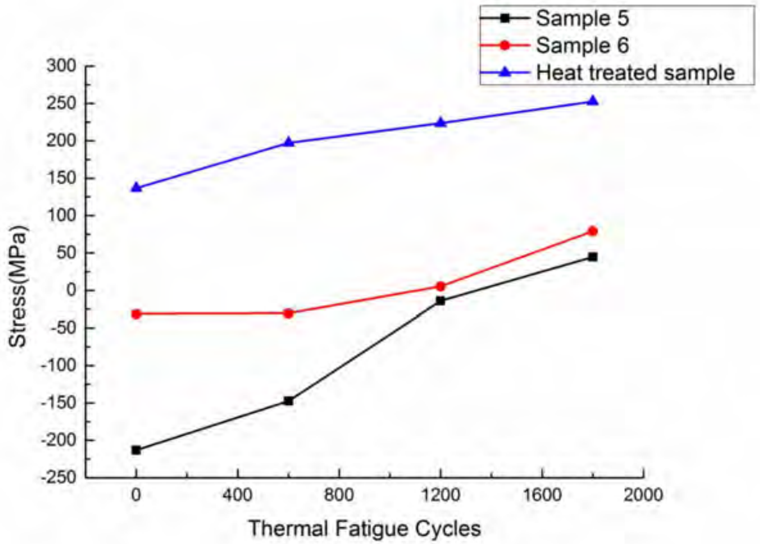

Fig 1. Variation of residual stress with different thermal fatigue times

Abstract ID No.16

Wrinkle Manipulation by Patterned Surface Material Properties for Structural Coloration

*Yeonghoon Jeong, *Jun Gyu Park, and *†Taesung Kim*
Department of Mechanical Engineering, Ulsan National Institute of Science and Technology (UNIST)

Abstract

Many attempts have been made to not only create wrinkles but also study natural winkle generation mechanisms. Generally, wrinkles are formed via the buckling of composite materials such as bilayers[1] and multilayers[2]. Wrinkles show a high surface to volume ratio, 1-D directionality and is characterized by their periodicity. Due to these features, wrinkles draw significant attention and show remarkable potential for various research fields such as chemical sensors, biomaterials, and wearable and electronic devices[3]. In particular, nanoscale wrinkles with a range of periodicity have been used for structural coloration with fast response and high repeatability[4]. However, it appears that the generation and control process of such winkles is still complicate and requires high-cost equipment. In this study, we describe a simple fabrication method assisted by an inkjet printer and show a structural coloration device integrated winkles.

Composite devices were fabricated by the process illustrated in Fig. 1. A relatively stiff material was printed on polydimethylsiloxane (PDMS) and then skin-layer, which is less stiff, was spin-coated to form a triple-layered structure. The material property of the interlayer was manipulated by adjusting the concentration of the ink while the skin layer thickness was controlled by the spinning speed. The process enabled to easily fabricate composite devices with various material property combinations.

An inward bending force was applied to the composite device as described in Fig. 2a. As a result, the skin-layer and the interlayer undergo compression, being in turn subject to winkle formation. The skin-layer on top of the printed interlayer formed surface winkles with a low periodicity. On the other hand, the skin-layer in the absence of the patterned interlayer formed surface winkles with a high periodicity. Because the interlayer was printed on demand, it was possible to generate various interlayer patterns on top of PDMS. Such periodic wrinkles behave as 1-D gratings, exhibiting angle-dependent structural colors as shown in Fig. 3. When light is illuminated into the wrinkles, diffraction and transmission occurs, depending on the wrinkle periodicity. It was demonstrated that iridescent colors are selectively designed and displayed by manipulating the surface winkles having 30~50 nm periodicity as shown in Fig. 3b and 3c.

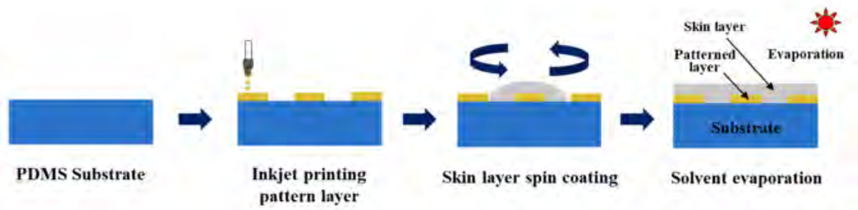

Figure 1: Schematic showing the fabrication process of the triple layer structure.

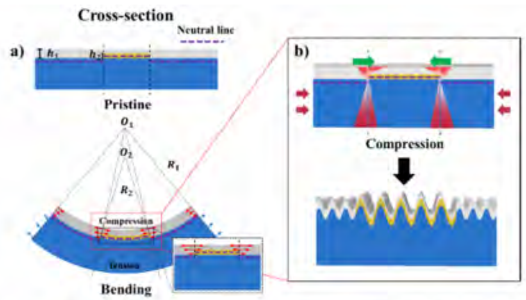

Figure 2: (a) Schematic illustration of the wrinkle formation mechanism by bending. b) Cross-sectional view of the winkles with different periodicities.

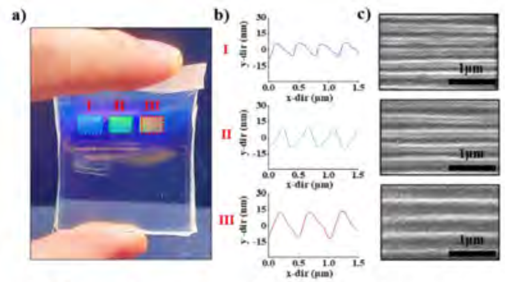

Figure 3: Structural coloration of the winkle patterns. a) Iridescent coloration of the winkle patterns on inward bending. b)-c) Characterization of the formed winkles with different periodicity obtained from AFM and SEM images.

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Abstract ID No.17

Turbulent Drag Reduction on Bioinspired Superhydrophobic Surfaces

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Abstract

Superhydrophobic surfaces similar to lotus leaves have attracted more and more attention because of their excellent drag reduction performance [1]. The bioinspired superhydrophobic surfaces with micro-posts structure have been found to have the potential of wide application [2]. Based on the lattice Boltzmann method (LBM) [3], the direct numerical simulations of turbulent drag reduction with superhydrophobic surfaces are carried out. The effects of the shape and the arrangement of micro-posts on drag reduction characteristics are focused. Firstly, the LBM code for direct numerical simulation of turbulent channel flow is developed. The solid wall and gas-liquid interface are modeled by applying the non-slip boundary condition and free slip boundary condition, respectively. The code and the boundary setting are verified by simulating the turbulent flow in the channel with smooth wall and superhydrophobic wall. Then, the turbulent drag reduction performance of superhydrophobic surfaces with three different shapes (square, circular, and rhombic) and two different arrangement modes (aligned and staggered) of micro-posts is studied. The results show that compared with staggered arrangement, the aligned arrangement can produce greater drag reduction effect, but there will be large pressure fluctuations at the front edge of micro-posts, which is not conducive to the stability of continuous drag reduction. Compared with the other two shapes, rhombic micro-posts has advantages in terms of drag reduction and interface stability. The results obtained in this study may shed some light on a better understanding of drag reduction on superhydrophobic surfaces and be helpful to optimize the surface design.

IWBE 2021

Abstract ID No.18

Simulation of Single-leg Adaptive Control Based on Position Impedance

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Beibu Gulf University

Abstract

The paper presents an adaptive control method of foot robot based on position impedance.Foot type robot in motion due to contact with the ground as the single point contact, therefore will have a great impact, the impact of the huge impact the performance of the robot movement, serious can cause damage to the body, so be based on the robot that could satisfy the requirement of position accuracy, through the study of the compliant control of robot legs, minimize the impact.Smooth control of the main control method for impedance control[1], mainly through without contact with the external environment on the foot end force and the adjustment of the parameters such as speed, thereby indirectly control the robot foot end of the relationship between environment and, but in the process of robot movement, the impedance control is difficult to accurately control the position and the foot end force for a more precise control. In this paper the impedance control principle, and are analyzed in this paper, the principle of the impedance control parameters analysis, through the adaptive control strategy [2] for the unknown parameters online speculation.

To calculate the values of the parameters to replace the original parameter values, feedback generation into the control system, and it is concluded that the final output, finally put forward the adaptive control method based on the location of the impedance.In this paper, the internal knee type quadruped robot driven by the motor is taken as the research object, and the single-leg simulation model of quadruped robot is established, and the co-simulation platform of ADAMS and MATLAB is built. The established single-leg model of quadruped robot is imported into ADAMS, and then it is imported into MATLAB after adding constraints.The simulation platform of the two control algorithms was built in the Simulink module of Matlab. The simulation data of the foot force were collected to obtain the foot force response curve, and the feasibility and adaptability of the adaptive control based on the position impedance were verified. At the same time, it was compared and analyzed with the impedance control.To provide the basis for the next experiment.

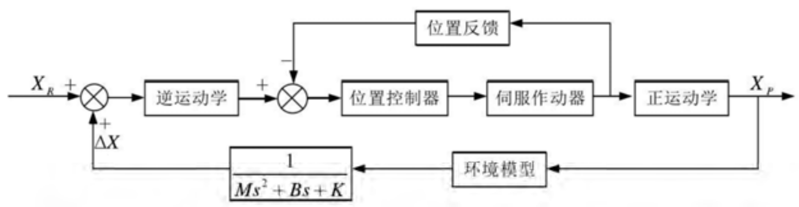

Figure 1: Impedance Control Block Diagram Based on Position Closed Loop [3]

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Guo Yunyu. Compliance Control of Hydraulic Quadruped Robot Based on Position Impedance [D].Harbin University of Science and Technology, 2020.

IWBE 2021

Abstract ID No.19

Near-infrared Light Accurately Controllable Superhydrophobic Surface

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Abstract

Great attention has been paid to superwetting surface with tunable water adhesion behaviors[1], but many challenges still remain for developing a surface with accurate regional control of the superwetting behaviors. Herein, a superhydrophobic surface that can reversibly transform between the water sticking to water repelling has been developed by regulating the near-infrared (NIR) light triggered shape memory polymer (SMP) micro/nanostructures. The superhydrophobic surface with intact micro/nanostructure arrays exhibits low water adhesion force, whereas the superhydrophobic surface with bending microstructure arrays demonstrates high water adhesion force. Owing to the NIR light triggered deformingrestoring action[2], the programmed tunable superwetting transition between those two models can be easily realized by their transformed morphologies. It was demonstrated that the smart superhydrophobic surfaces could not only simplify adjust droplet adhesive force in the microplates and droplet microarrays technology but also provide distinct microfluidic microreactors for different purposes, such as biochemical detection technology. These characteristics make the NIR light accurately controllable superhydrophobic surfaces for droplet manipulations in different areas.

Abstract ID No.20

Water Flow Energy Harvesting via Triboelectric Nanogenerator Based on Bionic Structure

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2. School of Mechatronic Engineering, Changchun University of Technology, Changchun, Jilin, China
3. Institute of Robotics and Intelligent Systems, Wuhan University of Science and Technology, Wuhan, China

Abstract

Water flow energy, as one of the significant renewable energies, is difficult to be harvested at low flow rates caused of its low frequency. Triboelectric nanogenerator (TENG) provides a potential approach for efficiently harvesting water flow energy due to its unique advantages at low frequencies. The design of the bionic structure has the characteristics of the high adaptive capacity for the different flow rates. Herein, a practical bionic structured triboelectric nanogenerator system for the unidirectional water flow energy harvesting is reported, which is comprised of bionic fins, bionic shell, multi-layer structured TENG, spring, and connection unit. Experiments show that the output performance significantly increases as the fin length and the height position increases. The bionic structure can generate an open-circuit voltage of 600 V, short-circuit current of 3.5 μA, and the maximum instantaneous power density of 7 W/m3, which can be used to supply power for 400 LEDs in series or a temperature sensor. The findings not only realizes the water flow energy harvesting, but also provides a new method for large scale energy harvesting.

IWBE 2021

Abstract ID No.21

Study on the Bionic Electric Actuation of Liquid Metal Column in Confining Channels

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Chongqing University of Arts and Sciences

Abstract

Due to the huge size, the traditional robot could not work in a tiny environment or inside human body, which was limited to its application. The micro-driven robot which could work in the internal environment was developed. In this paper, the electric driving behaviour of liquid metal column in confining channel was studied. In a confining channel, the liquid metal moved to the anode, and the electrolyte moved toward the cathode, which was not found in open system. Besides, the length and volume of the liquid metal would affect its motion and deformation behaviour. Both cylindrical liquid column (R=0.5 cm, L= 5 cm) and linear liquid column (R=0.5 cm, L=40 cm) exhibit deformable movements, which similar to the bionic movements of earthworms. The electrically driven of liquid metal in closed systems, could provide a theoretical basis for droplet actuation in microtubes. It has a very wide application prospect in the field of micro-drive machines.

Figure 1: The electric actuation of liquid metal column was similar to the movement of bionic earthworm.

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Abstract ID No.22

Fluid-owl Interaction: Experimental Study of the Flow over an Owl Wing

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Abstract

Small unmanned aerial vehicles can perform various tasks ranging from delivery of payloads, monitoring, surveillance and so forth. These tasks may requires covering large distances, perform fast manoeuvres in urban areas and reduce their aeroacoustics signature. Owls are nocturnal raptors that use stealth capabilities during hunting and carrying a relatively large payloads (i.e.: prey) whilst flying at slow speeds. Owls' wings have unique combination of morphological features including leading-edge serrations, velvety surface and thin fibres ('fringes') at the trailing edge region [1]. It was hypothesized in early works that these features assist in reducing noise. Yet, their role in their aerodynamic performance is unclear [2]. Furthermore, owls fly at relatively low speeds which raises the question of how they generate sufficient lift given their low aspect ratio planform [3]. We study the boundary layer developed over an owl wing in an open channel flow using particle image velocimetry (PIV) technique. The goal of this study is to question whether leading-edge serrations delay stall over the wing surface at high angles of attack. Delay of stall may augment lift during flight allowing slow flight and manoeuvring. A barred owl wing was digitally scanned and 3D printed. Two wings were printed: smooth and serrated. The serrated wing replicated the serrations of the leading edge. 2D-PIV was performed at five planes (streamwise-normal) along the span for three angles of attack: 6o, 12o and 20o. The mean velocity profiles presented in figure 1 for the plane located at the mid-region of the wing show the evolution of the flow over the wing and the formation of a separation bubble as function of angle of attack. The comparison between the smooth and serrated wings demonstrates that the separation region decreased and shifted towards the trailing edge region. Decreasing the separation region and shifting it away from the leading edge suggests that the maximal lift of serrated wings is increased relative to nonserrated wings of equal planform and profile. Herein, we will provide a detailed characterization of the boundary layer developed over the owl wing and complement these with estimating the aerodynamic forces exerted on the wing during flight from the wake flow field data. Such serrations hold promise of improving loitering and slow flight capabilities of small UAVs.

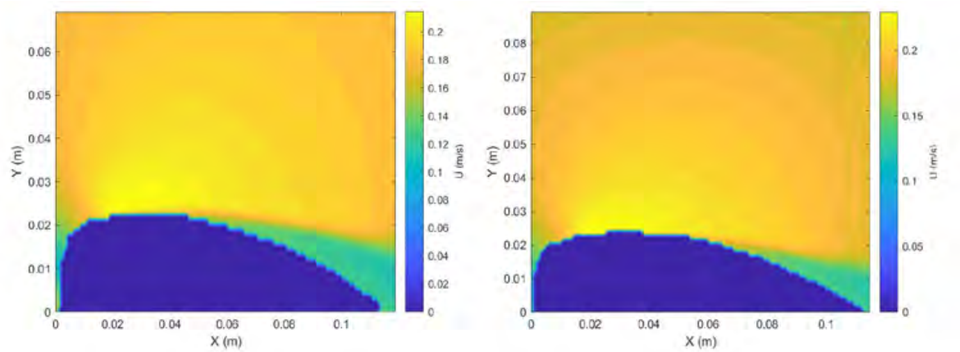

Figure 1: Mean streamwise velocity profiles over the wing surface; i) smooth wing and ii) serrated wing. The profiles presented are located at the middle plane in the spanwise direction over the planform. The colorbar represents the velocity magnitude. The blue color is the wing section and the region below it, where no data was observed

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Abstract ID No.23

A Bio-circular-economy Approach towards a Sustainable Construction Projects Unified Framework: A Case Study in Panama

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Abstract

The construction sector has a huge economic influence and presents great opportunities to face environmental and climate change challenges. For this reason, it is essential to work on the transition towards sustainability and circular economy principles in the process since it involves high consumption of resources and can negatively impact the environment. This transition already has positive results in terms of performance since, in green buildings, 50% less energy consumption has been achieved than conventional ones in reports allusive to energy [1]. It is expected that the construction industry to expand by 50% in global terms due to demographic growth [2]. In Panama, the population increase will be almost 300% by 2050 [3], according to the National Energy Plan. Thus, it is imminent that the construction industry must act with commitment and responsibility given its contributions to the environment, society, and economy.

There is currently a significant lack of reference frameworks beyond certifications, planning, management, and assessment tools for implementation. Similarly, a diversity of studies and taxonomies to integrate the triple bottom line as a scope of sustainability for the construction and management of projects. For this reason, we seek to develop a unified roadmap that includes phases, practices, and indicators under the scope of sustainability (triple bottom line) complemented with principles of circular economy and biomimicry ("biocircular"). The biological processes of nature must be emulated to achieve a transition from a linear to a circular economy to have a regenerative industrial system by intention and design [4].

Therefore, this project will strengthen the field of sustainable construction and its management, considering the life cycle and applying the circular economy concept with the innovation provided by biomimicry. Meanwhile, in the context of Panama, it will be validated with a residential construction project as a case study.

This Methodology is divided into two phases; the preliminary design phase, which consists of having exploration and investigation of organisms and ecosystems based on challenges, similar functions, extraction, and abstraction of principles where characteristics of the circular economy were included in the evaluation. Then the emulation phase, where ideas are transformed into designs, the biocircular model is applied to each phase, verifying scope in indicators and validating success with the case study.

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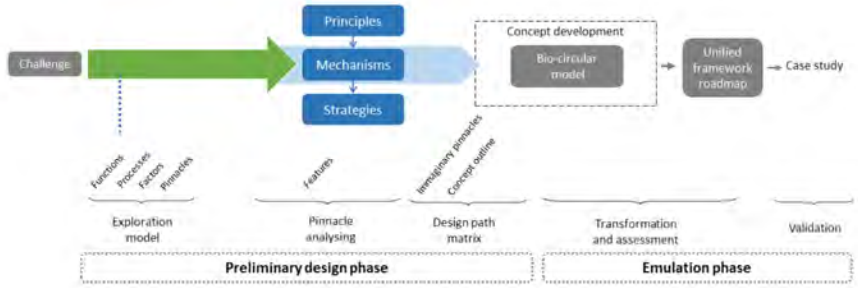

Figure 1: Problem-based approach methodology implemented.

Our research results are the biocircular model, supporting the definition of the roadmap for sustainable construction with four components in the phases of initiation, planning, design, construction, monitoring and control, and delivery. The components are active, alluding to dynamic and efficient processes; behavior by management, technical knowledge, and skills; housing, in terms of facility provision or service by which it is built. Finally, the characteristic of sharing in a circular economy focused on reuse and durability through maintenance, design, and retrofitting. The preliminary validation process was performed by introducing a survey applied to experienced construction sector employees, together with a SWOT analysis.

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Abstract ID No.24

Multi-Space Programmed 4D Printing of Bioinspired Solvent driven Morphing Composites

*L. Q. Ren, Z. S. Li,Q. P. Liu, L. Ren, B. Q. Li, Z. Y. Song, Q. Wu, X. L. Zhou**
Jilin University

Abstract

Therefore, this project will strengthen the field of sustainable construction and its management, considering the life cycle and applying the circular economy concept with the innovation provided by biomimicry. Meanwhile, in the context of Panama, it will be validated with a residential construction project as a case study.

This Methodology is divided into two phases; the preliminary design phase, which consists of having exploration and investigation of organisms and ecosystems based on challenges, similar functions, extraction, and abstraction of principles where characteristics of the circular economy were included in the evaluation. Then the emulation phase, where ideas are transformed into designs, the biocircular model is applied to each phase, verifying scope in indicators and validating success with the case study.

4D printing is an interdisciplinary research, which combines 3D printing technology, intelligent materials and design. Its powerful designability and versatility have excited the manufacturing industry and aroused great interest of researchers from different disciplines and fields. In this article we propose a biomimetic multi-space programmed 4D printing method. Using a DLP 3D printing process with magnetic assembly and fiber-resin composites, fiber-reinforced composites with aligned fibers that can produce programmable shape-changing under solvation/desolvation were developed. We investigated the influences of crosslinking density, sample geometry, formulation, and fiber architecture on deformation of the printed objects. Then, these contributory factors are used to control the shrinkage/swell orientation and magnitude of printed materials. This technology, termed as 'multi-space programmed 4D printing', has enabled us to replicate biological material morphing trick for producing materials that create highly programmed shape changing, such as site-specific bending and twist. Finally, as a proof of concept, various samples, including a hand, snowflake and leaf, were printed to verify the feasibility of the proposed 4D printing strategy. This multi-space programmed 4D printing method provides a simple and effective reversible strategy, taking the full advantages of 4D printing and expanding the design space of 4D printing.

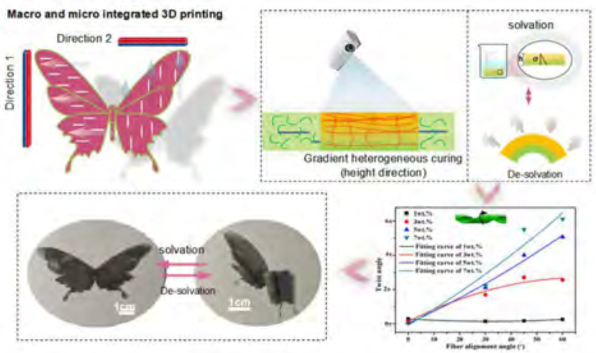

Figure 1: Multi-Space Programmable 4D Printing process

Abstract ID No.25

FE Modelling of Biomimetic Short-Stem Porous Hip Implant for Reducing Stress Shielding & Promoting Osseointegration

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3. Department of Mechanical Engineering, University College London, UK

Abstract

Currently, total hip replacement surgery is an effective treatment for osteoarthritis, where the damaged hip joint is replaced with an artificial joint [1]. Stress shielding is a mechanical phenomenon that refers to the reduction of bone density as a result of altered stresses acting on the host bone. Current orthopaedic prostheses undergo too much bone resorption secondary to stress shielding due to their solid metallic nature, which are much stiffer than the surrounding bone. With the use of 3D printing technology such as selective laser melting (SLM), it is now possible to produce porous graded microstructure hip stems to mimics the surrounding bone tissue properties [2].

To understand and determine the mechanical and fatigue properties of the hip implant, asymptotic homogenization has been used in several studies. With this method, it is now possible to accurately measure the stress distribution within the microstructure [1, 2]. The 3D printed implant needs to have an optimized topology which are defined and affected by the pore size, porosity gradient and the thickness of the manufactured cell elements [1]. In this study, we have compared the physical and mechanical properties of two triply periodic minimal surface (TPMS) lattice structure namely gyroid and diamond TPMS. Based on initial investigations, it was decided to design, and 3D print the gyroid and diamond scaffolds having pore size of 800 and 1100 um respectively. Scaffold of each type of structure were manufactured and were tested mechanically in compression (n=8), tension (n=1) and bending (n=1).

Upon FEA validation of the scaffold in Abaqus, the desired scaffold for hip implant application was evaluated to have a young's modules of 12.15 GPa, yield strength of 242 MPa and porosity of 55%. Topology and lattice optimization were performed using nTopology to design an optimised graded porous hip implant based on stress shielding reduction. It was understood that the designed optimised hip implant can reduce the stress shielding effect by more than 55% when compared to the conventional generic implant.

The designed hip implant presented in this work shows clinical promise in reducing bone loss while having enhanced osseointegration with the surrounding cortical bones. Hence, this will help reduce the risk of periprosthetic fracture and the probability of revision surgery.

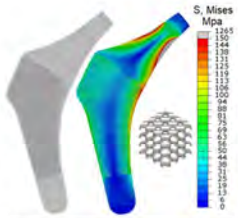

Fig. 1: Porous scaffold and section view of the porous hip implant with its respective FEA result when loaded with a jogging load of 4,839 N.

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Abstract ID No.26

Bioinspired Color-Changeable Organogel Tactile Sensor with Excellent Overall Performance

Yafeng Liu
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Abstract

Inspired by chameleons' structural color regulation capability, we present a simple swelling method to prepare ionic polyacrylamide (PAAm) organogel for simultaneous tactile sensing and interactive color changing. The PAAm organogel obtained by swelling the PAAm scaffold in the dimethyl sulfoxide solution of organic electrochromic material (OECM) shows an extremely large stretch-ability with an elongation of 1600%, a super softness with a Young's modulus of 7.2 kPa, an excellent transmittance up to 90% and a very fast response time. The PAAm organogel also suggests a universal design ability to tailor coloration spectra for tactile sensor via simply changing the type and content of OECM. The tactile sensor based on PAAm organogel is capable to serve as a wearable device for precisely tracing human body motion performance and directly visualizing the stress distribution via interactive color changing capability. It is demonstrated that the swelling method proposed here is a simple and practical strategy to prepare ionic organogel with both piezo-resistive and electrochromic effects. Consequently, the PAAm organogel sensor opens promising avenues for interactive wearable devices, e-skins, robotics, anti-counterfeiting, artificial prosthetics, and so forth.

Abstract ID No.27

Biomimetic Functional Surfaces with Wrinkle Pattern for Tissue Engineering

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Abstract

Wrinkle patterned surfaces are ubiquitous in whether in natural events or organism, endowing significant functions and thus bearing broad and fantastic applications. Due to its advantages of spontaneous nature, versatility, easy preparation in large-scale, and capability to be responsive to various stimuli, wrinkling or buckling surfaces offers a powerful alternative to prepare functional surfaces, which can tailor the encoded surface properties on demand and can find potential for wide applications in smart display, responsive microstructures, switchable wettability, smart adhesion and friction, and so on. We developed a series of dynamic wrinkled surfaces response to light, temperature, pH, and various chemicals in recent years, and explored the potential of theses microstructured surface for smart displays, memory, flexible electronics, tunable adhesion, friction, and wettability. Very recently, we present an interesting exploration of wrinkled pattern surface for regulating the behave of different tissue and stem cells such as cardiomyocytes and BMSCs and accelerating the repair of tissue injury, inspiring the new direction of functionally biomimetic bio-surfaces.

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Abstract ID No.28

Bio-inspired Water Lubrication Interface & Materials

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Lanzhou Institute of Chemical Physics, CAS

Abstract

Biolubrication is widespread in nature and the sliding interface is commonly in a low friction state. The extraordinary lubrication mechanisms from biological system can provide us inspiration for developing functional artificial lubrication materials and products. Herein, my presentation mainly focuses on hydrogel-based lubrication materials. Firstly, I will introduce some new modification methods to prepare functional hydrogels materials and coatings. Secondly, I will introduce a series of bio-inspired layered hydrogels materials with low-friction, loading-bearing and anti-wear properties. These as-prepared materials imitate the basic hydration and energy dissipation mechanism of natural articular cartilage system (NACS) under harsh mechanical conditions, so they exhibit good engineering application potential. Recently, one kind of layered composite materials with combination of polymer brushes and high strength hydrogel was prepared, for which can show stably low COF (~0.025) under 8 MPa contact pressure, and almost without any surface wear after 50000 test cycles.

Abstract ID No.29

Electrochemistry-Induced Improvements of Interfacial Adhesion of Hydrogels

Lidong Zhang,
East China Normal University

Abstract

Hydrogels have demonstrated great potential in biomedical and engineering areas. To improve its physical performances, development of efficient physical/chemical protocols is essential. This work reports an electrochemistry functionalization strategy that is capable of enabling the functional improvements of hydrogel in the interfacial adhesion. We demonstrate the electrochemistry adhesion on a hydrogel model of polyacrylamide (PAAm)@κ-carrageenan. The electrochemistry reaction generates metal ions (Fe3+) that migrates and coordinates with the sulfate groups of κ-carrageenan resulting in the prominent adhesion improvements. In comparison with untreated PAAm@κ-carrageenan hydrogel, it can improve the interfacial adhesion energy of the hydrogel on a glass surface from zero to 1400 J m–2, stronger than the bonding strength of tendons (adhesion energy: ~ 800 J m–2). The concept was from the adhesion mechanism of Boston ivy.[1] Upon the soft hydrogel contacting with the smooth substrate (glass slide), its porous network delivered water to the substrate to build a primary adhesion interaction. By applying two electrodes at the both ends of the hydrogel, a series of electrochemistry reactions consumed oxygen and water molecules between hydrogel and the substrate, which causes the formation of anchor points, and thus enhances the hydrogel adhesion interaction on the substrate.

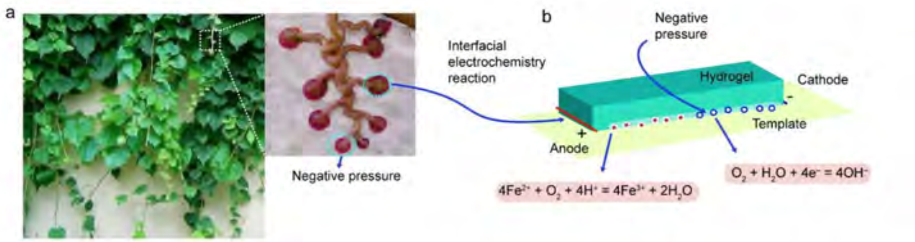

Figure 1: Bioinspired adhesion improvement. (a) The adhesion mechanism of Boston ivy on a wall. (b) Sketch demonstrating the Boston ivy-inspired adhesion mechanism of hydrogel on a glass template.

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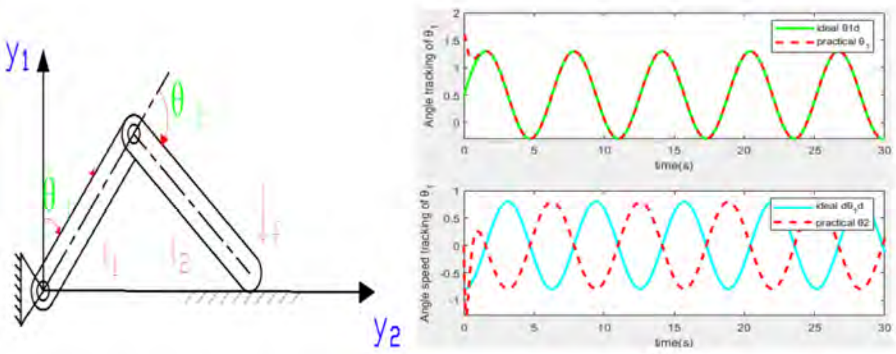
Abstract ID No.30

Slide Mode Control of Robot Single-leg Foot Force and Joint Angle

Y.Y. Zhao, J.H. Wang, G.H. Cao
Changchun University of Science and Technology

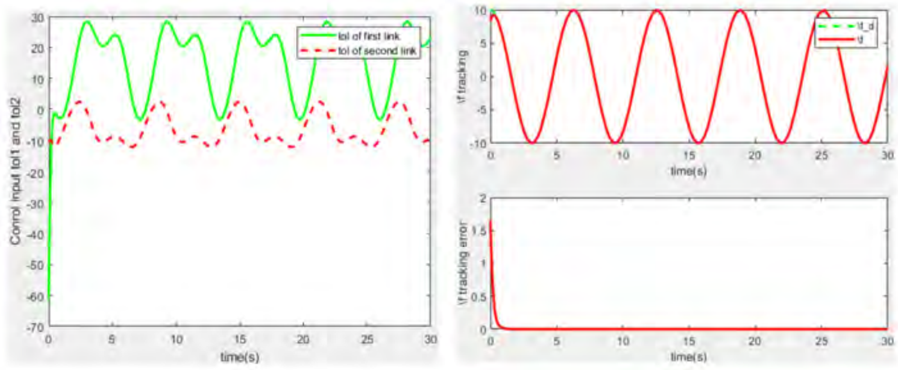
Abstract

The foot-legged robot is very adaptable to complex terrain[1], and its advantage is that it only needs to touch the ground intermittently, and can walk on the rigid flat ground, and also can surmount the ravine and the obstacle. In view of its complex, bad, unknown disaster relief, coal mines, agriculture and military and other fields, play a better role and complete the task. Therefore, the multi-legged robot has a better application prospect and higher research value and significance in these fields. It is difficult for a foot robot to take only position control into account when walking on different contact surfaces, because the actual contact force between foot and ground is variable, and the deviation of foot end position may lead to great destructive force, damage to the robot. At present, the foot-leg robot only has the poor foot tracking ability and the compliant control ability of the leg, especially in the aspect of the robot foot-end contact force and the position hybrid control, the theoretical research is still relatively lacking[2]. Therefore, this paper takes a two-joint single leg of a multi-legged robot as the research object, and controls the position and contact force simultaneously. Firstly, considering the foot and ground constraints and the dynamic contact force characteristics of the robot, the model can be reduced by constraint conditions. As can be seen from Figure 1, under the constraint of the foot and the ground, the degree of freedom of the double-jointed robot leg changes from 2 to 1. According to the descending order of the model and the sliding mode control principle, a sliding mode control scheme for the ground force and joint Angle of a single-legged robot was proposed, and the position control of the single-legged robot and the contact force control between the foot and the ground constraints were studied. Then, the stability and convergence of the system are proved by Lyapunov equation and LaSalle theorem after the theoretical analysis of the model reduction of the multi-joint robot dynamical system[3]. The conclusion is that it is effective to simplify the foot-leg model by model reduction, which not only satisfies the good performance of the end position control, but also guarantees the tracking stability under the constraint. Finally, the simulation verifies the theoretical analysis. In figure 2, (a) shows the relationship between the two joint angles and the good tracking of the instruction by the actual joint angles. (b) a normal change in the torque of the double joints. (c) reflect the actual force on the foot and the ideal force on the foot change information, as well as good tracking error. The experimental results show that the one-legged robot has fulfilled the initial requirements of the system and achieved good position and contact force control. This lays a foundation for sliding mode fault-tolerant control of foot force and position of foot-leg robot. At the same time, it provides a way of thinking for the design of sufficient ground force, and has the value of further popularization.



(a)

Figure 1: Double joint single leg with horizontal restraint



(b) (c)

Figure 2: (a) Angle and angular velocity tracking of joint 1. (b)Control input of joint 1 and 2. (c) Tracking of constraint force and tracking error

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Abstract ID No.31

Bio-Inspired Sensing Principles for Novel Artificial Electronic Skins

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Abstract

Artificial electronic skins that mimic the sensory functionalities of the natural skin are critical and highly desirable for the emerging fields of prosthetics and robotics. Complex sensing devices/systems have been explored to construct artificial electronic skins by spatially integrating multiple sensing elements or elaborately merging multiple sensing principles. However, the sophisticated fabrication, complex operation, and high power consumption pose challenges for their practical and widespread applications. Motivated by the limitations of the currently existing electronic skins and inspired by the sensing behaviors of natural human skin, in the past two years, we successfully developed a number of novel sensing mechanisms and created a whole set of innovative electronic skins with distinctive characteristics that cannot be achieved via state-of-the-art technologies (Fig. 1). These advantages include: 1) single-mode signal output and greatly simplified operation, 2) good stretchability but strain-insensitivity (up to 50% tensile strain), 3) passive signal output and ultralow power consumption (less than 1 nW), 4) good capability to resolve complex external stimulations, 5) simplified configuration and scalable manufacturing based on an all-solution-processing approach, and so on. Furthermore, we demonstrated that diverse environmental stimuli in our daily life (e.g., temperature variation, static and/or dynamic pressure, mechanical vibration, etc.) can be detected and recorded in real time with our electronic skins. These highly effective and energy-efficient electronic skins provide a much-improved human-machine interfacing medium and open up great opportunities for creating a new range of humanoid robotics, skin prosthetics, wearable healthcare devices, bioelectronics, and autonomous smart systems.

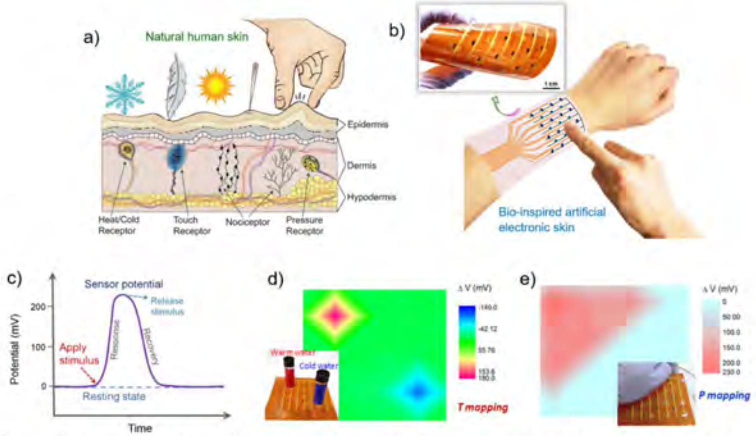

Fig. 1. Bio-inspired design of novel sensing mechanisms for artificial electronic skins with multifunctional sensing capabilities.

Abstract ID No.32

Articular Cartilage Inspired Hydrogel with Good Mechanical and Lubricating Performance

*Pan Jiang, Xiaolong Wang**
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Abstract

Articular cartilage possesses the functional characteristics of high load bearing yet low friction, which shows the great significancy to the movement of joint mechanism. As an excellent soft and wet polymer material, 3D printed hydrogel has the rich physical and chemical properties and personalized structural design, and is expected to be used to treat joint soft tissue injuries. However, the current 3D printed hydrogels exhibit low mechanical properties, which severely restrict their use under load, impact and lubrication conditions. Therefore, the development of 3D printing high-performance bionic lubricating hydrogel is of great significance. Here, we construct a dual physical cross-linking networks in the 3D printed hydrogels to realize the ultra-high-strength hydrogels manufacturing. Specifically, polyvinyl alcohol (PVA) and soluble short-chain chitosan (CS) are used to formulate 3D printing hydrogel ink. Based on the strong hydrogen bonding, electrostatic interaction and physical entanglement between PVA and CS. The hydrogel ink exhibits good shear thinning behaviour, excellent viscoelasticity and thixotropic properties, which can be used to print the complex three-dimensional hydrogel structures by direct ink writing. And then, the cyclic freeze-thawing and soaking in sodium citrate solution postprocessing can build the PVA physics crystalline network and the CS ion cross-linking network respectively, resulting in the highest strength of the printable hydrogels at present. Finally, inspired by the role of anionic mucopolysaccharide (Aggrecan) in articular cartilage in bio-lubrication, an anionic polymer network is introduced into the 3D printed ultra-high-strength hydrogel to simulate the mucopolysaccharide for improving lubricating performance. Using 3D printing technology and bio-lubricating hydrogel to prepare the meniscus structure of biological joint tissues provide a new idea for the repair of joint soft tissue damage.

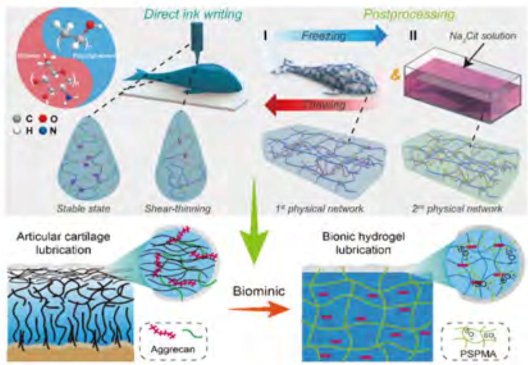

Figure 1: 3D printing of articular cartilage inspired hydrogel for bio-lubrication.

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Abstract ID No.33

Drop Bouncing on Superhydrophobic Surfaces

Y. H. Liu
Dalian University of Technology

Abstract

Regulating drop bouncing on superhydrophobic surfaces is essential to various potential applications, such as self-cleaning, water-harvesting, cooling and heat and mass transfer. However, this kind of research is still in the rough. For instance, there exists a theoretical contact time limit which is imposed by the classical hydrodynamics and the drop bouncing is still hard to be controlled. In this talk, I will briefly discuss our recent efforts to these puzzles. [1-4] Several droplet bouncing mechanisms were put forward to reduce the contact between impinging droplets and the underlying solid surfaces and the corresponding textured superhydrophobic surfaces have been sculptured to realize this goal. We believe the research which can achieve enhanced drop bouncing will stimulate new applications.

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Abstract ID No.34

A Bio-inspired Tactile Sensor and Its Processing Algorithm for Spike Signals

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Abstract

In order to sense dynamic forces from external forces, a type of tactile sensor was designed, based on which an enhanced signal processing system was developed to discriminate different surface roughness. Considering that signals transit in the form of electronic pulses, i.e., spikes, in human body, it is significant to develop an algorithm to process spike train signals mimicking the biological mechanism of human brain due to a lot of merits, such as low energy cost, high robustness, and fast transmission etc. However, traditional mature classification models cannot tackle the spike train signals directly while most specialized spiking neural networks are not free to access, which prevents the widely spread and development of neuromorphic approaches. In this work, we proposed a reference spike train based neurocomputing method to process spike train signals via a combination of traditional classifiers and three categories of features, which made it possible to tackle spike signals in a traditional way while high accuracy was maintained. The three categories included statistical features, spike metric features, and vector features. They were extracted from tactile signals after a differential spike train computation and binning. Relevant techniques were further analysed and discussed to explore how to configure an optimal reference spike train in order to achieve higher performance. Finally, effectiveness of the proposed method was validated via an application to tactile signal processing for roughness discrimination, which is also applicable to other occasions that require for classifications of spike train signals.

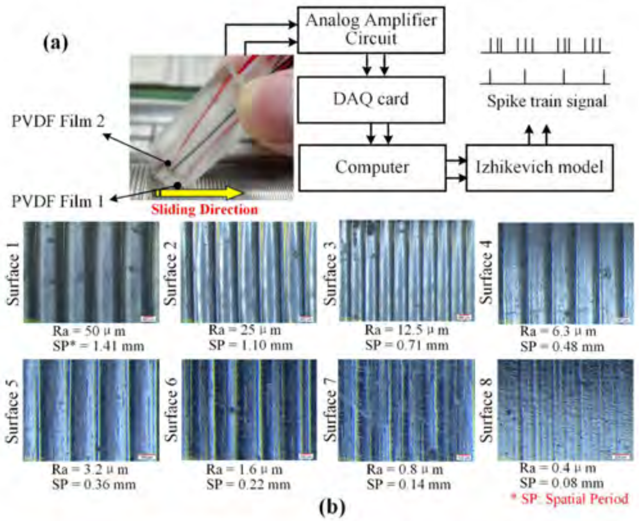

Figure 1: Developed Tactile Sensor and the Experimental Setup

Abstract ID No.35

Artificial Fingerprint-textured Liquid Crystalline Polymeric Coatings and Their Applications

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Abstract

Liquid crystalline polymers with ordered molecular alignment exhibit many interesting properties such as dielectric anisotropy and stimuli-induced anisotropic mechanical deformation, endowing them with possibilities in applications for various scenarios. We will present our research on functional devices made from liquid crystalline polymers with fingerprint textures, and demonstrate their applications in electrically controlled remote dry-cleaning and light-assisted object manipulation underwater.

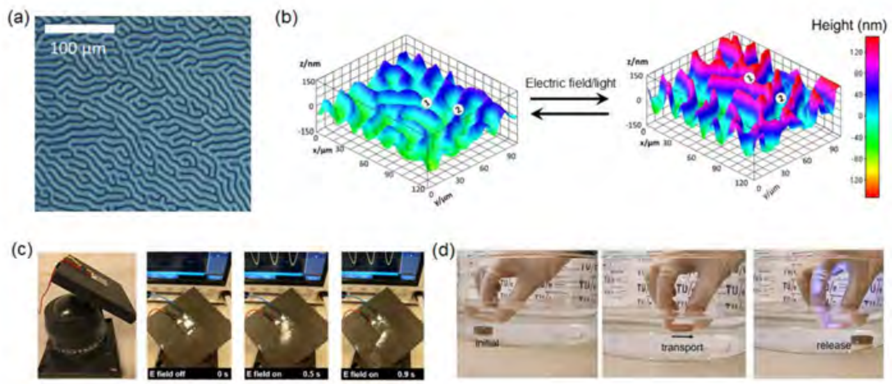

Figure 1: Fingerprint-textured liquid crystalline polymer coatings and their applications. [1][2] (a) Polarized microscope image of the "fingerprint" texture of liquid crystalline coatings. (b) Surface topographical deformation induced by electric field or light. (c) Application in dry cleaning using electrical stimulus. (d) Application in object manipulation underwater using UV light.

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Abstract ID No.36

Enzyme-powered Artificial Cell Models

Lei Wang
Harbin Institute of Technology, China

Abstract

The past two decades has witnessed the great advancement in the field of artificial swimmers (also named micro/nanomotors or micro/nano robots), due to their broad applications in life science, nanomedicine as well as environmental remediation. Enzymes, with efficient catalytic ability, nice biocompatibility and degradability, are excellent engine candidates for these artificial swimmers. Herein, to further broaden the library of enzyme engines and the biomimetics of cellular functions, different enzymes were explored to trigger the motion of artificial cell models.1-3 Besides, these models were either endowed with programmed autonomic behaviors, the blood lipid remover or artificial predators, thus providing new artificial platforms for future research on biomimicry, biomedical or environmental issues.4,5.

IWBE 2021

Abstract ID No.39

Bioinspired Engineering Holds Enormous Potential for Mankind: Need for Creating Better Awareness

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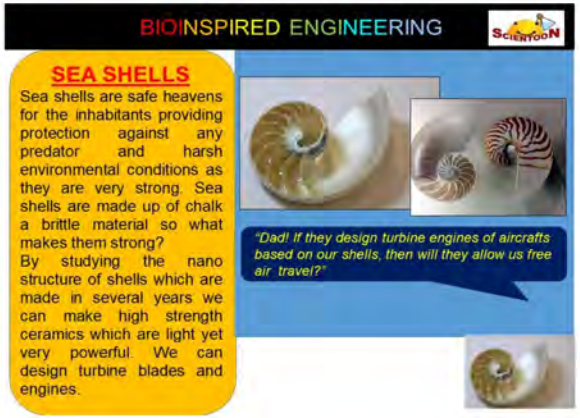
Abstract

Bioinspired engineering some times called biomimetics or biomimicry, basically biologically inspired engineering is defined as a “New science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems". Prof. Janine Benyus suggests looking to Nature as a "Model, Measure, and Mentor" and sustainability as an objective of Bioinspired engineering. Bioinspired engineering looks to nature and natural systems for inspiration. After millions of years of tinkering, Mother Nature has worked out some effective processes. In nature, there is no such thing as waste — anything left over from one animal or plant is food for another species. Human engineers and designers often look there for solutions to modern problems.

STENOCARA beetle, a MASTER WATER COLLECTOR, small black bug lives in a harsh, dry desert environment and is able to survive thanks to the unique design of its shell. The Stenocara's back is covered in small, smooth bumps that serve as collection points for condensed water or fog. The entire shell is covered in a slick, teflon-like wax and is channeled so that condensed water from morning fog is funneled into the beetle's mouth. Researchers at MIT have been able to build on a concept inspired by the Stenocara’s shell and first described by Oxford University's Andrew Parker. They have crafted a material that collects water from the air more efficiently than existing designs.

SEA SHELLS are made up of chalk a brittle material so what makes them strong? By studying the nano structure of shells which are made in several years we can make high strength ceramics which are light yet very powerful. We can design turbine blades and engines.

What is most important today is that people are not aware of the promises Bioinspired engineering holds for the future especially for a country like India and other developing countries with tropical climate which makes it biodiversity rich. Author who has started a novel concept of science communication called scientoon (a new class of cartoons based on science) and subsequently a new science called Scientoonics, will use this science to create awareness about Bioinspired engineering as what enormous future these hold specially in the area of reaching to unreached through science and technology and India being the country with enormous biodiversity holds a great future in this science.



Abstract ID No.40

Inside a Ladybird Coupling: Elastic Setae Store Energy for Elytra Deployment

*Qiufeng Yuan [1], Jie Zhang [2], Yunqiang Yang [1,] *, Jianing Wu [2]*
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2. School of Aeronautics and Astronautics, Sun Yat-Sen University, Guangzhou, 510006, P. R. China

Abstract

Million years of evolution drives animals to evolve a variety of specialized morphological features, which are exemplified in elytra of ladybirds (Coccinella septempunctata), deploying swiftly in 100 ms in advance to hind-wing extension. However, opening the elytra merely by basal muscles may be insufficient, because the coupling force in interdigitated sutures of elytra locked elytra firmly, and the lengthy arm of force possibly generates a non-negligible torque that is required to overcome. Despite these constraints, the elytra can open in the first phase during 0-3 ms, at an ultrahigh angular velocity of 647 RPM, rivalling ceiling fans speed with 600 RPM. To uncover how the ultrafast deployment happened, we first applied scanning electron microscopy and micro-computed tomography to reconstruct microstructures on the connection of elytra. We discovered that two rows of setae bearing on the internal edge of the elytra coupling would be compressed when the elytra were locked, and the elastic potential energy stored by setae might facilitate the rapid elytra deployment. To demonstrate the effects of compressed setae on the elytra unfolding, we amputated the unilateral elytra of ladybirds, and filmed kinematics of the elytra deployment. We found that the ladybirds with one elytron trimmed took about 4 times that of the normal ones to deploy. A mathematical model elucidated elastic force provided by the compressed setae offers 30% of the force required. The mechanism of energy-storage may inspire a rapid deployable structure potentially used in many engineering fields, such as foldable solar panels used for deep space exploration.

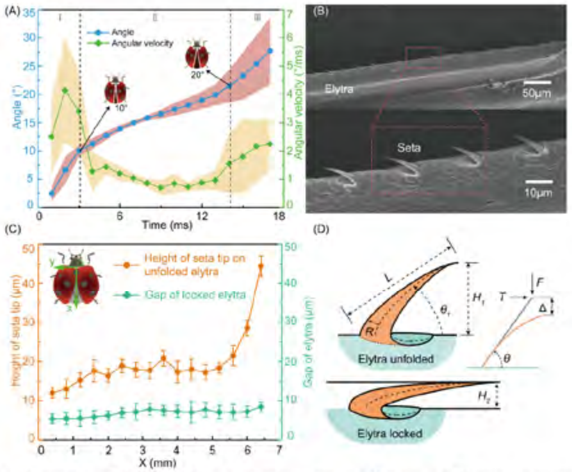

Figure 1: Kinematics of elytra unfolding, and microstructure of setae. (A) Kinematic parameter of ladybird elytra deployment. (B) Microstructure of setae. (C) Height of setae *H* and gap of locked elytra. The coordinate was built with the scutellum as the origin *o*. The *x* axis pointed from point *o* towards the tail, and the *y* axis was perpendicular to the *x* axis. (D) The condition of the setae when elytra were unfolded or locked.

IWBE 2021

Abstract ID No.41

The Development of a Two-finger Dexterous Bionic Hand with Three Grasping Patterns –NWAFU Hand

Xuewei Han, Zhiguo Li
Northwest A&F university

Abstract

Bionic inspiration from human thumb and index finger was the drive to design a high-performance two-finger dexterous hand. The size of each phalanx and the motion range of each joint in the human thumb and index finger were summarized, and the features of three grasping patterns were described in detail. Subsequently, a two-finger dexterous bionic hand with 6 Degrees of Freedom (DoFs) was developed. Both the mechanical thumb and index finger were made up of three rigid phalanx links and three mechanical rotation joints. Some grasp-release tests validated that the bionic hand can perform three grasping patterns: power grasp, precision pinch and lateral pinch. The grasping success rates were high under the following cases: (1) when power grasping was used to grasp a ring with external diameter 20 mm – 140 mm, a cylinder with mass < 500 g, or objects with cylinder, sphere or ellipsoid shape; (2) when the precision pinch was used to grasp thin or small objects; (3) when the lateral pinch was used to grasp low length-to-width ratio of objects. The work provided a method for developing two-finger bionic hand with three grasping patterns, and further revealed the linkage between the difference in finger structure and size and the hand manipulation dexterity.

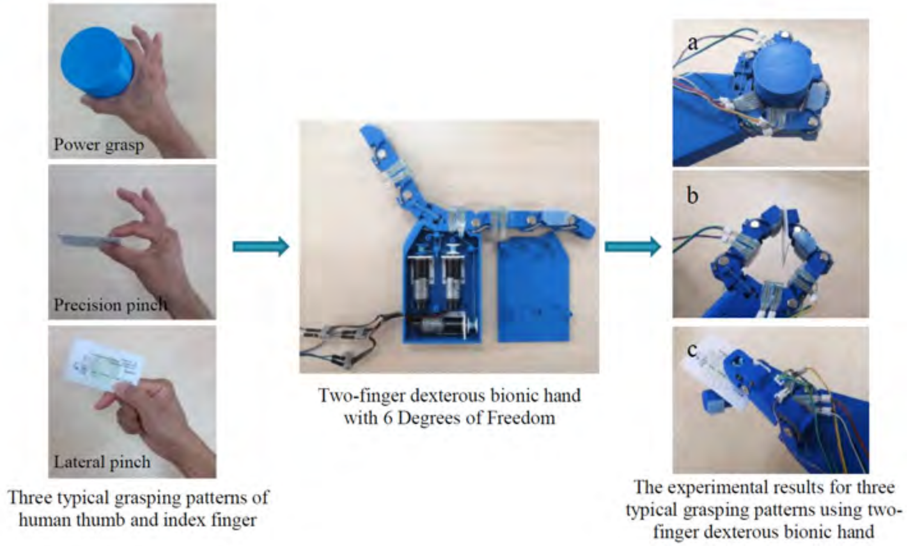

Figure 1: Two-finger dexterous bionic hand with 6 DoFs for three typical grasping patterns design

Abstract ID No.42

Hair Receptors on a Honey Bee Tongue Are Sensitive Tactile Sensors

Caiying Liao, Jianing Wu, Zhigang Wu*
Sun Yat-Sen University

Abstract

Haptic sensing has been emphasized in robotics community for a long time. Research into biomimetic whiskers, also known as dynamic tactile sensors measuring vibrations during contact, has also started to attract increasing attention in recent years. Here, we found that honey bees (Apis mellifera L.) can adjust the dipping rate at which they feed on nectar in accordance with nectar viscosity. We observed that some hair receptors, approximately 40 μm long, randomly distribute on the glossa of honey bees, by which they can distinguish a mechanical force of at an accuracy of 20 μN. We built a mechanical model elucidating that the hair receptor is more sensitive than the biomimetic whiskers. By mimicking the hair receptors, an artificial mechanosensor may be designed for real-time sensing, which is potential for tactile sensing in micro-robotic systems.

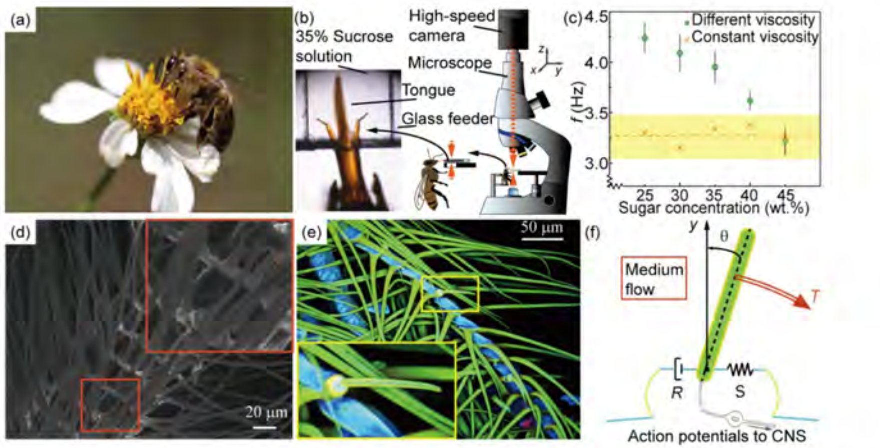

Figure 1: Functional Conservation, morphology and mechanisms of the hair receptors on honey bees' tongues.

IWBE 2021

Abstract ID No.43

3D Printed Template-Assisted Bioinspired Microfibers

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Abstract

Fog is an important source of water, especially in arid and semi-arid areas. Spider webs composed of periodically distributed spindle-knots and joints are capable of capturing dewdrops (Figure 1.a) [1,2]. we mimicked the functional spindle-knotted fibers via a 3D printed templated method in a well-controlled manner for fog harvesting (Figure 1.b). PDMS was used to cast firstly on the 3D printed fibers to obtain a PDMS negative mode structured channels. ABC solution was injected into the PDMS channels and solidified into hydrate fiber with cross-linking with Ca2+. Via dehydration-induced morphological shrinkage, the dehydrated ABC microfibers are endowed with lightweight, tunable dimensions, mechanical flexibility, and fog harvesting ability (Figure 1.c,d,e). The microfibers were characterized in terms of surface morphologies and wettability. The typical dehydrated ABC fiber featured a periodic alternation of spindle-knots and joints, which exhibited a similar structure with previously reported fibers (Figure 2.a). The surface of spindle-knots exhibited rough wrinkles, while that of joints had the relatively smooth wrinkles parallel to the axial of joints. The enhanced roughness endowed an improved surface energy gradient between spindleknots and joints, which promoted the directional migration of droplets to spindle-knots. The water collection process on the prepared fiber was monitored against time (Figure 2.b). The volume of water increases relatively linearly with time and the maximum hanging volume of droplets on the spindle-knots was about 21.57 μL, which is almost 96 times the volume of spindle-knots (0.224 μL) (Figure 2.c). These fibers have lightweight, changeable shapes, adjustable size, mechanical flexibility, and water collection ability, which have a wide prospect in large-scale water collection, directional transport of droplets, and drug delivery, and provide an alternative method for producing bioinspired spindle-knotted fibers.

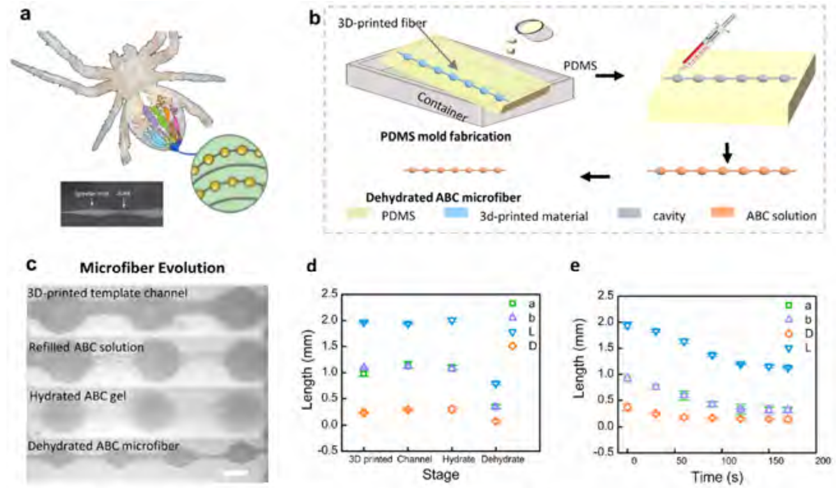

Figure 1: Fabrication of spider-silk-inspired dehydrated ABC microfibers

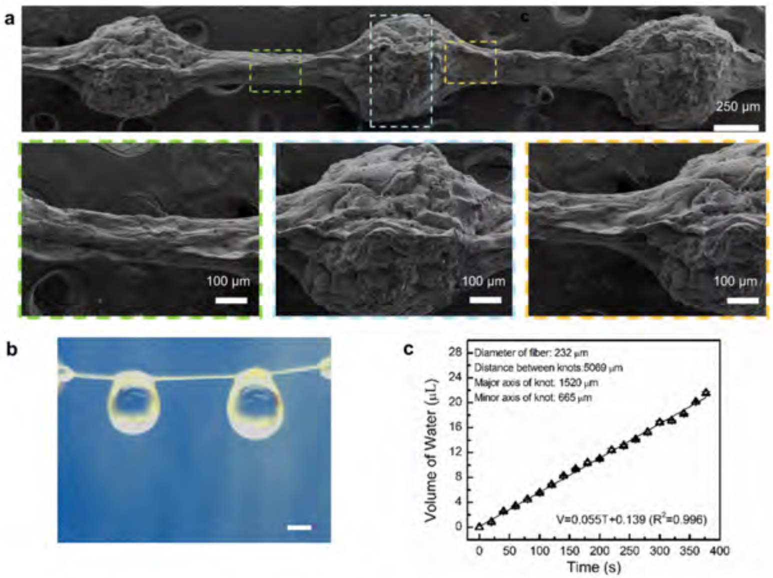

Figure 2: Characterization of the dehydrated ABC microfibers.

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Abstract ID No.44

X-ray Microtomography and Finite Element Analysis for the study of Plants and Its Implications for Bionics

F. L. Palombini, B. F. Oliveira, J. E. A. Mariath
UFRGS

Abstract

One of the main steps in bionics is the process of studying and analyzing the natural element before its application in a project. Therefore, making sure the observed element is corrected analyzed is essential to understanding the desired biological property. By increasing the magnification, newer insights can be obtained at micro- and nanoscopic levels, allowing a biological sample to be visualized with greater details. This study focuses on the importance of novel 3D technologies for the study of plants aiming at bionic design. In recent years, the use of X-ray microtomography (µCT) in biological materials has gained attention due to the possibilities of producing high-resolution 3D models, non-invasively (Fig. 1). µCT is based on the merging of sequential 2D X-ray imaging of a rotating sample, generating a 3D model like a nodal region of bamboo (Fig. 1A) and the inflorescence-tank of bromeliad (Fig. 1B).

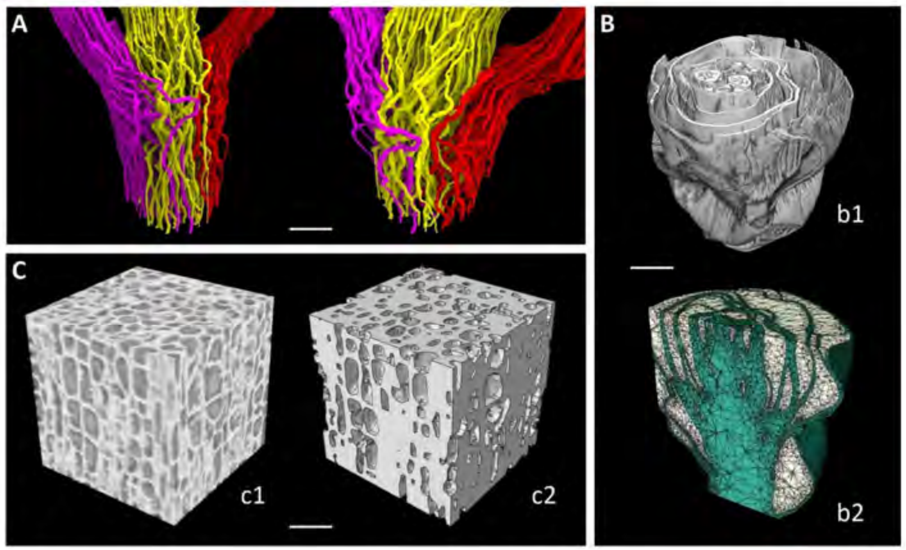

Figure 1: Examples of µCT scans and FEA models of: (A) bamboo node [1]; (B) bromeliad tank [2] with µCT (b1) and FEA (b2); (C) discretization of bamboo parenchyma [3] by voxel-based (c1) and geometry-based (c2). Scale bars: (A) 1 mm, (B) 0.09 mm, (C) 2 mm.

Besides permitting the visualization of fine structures, μCT models can be discretized for Finite Element Analysis (FEA) applications, using voxel- or geometry-based approaches (Fig. 1C). Discretized, the plant model can be virtually analyzed (Fig. 2), leading to newer comprehensions about its anatomy and structural behavior, like the mechanical importance of the parenchyma for bamboo (Fig. 2A). Finally, the information gathered about the plant can be used for the design of more efficient bionic structures (Fig. 2B), like thin-walled structures based on the vascular system, with better performance in axial compression and flexural tests.

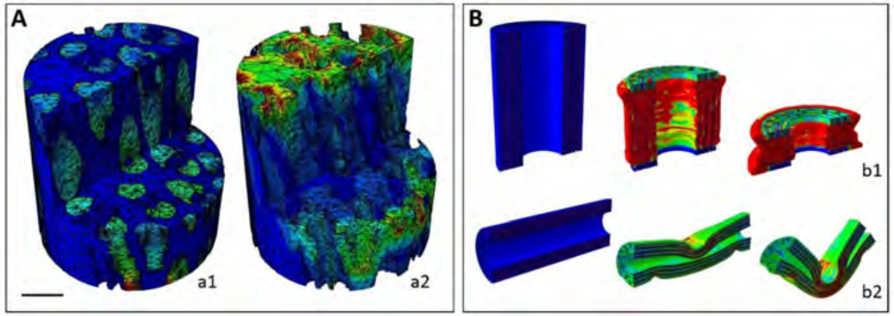

Figure 2: Examples of μCT-based FEA of (A) bamboo [4], with internal view cut of parenchyma and sclerenchyma (a1) and parenchyma only (a2); and (B) bionic design of thin-walled structure based on the vascular system of bamboo [5], at compression (b1) and flexural (b2) tests. Scale bar: (A) 0.5 mm.

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Abstract ID No.45

Uncover Motion Geometry and Timing of Human Arm Control

X. Xiong
University of Southern Denmark

Abstract

Human arm control is governed by motion geometry (followed trajectory) and timing (velocity along the trajectory). However, how the central nervous system determines this geometry and timing remains unclear. In this talk, I will present recent work on using robots and computational models to uncover motion geometry and timing in human motor control [1]. It shows that online impedance adaptation control is important in geometry and timing determination of human-like whipping (to hit a target) and cyclic motion tracking [2, 3]. My research paves a robotics inspired way forward to understanding human arm control (e.g., in deformable object manipulation).

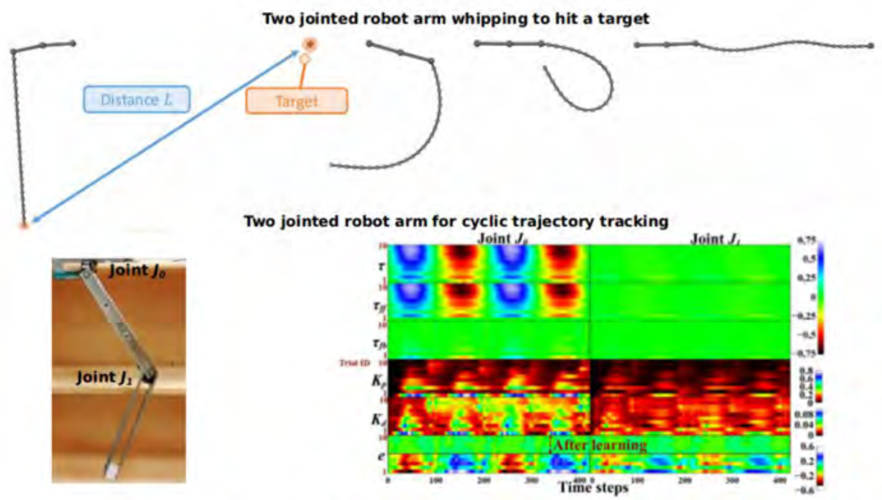

Figure 1: Human-like whipping and cyclic tracking [2, 3].

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Abstract ID No.46

Bio-inspired Smart Surface with Anisotropic Friction for Controllable Locomotion

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Lanzhou Institute of Chemical Physics, CAS

Abstract

Anisotropic friction generated by microstructured surfaces is ubiquitous in nature, like the highly ordered fibers of the snake skin, which exhibit a pronounced anisotropic friction force to propel its locomotion. Complicated physical phenomena and processes may be involved in natural anisotropic friction systems; however, in many cases, a typical phenomenon encountered in nature is anisotropic microstructures on surfaces that are oriented at a certain angle to the supporting layer and the stiffness of the biological surface. Hence, in this study, an epoxy-based shape memory polymer (SMP) incorporating Fe3O4 nanoparticles is used to create a smart surface with oriented structures to mimic anisotropic friction and exploit human-developed controllable locomotion systems. Applying the specific properties of the epoxy-based SMP, fast switching friction can be achieved by adjusting the topography and stiffness of the microstructures on the surface. In addition, the photothermogenesis effect of Fe3O4 nanoparticles induces changes in the asymmetric topography and stiffness on the SMP surface under the irradiation of near-infrared (NIR) light, thereby inducing a rapid switching of the friction force. Furthermore, a microbot is created to demonstrate remotely controlled locomotion, such as unidirectional and round-trip movements, and braking by switching the friction force under NIR light. These features render the shape memory smart surface highly favorable and broaden its functionality and applications for directional driving, cargo transportation, and areas involving anisotropic friction forces.

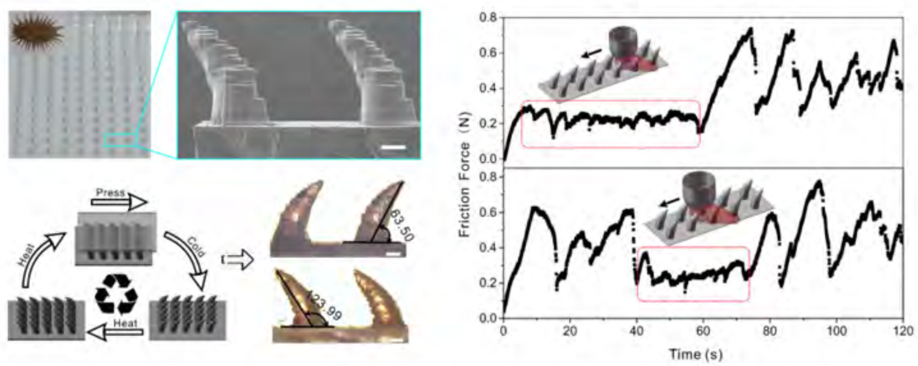

Figure 1: Bioinspired surface with dynamic orientation and its controllable friction force. Scale bar, 100 μm.

IWBE 2021

Abstract ID No.47

Contact Force Control of a Crocodile Moving across Different Substrates

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School of Aeronautics and Astronautics, Sun Yat-Sen University, Guangzhou, 510006, People's Republic of China

Abstract

Crocodiles are well-known for their high adaptability to various habitats such as rivers, lakes, and wetlands. They are capable of crawling across a range of surfaces; however, the mechanism of how they regulate contact forces on different substrates remains unexplored. Here, we observe a crocodile (Crocodylus siamensis) crawling by a high-speed camera and record the real-time contact forces by a force plate. We find that the crocodile uses different mechanical strategies to adapt to various substrates. On the solid surface, the hind feet rotate on a fixed axis around the toes to move forward; whereas on the granular materials, the hind feet squeeze and push the granules by foot webs. The peak vertical ground reaction force of hind limb on the granular surface is approximatle 2 times larger than that on the solid surface. Such a control mechanism may provide bioinspired foot design of robotics which can meet the requires of broad environmental adaptability.

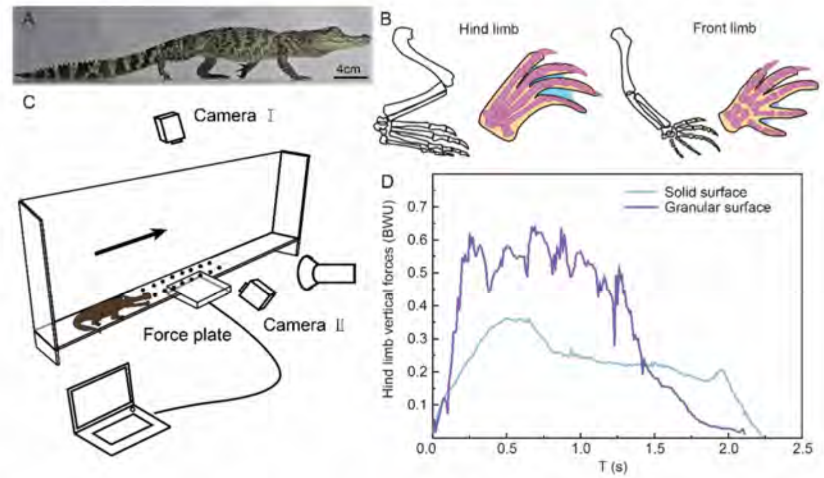

Figure 1: (A)Lateral views of *Crocodylus siamensis*. (B) The detailed feet structure and the skeleton of the front and hind limbs of the crocodile. (C) Configurations of the trackway for capture of ground reaction forces. (D) Ground reaction forces in body weight units (BWU) of crocodile crawling on the solid surface and granular surface.

IWBE 2021

Abstract ID No.48

Design of Bionic Grasping Robot

*Zhengguang Liu, Zhiguo Li**
Northwest A&F University

Abstract

With the rapid development of sensor detection, computer vision and control algorithm, the manufacturing and control technology of robot has made great progress and development. In many production fields of society, such as industry, national defense and agriculture, robot technology has integrated computer technology and Internet technology, created higher economic benefits, and played an important role in the progress of social science and the improvement of comprehensive economic strength.

At present, most robots are widely used in the industrial field. These industrial robots accurately grasp the same object in a fixed position with a fixed trajectory and running attitude in a relatively unified working environment, which saves a lot of labor. In other production fields, such as agriculture, due to the reduction of agricultural population and the increasing aging in China, there is also a great demand for robots. However, the temperature, humidity and complex agricultural production environment make the design and application of robots in the field of agriculture more difficult. Therefore, the development of robots in the field of agriculture should fully absorb the advantages of computer intelligent technology, improve productivity and provide sufficient, diverse and safe food for human diet, which is of great value and significance.

The grasping robot simulated a relatively complex working environment can automatically travel from position A to position B according to a predetermined path. After reaching position B, the grasping robot moves the end-effector above the object by adjusting the attitude of the mechanical arm. Then, the target object is scanned repeatedly to determine its accurate position. Finally, after grasping the target object, the grasping robot returns to the original position A and places the target object according to a certain operation. So far, the grasping robot has completed a work cycle.

The robot is mainly composed of two parts: a grasping mechanism for taking and placing objects and a walking mechanism for moving. Through the analysis of grasping target and the simulation of finger grasping mode during human harvesting, the grasping mechanism adopts the design of three finger end-effector (Fig.1). At the same time, in order to determine the specific position, color and size of the target object, accessories such as GP2D120 infrared ranging sensor, E18-F10NK color code sensor and limit switch were installed at different positions of the end effector. The walking mechanism controlled by AVR single-chip microcomputer is composed of a movable platform driven by DC motor and a mechanical arm driven by stepping motor (Fig.2). In order to prevent obstacles, an ultrasonic sensor was installed in front of the walking mechanism to realize the obstacle avoidance function.

The results of grasping experiments on spherical objects of different colors and sizes show that the color recognition performance of the grasping robot is stable, and it can complete the object classification by detecting the color and size of objects (such as tomatoes, apples, etc.), and transport the classified objects to the designated place for storage.

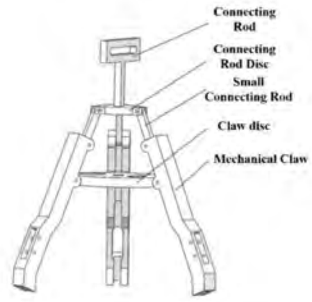

Fig.1 End-effector with three fingers

Fig.2 Composition of bionic grasping robot

Abstract ID No.49

Human Tactile Sensing and Sensorimotor Mechanism: From Input Afferent Tactile Signals to the Output Motor Control and Its Applications on Robotics

Yuyang Wei, Lei Ren and Guowu Wei**
The University of Manchester, UK

Abstract

The understanding of human tactile sensing mechanism and sensorimotor control still remain primitive due to the difficulties of capturing population-level afferent tactile signals during active exploration [1-3]. A reliable and effective method is required to compute the population-level afferent tactile signals and explore the neural coding mechanism and sensorimotor control strategy [4, 5]. Meanwhile, these performances are demanded to be restored on robotic/prosthetic hands and move a further step towards the applications of next-generation prosthetics with tactile feedback. In this study, population-level cutaneous and cuneate neural dynamics evoked during active touch were computed through a validated multi-level numerical model. The sensorimotor controlling algorithm was summarized between the input cuneate neural dynamics and the output activation level of muscle synergy. An artificial tactile sensory system (ATSS) composed of a tendon-driven biomimetic hand and a tactile sensor array integrated with the neural dynamic model optimized against the in-vivo microneurography results was developed. The active and reactive grasping under summarized sensorimotor algorithm were performed by the artificial tactile sensory system, comparable sensing capability, contact pressure and afferent signals with the human subject were achieved. The grasping performance of the biomimetic hand was improved after adopting the sensorimotor control strategy. It was also found that the human subject may apply the similar sensorimotor strategy to actively or reactively grasp different objects while the re sponse time of this closed-loop control could be affected

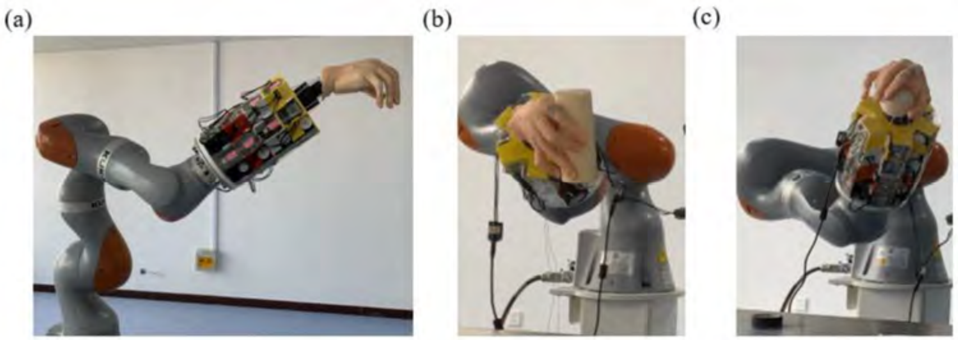

Fig.1 The artificial tactile snesory system. (a) The ATSS was mounted on a KUKA robotic arm to perform active and reactive grasping. The tactile sensor was directly 3D printed onto the distal index phalange of the biomimetic hand and produced the tactile feedback. (b) Cylinderical grasping performed by the ATSS. (c) Spherical grasping performed by the ATSS

Abstract ID No.50

Hollow Mandibles: Structural Adaptation to High-speed Strike in the Trap-jaw Ant Odontomachus Monticola

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Abstract

The extremely rapid mandible strikes of the trap-jaw ant O. monticola require both morphological and biomechanical feats. Micro-CT imaging shows the mandibles are hollow, which may augment the mandible acceleration to 105 m/s2 or a higher clamping force. However, this hollowness might challenge the structural strength under such a high impact force. In this experimental and theoretical combined study, by employing micro-CT scanning, we built finite element models to elucidate how a counterbalance in the hollowness of mandibles can satisfy the contradictive demands of both rapid and powerful clamping. Results of the finite element analysis (FEA) showed that the impact force of the hollow mandible is 1.76 times that generated by the solid mandible under the same kinematic characteristic. Moreover, under the same driving energy of the mandibles, the impact force of the hollow mandible is 2.24 times that generated by the solid mandible. We also found that the structural strength of the hollow mandible approximates the solid mandible in response to the same load. The hollow mandible has remarkable structural adaptation to meet the demands of rapid and powerful strikes. This study bridges the structure and function of ant mandibles, which may inspire the future design of rapid robotic grippers.

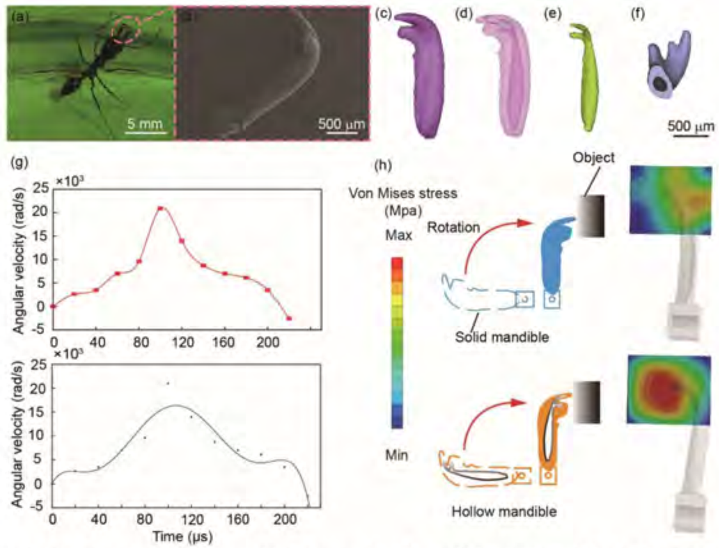


Figure 1: Microstructure of ant mandible, kinematic of mandible strike, and finite element analysis (FEA). (a) The ant *Odontomachus monticola*. (b) Microstructure of ant's mandible. (c) Morphology of the mandible. (d) Inner structure of the mandible. (e) Structure of the air sac inside the mandible. (f) Cross section of the mandible. (g) Kinematic characteristic of the mandible. (h) Results of the finite element analysis.

Abstract ID No.51

A Two-Step Carbon Fiber Modification for Enhanced Fibrous Composites Inspired by Hook-Groove Interlock Structure of Raptor's Flying Feathers

*Yufei Wang, Zhiyan Zhang, Wenda Song, Linpeng Liu, Binjie Zhang, Yujiao Li. Bo Li, Junqiu Zhang, Shichao Niu, Zhengzhi Mu, *Zhiwu Han, *Luquan Ren*
Jilin University,China

Abstract

Low interfacial activity and poor wettability between fiber and matrix are known as two main factors that restrict the mechanical properties of fiber reinforced polymer composites. In this case, inspired by high strength and toughness characteristics of wing feathers of Black Kite (Milvus migrans), the original interlock structure between microscale hook and groove was carefully investigated. Biomimetic hook-groove structures (BHGSs) based on ZnO nanowires and dopamine-functionalized carbon fibers were constructed successfully by a two-step hydrothermal method. Further, fiber-resin composites with BHGSs were prepared by a contact molding assisted with vacuum forming method. Mechanical properties of the prepared bio-inspired composites were tested and compared with the conventional ones. It confirmed that flexural strength and modulus of the composites with BHGSs were effectively improved. Specially, interlaminar shear strength was greatly enhanced. The biomimetic fabrication method proposed in this study was flexible and effective for improving interfacial adhesion and mechanical properties of resin-fiber composites. It was anticipated to provide a considerable fabrication strategy for novel resin-fiber composites with excellent mechanical properties

IWBE 2021

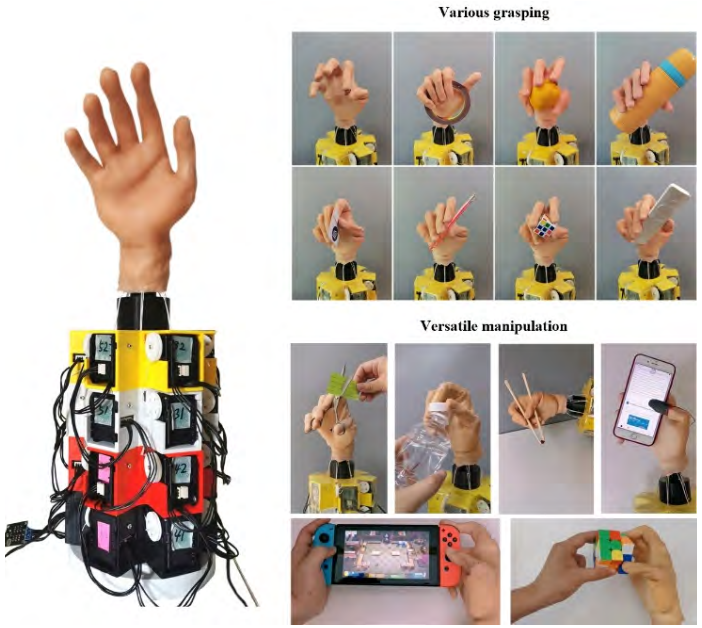
Abstract ID No.52

An Anthropomorphic Robotic Hand with Human-like Grasping and Manipulation Capabilities by Exploiting the Biomechanical Advantages of the Human Hand

Yiming Zhu, Guowu Wei and Lei Ren
The University of Manchester, UK

Abstract

Except for the neural control and sensing system, the innate biomechanical advantages empower human hands with outstanding dexterity and versatility to perform various grasping and complex manipulations. Recent years have witnessed extensive emerging of highly biomimetic robotic hands, aiming to realize human-hand-like functions by adopting biological features on robotic hands. However, few breakthroughs have been made due to the lack of investigation on the underlying biomechanical advantages of human hands. To fill this gap, a novel anthropomorphic robotic hand with multi-layer structure was developed in this paper. By using simple position control, the proposed robotic hand completed all the grasping types in Cutkoskey and Feix grasp taxonomies and accomplished various complex manipulations, including using chopsticks, screwing off the bottle cap, controlling the joystick, etc. Three biomechanical advantages associated with the ligamentous joint, the reticular extensor mechanism and the flexible tendon sheath were then explored through comparative experiments on different robotic hand models, with the results showing that the performance of the robotic hand can be relatively improved by exploiting these three human-hand-like features.



Abstract ID No.54

Rapid, Energy-saving Bioinspired Soft Switching Valve Based on Snapping Membrane Actuator

Fangzhou Zhao, Yingjie Wang, Chunbao Liu, Luquan Ren, Lei Ren
Jilin University

Abstract

Natural organisms, such as mammals (humans), soft marine organisms (squids) and crawling organisms (earthworms), can operate their delicate structures to obtain high-efficiency fluid control mechanisms. They store energy based on the intrinsic property of connective tissue, and using muscles as a power source to drive the passive deformation of fluid cavity by the shape change, thus to achieve high-efficiency, energy-saving, and fast fluid drive and control. However, it still remains a challenge in soft robots. Most soft robots are actuated by flexible fluidic actuators, whereas their energy supply and control usually using rigid pumps or valves, which limits the flexibility and reduces the response speed. Herein, inspired by the natural control mechanisms, we present a bioinspired soft switching valve (BSS valve) based on snapping membrane actuator (SM actuator) driven by dynamic gas pressure changes. We have optimized the characteristics of SM actuator with different curvature radius (spherical, spherical crown and flat) and the wall thickness parameters, and obtained reasonable SM actuator configuration. And, we propose two applications of valve with reasonable SM actuator. First, form a sequential drive system by connecting different curvature membrane valves to a pneumatic elastomer driver. In addition, form a peristaltic pump by the spherical membrane valves. The liquid transportation results demonstrate pump embedded with BSS valve has a long cycle life (~2000 times), a low cycle energy consumption (~1.22w), a high specific pressure (~1982ml/min/kg) and a specific flow rate (~846kpa/kg) . We believe that the developed BSS valve can provide a new way for low energy consumption, fast drive and simple control.

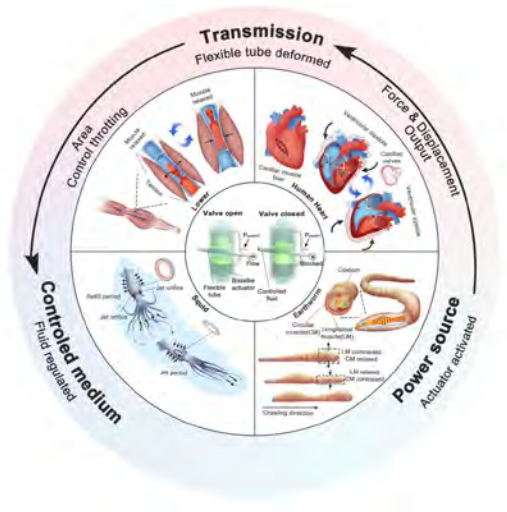


Figure 1: Design principles of the BSS valve inspired by biological fluid control mechanisms

IWBE 2021

Abstract ID No.55

Biomimetic Foam Core Sandwich Composites with High Mechanical Performance Inspired by Hierarchical Structure of Bubo bubo Feather Shaft

Zhiyan Zhang, Zhengzhi Mu, Yufei Wang, Wenda Song, Yujiao Li, Binjie Zhang, Bo Li, Junqiu Zhang, Shichao Niu, Zhiwu Han,* Luquan Ren*
Key Laboratory of Bionic Engineering of Ministry of Education, Jilin University , Changchun, China

Abstract

The foam core sandwich structures were proved with high specific stiffness and strength. However, low strength of face sheets and interlayers between core and face sheets is the main factor leading to unsatisfactory mechanical performance of sandwich materials. Bubo bubo’s feather is featured with light weight and high strength, which is closely related to the hierarchical structure of its feather shaft. Feather shaft can be divided into cortex layer composed of hierarchical ordered fibers and porous medulla layer composed of disordered fibers. Herein, inspired by this novel hierarchical structure, biomimetic foam core sandwich composites were successfully fabricated with contact molding method. First, small amount of short carbon fibers (SCF) epoxy resin/hardener mixture was added between plain-woven carbon fibers fabric (CFF). Furthermore, through polydopamine (PDA) functionalization of SCF, COOH-functionalized multi-walled carbon nanotubes (MWCNT-COOH) were loaded to form SCF@PDA-MWCNT-COOH for micro-/nanoscale toughening. Finally, Bubo bubo feather shaft-inspired sandwich composites were well prepared, containing orderly CFF face sheets, unordered SCF, and Polymethacrylimide (PMI) foam core. Mechanical properties of the biomimetic composites were carefully characterized and compared with CFF-PMI foam (CPF), CFF-SCF-PMI foam (CSPF), and CFF-SCF@PDA-MWCNT-COOH-PMI foam (CSPMPF). As a result, mechanical performance including bending strength, impact strength and interlaminar shear strength (ILSS) of the biomimetic composites was significantly improved. Further observation revealed that fiber bridging effect between face sheets and interlayer between core and face sheets was sharply enhanced by SCF. Considering unordered SCF is readily available, the fabrication method proposed in this work can effectively improve mechanical properties of foam core sandwich structures, which provides a new strategy for handy preparation of novel foam sandwich composites.

Abstract ID No.56

Integrated Real-time Polarization Sensor for Autonomous Navigation

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Dalian University of Technology

Abstract

Over billions of years evolution, some insects have acquired the ability to navigate by stable polarization pattern in the atmosphere [1,2]. Prior researches have demonstrated that the dorsal rim area (DRA) of some insect compound eye has special regularly arranged ommatidium which is sensitive to the oscillation plane (e-vector) of the polarized light, making them easier to perceive the polarized light information [3,4]. Relying on the stable polarization distribution pattern in the atmosphere, insects could perceive the angle between their body axis and solar meridian [5], and achieving linear homing after foraging [6,7]. In this paper, imitating the polarization-sensitive structure in insect compound eyes, an integrated polarization navigation sensor is designed. Based on nanoimprint lithography (NIL), a multi-orientation nanowire polarizer is integrated on the CMOS image sensor to detect polarized light. The nanowire polarizer is comprised with three pairs of vertical bilayer metal nanogratings, with the orientation of 0, π/2, π/3, 5π/6, 2π/3, and 7π/6 respectively. FPGA is used as processing module to process polarization information and display polarization image in real time. The laboratory tests indicated that the sensor, with ± 0.1° measured error, had potential application prospects in polarization navigation.

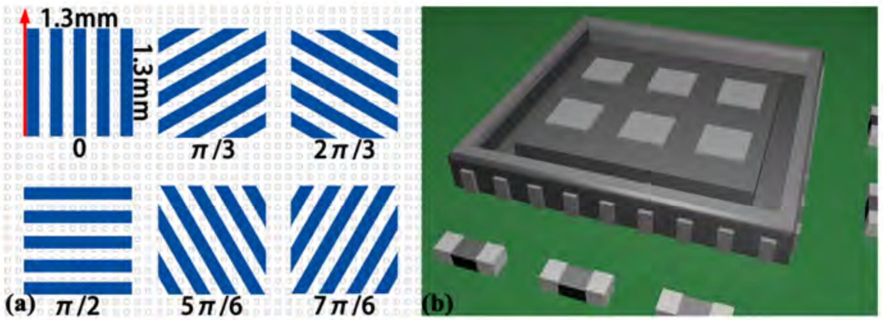

Figure 1: (a) Schematic view of the multi-orientation nanowire polarizer; (b) The integrated polarization sensor is fabricated by integrating a multi-orientation nanowire polarizer on CMOS in one step.

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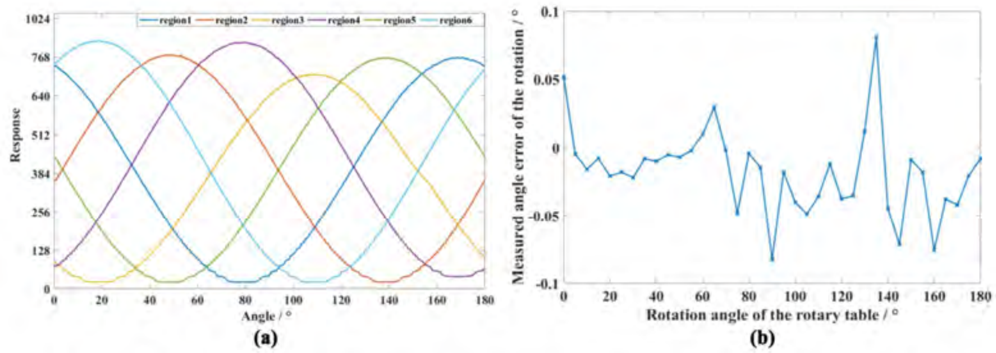

Figure 2: (a) The response of each polarization-sensitive unit; (b) The measured error of the integrated polarization sensor.

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Abstract ID No.57

Numerical investigation of aerodynamic characteristics of bionic airfoils inspired by owl feather

R.B.Gao
Xinjiang University

Abstract

Wind energy is a clean energy[1], and wind turbine converts wind energy into electricity. Flow separation is common in wind turbine blades during operation. The flow separation phenomenon seriously affects the aerodynamic performance of the blade and reduces the overall efficiency of the wind turbine. Due to the generation of flow separation, the periodic separation of the vortex on the blade surface causes the vibration of the blade during operation, which seriously affects the stability of the overall operation of the wind turbine. The wind turbine airfoil is the core component that determines the aerodynamic performance of the blade. Using effective flow separation control method to suppress the flow separation on the surface of wind turbine airfoil could improve the aerodynamic performance of wind turbine airfoil. In this paper, according to the microstructure of the owl feather, a wind turbine airfoil with herringbone structure is designed. The influence of herringbone structure on aerodynamic performance of wind turbine static and pitching airfoil is analyzed by numerical simulation.

First, NACA4412 airfoil is chosen as the standard airfoil. According to ref.[2], the chord of airfoil is 901.2 mm and the span is 1991 mm. The fluid velocity 27.13 m/s, and Re= 1.52×106. The simulation utilize an incompressible Reynolds-Averaged Navier-Stokes solver and shear stress transport (SST) k-ω turbulent model. The reliability of numerical simulation is demonstrated by comparing the simulation results of NACA4412 airfoil with experimental data. Analysis of surface pressure, wind speed and flow field of standard airfoil, and analysis of flow separation point.

Secondly, according to the microscope image of owl feathers, a two-dimensional sketch of the herringbone structure was designed (Figure 2). The width s is 10 mm, the spacing c is 10 mm, the angle θ was 60° , and the length l was 900 mm. sm is the spacing between two rows of herringbone structures, and sm is 191 mm. The design of herringbone structure on the blade is divided into two forms: herringbone groove structure and herringbone ridge structure. According to the separation zone of the standard airfoil in the previous paper, the herringbone structure is designed in the unseparation zone, separation zone and complete separation zone. Six types of airfoils with herringbone structure are designed. The static numerical calculation of six types of modified airfoils is carried out, and the lift, drag and lift-drag ratio of the modified airfoil are analyzed. The influence of herringbone groove structure and herringbone ridge structure on airfoil and the influence of design position on airfoil performance are discussed. The wind turbine airfoil with the best performance among the six modified blades are selected.

Finally, the performance of the modified airfoil with the best performance and the standard airfoil are compared and analyzed. The influence of herringbone structure on aerodynamic performance and flow separation of static airfoil is analyzed, and the operation mechanism of herringbone structure is analyzed. In turbulent flow, the two wing models oscillate around the leading edge at reduced frequency k = 3. The pitching amplitude is 10° and 20° , respectively. The influence of herringbone structure on pitching airfoil is analyzed.

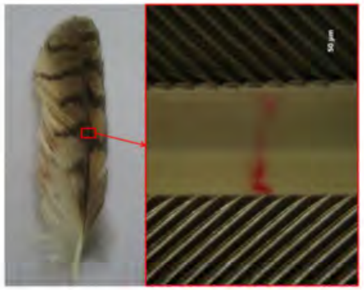

Figure 1: Owl feather

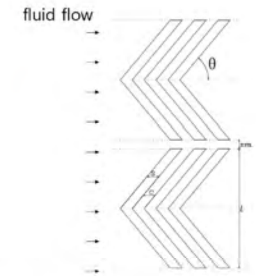

Figure 2: Schematic diagram of herringbone structure

Finally, the performance of the modified airfoil with the best performance and the standard airfoil are compared and analyzed. The influence of herringbone structure on aerodynamic performance and flow separation of static airfoil is analyzed, and the operation mechanism of herringbone structure is analyzed. In turbulent flow, the two wing models oscillate around the leading edge at reduced frequency k = 3. The pitching amplitude is 10° and 20° , respectively. The influence of herringbone structure on pitching airfoil is analyzed.

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Abstract ID No.58

Water-Based Robust Transparent Superamphiphobic Coatings for Resistance to Condensation, Frosting, Icing, and Fouling

W. C. Gu, K. X. Song, Z. Cheng, Q. L. Wang, S. L. Wang, X. K. Wang, X. Q. Yu, and Y. F. Zhang
Southeast University

Abstract

Due to the considerable demand for improving energy conservation and emission reduction, superhydrophobic coatings mainly derived from organic solvents have attracted significant interest, based on their potential role in enhancing heat transfer. Although water-based coatings are relatively safe and economical, and contain low volatile organic compounds (VOCs), the realization of coatings with excellent anti-condensation, anti-frosting, anti-icing, and passive self-cleaning properties remains challenging, owing to the Wenzel state of small-sized condensate micro-drops. Herein, a water-based transparent superamphiphobic coating is developed through a single-step spraying method performed at ambient temperature using water and liquid rheological additives to disperse fluorinated SiO2 nanochains. The coating exhibits resistance to damage induced by low- and high-temperature processing, chemical solution attacks, outdoor exposure, and freeze–thaw cycles. Most importantly, the porous structure consisting of nanopores and sub-micropores, results in the suppression of condensation, frosting, and icing as well as facile removal of condensate micro-drops, sparse frost, and ice. Furthermore, fouling can be eliminated via condensation or a cycle of frosting and defrosting utilizing the moisture in the air. The findings of this study may represent a significant advance in long-term, efficient, and low-VOC superamphiphobic technologies for large-scale applications.

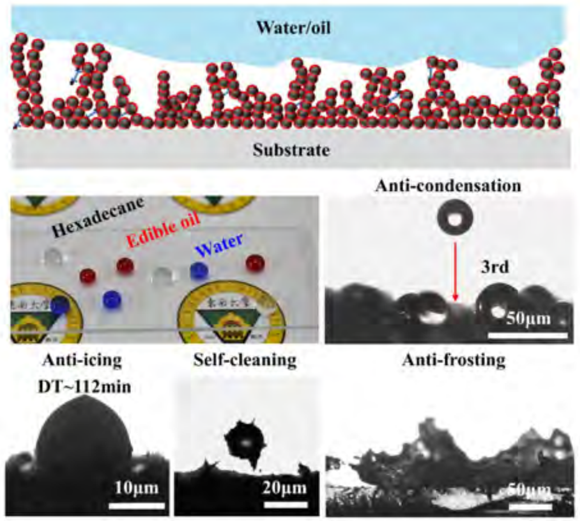

Figure 1: A water-based transparent superamphiphobic coating with the excellent resistance to condensation, frosting, icing and fouling, owing to the porous structure.

IWBE 2021

Abstract ID No.59

Anti-moisture Active Carbon Mediated by ZIF-8 Shell

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Southeast University

Abstract

Activated carbon (AC) has been widely used in the recent years to collect and store carbon dioxide (CO2) to post-combustion carbon capture. With the improved adsorption capacity of AC, their adsorption stability under high-humidity environments has attracted increasing attention as a next challenge. The occupation of adsorption sites by H2O molecules will decrease sharply in the adsorption capacity of AC under high humidity. Here, the hydrophobic ZIF-8 shell was grown after PDA treatment of AC (AC@ZIF-8). The AC@ZIF-8 exhibited the highest hydrophobic ability (water contact angle 139 ± 2°) with highest surface area (1118 m2/g). The ZIF-8 can reduce the capture performance toward the smaller H2O molecule (0.265 nm) and, thus, the H2O permeation rate. This is highly desirable for securing good molecular sieving ability with CO2 (0.33 nm) perm-selectivity in the presence of H2O vapor. This study proposed a novel method to enhance the adsorption and selectivity capacity for gas sorption for the porous material in the presence of water.

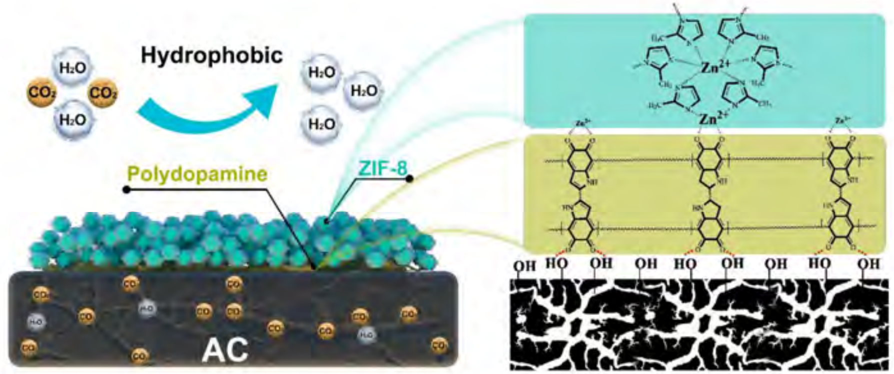

Figure 1: Bio-inspired anti-moisture active carbon fabrication

Abstract ID No.60

Development of Expandable Drill for Landfill Aeration

*Y. Kim, D.-G. Lee, Y. Jung, Y. D. Jung, J. Lee, S. H. Lee, and Wan-Doo Kim**
Korea Institute of Machinery & Materials

Abstract

We developed an expandable drill inspired by 'nut weevils' that used to make larger cavity than opening hole. Landfills, filled with municipal solid waste, initially filled with toxic gases (ammonia, hydrogen sulfide, etc) due to anaerobic environment. It is well known that it can be chemically stabilized by blowing fresh air into landfills and turning them into aerobic environment.[1] This process, called aeration, has been carried out by connecting an air pump to a cylindrical pressure well made with a uniform cross-sectional area. Here, we proposed a new expandable drilling tool that allows us to make a bottle-shape pressure well. The expansion of internal cavities has increased the area of air exposure in landfills, resulting in increased volume flow rates of airflow. For optimal structural design of the drilling tip, we performed structural analysis using commercial software ABAQUS. Also, using COMSOL, we checked increased volume flux rate when the expanded cavity is formed. Finally, we fabricated a drilling device and made expanded holes to experimentally verify the optimal design. We expect this new drill to enable significant time savings in aeration process.

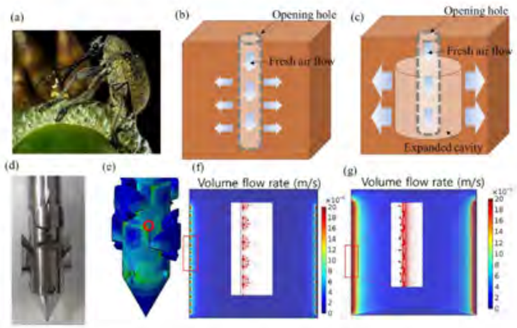

Figure 1: Expandable drill. (a) 'nut weevils' snapshot which motivates expandable drill. Schematic figures of a pressure well made with (a) existing drill and (b) proposed drill. (c) FEM simulation of the proposed drill tip. Volume flow plots of a pressure well made with (d) existing drill and (e) proposed expandable drill.

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IWBE 2021

Abstract ID No.61

A linkage-Spring-tendon-integrated Compliant Modular Anthropomorphic Robotic Hand: MCR-Hand

Haosen Yang, Guowu Wei and Lei Ren
The University of Manchester, UK

Abstract

This paper presents the design, analysis and development of a modular anthropomorphic robotic hand, i.e., MCR-Hand III. According to the investigation of human hand anatomical structure, mechanical design of the MCR-Hand III is presented. Then, a detailed introduction for mechanical compliance of the hand is provided, which is achieved through the combinations of springs with four-bar 4R linkages and tendons. Using D-H convention, kinematics and force analysis of the hand are formulated and illustrated with numerical simulations, laying background for comparison and evaluation. Subsequently, a prototype of the proposed robotic hand is developed. The modular design is achieved in this prototype, each finger can be separated from the palm by separated the proximal phalanx. A three-stage algorithm for object stiffness identification and adaptive grasping is proposed and evaluated, and grasping evaluation based on the Cutkosky taxonomy with additional deformable object lifting operation and piano manipulation is carried out. The experimental results indicate that the proposed hands can implement the grasp and manipulation for most of the objects used in daily life.

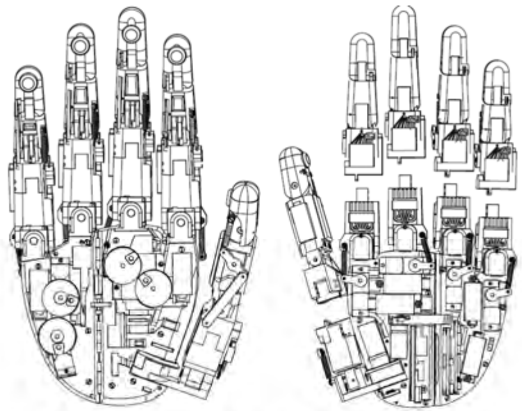

Figure 1: (a) The mechanical structure of the MCR-Hand; (b) Fingers separated from the palm. [1]

References

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Abstract ID No.62

Six Biological Models for Bionic Design of High Strength and Tough Structures

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Nanjing University of Aeronautics and Astronautics

Abstract

High strength and tough materials can prolong life spans of engineering products. Therefore, designing high strength as well as large toughness of engineering materials is in pressing need. However, increasing strength does not always lead to increase of toughness [1]. For instance, to increase strength by lowing ductility, the toughness can be severely reduced. To serve both strength and toughness, composite structures are generally utilized. Nonetheless, current composite structures are mostly based on empirical practices, the models of which lack theoretical verifications and are difficult to obtain desired strength and toughness. Accordingly, exploring new models to improve strength and toughness remains active research field.

Biological organisms possess specific functions by their unique structures during long periods of natural selection and evolution. For the mechanical properties of strength and toughness, the micro- and meso-structures of the biological organisms play vital roles. In order to propose biological models with similar functions of biological structures, the biological structures and their mechanisms of a range of natural structural materials have been studied [2-3]. Besides, the structure-mechanics of several biological models of biological organisms are analysed [4]. Moreover, simulation approaches to predict mechanical properties of bionic structures have been developed [5]. In addition, current techniques for synthesising biological structures are discussed.

Although the above research have provided significant knowledge in guiding bionic design of high strength and toughness structures, successful bionic structures are not always obtained. This may be attributed to that biological models and corresponding mechanisms for high strength and toughness are not clearly classified. It can be also ascribed to the fact that the mechanical models used for predicting strength and toughness have not yet appropriately formulated. Furthermore, the simulation and experimental techniques to verify biological models have not been properly conducted. As a result, a systematical research on the basic biological models, function mechanisms, mechanical models, simulation and experimental methods is essential to carry out.

To promote bionic design progress of high strength and tough structures, this paper classifies six basic biological models of biological organisms on the basis of their micro- and meso-structures. Furthermore, the corresponding strengthening and toughening mechanisms are analysed. Of them the layered, tubular, columnar, sutured and sandwich structures are unidirectional in generating high strength and toughness, whereas helical structures are multidirectional. The mechanical models and equations to straightforward predict strength and toughness of biological models are presented. The simulation and experimental methods to predict strength and toughness are exemplified. Finally, this paper discusses the challenges and prospects, and concludes that bionic design of high strength and tough structures will significantly enhance applications in various engineering fields.

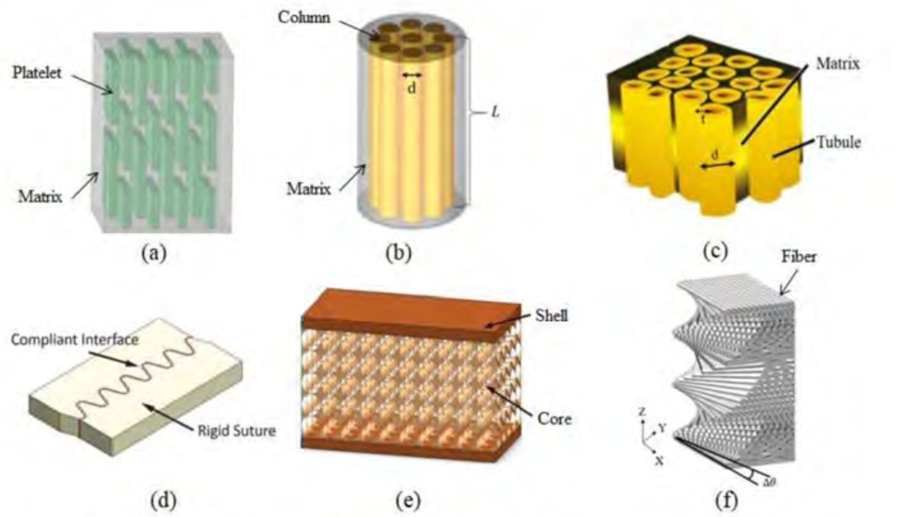

Figure 1: Six basic biological models for high strength and toughness material design [3]

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Abstract ID No.63

A Bio-Inspired Interleaf for Enhanced Interlaminar Fracture Toughness of Carbon Fiber Reinforced Polymers

Wenda Song, Zhengzhi Mu, Yufei Wang, Zhiyan Zhang, Yujiao Li, Binjie Zhang, Bo Li, Junqiu Zhang, Shichao Niu, Zhiwu Han,* Luquan Ren*
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Abstract

Carbon fiber reinforced polymers (CFRPs) with lightweight, high-strength and high-modulus properties are in high demand across the fields of aerospace engineering, urban mass transit, new energy, and architectural design. However, most CFRPs suffer from delamination owing to weak interlayer which plays an important role to transfer perpendicular load to the ply. Inspired by typical hierarchical structures of raptor’s feathers, a biomimetic interleaf with multiscale structures was designed and experimentally proved to be effective for significant enhancement of anti-delamination performance towards conventional CFRPs. Novelly, ZnO nanorods grown on electrospun nanofibrous mats with carbon fiber bundles form a set of cross-scale structures, which are very similar to the hierarchical structures of rachis, barbs, and barbules in raptor’s feathers. It indicated that the introduced nanostructures assuredly enhanced the interlayer toughening performance *via* substantial energy dissipation. Surprisingly, when compared with original CFRPs, the obtained biomimetic CFRPs featured with a feather-inspired interleaf represent considerable increasements in Mode I and Mode II interlaminar fracture toughness. The biomiemtic design developed in this work was anticipated to provide a feasible way to effectively improve mechanical performance of traditional CFRPs and help promote potential application of biomimetic CFRPs in the broad engineering field.

IWBE 2021

Abstract ID No.64

High-Performance Ionic Polymer-Metal Composites: towards Large-Deformation and Fast-Response Artificial Muscles

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Abstract

As promising candidates in the field of artificial muscles, ionic polymer-metal composites (IPMCs) still face the challenge to perform large deformation and fast response simultaneously, which has strictly limited their practical applications. To target this difficult issue, here, Nafion based IPMCs with high-quality metal electrodes are fabricated through a novel isopropanol-assisted electroless plating process. Under low direct current (DC) driving voltage, the IPMCs can exhibit large tip movement (35.3 mm, 102.3 °); when actuated using alternating current (AC) voltage, the IPMCs exhibit ultra-fast response (>10 Hz). More importantly, an integration of large deformation and fast response can be achieved simultaneously by IPMCs under high-frequency (19 Hz) AC voltage, where the largest bending amplitude is 5.9 mm, and the highest bending speed can reach to 224.2 mm s^{-1} and 596.2 deg s^{-1}. Additionally, the light-weight IPMCs have a decent load capacity and can lift objects 20 times its own weight. The outstanding performances of the Nafion IPMCs have been demonstrated by mimicking biological motions such as petal opening/closing, tendril coiling, and high-frequency wing flapping. This study opens up a new avenue to fabricate light-weight actuators with simultaneous large movement and fast response for promising applications in biomedical devices and bio-inspired robotics.

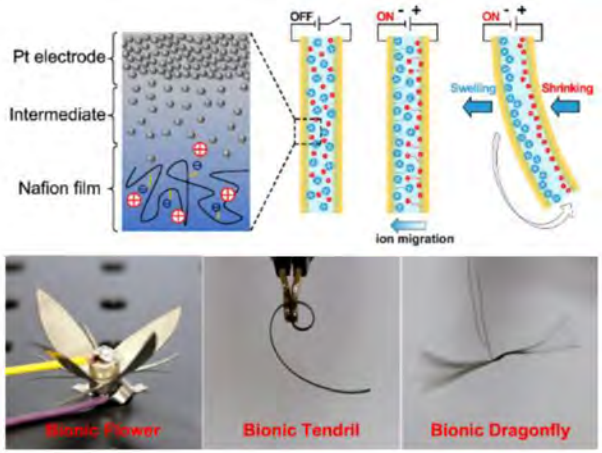

Figure 1: Bionic applications of IPMC soft actuator [1]

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IWBE 2021

Abstract ID No.65

Essential Role of Longitudinal Segmental Spacing in Nectar Capture

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Abstract

Honey bees use their versatile tongues to lap nectar from a large spectrum of flowering plants. A bee dips nectar by fast reciprocating movements of the hairy tongue, with glossal hairs erecting rhythmically. Hair erection is validated to coordinate with periodic elongation of glossal segments, which, significantly, may augment the nectar intake rate. We examined 14 bee species with approximately 150-folds diversity in body weight and found the segmental spacing of the bee tongue stays almost constant at 24 μm. To understand this remarkable trend, we investigated the dynamics of fluid capture by *Apis mellifera* L. as a model system. We built an elastoviscous theoretical model to elucidate that the relaxation dynamics of segmented tongue is governed by segment length. We arrived at a theoretically optimal hair spacing that could contribute a maximum nectar intake rate, which is close to the natural hair spacing. Our findings bridged the relationship between tongue geometry and capability in capture nectar, which may open up a new way of designing facilities for microfluidic transport.

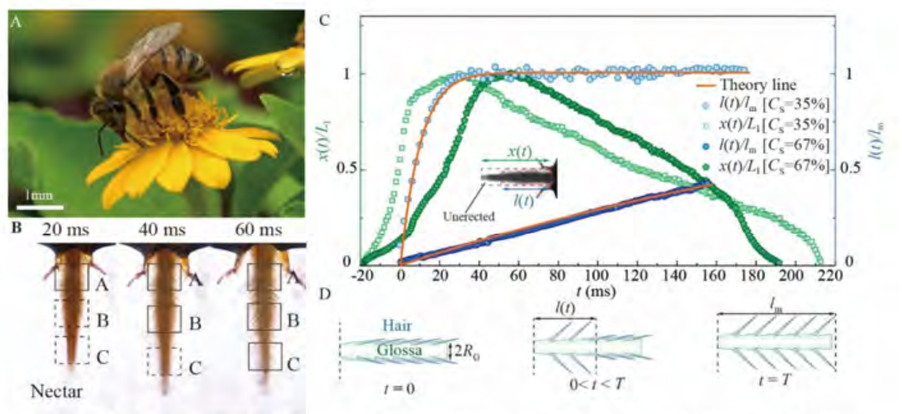

Figure 1: Schematic of the tongue kinematics and relaxation dynamics pattern of the tongue.

To understand this invariability of the segmented spacing across three orders of magnitude in body weight, we investigated the dynamics of fluid capture by Apis mellifera L. as a model system. During the dipping process, we discovered that the glossal hairs were erected together with segment elongation in a drinking cycle and the erected distance from the proximal of the tongue for three different tongue regions was measured using high-speed video.

The glossal hairs start to erect asynchronously, at 20 ms (regions A), 40 ms (region B), and 60 ms (region C) [Fig. 1(B)]. The temporal variations of the position of the tongue tip with respect to the galea, $x(t)$, and of the erected distance $l(t)$ between the erected hair and the proximal of the tongue during the capture process are shown in Fig. 1C. At low sugar concentration, C_s, the distance of erected hair reach a maximum distance l_m along the axial direction before the tongue completely retracts out of the liquid. In contrast, at larger C_s, the hairs do not have the time to completely open during a protraction–retraction cycle due to the viscous dissipation [Fig. 1C]. We built an elastoviscous theoretical model to describes the relaxation dynamics of the tongue governed by segmental spacing as shown schematically in Fig. 1D. At $t=0$, $l(0)=0$, the hair adheres to the glossa due to the compression of the tongue segment. At $t=T$, $l(T)=l_m$, the tongue segment was elongated and the hairs were fully open. Using the parameter values reported for *Apis mellifera* L, the temporal evolution of $l(t)=l_m$ is found to be in very good quantitative agreement with in vivo measurements of the segmental tongue relaxation dynamics [Fig. 1C].

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Abstract ID No.66

Pufferfish-inspired Testing of Bionic Surface Drag Reduction Performance

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Abstract

The intensification of the energy crisis and the incremental demand for high-performance ship performance face new challenges. The emergence of bionics inspires humans to learn from nature a wide variety of functional surfaces inspired by biology[1] [2]. Previous extensive studies have documented that pufferfish is known of its extension of the tiny spines covered skin which is not only for protection but also possessing drag reducing properties[3][4]. Therefore, the flexible outer skin of the pufferfish wraps the raised spine's structure to be imitated by using sintering technology and coating a flexible layer. The biomimetic spine-covered protrusion samples sparse 'k-type' arrangement with roughness height $k+$=5.5~6.5 (nearly hydraulically smooth) and smooth case were tested in bulk Reynolds number Re_b=77893, 93472. The results of turbulence statistics and the analysis of vortex structure indicate that Flexible layers have about 17.5% drag reduction effect, of which the turbulent boundary layer is more stable and clearer than the smooth surface. Further comparison found that the introduction of the flexible surface layer increases the drag reduction performance of the bionic surface by 7%, which shows that the drag reduction effect of the puffer fish is combined by the bone spines and the epidermis covering it. In summary, the underwater drag reduction bionic surface inspired by pufferfish has a flexible surface layer and a rigid inner layer. Its self-healing and abrasion resistance may lead to the rapid development and wide application of new drag reducing materials.

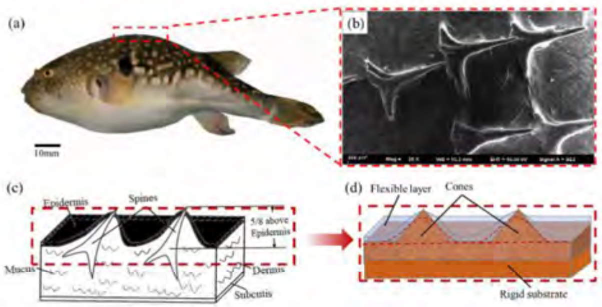

Figure.1 (a) Schematics of the back and overall shape of pufferfish (Takifugu flavidus). (b) Scanning electron microscope (SEM) images of spine on dried skin. (c) Schematics of the pufferfish skin structure. (d) Schematics of the biomimetic spine-covered protrusion surface.

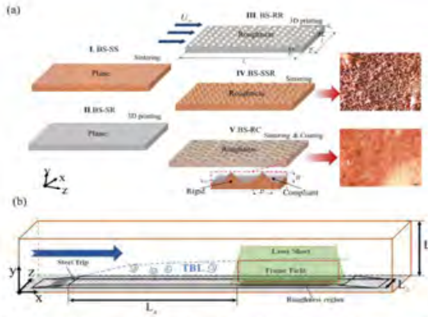

Figure 2. (a)Schematics of experimental biomimetic spine-covered protrusions samples. (b) Test section of water tunnel with test plate paralleled in the streamwise direction.

Table 1 Flow parameters of TBL over smooth and rough walls, including roughness height $\boldsymbol{k^+}$, equivalent height $\boldsymbol{k_s}^+$, the rough regions coverage density is defined as $\rho_\lambda \equiv A_f/A$, where A_f is the total rough surface area and A is the total projected area. solidity parameter λ, friction velocity $\boldsymbol{u_\tau}$, flow speed $\boldsymbol{U_\infty}$, bulk Reynold number $\boldsymbol{Re_b}$, friction Reynold number $\boldsymbol{Re_\tau}$, roughness function $\Delta\boldsymbol{U^+}$, dimensionless spacing of PIV analysis grid $\Delta\boldsymbol{x^+}$, $\Delta\boldsymbol{y}$, and drag reduction rate φ

Reynolds numbers	Case	k^+	k_s^+	ρ_λ	λ	u_τ/U_∞	Re_τ	$-\Delta U^+$	Δx^+	Δy^+	φ
Re_b=77893	BS-SS	13.23	–	–	–	0.071	1026	0.081	31.32	15.66	4.3%
	BS-SR	13.53	–	–	–	0.073	1049	–	32.02	16.01	-
	BS-RR	13.20	2.47	2.497	0.0129	0.071	1023	0.089	31.25	15.62	0.4%
	BS-RRS	12.49	2.47	2.49	0.0129	0.067	968	0.875	29.56	14.78	10.9%
	BS-RC	12.01	2.47	2.93	0.0145	0.064	931	1.401	28.44	14.22	17.5%
Re_b=93472	BS-SS	14.51	–	–	–	0.065	1022	0.106	34.34	17.17	7.3%
	BS-SR	15.07	–	–	–	0.067	1061	–	35.67	17.83	-
	BS-RR	14.24	2.47	2.49	0.0129	0.064	1003	0.043	33.70	16.85	3.6%
	BS-RRS	14.09	2.47	2.49	0.0129	0.063	992	0.648	33.35	16.67	5.6%
	BS-RC	13.64	2.47	2.93	0.0145	0.061	961	1.101	32.30	16.15	11.5%

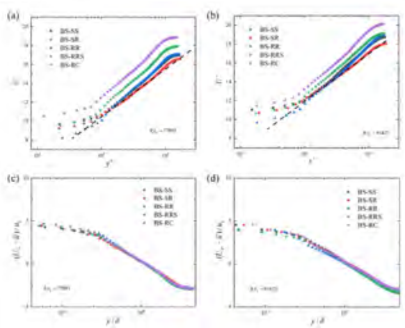

Figure 3. Profiles of mean flow at (a) Re_b=77893 and (b) Re_b=933472. velocity defect profiles at (a) Re_b=77893 and (b) Re_b=933472. The dashed black lines show the logarithmic law, the defect profiles on a semi-log plot

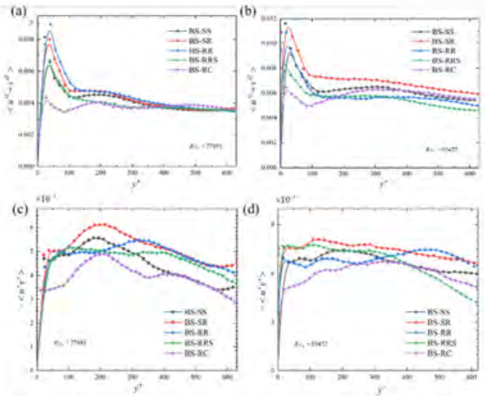

Figure 4. Reynold shear stress $< u'v' >$ of (a) $Re_b = 37129$ and (b) $Re_b = 44554$ in wall-normal direction. Turbulent kinetic energy $< u'^2 + v'^2 >$ of (c) $Re_b = 37129$ and (d) $Re_b = 44554$ in wall-normal direction.

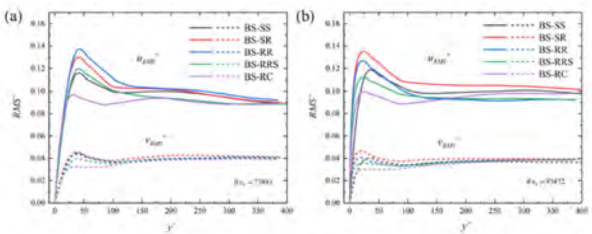

Figure 5. Root-mean-square (rms) of fluctuation velocity in wall-normal direction. ${u'_{rms}}^+$ and ${v'_{rms}}^+$ are normalized by U_∞. (a) $Re_b = 37129$ and (b) $Re_b = 44554$

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IWBE 2021

Abstract ID No.67

The Micromechanics of the Diatom Corethron Criophilum: An Experimental Study Utilizing 3D Printing

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Abstract

The micromechanics of the diatom Corethron criophilum have puzzled experts for decades. Uniquely among microorganisms, its silicate shell contains joints that allow hooked spines to move after cell division, until they have locked into a permanent resting position. Not only is the mechanism itself poorly understood, but the purpose of the spines themselves is also unknown. The complex structure of the joints has prevented researchers from accurately recreating the joints, while the nature of diatoms prevents observing many of the proposed purposes of the spines.

With 3D printing, this paper aims to test experimentally most of the hypotheses that have been brought forth since. Recreated from SEM and optical microscope images, the relevant parts were printed with a commercial fused deposition modelling (FDM) printer for testing. An FDM printer, like the Prusa I3 Mk3s used, deposits plastic filament from a heated nozzle. While not as detailed as stereolithography or powder bed printing, it allows for more material flexibility, like the transparent plastics essential for visualisation, or flexible materials that may or may not be required.

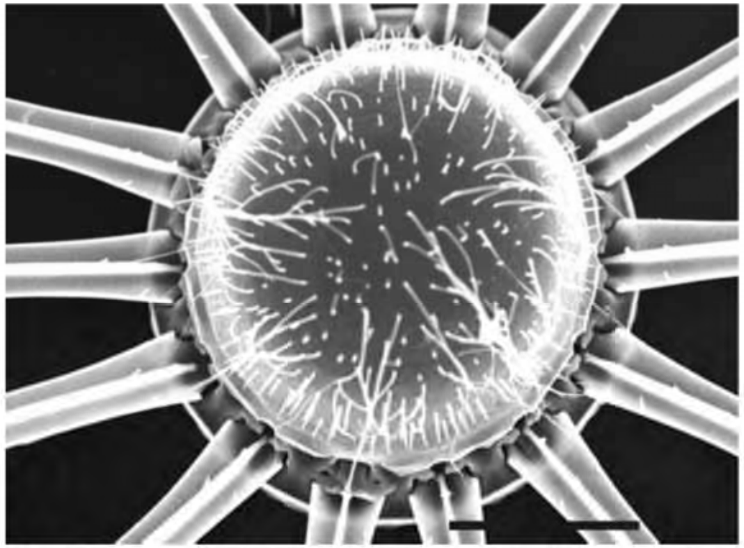

Figure 1: SEM image of a valve of *Corethron criophilum* in resting position, showing spines entering joints along valve circumference.

The most common explanation, suggested by Crawford and Gebeshuber [1][2], is that the joints contain some form of a click-stop mechanism to keep the joints locked after unfolding, while the hooked spines either lock the spines during cell growth to prevent twisting, or hold colonies together while maintaining enough distance to prevent overlaps. However, no click-stop can be found in microscope images, suggesting a friction-based one-way mechanism.

While the research is far from done, this unique organism might serve as a best practice example from nature on how to create joints with hard parts, especially when creating complex micromachinery such as MEMS.

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Abstract ID No.68

Design and Analysis of a Novel Bio-Inspired Tracked Wall- Climbing Robot with Flexible Spines

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Abstract

In order to improve the wall-climbing robot's applicability to the rough wall, a new type of bio-inspired tracked wall-climbing robot with flexible spines is proposed in this paper. Inspired by spines of some insects, a track with flexible spines mechanism is designed so that the robot can use it to hook on the rough surface of walls. Based on a lot of research on catch and detachment, a special track mechanism is designed to make it flexible to catch and detach from the surface. And several related simulation analyses have been carried out and the results turn out good. In addition, the statics and kinematics analysis of the robot during climbing process are also carried out. The robot prototype is developed and several climbing experiments and tests have been done. The results show that the tracked wall-climbing robot with flexible spines has good stability and can run at a desired speed on several different wall surfaces.

Figure 1: Insects with spines

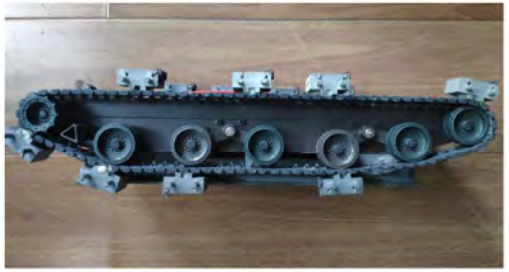

Figure 2: The robot prototype

IWBE 2021

Abstract ID No.69

Structural Bactericide by Biomimetics of the Nanopillars on Cicada Wings

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Abstract

Recent studies show that the wings of certain insects such as cicadas and dragonflies reveal amazing properties. Not only are they super-hydrophobic and self-cleaning comparable to the famous lotus leaf, but also capable of actively killing bacteria [1]. The underlying mechanism is not a chemical bactericide, but tiny nanostructures that mechanically destroy the bacterial cells [2].

This study investigates the surface structure of two New Zealand cicada species (Amphipsalta cingulata and Kikihia scutellaris) with various methods such as AFM (Figure 1). The focus lies in investigating antibacterial structure properties via bacterial tests and establishing low-cost bioimprinting techniques ([3]) to transfer these structures to artificial surfaces, which would open a huge field of manifold applications such as hospital surfaces, medical instruments, smartphone displays and door handles. Since bacteria cannot develop resistance to physical structures as they do to chemical bactericides, this method would be of great advantage.

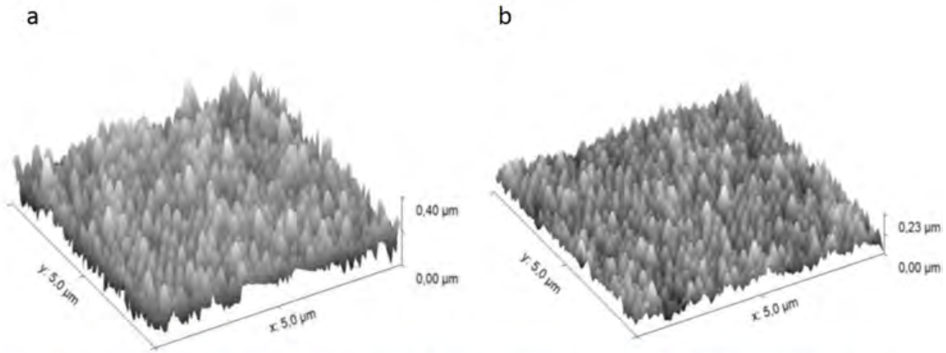

Figure 1 Three-dimensional reconstruction (AFM) of wing membrane surfaces of: a) *Kikihia scutellaris,* b) *Amphipsalta cingulata.*

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Abstract ID No.70

Biomimetic Passive Cooling

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Abstract

With the rise of the average global temperature due to the ongoing climate change, more and more households need a way of keeping their living environment at bearable temperatures. As it is a simple and seemingly effective method, many households invest in air conditioning. But air conditioning has a significant global environmental impact. Better long-term solutions might be passive cooling systems. This work explores possibilities of biomimetic passive cooling using structured surfaces. The focus is put on structures that, when applied on the surface of a body, can lower the average temperature of the body, compared to its temperature without the structured surface, without the need of electricity or replenishable resources. The physical principles enabling such cooling effects include the usage of shadow [1] and stimulated convection [2], total internal reflection [3], scattering [4], multilayer interference and diffraction [5], as well as enhanced emission via radiators [6]. When it comes to passive cooling even under direct sunlight, the increase of reflectivity and the decrease of absorption is important to reduce the gain of thermal energy from sunlight in the range from approximately 250 nm (UV) to about 2500 nm (IR) (Figure 1, yellow area). The other key point for effective daytime passive cooling is high emissivity in the infrared atmospheric window.

Earth's average temperature is at approximately 288 K, or roughly 15° C [7]. Its outgoing radiation (Figure 1, blue area) has its peak at a wavelength around 10 µm. As depicted in Figure 1, most of that radiation gets absorbed by the atmosphere which radiates part of that energy back to Earth, keeping it warm just like a blanket. But what is also observable in this picture is a hole in the absorption spectrum reaching from 8 to 13 µm, referred to as the infrared atmospheric window, which conveniently is right where Earth radiates the most. In this range, dry air is transparent and Earth and all bodies on Earth with a similar temperature can send their thermal energy out into space. [8] Instead of a high reflectivity, enhancing the absorptivity and thus the emissivity in this range increases the ability of a body to cool down.

Biomimetics, the abstraction of good design from Nature, helps to find novel non-polluting ways to achieve such cooling structures. Various examples for passive thermoregulation without evaporative cooling found in Nature will be explained in the presentation, focusing on fauna and flora in hot and arid regions. Possible attempts to use those with a breakdown of their environmental impact will be illustrated, differentiating between the effectivity in different habitats.

In conclusion it can be said that there are already great attempts for passive cooling, some even with a focus on sustainability. Yet more studies are needed, especially for large-scale production and usage. There is a lot to be learned from the beauty and expediency of living Nature. When it comes to optimizing technical cooling by inspiration from Nature, best practice examples range over various length scales and comprise a large variety of sometimes surprising organisms. Smart collaboration between experts from biology, engineering and further fields can pave the way towards innovative new applications with an added benefit of sustainable approaches.

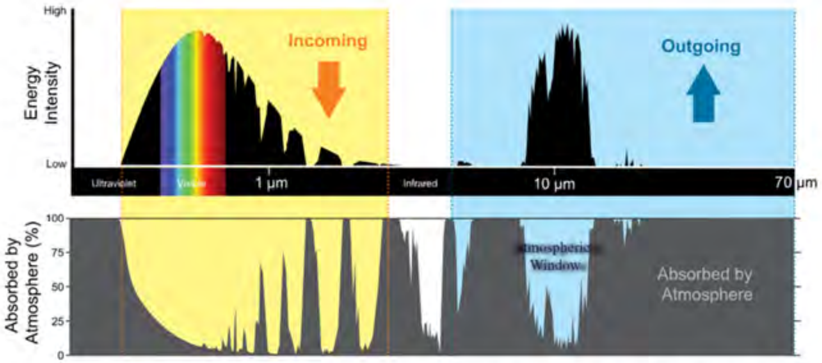

Figure 1: Top: Incoming energy from the sun and outgoing energy from the Earth relative to the wavelength. Bottom: Absorbance of the atmosphere relative to the wavelength. © National Weather Service [9]

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Abstract ID No.71

An active 3-DoF Soft Joint for Soft Robot Movement

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Abstract

Soft joint with multiple degrees of freedom (DoF) is crucial to dexterous movements of soft robots. For instance, the movements of wrist depend on the 3-DoF of flexion-extension(X-Y plane), radioulnar deviation (X-Z plane) and rotation (Z-axis). Similarly, in the design of neck, spine and many other parts in soft robots, multiple DoF soft joint are required. Unfortunately, current joint designs are based on elastic materials cannot actively produce multiple DoF and thus severely limit the movements of soft robots. This paper illustrates an active 3-DoF soft joint that is based on pneumatic soft actuator and combining with structure design (Figure 1a). It consists of four parallel soft cylindrical drive actuators adhere to each other. The four actuators have circle chambers and helical structures. The cross-section of the four connected rods displays four couples of concentric circles. Each soft actuator is composed of PDMS chamber, Kelar fiber and Ployester monofilament. The fiber winds the chamber along the helix grooves. The monofilament is adhere to the outer surface of the actuator along axial direction and is indicated by red colour at the cross-section inner area (Figure 1b). For each of the pressurized actuator, it produces a bending force and a torque with respect to the restraining layer (red line at the cross-section Figure 1b) [1]. For pressuring two of these chambers, bending or twisting actions can be obtained depends on combination results [2]. For instances, when pressuring channel a & b, the torques are off-set, and only leave the bending force with respect to the restraining layers which results bending actions (Figure 2(a&b)). When pressuring a & d, the bending forces are off-set, and only leave the torques which lead to twisting actions (Figure 2(a&b)) [3]. The total six actions for the 3Dof in accordance to pressurization of the different channels are listed in Tab

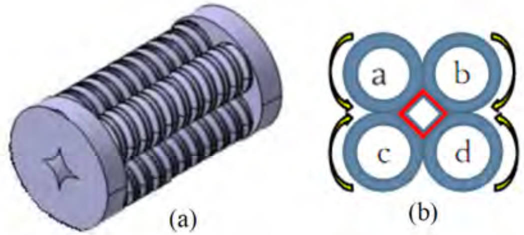

Figure 1: A soft hand with 3DoF wrist (a) 3D model (b) cross-section of the 3 DoF joint

Table 1 Actions of the soft joint subjected to pressurization of different channels

DoF	Joint Actions	Channel a	Channel b	Channel c	Channel d
X-Y plane	Bending up	Unpressurized	Unpressurized	Pressurized	Pressurized
	Bending down	Pressurized	Pressurized	Unpressurized	Unpressurized
X-Y plane	Bending left	Unpressurized	Pressurized	Unpressurized	Pressurized
	Bending right	Pressurized	Unpressurized	Pressurized	Unpressurized
Z-axis	Twisting left	Unpressurized	Pressurized	Pressurized	Unpressurized
	Twisting right	Pressurized	Unpressurized	Unpressurized	Pressurized

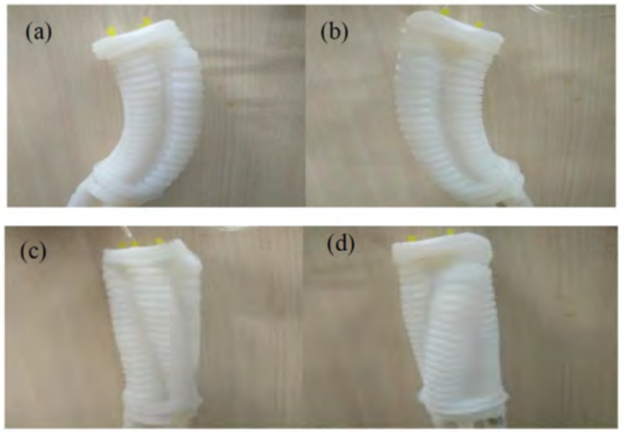

Figure 2: Illustrations of the actions of the soft joint; (a) and (b) shows bending, (c) and (d) displays twisting

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Abstract ID No.72

Robust Superhydrophobic Surface by Plasma Coating

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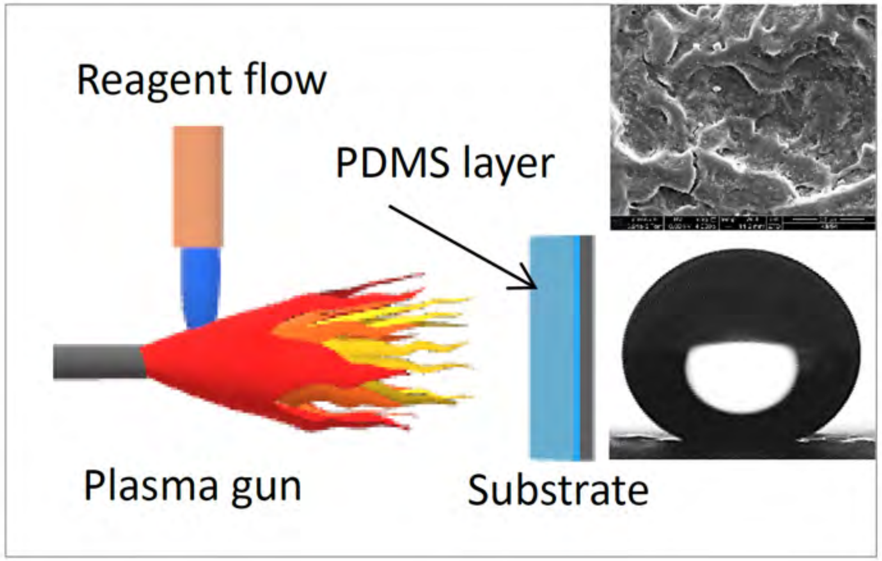
Korea Institute of Machinery and Materials

Abstract

Bioinspired surfaces provide the wonderful functions into devices. In particular, superhydrophobic surfaces that have a water contact angle (WCA) greater than 150° and contact angle hysteresis (CAH) less than 10° have shown a great potential in various applications, including self-cleaning, anti-(bio)fouling, anti-corrosion, anti-icing, anti-frosting, drag reduction, and even the enhanced heat transfer. Most of the artificial superhydrophobic surfaces involve complicated multistep fabrication methods and limited to small area, showing the restriction in real practical application. Here we report a method for the formation of a robust superhydrophobic surface by plasma coating which is easy, fast, and applicable for large-scale coating. The inorganic precursors were used to make the ecofriendly and robust aurface, and high temperature of plasma process was performed to react the precursors and anneal the surface. Tha formation nano/micro rough stuctures and the low surface tension materials on the surface exhibit the superhydrophobicity of water contact angle, 162º. To increase the adhesion between the coating layer and substrate, PDMS layer acts as a binding material on stainless steel. More interesting thing of this approach is the high-temperature resistant where the water contact angle measured after heating the surface at 350°C is 157º.



Abstract ID No.73

An Anthropometric Study for the Anthropomorphic Design of Tomato-harvesting Robots

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Abstract

To explore how humans can dexterously pick fruits of various sizes from a tomato plant from different positions and postures, some anthropometric dimensions related to the hand-harvesting of the fruits were determined within 261 volunteers, and their correlations were investigated using a bivariate correlation analysis method. The heights of the body (stature), shoulder tip, waist and knee of participants ranged from 111.2 to 193.6, 87.5 to 163.0, 62.1 to 117.3, and 31.0 to 56.0 cm, respectively; the ratios of the knee height, waist height, and shoulder tip height to the stature were 0.25–0.33, 0.52–0.65, and 0.76–0.87, respectively; the shoulder tip breadth, upper limb length and foot length of participants ranged from 26.0 to 48.5, 45.4 to 85.6, and 19.5 to 28.0 cm, respectively; and the length ratios of the hand, forearm, and upper arm to the upper limb were 0.23–0.31, 0.29–0.38, and 0.35–0.45, respectively. There were high linear correlations among the stature, waist height and knee height, between the forearm and hand lengths, and among the stature, hand length and arm

length and moderate linear correlations between most hand dimensions. These human body dimensions de-termine the upper limb workspace, body balance, working comfort and lower limb movement frequency during picking, and this information will be useful for the bionic dimensional synthesis design of a harvesting robotic arm, walking mechanism and body. The results of multiple comparisons in ANOVA showed that there were significant differences between some of the finger dimensions and between some of the hand-scaling dimensions, which is one of the main features enabling the human hand to pick various sizes of fruits. This study can provide guidance and inspiration for the anthropomorphic design of robotic tomato-harvesting end-effectors.

IWBE 2021

Abstract ID No.74

Inflatable Bioinspired Robots for Space

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Abstract

Soft robots with deformable bodies and powered by soft actuators inspired by starfish podia, may fill a hitherto unexplored niche in outer space. All space-bound payloads are heavily limited in terms of mass and volume, due to the cost of launch and the size of spacecraft. Being constructed from flexible materials allows many possibilities for compacting soft robots for launch and later deploying into a much larger volume, including folding, rolling, and inflation. This morphability can also be beneficial for adapting to operation in different environments, providing versatility, and robustness.

To be truly soft, a robot must be powered by soft actuators. Dielectric elastomer transducers (DETs, figure 1 left) offer many advantages as artificial muscles, they are lightweight, have a high work density, and are capable of artificial proprioception. Taking inspiration from nature, we have developed low-mass robots capable of performing complex motion and being compacted to a fraction of their operating size using DETs incorporated into inflatable polymer structures (see figure 1 right).

One of the key benefits of our designs compared to other inflated actuators (such as McKibben) is being actuated electronically rather than pneumatically/hydraulically, doing away with the need for bulky compressors. Only requiring inflation once opens avenues for alternative inflation mechanisms, such as sublimating solids, drastically reducing system mass.

Thus through inflation, low mass sublimating mechanisms, and artificial muscle technology we can produce a new generation of space robot.

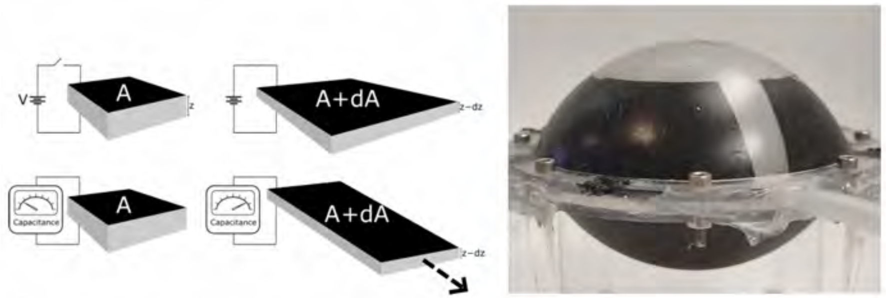

Figure 1: Left: Operating principles of a Dielectric Elastomer Transducer as actuator (top) and sensor (bottom). Right: Inflatable robot with integrated DETs for walking.

Abstract ID No.75

Toward Yaw Stability of Bionic Propulsion in Flow Field

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Abstract

Currently, most of studies about robotic fish were conducted in static water indoor or outdoor environment with negligible water flow. But for robotic fish to execute tasks in filed environment, the water flow and disturbances should be considered. Although, a few studies have involved water flow in their systems to explore the performance and interactions of robotic fish [1,2], yaw stability of robotic fishes in water flow was seldom studied.

As for the yaw stability of robotic fish, more scholars will directly control the yaw angle of robotic fish to maintain its lateral stability through algorithms [3]. However, without controlling the swimming of robotic fish, there are still some factors affecting its yaw stability. In this paper, we investigate the effects of different rotation center positions and different propulsion styles (i.e. bionic propulsion and screw-propeller propulsion shown in Fig. 1) on yaw stability of robot fish.

The dynamic model and computational fluid dynamics (CFD) model of fish undulatory propulsion in flow field were constructed to investigate the yaw stability of robotic fish [4,5]. Simulations and experiments were conducted to explore the influence of the position of rotation center on the yaw stability of robotic fish model. Results indicated that robotic fish with the rotation center in the back is most affected by the water flow. In addition, we compared the yaw stability of screw-propeller propulsion and bionic propulsion in flow field, and found that when the rotation center is in the back of the fish body, the bionic propulsion has better yaw stability and is less affected by the water flow. These results offer valuable insights for peers to design and control fish robots with better motion stability.

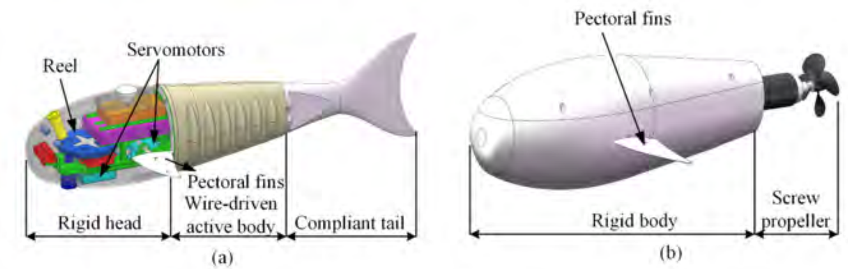

Figure 1: Robotic fish with different propulsion styles. (a) bionic propulsion (b) screw-propeller propulsion

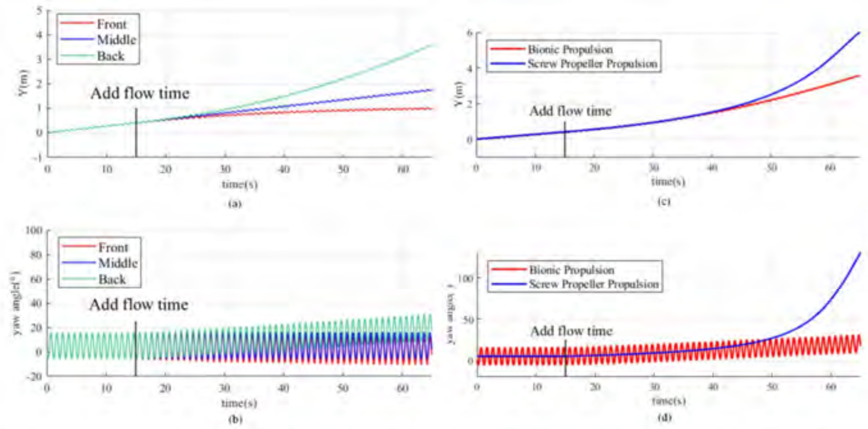

Figure 2: a-b: Simulation results of robotic fish with three different rotation centers in flow field. (a: the deviation of robot fish along the Y axis. b: yaw angle variations of the robot fish.) c-d: Simulation results of robotic fish with two different propulsion styles in flow field. (c: the deviation of robot fish whose rotation center is in the back of the fish body along the Y axis. d: yaw angle variations of the robot fish whose rotation center is in the back of the fish body.)

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Abstract ID No.76

Crashworthiness Optimisation of a Multicellular Thin-walled Tube with Triangular Cells

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Abstract

Nowadays, thin-walled tubes with multi-cell cross-sections, as an effective way to increase the number of cross-sectional corners, have attracted the attention of researchers due to their high energy absorption efficiency and lightweight properties. This paper proposes a multicellular thin-walled tube with N- equilateral triangles (MTTN), which was inspired from the microstructure of the cross section of bamboo. The crashworthiness of MTTN under axial impact was analysed, and the finite element model was validated by the quasi-static axial crush tests of MTT12, MTT16 and MTT28. According to our previous study [Yao et al. 2020], MTT24 with a progressive buckling mode exhibited the best crashing performance among MTTNs with N ⩽ 30. Then, sensitivity analysis was conducted for the key parameters that affect the crashworthiness of MTT24. It was found that the order in radial direction had a weak influence on the crashworthiness of MTT24, while the cell-wall thickness and the inner-tube diameter significantly affected the crashworthiness of MTT24 in varying degrees. Subsequently, multi-objective optimisation was carried out for MTT24 to further improve its crashworthiness. The wall thickness and inner diameter of the thin-walled tube were selected as design variables, while the minimum peak crushing force (PCF) and the maximum specific energy absorption (SEA) were set as objectives of the optimisation problem. The obtained Pareto front enables the thin-walled tube to achieve the best possible crash resistance under the conditions of maximum SEA and minimum PCF. With a constraint of PCF ⩽ 200kN, the SEA and MCF of MTT24 were improved by 11.40% and 68.20%, respectively.

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Abstract ID No.77

Root Systems Research for Biomimetic Design of Foundations and Coastal Engineering

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Abstract

The expansion of the built environment, as a result of increasing population growth, often impedes the surrounding natural environment’s ability to respond to heavy precipitation, storm, and flooding events. Particularly in unstable, easily erodible soils, urban expansion results in material overuse and overdesign of existing foundations to stabilize building structures to a high safety factor.

These foundations are static, limited by insertion techniques, monofunctional and unable to adapt to variable soil conditions. In nature, root systems are dynamic, growing through many media, multifunctional for the tree and environment, self-healing, and support the tree through mechanical and chemical anchoring. Principles found in root systems can inform the design of multifunctional foundations and engineered structures to improve coastal resilience. The talk presents a biomimetic process towards root-inspired foundation systems: photogrammetric imaging of root systems and generation of 3D models, topological study of root systems and abstraction algorithm, definition of root principles of interest for civil engineering applications, and design of root-inspired concepts to implement in building foundations and coastal fortification at a conceptual stage.

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Abstract ID No.78

Influence of Prednisolone and Alendronate on the *de novo* Mineralization of Zebrafish Caudal Fin

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2. Department of Mechanical, Materials and Aerospace Engineering, University of Liverpool, Liverpool, UK
3. Department of Medical Science and Institute of Bioinformatics and Structural Biology, National Tsing Hua University, Hsinchu Taiwan, China

Abstract

Dysregulated balance between bone resorption and formation mediates the onset and progression of osteoporosis. The administration of prednisolone is known to induce osteoporosis, whereas alendronate is commonly used to reverse the process. However, the assessment of the effects of such medicines on the nanostructure of bone remodelling and mechanical properties remains a major technical challenge. In this paper, a number of analytical approaches are applied to evaluate the compositional, morphological, and mechanical properties of regenerative zebrafish caudal fin bony rays affected by prednisolone and alendronate. Adult wild-type AB strain zebrafish were first exposed to 125μM of prednisolone for 14 days to develop glucocorticoid-induced osteoporosis. Fish fins were then amputated and let to regenerate for 21 days in tank water containing 30μM of alendronate or no alendronate. The lepidotrichia in the proximal and distal regions were evaluated separately using confocal microscope, scanning electron microscope, electron-dispersive spectroscopy,

Raman spectroscopy, atomic force microscopy, and a nanoindenter. As expected, prednisolone led to significant osteoporotic phenotypes. A decrease of Ca/P ratio was observed in the osteoporotic subjects (1.46 ± 0.04) as compared to the controls (1.74 ± 0.10). Subsequent treatment of alendronate overmineralized the bony rays during regeneration. Enhanced phosphate deposition was detected in the proximal part with alendronate treatment. Moreover, prednisolone attenuated the reduced elastic modulus and hardness levels (5.60 ± 5.04 GPa and 0.12 ± 0.17 GPa, respectively), whereas alendronate recovered them to the pre-amputation condition (8.68 ± 8.74 GPa and 0.34 ± 0.47 GPa, respectively). As an emerging model of osteoporosis, regrowth of zebrafish caudal fin was shown to be a reliable assay system to investigate the various effects of medicines in the de novo mineralization process.

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