



状态空间方法

状态空间方法是以状态空间模型为种子
长出来的一棵大树, 已近苍老



全驱系统方法

全驱系统方法是以全驱系统模型为种子
长出来的一棵新树, 正在茁壮成长

全驱系统赋新意，控制科技再腾飞



全驱系统控制理论

诞生背景、发展现状与应用进展
(第四版)

二零二五年八月

国家自然科学基金委基础科学中心项目组编制

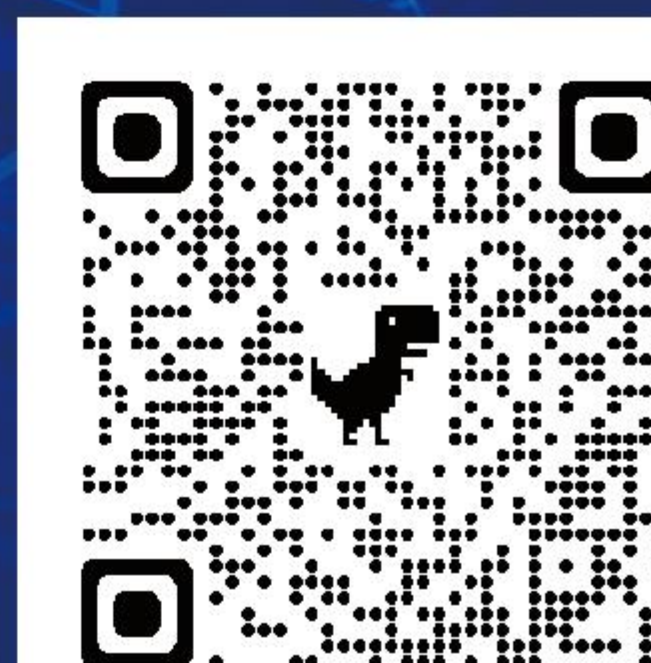
项目名称: 高阶全驱系统理论与航天器控制技术

依托单位: 哈尔滨工业大学

合作单位: 中国航天科工集团有限公司 南方科技大学

项目经费: 6000万元

执行年限: 2022.01~2026.12



“

勇于挑战最前沿的科学问题, 提出更多原创理论, 作出更多原创发现, 力争在重要科技领域实现跨越发展, 跟上甚至引领世界科技发展新方向,

”

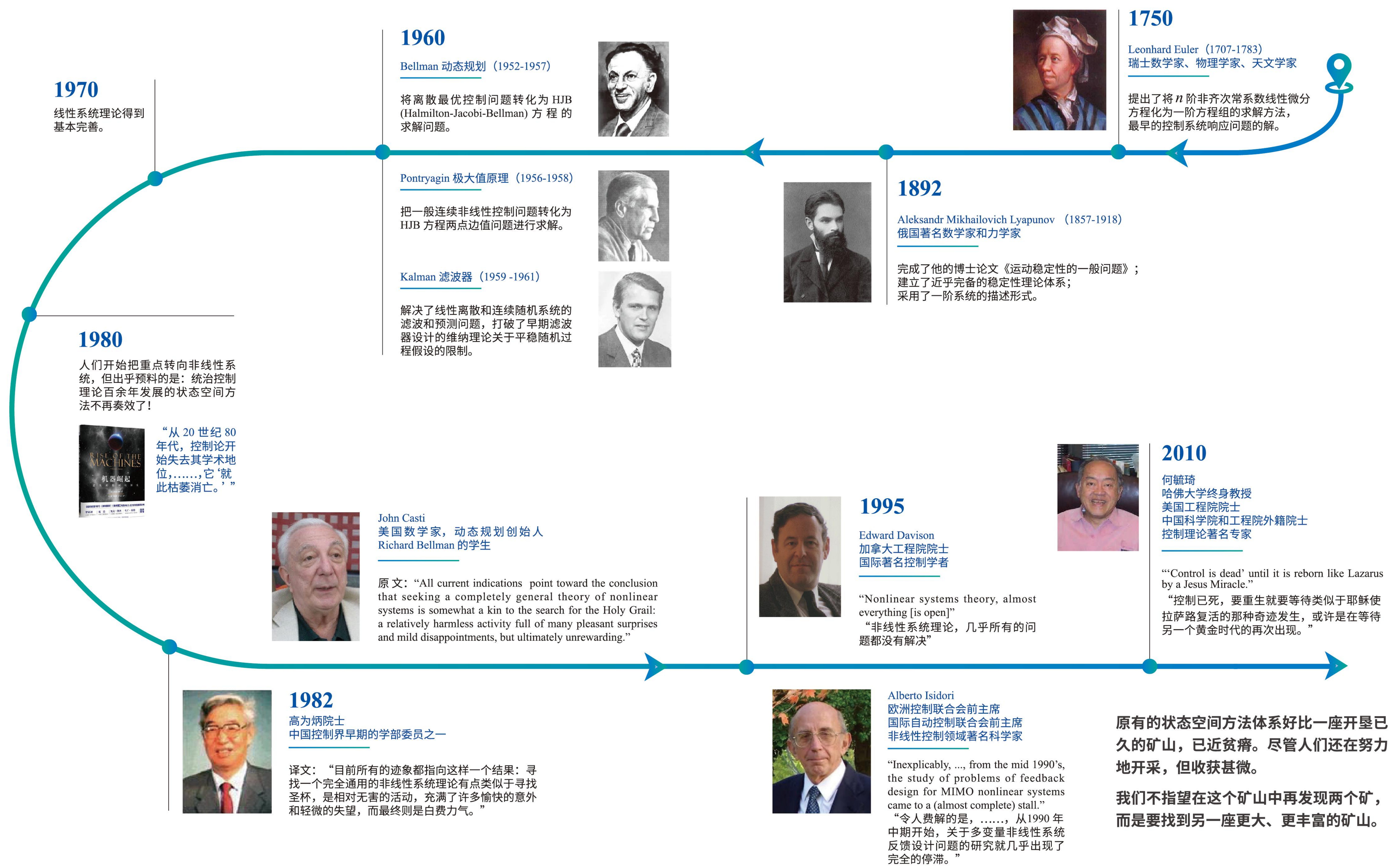
——习近平

原创驱动 引领发展

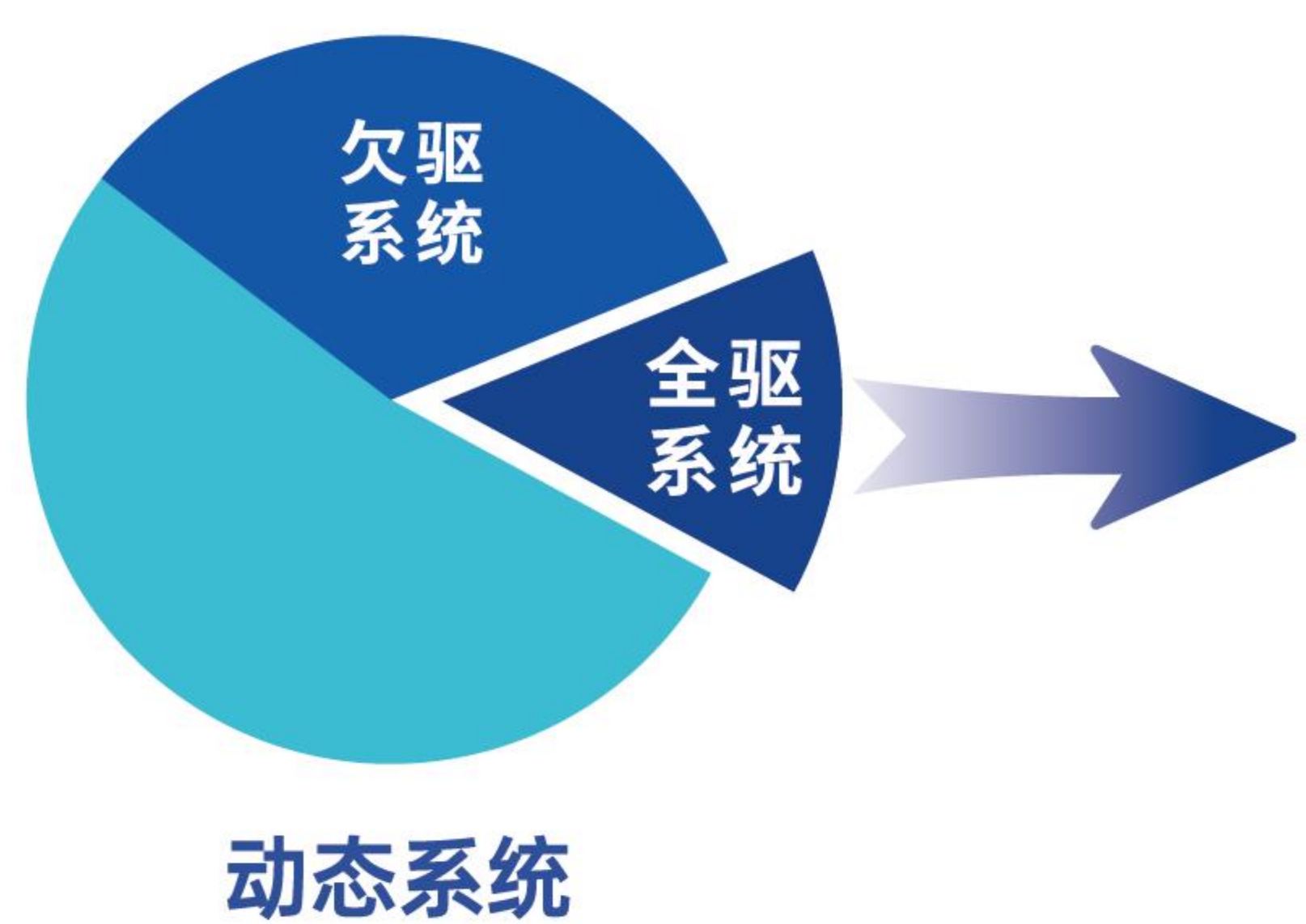
——在短短四年的时间里, 全驱系统理论体系走过了“从无到有、从小到大、由弱到强”的发展历程, 当前在众多国内外控制界同仁的呵护下, 正在飞速发展!

一、原创篇

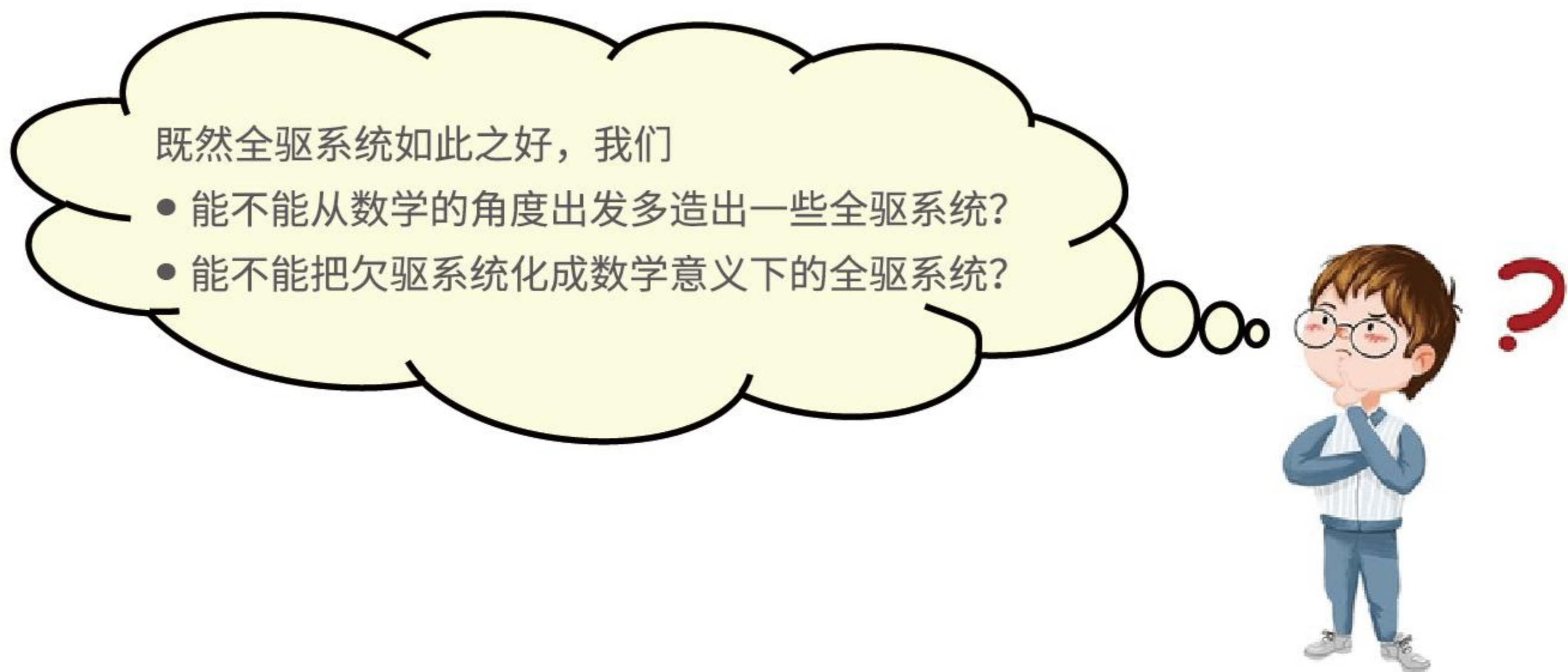
状态空间方法的兴衰



全驱系统(FAS)方法的诞生



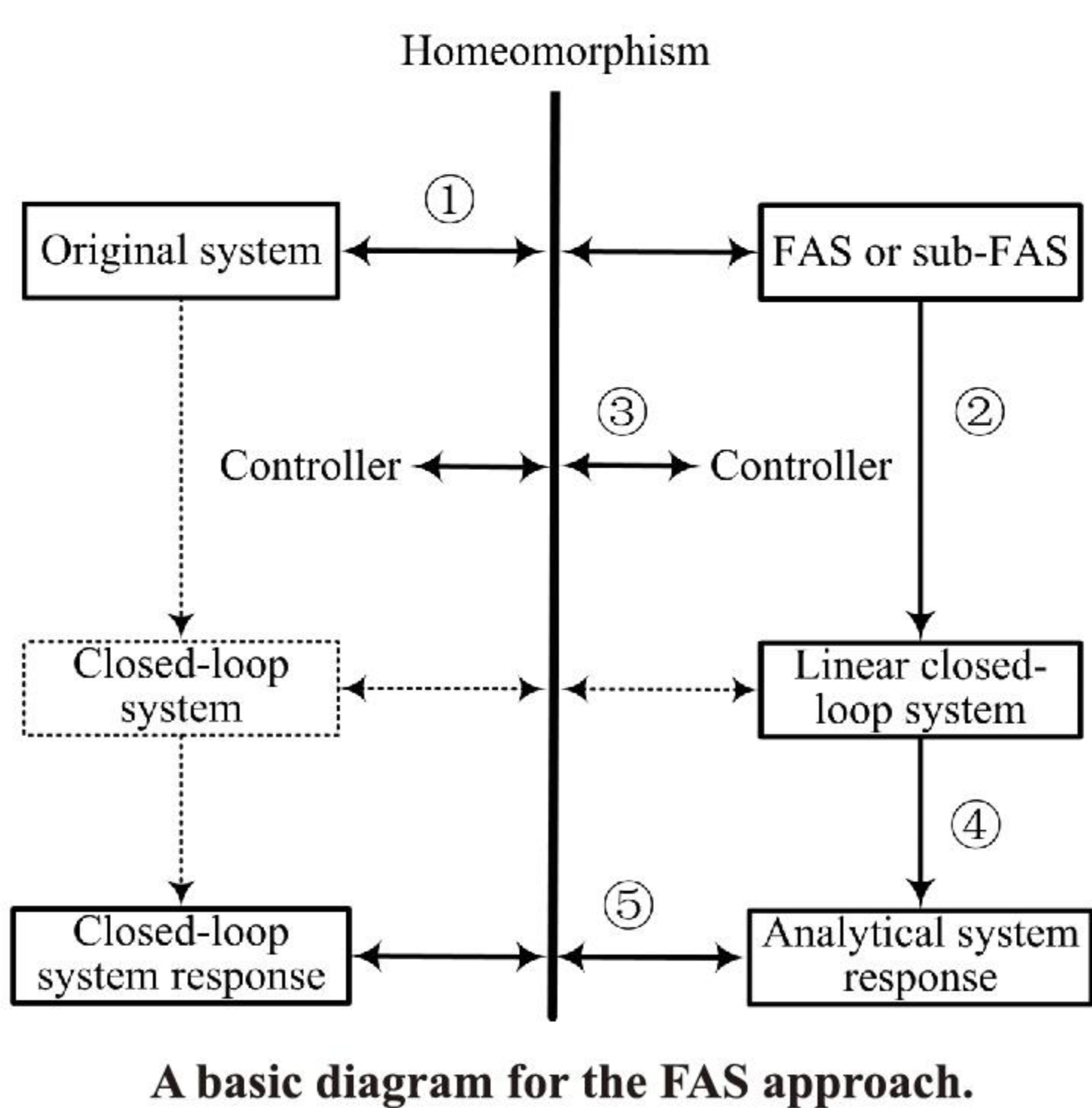
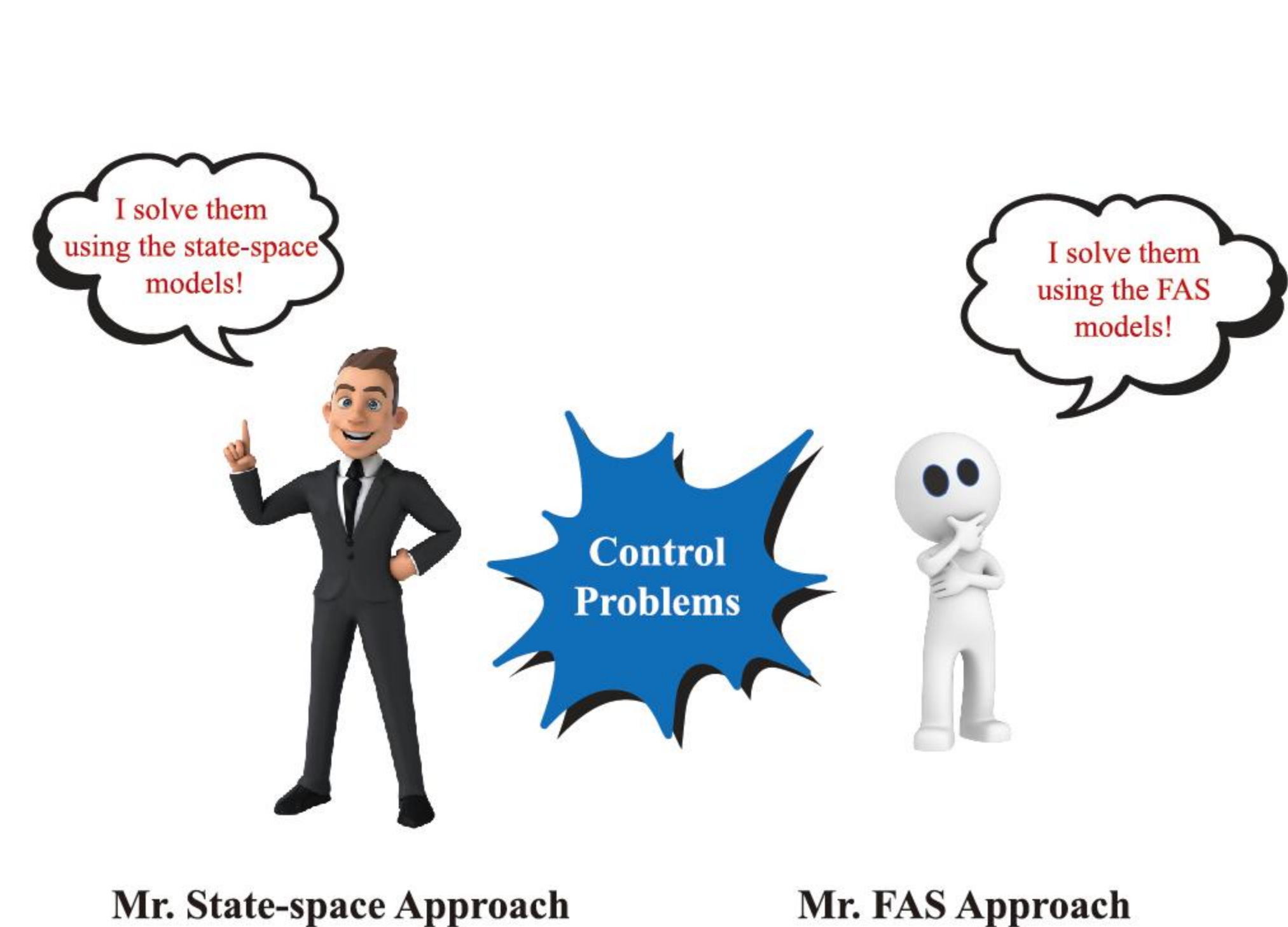
- 机械系统中的一类系统
- 每个自由度都配有执行器
- 很容易实现控制系统设计
- 闭环系统可为线性定常系统
- 贵族般的存在，得天独厚、与众不同
- 只可惜太少



推广的全驱系统模型

$$x^{(m)} = f \left(x^{(0 \sim m-1)}, t \right) + B \left(x^{(0 \sim m-1)}, t \right) u$$
$$\begin{bmatrix} x_1^{(\mu_1)} \\ x_2^{(\mu_2)} \\ \vdots \\ x_n^{(\mu_n)} \end{bmatrix} = \begin{bmatrix} f_1 \left(x_k^{(0 \sim \mu_k-1)} \right)_{k=1 \sim \eta} \\ f_2 \left(x_k^{(0 \sim \mu_k-1)} \right)_{k=1 \sim \eta} \\ \vdots \\ f_n \left(x_k^{(0 \sim \mu_k-1)} \right)_{k=1 \sim \eta} \end{bmatrix} + B \left(x_k^{(0 \sim \mu_k-1)} \right)_{k=1 \sim \eta} u$$
$$x_k^{(\mu_k)} \Big|_{k=1 \sim \eta} = f \left(x_k^{(0 \sim \mu_k-1)} \Big|_{k=1 \sim \eta}, t \right) + g \left(x_k^{(0 \sim \mu_k-1)} \Big|_{k=1 \sim \eta}, u, t \right)$$
$$\begin{cases} x_i^{(\mu_i)} \Big|_{i=1 \sim \eta_x} = f_x^M(\cdot, t) + B_x^M(\cdot, t) u_x \\ y_i^{(\mu_i)} \Big|_{i=1 \sim \eta_y} = f_y^M(\cdot, t) + B_y^M(\cdot, t) u_y \\ z_i^{(\mu_i)} \Big|_{i=1 \sim \eta_z} = f_z^M(\cdot, t) + B_z^M(\cdot, t) u_z \end{cases}$$

动态系统模型的两个极端	
状态空间模型	全驱系统模型
微分阶次最低	微分阶次最高
标量方程个数最多	标量方程个数最少
由原始物理方程增广得到	由原始物理方程消元得到
以状态向量为主角	以控制向量为主角
更适合解决状态相关问题	更适合解决控制问题



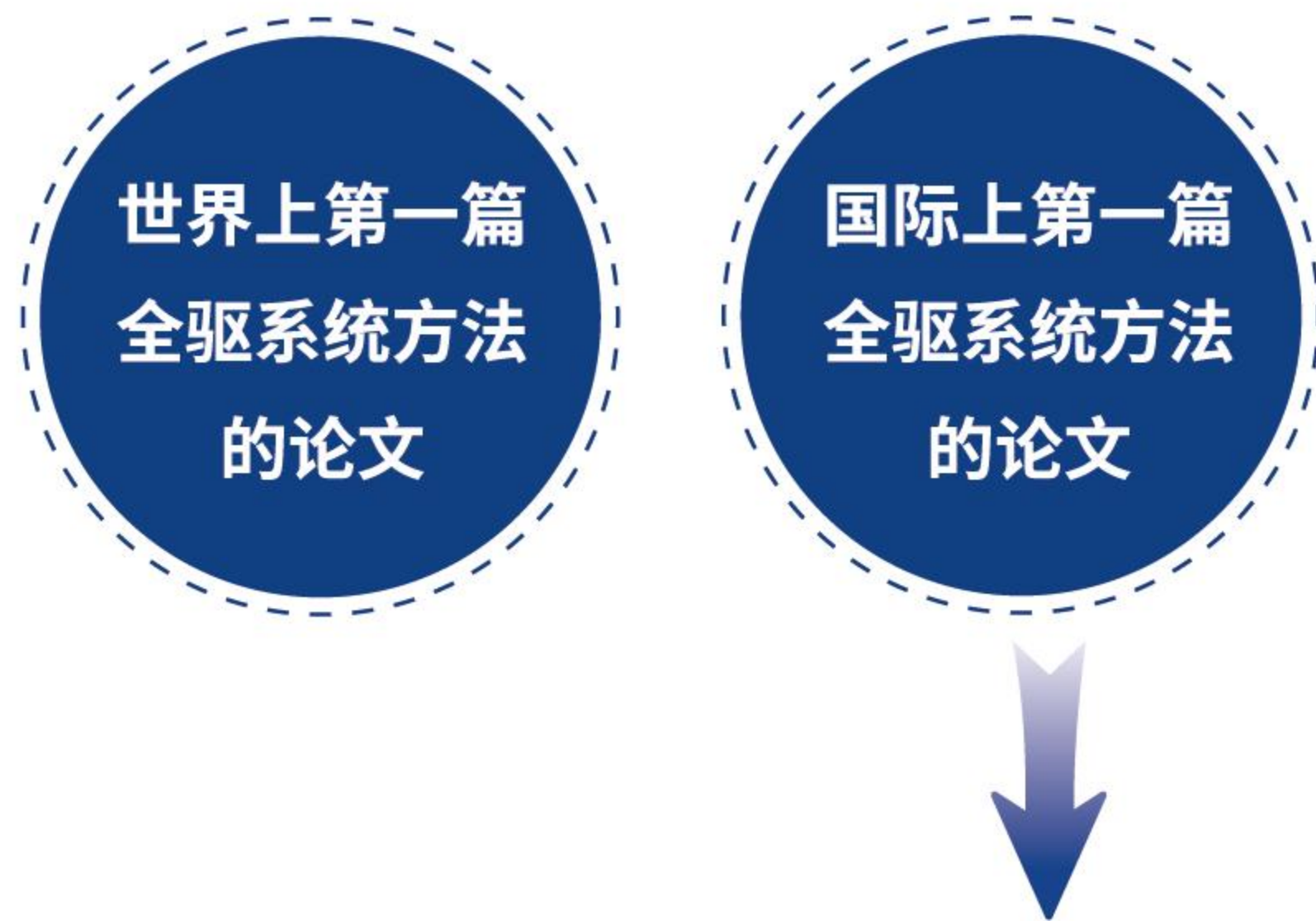
全驱系统理论体系突破了状态空间方法难以处理的非线性、时变性、时滞特性、非完整约束特性等复杂特性的束缚，为控制理论发展开辟了崭新的途径。

自动化学报“高阶系统方法”系列论文

——提出了全驱系统理论的部分基本概念和基本思想。

段广仁. 高阶系统方法, 自动化学报

- I. 全驱特性与参数化设计. 2020, 41(7): 1333–1345.
- II. 能控性与全驱性. 2020, 46(8): 1571–1581.
- III. 能观性与观测器设计. 2020, 46(8): 1885–1895.



国际系统科学杂志 (Int. J. Systems Science) 系列论文

——解决了复杂非线性系统的反馈镇定、鲁棒控制、自适应控制等一系列问题，建立了全驱系统理论的体系框架。

Guang-Ren Duan, High-order fully actuated system approaches, Int. J. Systems Science

- Part I. Models and basic procedure, 2021, 52(2): 422–435.
- Part II. Generalized strict-feedback systems, 2021, 52(3): 437–454.
- Part III. Robust control and high-order backstepping, 2021, 52(5): 952–971.
- Part IV. Adaptive control and high-order backstepping, 2021, 52(5): 972–989.
- Part V. Robust adaptive control, 2021, 52(10): 2129–2143.
- Part VI. Disturbance attenuation and decoupling, 2021, 52(10): 2161–2181.
- Part VII. Controllability, stabilizability and parametric design, 2021, 52(14): 3091–3114.
- Part VIII. Optimal control with application in spacecraft attitude stabilization, 2022, 53(1): 54–73.
- Part IX. Generalized PID control and model reference tracking, 2022, 53(3): 652–674.
- Part X. Basics of discrete-time systems, 2022, 53(4): 810–832.





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► High-order fully actuated (HOFA) system approaches

 International Journal of Systems Science

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High-order fully actuated (HOFA) system approaches

High-order fully actuated (HOFA) systems represent a nuanced frontier in control theory, bridging intricate dynamics with profound control capabilities. Rooted in the realm of systems with advanced differential degrees, these systems, which are often derived from complex physical laws such as Lagrangian mechanics, boast a balanced ratio of control inputs to system outputs. This characteristic, synonymous with being “fully actuated”, ensures a more direct control strategy, rendering them particularly favorable in fields like mechanical engineering, aerospace, and electrical systems. While their high-order nature encapsulates multifaceted behaviors, the full actuation empowers engineers and scientists with a robust platform to achieve precise and desired system responses. Included in this collection is a set of ten seminal papers published in the International Journal of Systems Science, which forms the foundation of the HOFA systems theory. In fact, due to their theoretical significance and practical importance, HOFA systems have already attracted widespread attention with applications to various control problems such as robust control, adaptive control, disturbance rejection, optimal control, and tracking control. It is envisaged that this collection of the pioneering results would help disseminate the HOFA systems theory, which would have a lasting impact on control theory and control engineering.

1

High-order fully actuated system approaches: Part I. Models and basic procedure

Duan, GR

Jan 25 2021 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE ▼ 52 (2) , pp.422-435

364

Citations

38

References

2

High-order fully actuated system approaches: Part II. Advanced control strategies

Duan, GR

Feb 17 2021 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE ▼ 52 (3) , pp.436-445

226

Citations

29

References

3

High-order fully actuated system approaches: Part III. Robust control

Duan, GR

Apr 4 2021 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE ▼ 52 (4) , pp.446-455

229

Citations

33

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4

High-order fully actuated system approaches: Part IV. Adaptive control

Duan, GR

Apr 4 2021 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE ▼ 52 (4) , pp.456-465

203

Citations

51

References

5

High-order fully actuated system approaches: Part V. Robust adaptive control

Duan, GR

Jul 27 2021 | INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE ▼ 52 (10) , pp.2129-2143

143

Citations

27

References

represent a nuanced frontier in control theory

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already attracted widespread attention with applications to various control problems

pioneering results

have a lasting impact on control theory and control engineering

代表了控制理论领域的一个精妙的前沿

深邃的控制能力

确保更加直接的控制策略

备受青睐

涵盖了多样化的动力学行为

为工程师和科学家们提供了一个强大且鲁棒的平台

十篇开创性的系列论文

奠定了高阶全驱系统理论的基础

理论和实践上的重要性

已经得到了广泛关注并已被成功应用于各种控制问题

先驱性的结果

对控制理论与工程产生深远的影响

Impact factors of main SCI journals in systems and control (2024)			
Journals in Systems and Control	IF	Journals in Systems and Control	IF
1. IEEE Trans. Automatic Control	6.2	44. Autonomous Agents and Multi-Agent Systems	2.0
2. Int. J. Systems Science	4.9	45. Information Technology and Control	2.0
3. IEEE Trans. Control Systems Technology	4.9	46. Robotica	1.9
4. Automatica	4.8	47. Assembly Automation	1.9
5. IEEE Trans. Signal Processing	4.6	48. J. Systems Engineering and Electronics	1.9
6. IEEE Trans. Biomedical Engineering	4.4	49. Mathematics of Control, Signals, and Systems	1.8
7. Robotics and Autonomous Systems	4.3	50. IFAC J. Systems and Control	1.8
8. J. Machine Learning Research	4.3	51. Automatika	1.7
9. IEEE Trans. Industry Applications	4.2	52. Control Theory and Technology	1.7
10. IEEE Trans. Control of Network Systems	4.0	53. Transactions of the Institute of Measurement and Control	1.7
11. IEEE Trans. Circuits and Systems II-Express Briefs	4.0	54. J. Dynamic Systems, Measurement & Control	1.7
12. IEEE Control Systems Magazine	3.9	55. Int. J. Control	1.6
13. Int. J. Adaptive Control & Signal Processing	3.9	56. IMA J. Mathematical Control and Information	1.6
14. J. Franklin Institute-Eng. Appl. Math.	3.7	57. Int. J. Applied Mathematics and Computer Science	1.6
15. Nonlinear Analysis-Hybrid Systems	3.7	58. J. Optimization Theory and Applications	1.6
16. Int. J. Automation and Computing	3.7	59. IET Cyber-systems and Robotics	1.5
17. IEEE/ACM Trans. Computational Biology and Bioinformatics	3.6	60. J. Control and Decision	1.5
18. Int. J. Fuzzy Systems	3.6	61. J. Control Automation and Electrical Systems	1.5
19. IEEE Trans. Human-Machine Systems	3.5	62. Discrete Event Dynamic Systems-Theory and Applications	1.4
20. J. Process Control	3.3	63. Proceedings of the Institution of Mechanical Engineers Part I-J. Systems and Control Engineering	1.4
21. Int. J. Robust & Nonlinear Control	3.2	64. J. Robotics	1.4
22. Systems Science & Control Engineering	3.2	65. Measurement & Control	1.3
23. Mechatronics	3.1	66. ESAIM-Control Optimisation and Calculus of Variations	1.3
24. J. Intelligent & Robotic Systems	3.1	67. Int. J. Automation and Control	1.3
25. Unmanned Systems	3.0	68. Studies in Informatics and Control	1.2
26. Int. J. Advanced Manufacturing Technology	2.9	69. Archives of Control Sciences	1.2
27. Asian J. Control	2.7	70. J. Control Science and Engineering	1.0
28. J. Operational Research Society	2.7	71. Mechatronic Systems and Control	1.0
29. Nonlinear Analysis-Modelling and Control	2.6	72. Mathematical Control and Related Fields	1.0
30. J. Nonlinear Science	2.6	73. Int. J. Automation Technology	0.9
31. European J. Control	2.5	74. Int. J. Robotics and Automation	0.8
32. Int. J. Control, Automation & Systems	2.5	75. J. Advanced Mechanical Design Systems and Manufacturing	0.8
33. IEEE Control Systems Letters	2.4	76. Modeling Identification and Control	0.7
34. J. Guidance, Control, & Dynamics	2.3	77. AT-Automatisierungstechnik	0.7
35. J. Vibration and Control	2.3	78. J. Advanced Computational Intelligence and Intelligent Informatics	0.7
36. IET Control Theory & Applications	2.2	79. J. Dynamical and Control Systems	0.6
37. IEEE Trans. Information Theory	2.2	80. J. Applied Nonlinear Dynamics	0.6
38. SIAM J. Control and Optimization	2.2	81. Int. J. Modelling Identification and Control	0.6
39. Int. J. Dynamics and Control	2.2	82. Automation and Remote Control	0.6
40. Systems & Control Letters	2.1	83. Automatic Control and Computer Sciences	0.6
41. IEEE Trans. Magnetics	2.1	84. Control Engineering and Applied Informatics	0.4
42. Int. J. Computers Communications & Control	2.0		
43. Optimal Control Applications & Methods	2.0		

Int. J. Systems Science 创刊于1970年，已有50多年历史，是国际控制界的优秀期刊。其2024年的影响因子在控制界的诸多重要刊物中名列前茅。

05 | 全驱系统控制理论

全驱系统控制理论 | 06

引证检索报告

一、委托信息

- 1. 被检作者：段广仁
- 2. 委托单位/作者单位：哈尔滨工业大学
- 3. 检索目的：国家自然科学基金
- 4. 论文发表年：2020-2021 年
- 5. 代表作篇数：6 篇

二、检索范围

- Science Citation Index Expanded (SCI-EXPANDED) 1900-至今
- WOS (SCI/SSCI/CPCI/ESCI/CSCD 等) 1900-至今
- Essential science Indicators(ESI) 2015-至今
- 中国科学引文库(CSCD) 1989-至今
- SCOPUS 2000-至今

三、检索结果

1、收录引用情况

(引用文献中有论文任一作者视为自引，其它情况视为他引)

序号	第一作者	出处	收录情况	WOS总引次数	WOS他引次数	SCOPUS总引次数	SCOPUS他引次数
1	段广仁, Duan Guangren	高阶系统方法-I.全驱系统与参数化设计. High-order System Approaches: I. Fully-actuated Systems and Parametric Designs 自动化学报. Acta Automatica Sinica 2020 2020 46 7 1333 1345 0254-4156(2020)46:7<1333:GJXTFF>2.0.TX;2-Y	CSCD	189	123	215	152
2	Duan, Guangren	High-order fully actuated system approaches: Part I. Models and basic procedure INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE JAN 25 2021 2021 52 2 422 435 10.1080/00207721.2020.1829167	SCI ESI	354	265	392	302
3	Duan, Guangren	High-order fully actuated system approaches: - part II. Generalized strict-feedback systems INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE FEB 17 2021 2021 52 3 437 454 10.1080/00207721.2020.1829168	SCI	218	151	232	165
4	Duan, Guangren	High-order fully actuated system approaches: Part III. Robust control and high-order backstepping INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE APR 4 2021 2021 52 5 952 971 10.1080/00207721.2020.1849863	SCI	226	149	232	158
5	Duan, Guangren	High-order fully actuated system approaches: Part IV. Adaptive control and high-order backstepping INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE APR 4 2021 2021 52 5 972 989 10.1080/00207721.2020.1849864	SCI	198	127	211	144
6	Duan, Guangren	High-order fully actuated system approaches: Part V. Robust adaptive control INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE JUL 27 2021 2021 52 10 2129 2143 10.1080/00207721.2021.1879964	SCI	141	86	150	97
合计				1326	901	1432	1018

2、引用次数排名情况

- 期刊《自动化学报》2020 年至今共登载论文 1077 篇，作者提供的上述代表性论文 1 的引用次数在这 1077 篇论文中居于首位。
- 期刊《INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE》2021 年至今共登载论文 1187 篇，作者提供的上述代表性论文 2~5 的引用次数在这 1187 篇论文中分别列第一、第三、第四和第五位。
- 上述代表性论文 2 被 ESI 高被引论文收录。

3、引用文献分析

1) 6 篇代表性论文

6 篇代表性论文的第 1 篇取自段广仁作为唯一作者发表在《自动化学报》上的题为“高阶系统方法”的 3 篇系列论文（2020 年第 46 卷第 7、8、9 期）中的第一篇。第 2~6 篇取自段广仁作为唯一作者发表在 *Int. J. Systems Science* 上的题为“High-order fully actuated system approaches”的 10 篇系列论文中的前 5 篇（分别为 2021 年第 52 卷的第 2、3、5、5、10 期）。

2) 全驱系统方法方向上的已发表论文

现已发表的引用了段广仁发表的 6 篇代表性论文中的某一篇，并且论文题目、摘要或者正文中明确包含全驱字样（“全驱”、“fully actuated”、“fully-actuated”、“FAS”、“FASA”、“high-order”、“HOFA”、“full actuation”）的论文共 517 篇，其中题目中包含全驱字样的论文 473 篇；IEEE 汇刊论文 89 篇（题目中包含全驱字样的 77 篇），另有 *IEEE/CAA Journal of Automatica Sinica* 论文 9 篇；应用性期刊论文 141 篇（带有实验结果的论文 53 篇）。

3) 6 篇代表性论文被引用文献评价的情况

引用文献评价类型	引用文献描述情况	评价频次/篇数
突破性评价	A1. 使用“break (overcome, counteract, get rid of 等) +名词”的评价； A2: 针对现存的 challenge、dilemma、limitation、shortcoming、difficulty 等取得突破进展的评价。 如“breaks the limits of the traditional framework of first-order state-space system methods”、“overcome the difficulty of the traditional FOSS model”、“gets rid of the bondage of the state-space model”、“breaks away from traditional thinking”、“overcome the above dilemmas”、“to address these limitations, ...”、“in view of the shortcomings of first-order nonlinear state space models, ...”。	35/35
科学价值评价	B1. 使用 remarkable, significant, great, efficient, excellent, superior, simple, prominent, notable, outstanding, holistic, effective, vigorous, solid, wonderful, fundamental, convenient, concise, potential, substantial, brilliant, promising, comprehensive, noteworthy, widespread, unique, strong, immense, solid, fruitful, distinct, notable, considerable, better 等形容词的评价。 B2. 使用 significantly, greatly, considerably, incredibly, effectively, extremely, admirably, thoroughly, conveniently, easily 等程度副词的评价，如“incredibly practical and efficient”, “extremely powerful”。	131/95
原创性评价	C1. 使用 groundbreaking, novel, innovative, pioneering, seminal, emerging, new, fresh 等词汇的评价，如“opened up a new direction”、“pioneered an innovative approach”、“provided a new perspective”等。 C2. 使用“副词 + 动词”结构的评价，包括“originally (firstly, newly, innovatively, creatively, initially, constructively) + propose (present, introduce, establish, develop, put forward, conduct, design)”。	153/132
引领性、启发性评价	D1. 引文中将代表性论文中的结果作为引理或者命题使用； D2. 使用下述一些句式的评价：“inspired (motivated, enlightened) by”、“according to”、“based on”、“grounded in”、“following”、“by using”、“taking inspiration from”、“from the perspective of”、“building on this foundation”、“on this basis of”、“in the light of”等。	236/166

检索报告人：邵伟文

报告单位：中国科学院文献情报中心

完成时间：2025 年 6 月 20 日

化状态空间模型为全驱系统模型 (举例)

线性系统

$\dot{x} = Ax + Bu, \quad x \in \mathbb{R}^n, u \in \mathbb{R}^r$
(A, B) is controllable $\longleftrightarrow$ $x_k^{(\mu_k)}|_{k=1 \sim \eta} = L \left(x_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} \right) + B_0 u$
 $L(\cdot)$ is linear, $\det B_0 \neq 0$

非线性系统

$\dot{x} = f(x, u), \quad x \in \mathbb{R}^n, u \in \mathbb{R}^r$ (1)

可反馈线性化系统

如果系统 (1) 可通过下述形式的控制律实现反馈线性化：

$u = \xi(x, v), \quad \xi(x_0, 0) = u_0, \quad \text{rank} \frac{\partial}{\partial v} \xi(x_0, 0) = r$

则其可等价化为全驱系统。

非完整系统

在非线性系统理论中占有重要位置的非完整系统均可以化为亚全驱系统和单向关联全驱系统，并且基于全驱系统方法还可以处理一大批推广的具有时变和时滞特性的非完整系统。

完全 (fully) 平坦系统

如果系统 (1) 存在输出 $y = y_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} \in \mathbb{R}^r, y_k \in \mathbb{R}^{r_k}$ 满足

$x = \varphi \left(y_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} \right)$
 $u = \psi_0 \left(y_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} \right) + G \left(y_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} \right) y_k^{(\mu_k)}|_{k=1 \sim \eta}$ (2)

和 $\sum_{k=1}^{\eta} r_k \mu_k = n$ ，且上述第 (2) 式构成微分同胚，则该系统可等价化为亚全驱系统。

具有完全相对阶的系统

假设系统 (1) 的输出 $y = y_{1 \sim \eta} = h_{1 \sim \eta}(x) \in \mathbb{R}^r, y_k \in \mathbb{R}^{r_k}$ 具有一组完全的相对阶 $\mu_k, k = 1 \sim \eta$ ，则

$y_k^{(0 \sim \mu_k - 1)}|_{k=1 \sim \eta} = \varphi_{1 \sim \eta}(x)$
 $y_k^{(\mu_k)}|_{k=1 \sim \eta} = f_{1 \sim \eta}(x) + b_{1 \sim \eta}(x) u$ (3)

且 $\sum_{k=1}^{\eta} r_k \mu_k = n$ 。如果上述第 (3) 式构成微分同胚，则该系统可等价化为亚全驱系统。

(亚) 严反馈系统 (SFS)

$$\begin{cases} \dot{x}_1 = f_1(x_1, t) + G_1(x_1, t)x_2 \\ \dot{x}_2 = f_2(x_{1 \sim 2}, t) + G_2(x_{1 \sim 2}, t)x_3 \\ \vdots \\ \dot{x}_{n-1} = f_{n-1}(x_{1 \sim n-1}, t) + G_{n-1}(x_{1 \sim n-1}, t)x_n \\ \dot{x}_n = f_n(x_{1 \sim n}, t) + G_n(x_{1 \sim n}, t)u, \end{cases}$$

$x_i \in \mathbb{R}^{r_i}, i = 1, 2, \dots, n, u \in \mathbb{R}^r$
 $\mathbb{G}_i = \{x_{1 \sim i} \mid \text{rank} G_i(x_{1 \sim i}, t) = r_i, t \geq 0\}$
 $\mathbb{G}_i = \mathbb{R}^{r_1 + r_2 + \dots + r_i}, i = 1, 2, \dots, n$: SFS
 $\mathbb{G}_i \neq \emptyset$ or $\mathbb{R}^{r_1 + r_2 + \dots + r_i}, i = 1, 2, \dots, n$: sub-SFS

	严反馈系统	亚严反馈系统
$r_i = r, i = 1, 2, \dots, n$	single-order FAS	single-order sub-FAS
$r_{i+1} \geq r_i, i = 1, 2, \dots, n$	multi-order FAS	multi-order sub-FAS

- 上述例子说明，基于状态空间方法的若干种主要控制系统设计方法都可以纳入全驱系统方法的框架。
- 全驱系统方法不限于研究状态空间模型描述的系统，它可以研究由物理定律导出的任何形式的动态系统。
- 全驱系统方法不只研究可化为全驱系统的系统，它也研究子系统可化为全驱系统的系统。
- 上述各种情形可以推广到时变和时滞系统。

二、开拓篇

国家自然科学基金基础科学中心
高阶全驱系统理论与航天器控制技术(62188101)

核心成员



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陈立群
哈尔滨工业大学（深圳）
国家杰青
教育部高层次人才

揭牌仪式



2022年8月 哈尔滨 会议现场

基金委基础科学中心项目组发表论文概况 (截止2025年6月)

截止 2025 年 6 月，基础科学中心项目组发 SCI 期刊论文 398 篇，其中 IEEE 汇刊 129 篇，自动化学报英文版 6篇，其他期刊论文 265 篇。

IEEE汇刊论文(129篇)

IEEE Transactions on	篇数
• Aerospace and Electronic Systems	9
• Automatic Control	10
• Automation Science and Engineering	6
• Circuits and Systems I-Regular Papers	18
• Circuits and Systems II-Express Briefs	4
• Control of Network Systems	1
• Cybernetics	22
• Geoscience and Remote Sensing	1
• Industrial Electronics	18
• Industrial Informatics	10
• Instrumentation and Measurement	2
• Mechatronics	9
• Network Science and Engineering	2
• Neural Networks and Learning Systems	2
• Power Electronics	1
• Smart Grid	3
• Systems Man Cybernetics-Systems	11

其他期刊论文(271篇)

期刊名称	篇数
• Automatica	18
• SCIENCE CHINA Information Science	15
• Aerospace Science and Technology	12
• Int. J. Robust and Nonlinear Control	19
• IET Control Theory and Applications	19
• ISA Transactions	10
• Int. J. Systems Science	16
• Int. J. Control Automation and Systems	3
• Acta Astronautica	4
• Control Engineering Practice	4
• Systems &Control Letters	3
• Mathematical Biosciences and Engineering	2
• J. Systems Science & Complexity	15
• Nonlinear Dynamics	7
• Mechanical Systems and Signal Processing	6
• Journal of the Franklin Institute	10
• Advances in Space Research	5

中国科学英文版系列

Guang-Ren Duan
SCI. CHINA INFORM. SCI.

- Discrete-time delay systems 系列
 - ◆ Part I. Global fully actuated case, 2022, 65(8): 182201
 - ◆ Part II. Sub-fully actuated case, 2022, 65(9): 192201
 - Fully actuated system approaches for continuous-time delay systems 系列
 - ◆ Part I. Systems with state delays only, 2023, 66(1): 112201
 - ◆ Part II. Systems with input delays, 2023, 66(2): 122201
 - A FAS approach for stabilization of generalized chained forms 系列
 - ◆ Part I. Discontinuous controllers, 2024, 67(2): 122201
 - ◆ Part II. Continuous controllers, 2024, 67(3): 132201
- 该3系列论文平均长度22页/篇

国际系统科学杂志

Guang-Ren Duan
Int. J. System Science
Unidirectionally connected FASs系列
Part I. Models,
DOI:10.1080/00207721.2025.2466806
Part II. Sub-stabilisation,
DOI:10.1080/00207721.2025.2466806
Part III. Applications,
DOI:10.1080/00207721.2025.2466806

国家自然科学基金委基础科学中心项目“高阶全驱系统理论与航天器控制技术”中期检查会议
2024.12.14 哈尔滨



国家自然科学基金委基础科学中心项目
“高阶全驱系统理论与航天技术控制技术”中期检查 成绩优秀

全驱系统理论与航天器控制技术基础科学中心第一届学术委员会名单

职 务	姓 名	工作单位及介绍
主 任	桂卫华	中南大学，中国工程院院士
	郭 雷	北京航空航天大学，中国科学院院士
副主任	周东华	清华大学，国家杰青、教育部高层次人才
	姜 斌	南京航空航天大学，教育部高层次人才
委 员	柴 利	浙江大学，国家杰青
	陈 虹	同济大学，国家杰青、教育部高层次人才
	陈 谋	南京航空航天大学，国家杰青
	董海荣	山东科技大学/北京交通大学，国家杰青、教育部高层次人才
	段广仁	哈尔滨工业大学/南方科技大学，中国科学院院士
	段海滨	北京航空航天大学，国家杰青、教育部高层次人才
	侯增广	中国科学院自动化研究所，国家杰青
	华长春	燕山大学，国家杰青、教育部高层次人才
	贾英民	北京航空航天大学，国家杰青、教育部高层次人才
	李少远	青岛科技大学，国家杰青
	李贻斌	山东大学，国家百千万人才工程
	孙希明	大连理工大学，国家杰青、教育部高层次人才
	谭 民	中国科学院自动化研究所，国家杰青
	田玉平	南方科技大学，国家杰青、教育部高层次人才
	王 龙	北京大学，国家杰青、教育部高层次人才
	徐胜元	南京理工大学，国家杰青、教育部高层次人才
	张焕水	山东科技大学，国家杰青、教育部高层次人才
	张纪峰	中国科学院数学与系统科学研究院，国家杰青
	赵千川	清华大学，国家杰青
	赵玉新	哈尔滨工程大学，国防卓青

注：委员按姓氏拼音排序



——“一个由中国学者原创并引领的全新的控制理论体系已经完成。”

2024 年 5 月 10 日

——“全驱系统方法的 6 篇代表性论文四年时间里在国际控制界的认可程度是半个世纪以来罕见的。全驱系统方法在国家自然科学基金委基础科学中心项目支持下，其发展速度之快、影响程度之深是过去半个世纪里国际控制理论界中罕见的。

2025 年 7 月 4 日



中国自动化学会全驱系统理论与应用专业委员会

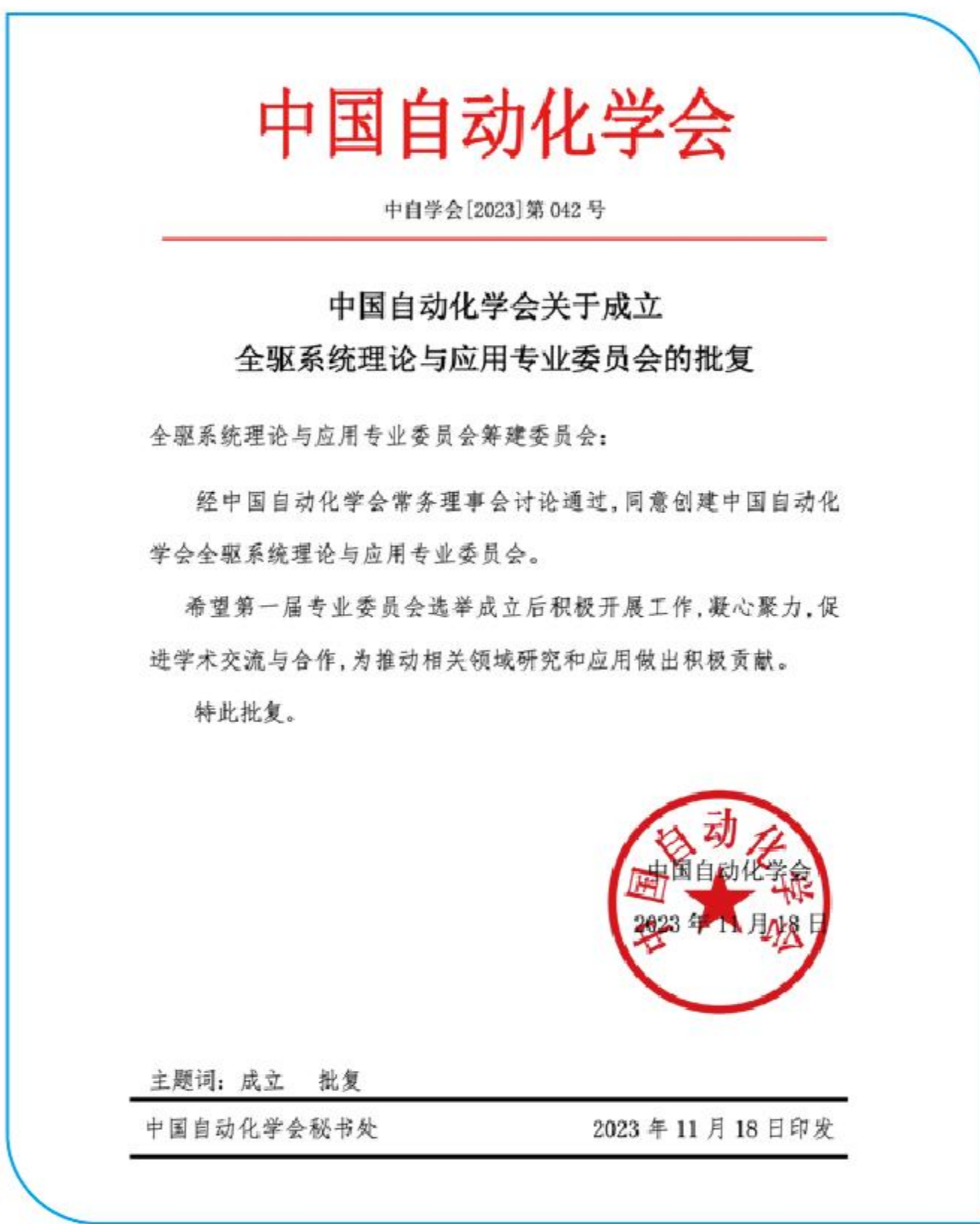
Technical Committee on Fully Actuated System Theory and Applications, Chinese Association of Automation

第一届全驱系统理论与应用专业委员会领导机构

主 任：	段广仁
副主任：	周东华、邹 云、冯俊娥、华长春、吴爱国、徐 翔
秘书长：	张 颖

该专委会于2022年5月得到中国自动化学会的筹备创建批复，2023年11月得到中国自动化学会的成立批复。

网址：<http://www.fasta.org.cn>.



中国自动化学会公开报道：<http://www.caa.org.cn/article/201/3013.html>



第一届 ACA 全驱系统理论与应用专业委员会

Chair:

Guang-Ren Duan Harbin Institute of Technology, China

Vice Chair:

Ju H. Park Yeungnam University, Republic of Korea

Lam James University of Hong Kong, China

Michael V. Basin Autonomous University of Nuevo Leon, Mexico

Changchun Hua Yanshan University, China

Huijun Gao Harbin Institute of Technology, China

Aiguo Wu Harbin Institute of Technology (Shenzhen), China

Secretaries:

Kemi Ding Southern University of Science and Technology, China

Tao Liu Southern University of Science and Technology, China

Members:

Currently 125 members across the world, including 40 IEEE Fellows

Joining Process

Nomination: Nominated by two current members of this committee.

Application: Submit a formal membership application. Please contact the committee secretariat: Kemi Ding (dingkm@sustech.edu.cn), Tao Liu (liut6@sustech.edu.cn).

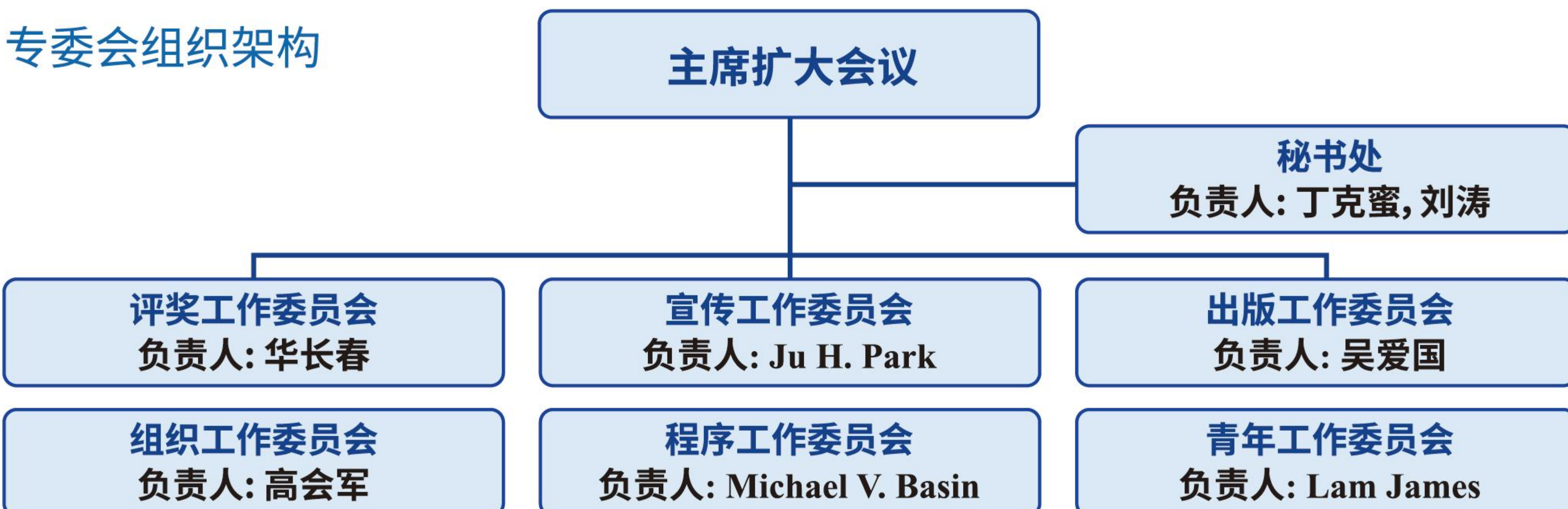
Review: Initial qualification review by the committee secretariat.

Vote: Approval by a two-thirds majority vote of committee members present at a plenary committee meeting.

Missions:

- ◆ In scientific research, the TC and its activities will be focused on proposing new results in the field of systems and control based on FAS approach;
- ◆ In technical development, the TC will support the transfer of discovered "know-how" in the area of system and control theories to potential practical applications;
- ◆ In education, the TC will support young scientists in the field of control systems and applications, and disseminate discovered "know-how" amongst scientific community.

专委会组织架构



该专委会于2025年3月得到亚洲控制协会的成立批复。

网址: <http://aca.fasta.org.cn/>

Committee Activities

◆ Annual Conference on Fully Actuated System Theory and Applications

Co-organized by ACA TC FASTA and CAA TC FASTA

Premier global event on fully actuated system theory, recognized for its academic excellence and rapidly expanding participation

Held annually in July

◆ Annual Young Scholars Forum on Fully Actuated System Theory and Applications

Organized by the Young Professionals Committee of ACA TC FASTA

Flagship platform for early-career researchers to present and discuss cutting-edge advances in fully actuated system theory and applications

Held annually in November

亚洲控制协会全驱系统理论与应用专业委员会成立大会



亚洲控制协会全驱系统理论与应用专业委员会成立大会

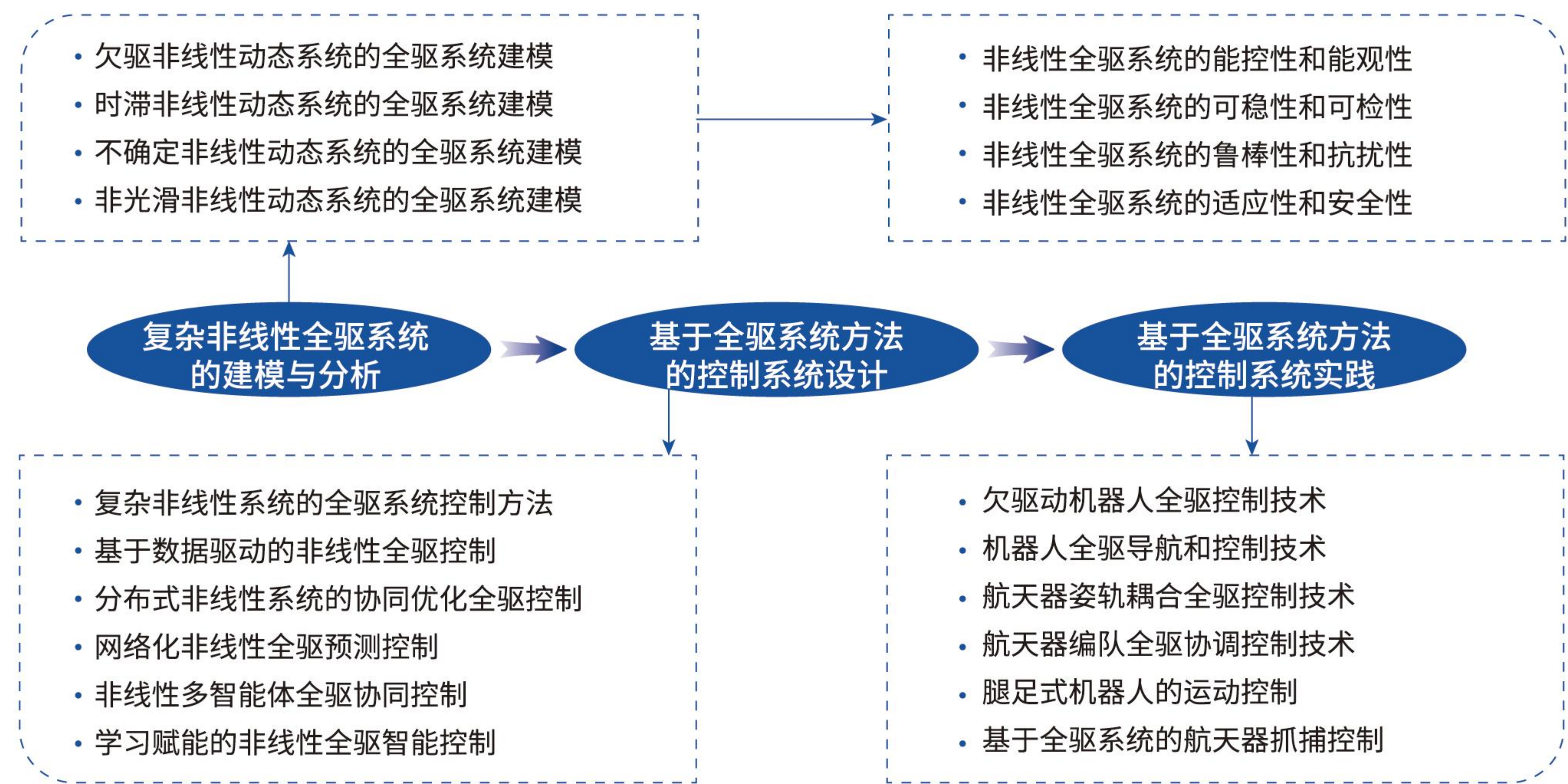
2025年7月4日 南京



在原来状态空间方法陷入困境的背景下，我们于2020年提出了一个全新的全驱系统控制理论体系，打破了控制理论的发展僵局。该实验室将推进这一新的控制理论体系，实现控制理论研究从状态空间方法到全驱系统方法的国际性重大转折！



研究内容



全驱系统理论方向科研项目

深圳市孔雀团队:全驱系统理论与应用

负责人：段广仁

核心成员：刘国平、林志赞、孔贺

资助金额：1500万元

项目期限：2023年10月1日至2028年10月1日

依托单位：南方科技大学

管理单位：深圳市科技创新委员会



核心成员



全驱系统方法相关科研项目

序号	负责人	项目名称	项目来源	金额(万元)
1	孔 贺	综合状态空间与全驱系统方法的复杂非线性航天器的自主智能估计与控制技术	国家自然科学基金原创探索计划项目	100
2	孔 贺	复合欠驱航天器的智能全驱控制：从分析到综合	国家自然科学基金原创探索计划项目 - 延续资助	200
3	李 萍	基于高阶全驱系统方法的柔性伺服系统自抗扰控制技术研究	国家自然科学基金青年科学基金项目	30
4	赵 琴	面向非合作目标的组合体航天器位姿联合接管控制	国家自然科学基金青年科学基金项目	20
5	刘卫振	参数估计误差收敛的高阶严格反馈系统自适应反步控制	国家自然科学基金青年科学基金项目	30
6	王玉仲	基于全驱系统方法的严反馈非线性系统事件触发自适应控制研究	国家自然科学基金青年科学基金项目	30
7	任炜杰	基于全驱系统方法的主动故障诊断与容错控制	国家自然科学基金青年学生基础研究项目（博士研究生）	30
8	王玉仲	基于全驱系统方法的严反馈非线性系统的事件触发自适应滑模控制研究	博士后创新人才支持计划项目	64
9	刘卫振	基于全驱系统方法的非线性系统极值搜索镇定控制	博士后创新人才支持计划项目	64
10	田广泰	面向非合作目标的欠驱动组合体航天器的预设性能姿轨联合控制	中国博士后科学基金第 17 批特别资助项目	18
11	张大蔚	多源受扰非线性全驱系统的干扰预测控制及应用	中国博士后科学基金第 77 批面上项目	8
12	任炜杰	全驱系统控制理论与航天器控制技术	首批中国科协青年人才托举工程博士生专项计划	4
13	李 萍	基于高阶全驱系统方法的欠驱动机械系统控制方法研究	广东省自然科学基金面上项目	15
14	王 萍	非线性多无人系统基于高阶全驱系统方法的固定时间协同控制研究	广东省自然科学基金面上项目	10
15	田广泰	基于全驱系统方法的欠驱动空间组合机器人的鲁棒预设时间姿态跟踪控制	广东省基础与应用基础研究基金 - 粤深联合青年基金	10
16	李 萍	基于全驱系统理论的复杂多电机驱动系统精密运动控制技术	深圳市自然科学基金面上项目	30



全驱系统理论与应用国际学术年会 (FASTA)

International Conference on Fully Actuated System Theory and Applications

FASTA2022（哈尔滨，2022.08.05至2022.08.07）



大会报告

- ◆ 魏毅寅 (中国航天科工集团有限公司), 精确打击武器集群协同技术发展探讨
- ◆ 乔 红 (中国科学院自动化所), 受人启发的机器人系统
- ◆ 周东华 (清华大学), Stochastic High-order Fully-actuated Systems: Model, Equivalence and Stabilization
- ◆ 刘国平 (南方科技大学), 高阶全驱预测协调控制
- ◆ 华长春 (燕山大学), 基于全驱动系统方法的一类非线性时滞系统的自适应控制
- ◆ 刘腾飞 (东北大学), 一类全驱系统的主动安全控制问题
- ◆ 邹 云 (南京理工大学), 完全能达性:系统状态的行为主义目的论视角观察

FASTA2023（青岛，2023.07.14至2023.07.16）

会议网址：<http://cfasta2023.sdust.edu.cn/index.htm>



来自全球相关高校及科研院所的430余位专家学者参加了会议，参会代表和论文来自中国（包括台湾和香港）、美、加、英、澳、土耳其、比利时和新加坡等9个国家和地区。自本届起，该会由IEEE协办，会议论文集已经进入IEEE Xplore数据库并被EI检索。

大会报告

- ◆ 段广仁 (南方科技大学/哈尔滨工业大学), Fully Actuated System Approach for Control — Results Overview and Further Problems
- ◆ Guo-Xiang Gu (美国路易斯安那州立大学), Asymptotic Full Actuation Control with Applications to Control of Autonomous Vehicle Platoons
- ◆ Xiao-Ping Liu (加拿大Lakehead大学), Weak Disturbance Decoupling of High-order Fully Actuated Nonlinear Systems

FASTA2024（深圳，2024.05.10至2024.05.12）

会议网址：<http://fasta2024.fasta.org.cn>



FASTA2024由南方科技大学和中国自动化学会全驱系统理论与应用专委会主办。参会代表610余人，会议共收到来自中、美、加、法、日、澳、新加坡、荷兰等12个国家和地区的投稿论文353篇，经过严格、认真的评审程序，最终录用308篇。

大会报告

- ◆ Zhong-Ping Jiang (New York University), Small-Gain Theory for Stability and Control of Interconnected Systems
- ◆ Guo-Ping Liu (Southern University of Science and Technology), High-order Fully Actuated Predictive Control for Networked Systems
- ◆ Michael V. Basin (Autonomous University of Nuevo Leon), Predefined-Time Convergent Continuous Controllers: Design and Applications



Prof. Z. P. Jiang



Prof. G. P. Liu



Prof. M. V. Basin

FASTA2024 剪影



FASTA 2025 (南京, 2025.07.04 至 07.06)

会议网址: fasta2025.scimeeting.cn



FASTA2025 由南京理工大学、中国自动化学会全驱系统理论与应用专业委员会和亚洲控制协会全驱系统理论与应用专业委员会联合主办。参会代表 1040 余人，会议共收到来自中、美、日、英、新加坡、加拿大等 9 个国家和地区的投稿 665 篇，经过严格、认真的评审程序，最终录用 589 篇。

大会报告

- ◆ Alessandro Astolfi (Imperial College London, UK): Dynamic Linearizability Implies Static Stabilizability and Related Results.
- ◆ Hyungbo Shim (Seoul National University, South Korea): Synchronization of Heterogeneous Multi-agent Systems through Singular Perturbation.
- ◆ Donghua Zhou (Southeast University, China): Fault Tolerant Control of High-Order Fully Actuated Systems.



Prof. A. Astolfi



Prof. H. Shim



Prof. D. H. Zhou

FASTA 2025 剪影



FASTA2026 (秦皇岛, 2026.06.26-2026.06.28)

承办单位：燕山大学

会议网址：fasta2026.scimeeting.cn



2026年全驱系统理论与应用会议

2026年6月26-28日 中国·秦皇岛



征文通知



秦皇岛
city walk

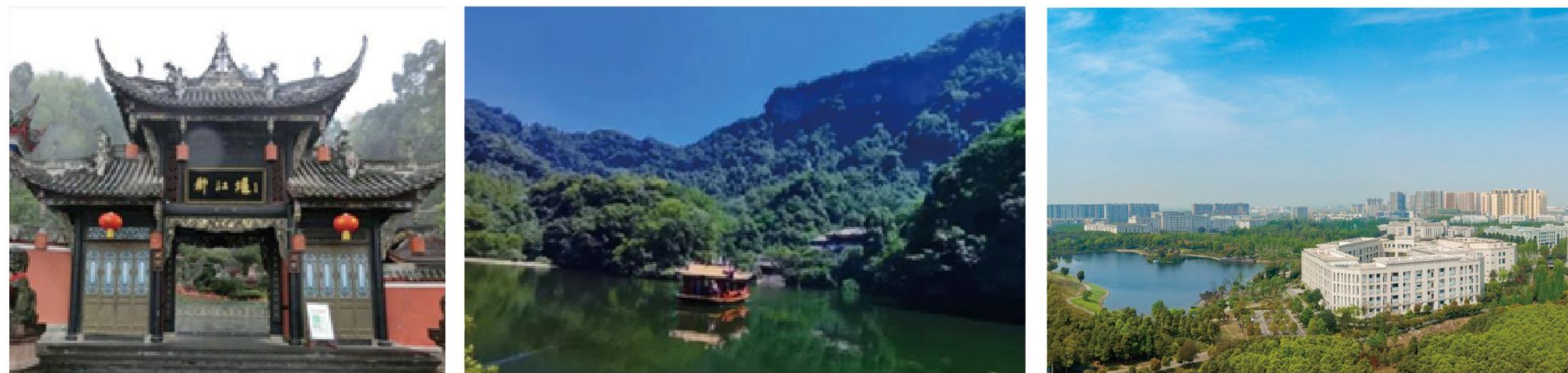
主办单位：
燕山大学
中国自动化学会全驱系统理论与应用专业委员会
亚洲控制学会全驱系统理论与应用专业委员会
承办单位：
燕山大学电气工程学院
协办单位：
IEEE Guangzhou Chapter
IEEE Harbin Chapter

第五届全驱系统理论与应用会议由燕山大学、中国自动化学会全驱系统理论与应用专委会、亚洲控制学会全驱系统理论与应用专委会联合主办，燕山大学电气工程学院承办。将于2026年6月26-28日在河北省秦皇岛市召开。会议旨在为从事相关领域和研究的国内外专家、学者及工程技术人员提供一个学术交流平台，展示最新的理论与技术成果。会议采用大会报告、分会报告、专题报告和张贴论文等形式进行交流。

秦皇岛市，简称秦，别称港城，位于河北省东北部，地处华北地区、河北省东北部，东临渤海，北依燕山，西靠内陆，南临渤海湾，是京津冀协同发展的重要节点城市。

FASTA2027 (成都, 2027.07)

承办单位：成都电子科技大学·四川大学



首届全驱系统理论与应用青年学者论坛



FASTA 会议论文奖

为表彰全驱系统理论与应用会议中的优秀论文,2023 年起设立 FASTA 优秀青年论文奖和FASTA 最佳学生论文奖,2025 年起设立 FASTA 优秀张贴论文奖。

FASTA 优秀青年论文奖

历届会议	获奖人	获奖论文
FASTA2023	Ping Li (Southern University of Science and Technology)	High-order Fully Actuated Control Approach for Flexible Servo Systems Using Dynamical Compensator
	Xiang Xu (Southern University of Science and Technology)	High-order Fully Actuated System Models for Discrete-Time Strict Feedback Systems with Increasing Dimensions
FASTA2024	Peng-Ju Ning (YanshanUniversity)	Global Prescribed-Time Control Fully Actuated Nonlinear Systems
FASTA2025	Cai Miao (Tsinghua University)	Fault-Tolerant Control for High-Order Fully Actuated Systems with Dead-Zone Observers
	Huaiyuan Jiang (Harbin Institute of Technology)	Bias-Policy Iteration Based Adaptive Dynamic Programming for First-Order Fully Actuated Systems

FASTA 最佳学生论文奖

历届会议	获奖人	获奖论文
FASTA2023	Cai Miao (Tsinghua University)	Sensor Fault Tolerance for High-Order Fully Actuated Systems
FASTA2024	Wei-Jie Ren (Southern University of Science and Technology)	A Fully Actuated System Approach for Interval Observer Design and Fault Detection
	Zhi bin Mo (Sun Yat-sen University)	Fully Actuated Behavioral Control for Multiple Omnidirectional Mobile Robots System with Uncertain Dynamics
FASTA2025	Shunli Li (Harbin Institute of Technology)	On the Perfect Output Regulation of High Order Fully Actuated Systems with Invariant Zeroes
	Yulin Duan (Southern University of Science and Technology)	Prescribed Performance Tracking Control for Uncertain-Strict-Feedback Systems Using Fully Actuated System Approach
	Baisen Wang (National University of Defense Technology)	Adaptive Prescribed Performance Control for Variable-Sweep Aircraft Based on Fully-Actuated System Approach

FASTA 优秀张贴论文奖

历届会议	获奖人	获奖论文
FASTA2025	Fuxing Yao, Zhijie Liu, Liangming Chen, Tianqi Yue, He Kong	Further results on the fully actuated system approach to control of overhead cranes
	Yangqianhui Zhang, Keyuan Wang, Ziyue Wang, Tianqi Yue, Dong Han, Liang Zhao	Incomplete Multiview Clustering Based on Fully Actuated System Theory
	Huilin Dai, Haoping Wang, Yang Tian, Liuchang Zhang	Model Free Extended State Observer Based Sliding Mode Prescribed Time Control for Series Elastic Actuator-Based Manipulator
	Jiaping Qiang, Li Li, Yipeng Cao, Chao Liu	Practical prescribed-time tracking control for underactuated WMR: a fully actuated system approach
	Wushan Jia, Xiaochen Xie, Huijun Gao	A Composite Adaptive Control Approach for a Class of Uncertain Fully Actuated Systems

全驱奖与全驱青年奖

为表彰在全驱系统理论与应用领域做出突出贡献的学者,亚洲控制协会全驱系统理论与应用专业委员会于2025年起设立全驱奖和青年全驱奖。这两个奖项由专委会评奖委员会提名并通过严格评审产生,在每年的全驱系统理论与应用会议上颁发。

获奖类型	获奖人	介绍
2025 全驱奖	周东华教授 (东南大学)	周东华教授提出了确定性全驱系统容错控制系统性方法,开创了随机全驱系统容错控制新方向,在全驱系统方向发表了 SCI 论文 14 篇,包括全驱方向首篇 Automatica 长文和10篇IEEE汇刊,指导的全驱系统方向博士获得了清华大学优秀博士学位论文奖等。
	华长春教授 (燕山大学)	华长春教授针对不确定全驱非线性系统,提出了全局自适应控制的系统化方法,并成功应用于机器人和工程机械等控制中,相关成果录用和发表论文 40 余篇,其中 8 篇发表于 IEEE Transactions 系列期刊。这些研究成果丰富和发展了非线性全驱自适应控制理论。
2025 全驱青年奖	张大蔚博士 (南方科技大学)	张大蔚博士提出了全驱系统预测控制框架,并应用于多智能体协同控制,还通过航天器编队控制等实际场景验证了可行性和实用价值;相应成果在 IEEE Transactions 等国内外顶尖期刊发表论文 18 篇。
	张柯教授 (南京航空航天大学)	张柯教授提出了基于全驱系统方法的无人集群系统协同安全控制,部分理论成果应用于无人机编队实际飞行,发表了 12 篇国际期刊论文,包括 Automatica 和 5 篇 IEEE 汇刊论文。



三、引领篇

截至目前, 我们的开创性工作已经引领了全球 20 多个国家的 140 多所大学和研究机构发表全驱系统理论与应用方面的论文 520 余篇。

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部分IEEE汇刊论文

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涉及的研究方向

Control Methods Stabilization and tracking control Adaptive control Predictive control Fault-tolerant control Observers/observer-based designs Prescribed performance control Disturbance decoupling Saturation and constrained control Safety control Sliding mode control Output feedback control Actuator saturation control	Dynamical Systems Linear systems Sub-fully actuated systems Nonholonomic systems Strict feedback systems Time-varying systems Time-delay systems Impulsive systems Fractional order systems Periodic systems Multi-agent systems Stochastic systems Discrete-time systems	Applications Spacecraft control Aircraft and quadrotors Robotic control Servo system control DC microgrid control Underactuated systems Inverted pendulum systems Intelligent vehicle systems Heterogeneous MASs systems Thermoacoustic systems Fuel cell air feed systems Engine control
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全驱系统理论与应用方向的大会报告

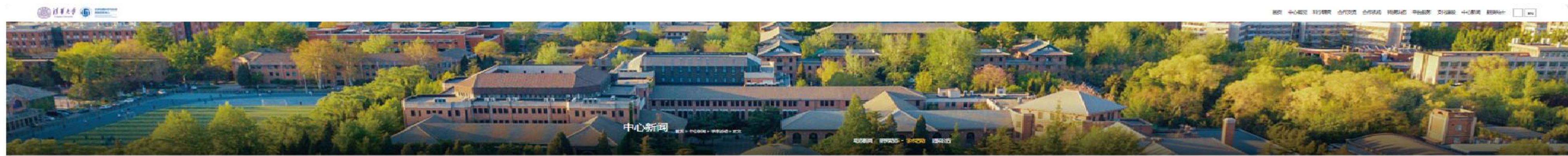
近5年,中国学者在国际学术会议上作全驱系统理论与应用方向的主旨报告50余次,其中包括国内外许多顶级会议,如:

- IEEE工业电子学会的顶级会议IEEE IECON 2023
 - 我国导航制导与控制领域顶级国际会议ICGNC 2022
 - 国际自动控制联合会时滞系统领域顶级会议IFAC TDS 2021
 - 机器人与自动化领域重要会议IEEE CYBER 2023
 - 国际先进机器人与机电一体化领域重要会议IEEE ARM 2020
 - 国际智能计算会议ICIC 2021
 - 控制与计算机视觉国际会议ICCCV 2022
 - 全驱系统理论与应用会议FASTA 2023
 - 国际数值优化和数值线性代数会议 ICNONLA 2025
 - 国际复杂性系统和智能科学会议 IEEE CSIS-IAC 2025
 - 第 40 届中国自动化学会青年学术年会 YAC 2025
- 我国控制理论界顶级国际会议CCC 2021
 - 我国控制与决策领域顶级国际会议CCDC 2021
 - 国际机器人领域顶级会议IEEE ICRA 2021
 - 国际优化领域重要会议POC 2023
 - 全国复杂网络学术会议 CCCN 2021
 - 全国预测控制与智能决策大会CPCID 2023
 - 计算机科学与智能控制国际会议ISCSIC 2023
 - 中国自动化大会CAC 2024
 - 国际数值优化和数值线性代数会议 ICNONLA 2025
 - 国际复杂性系统和智能科学会议 IEEE CSIS-IAC 2025
 - 第 40 届中国自动化学会青年学术年会 YAC 2025

重要大会主旨报告(2021-2025)

1. Guang-Ren Duan. Tracking Control in Satellite Optical Communication: A Parametric Comprehensive Design, *The 5th IEEE International Conference on Advanced Robotics & Mechatronics (IEEE ARM 2020)*, China, Shenzhen, 2020-12-19~2020-12-20.
2. Guang-Ren Duan. Controllability and Stabilizability: Frameworks in State-Space Approaches and Fully Actuated System Approaches, *Chinese Conference on Decision and Control (CCDC 2021)*, China, Kunming, 2021-05-22~2021-05-24.
3. Guang-Ren Duan. Full Actuation—From Physical to Mathematical, *2021 IEEE International Conference on Robotics and Automation (IEEE ICRA 2021)*, China, Xi’an, 2021-06-02~2021-06-03.
4. Guang-Ren Duan. State-Space Approaches vs Fully Actuated System Approaches, *Chinese Control Conference (CCC 2021)*, China, Shanghai, 2021-07-27~2021-07-30.
5. Guang-Ren Duan. Time-delay Systems: A Fully Actuated System Approach, *The 17th IFAC Workshop onTime-delay Systems (IFAC TDS 2021)*, China, Guangzhou, 2021-09-29~2021-10-01.
6. Guang-Ren Duan. Fully Actuated System Approach and Nonholonomic Systems, *2022 International Conference on Guidance, Navigation and Control (ICGNC 2022)*, China, Harbin, 2022-08-05~2022-08-07.
7. Guang-Ren Duan. Fully Actuated System Approach and Data Driven Control, *2023 IEEE 12th Data Driven Control and Learning Systems Conference (DDCLS 2023)*, China, Xiangtan, 2023-05-12~2023-05-14.
8. Guang-Ren Duan. Fully Actuated System Approach for Control, *International Conference on CYBER Technology in Automation, Control, and Intelligent Systems (IEEE CYBER 2023)*, China, Qinhuangdao, 2023-07-11~2023-07-14.
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- 12.Guang-Ren Duan. Full Actuated System Approach for Discrete-Time Systems, *2021 International Conference on Intelligent Computing (ICIC 2021)*, China, Shenzhen, 2021-08-11~2021-08-14.
- 13.Guang-Ren Duan. Full Actuated System Approach for Time Delay Systems, *The 17th Chinese Conference on Complex Networks (CCCN 2021)*, China, Beijing, 2021-10-29~2021-10-31.
- 14.Guang-Ren Duan. Fully Actuated System Approach—Background, Developments and Advances, *5th International Conference on Control and Computer Vision (ICCCV 2022)*, China, Xiamen, 2022-08-19~2022-08-20.
- 15.Guang-Ren Duan. Fully Actuated System Approach for Control—Results Overview and Further Problems, *2023 Conference on Fully Actuated System Theory and Applications (FASTA 2023)*, China, Qingdao, 2023-07-14~2023-07-16.
- 16.Guang-Ren Duan. Fully Actuated System Approach: An Overview, *The 38th Youth Academic Annual Conference of Chinese Association of Automation (YAC 2023)*, China, Hefei, 2023-08-27~2023-08-29.
- 17.Guangren Duan. Fully Actuated System Approach—Converting Nonlinearity to Linearity, *The 4th Chinese Conference on Predictive Control and Intelligent Decision (CPCID 2023)*, China, Guangzhou, 2023-05-05~2023-05-06.
- 18.Guang-Ren Duan. Fully Actuated System Approach for Control—Sub-Stability and Sub-Stabilization, *The 7th International Symposium on Computer Science and Intelligent Control (ISCSIC 2023)*, China, Nanjing, 2023-10-27~2023-10-29.
- 19.Guang-Ren Duan. Fully Actuated System Approach Theory—Backgrounds, Development Statuses and Application Progresses, *The 2024 China Automation Congress (CAC 2024)*, China, Qingdao, 2024-11-01~2024-11-03.
- 20.Guang-Ren Duan. Fully actuated system approach-A new framework for dynamic system control, *The 40th Youth Academic Annual Conference of Chinese Association of Automation (YAC 2025)*, China, Zhengzhou, 2025-05-17~2025-05-19.
21. Guang-Ren Duan. Fully Actuated System Approach and Its Applications, *The 35th Chinese Process Control Conference (CPCC 2024)*, China, Sanya, 2024-07-25~2024-07-27.
22. Guang-Ren Duan. Fully Actuated System Approach for Control — An Introduction, *The 7th International Conference on Robotics, Control and Automation Engineering (RCAE 2024)*, China, Wuhu, 2024-09-24~2024-09-25.
23. Guang-Ren Duan. System Control: From State-space Approach to Fully Actuated System Approach, *The 15th International Conference on Numerical Optimization and Numerical Linear Algebra (ICNONLA 2025)*, China, Harbin, 2025-08-04~2025-08-04-07.
24. Guang-Ren Duan. Sub-fully Actuated Systems and Dynamical System Control, *2025 International Annual Conference on Complex Systems and Intelligent Science(IEEE CSIS-IAC 2025)*, China, Shenzhen, 2025-05-16~2025-05-18.
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系列交叉论坛(第89期) - 在线听众人数39万



北京信息科学与技术国家研究中心系列交叉论坛(第八十九期) 举办

发布时间:2024-12-23 点击数:250

12月19日晚,北京信息科学与技术国家研究中心系列交叉论坛(第八十九期)通过线上会议和直播的形式举办,本次论坛邀请了中国科学院院士、自动控制领域专家段广仁作题为“全驱系统控制理论——诞生背景、发展现状与应用进展”的报告。论坛由清华大学信息学院院长、信息国家研究中心主任戴琼海院士和信息学院副院长任天令教授共同主持。信息国家研究中心党政联席会成员、群体负责人以及校外外师生等300余人通过腾讯会议在线参加论坛,累计约39万人次通过上直播、新浪、百度等直播平台在线观看。



段广仁作报告

尽管当今的控制工程领域依然繁荣发展,但控制理论体系早已面临困境。就在基础控制理论走向沉寂的时候,受物理上全驱系统的启发,段广仁团队于2020-2021年提出了一个全新的全驱系统理论体系的基本框架,得到了国内外众多控制学者的认同和参与。目前,在全体全驱系统方法研究者的共同努力下,一个全新的全驱系统理论体系已经形成,它在处理非线性、时变、时滞、不确定、复杂问题上显示了极其强大的优越性,为控制理论发展开辟了一条崭新的途径。报告中,段广仁详细阐述了全驱系统理论体系的形成背景、基本框架、主要成果、应用前景,并介绍了全驱系统理论体系的研究现状和应用进展做了系统的概述。



全驱系统方法进一步发展等问题进行了充分解读。

供稿 | 信息学院/信息国家研究中心联合办公室

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审核 | 丁贵广

<https://www.bnrst.tsinghua.edu.cn/info/1109/3371.htm>

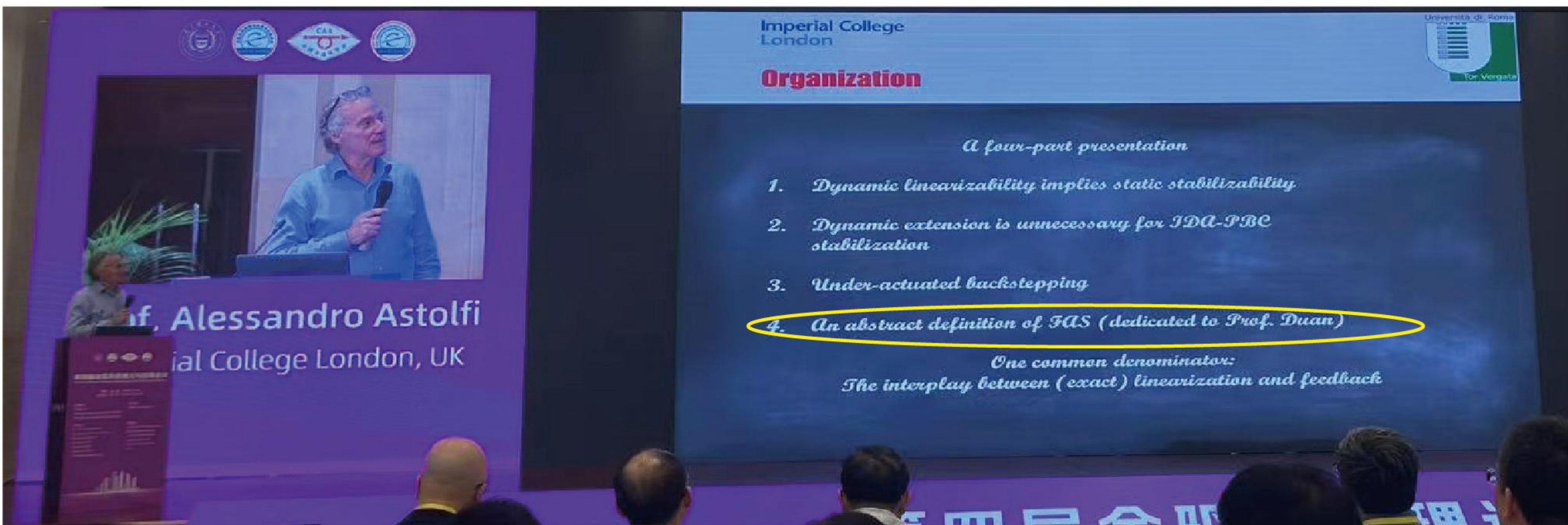
墨西哥科学院院士、*Journal of the Franklin Institute*前主编Michael V. Basin在国际学术会议上做大会报告

- ◆ The FAS approach was originally and constructively proposed by Prof. Duan via his set of 10 seminal papers published in *Int. J. Systems Science*.
 - ◆ His significant discoveries of the generalized mathematical FAS models allow him to establish a whole new framework for analysis and control of dynamical systems.
 - ◆ Unlike the state-space approach, the FAS approach possesses a natural advantage in controller designs, and obtains, completely or partially, constant linear closed-loop systems with desired eigenstructure.
 - ◆ By now, his ideas and works have attracted many researchers and have also inspired numerous new publications in this field.
 - ◆ I personally believe that the FAS approach surely will have a great impact on control.
- ◆ 全驱系统方法最初是由段广仁教授在国际系统科学杂志上发表的10 篇开创性论文中建设性地提出。
 - ◆ 他关于推广的数学的全驱系统模型这一重大发现让他建立了关于动态系统分析与控制的一个全新的体系框架。
 - ◆ 不同于状态空间方法,全驱系统方法在控制器设计上具有一个自然的优势:可以部分或完全地获得一个具有希望特征结构的定常线性闭环系统。
 - ◆ 目前他的思想和工作吸引了众多研究者,并且激发了该领域的大量论文。
 - ◆ 我个人相信,全驱系统方法一定会对控制科学与工程产生重大影响。



欧洲科学院院士、国际控制界顶级刊物《IEEE自动控制汇刊》主编、英国帝国理工教授 A. Astolfi在国际会议上做大会报告

- ◆ 非线性领域的著名专家A. Astolfi教授也加入了全驱系统方法的研究行列。他在大会报告中用20页PPT(整个报告共51页)介绍他在全驱系统方法方面的工作和想法,并在其报告PPT的目录页明确标注该部分工作是“献给段教授 (dedicated to Prof. Duan)”。
- ◆ 和许多学者一样, A. Astolfi教授先是对全驱系统方法持反对和怀疑的态度,随着他对全驱系统方法的进一步了解,如今他的态度也从反对和怀疑转向了接纳和认可,并且身心力行,已经开展了许多具体工作。



全驱系统理论方向的博士论文

◆ 已通过答辩的全驱系统理论方向的博士论文

序号	姓名	博士论文题目	学校	导师
1.	蔡 苗	高阶全驱系统的容错控制研究	清华大学	周东华
2.	郑 玥	预设性能下的列车编队运行全驱控制方法	北京交通大学	董海荣
3.	刘寅东	二阶伪线性系统的参数化控制方法研究	沈阳工业大学	王丽梅
4.	宁鹏举	不确定非线性系统自适应预设时间控制	燕山大学	华长春
5.	孟 蕊	下三角非线性随机系统预设约束控制	燕山大学	华长春
6.	赵 琴	具有惯性参数辨识的组合体航天器位姿联合控制	哈尔滨工业大学	段广仁
7.	田广泰	不确定二阶系统的鲁棒模型参考跟踪及其应用	哈尔滨工业大学	段广仁
8.	刘卫振	不确定高阶严反馈系统的指令滤波反步法控制设计	哈尔滨工业大学	段广仁
9.	高亚军	几类不确定高阶系统的控制方法研究	哈尔滨工业大学	段广仁
10.	王秀博	非线性全驱系统的预测控制及应用	哈尔滨工业大学	段广仁
11.	崔凯鑫	基于离散全驱系统方法的一类组合航天器的位姿控制	哈尔滨工业大学	段广仁
12.	赵天一	基于状态观测器的控制系统参数化设计及其应用	哈尔滨工业大学	段广仁
13.	杨义鹏	面向空中操作的过驱动矢量旋翼飞行系统建模与控制	哈尔滨工业大学	高会军
14.	张大蔚	网络化高阶全驱多智能体系统的预测协同控制	哈尔滨工业大学	刘国平
15.	段广全	基于全驱系统方法的组合航天器位姿控制	哈尔滨工业大学	刘国平
16.	范睿超	空间非合作目标捕获任务的位姿规划与控制方法	哈尔滨工业大学	刘 明
17.	张高望	带有旋扫成像载荷的航天器姿态控制方法研究	哈尔滨工业大学	刘 明 王 峰
18.	田聪聪	有向图下不确定多智能体系统的分布式一致性与博弈	哈尔滨工业大学（深圳）	梅 杰
19.	黄 奕	新能源发电系统的网络化预测控制与优化研究	武汉大学	刘国平
20.	胡利耀	不确定全驱系统的鲁棒自适应保性能控制	哈尔滨工业大学	段广仁
21.	刘雪庆	随机全驱系统的容错控制研究	清华大学	周东华
22.	朱令臣	下三角结构关联时滞非线性系统的性能约束控制	燕山大学	张柳柳

◆ 当前在研的全驱系统理论方向的博士论文

序号	姓名	博士论文题目	学校	导师
1.	尉俊超	基于全驱系统方法的欠驱动机器人系统的安全控制研究	曲阜师范大学	张中才
2.	龚梦彤	不确定高阶亚全驱系统的容错控制研究	清华大学	周东华
3.	章招铭	基于全驱系统方法的方位角观测编队控制	上海交通大学	杨紫雯
4.	卢 园	基于全驱系统方法的无人机编队容错控制与动态航路规划	南京航空航天大学	张 柯
5.	莫智斌	基于全驱系统方法的多机器人协同控制理论与应用	中山大学	刘万泉
6.	李元恩	基于全驱系统方法的非线性脉冲系统控制	中山大学	刘万泉
7.	赵玉卓	基于全驱系统理论的热声耦合系统自适应主动控制方法研究	东北大学	马 丹
8.	高 阳	基于全驱系统方法的欠驱动起重机防摆摇控制研究	东南大学	郭 雷 武玉强
9.	黄勤博	基于全驱系统方法的脉冲系统分析与控制	同济大学	孙继涛
10.	刘泉志	基于观测器的挠性航天器姿态控制方法研究	吉林大学	张 刘
11.	马永浩	基于全驱系统方法的异构多智能体系统协同容错控制	南京航空航天大学	姜 斌
12.	刘清怡	非线性物理和网络互联系统的容错控制及优化研究	南京航空航天大学	张 柯
13.	孟 波	非线性无人机编队自适应容错控制及最优任务分配	南京航空航天大学	张 柯
14.	杨蕴思	有限域线性动态控制系统的高阶全驱系统方法	山东大学	冯俊娥

序号	姓名	博士论文题目	学校	导师
15.	于 淼	有限域非线性动态系统的高阶全驱系统方法	山东大学	冯俊娥
16.	吴晨彬	基于全驱系统理论的无人集群体系决策控制一体化方法研究	中国地质大学（武汉）	葛明峰
17.	陈 谦	基于分层强化学习的不确定无人集群系统全驱优化调控方法研究	中国地质大学（武汉）	葛明峰
18.	李一凡	基于全驱系统方法的混杂智能无人系统协同与博弈策略研究	中国地质大学（武汉）	葛明峰
19.	高嘉伟	高动态对抗环境下多机器人系统的全驱控制与自主决策方法研究	中国地质大学（武汉）	葛明峰
20.	王 坦	基于全驱系统方法的互联非线性系统控制研究	南方科技大学	段广仁
21.	任炜杰	基于全驱系统方法的主动故障诊断与容错控制	南方科技大学	段广仁
22.	王京旭	非线性系统的全驱预测控制方法与应用	南方科技大学	刘国平
23.	张 恒	基于深度强化学习的起重系统全驱控制方法研究	燕山大学	丁伟利
24.	周晓双	基于全驱系统理论一类欠驱非线性系统的滑模控制	燕山大学	杨亚娜
25.	崔海龙	基于全驱系统方法的多智能体事件触发控制	燕山大学	赵广磊
26.	姜慧欣	基于全驱系统理论的遥操作机器人系统的控制	燕山大学	杨亚娜
27.	周家峰	具有输出约束和输入时滞的液压伺服机器人高性能控制	燕山大学	华长春
28.	庞可立	面向参数不确定全驱系统的有限 / 固定时间复合学习控制研究	燕山大学	华长春
29.	冯帅刚	全驱非线性时滞多智能体系统一致性控制研究	燕山大学	李亚峰
30.	潘文龙	基于全驱系统理论的不确定非线性系统切换控制	燕山大学	华长春
31.	张 波	未知参数下的机器人自适应全驱控制研究与应用	燕山大学	段广仁
32.	肖永强	基于全驱系统方法的高阶严反馈系统自适应控制研究	火箭军工程大学	蔡光斌
33.	位亚东	无电解电容单级PFC变换器及其神经网络建模与全驱控制	华南理工大学	张 波
34.	蒋 宏	基于观测器的全驱系统控制器设计	哈尔滨工业大学	段广仁
35.	李顺利	全驱系统的输出反馈可稳性及其性能极限研究	哈尔滨工业大学	段广仁
36.	曹世达	基于全驱系统方法的不全信息包围控制	哈尔滨工业大学	段广仁
37.	张仕钰	不确定高阶全驱系统的鲁棒控制设计	哈尔滨工业大学	段广仁
38.	陈志俊	基于全驱系统方法的自适应鲁棒轨迹跟踪控制及应用	哈尔滨工业大学	段广仁
39.	刘 林	非线性全驱系统的量化控制研究	哈尔滨工业大学	段广仁
40.	张 雪	基于全驱系统方法的临界有理系统有限时间控制	哈尔滨工业大学	段广仁
41.	张俊宁	基于高阶全驱系统方法的多指灵巧手自主操控研究	哈尔滨工业大学	段广仁
42.	刘 宇	时滞系统的微分平坦性和全驱化研究	哈尔滨工业大学	李朝艳
43.	金东焱	基于全驱系统理论的航天器姿轨一体化控制研究	哈尔滨工业大学	邱剑彬
44.	贾世翔	基于全驱系统方法的航天器姿态容错控制与编队控制研究	哈尔滨工业大学	邱剑彬
45.	张立轩	全驱多智能体系统的一致性研究	哈尔滨工业大学	周 彬
46.	方乐言	带修正参数估计的非线性自适应迭代学习控制	哈尔滨工业大学	侯明哲
47.	肖辅政	基于对偶四元数的充液航天器无退绕全驱系统位姿控制	哈尔滨工业大学（深圳）	陈立群
48.	王天翼	基于全驱系统理论的航天器姿轨一体化控制	哈尔滨工业大学（深圳）	吴爱国
49.	陈宇轩	高阶亚全驱系统的抗饱和和鲁棒控制	哈尔滨工业大学（深圳）	吴爱国
50.	罗毓聪	基于全驱系统方法的航天器近距离逼近控制方法研究	哈尔滨工业大学（深圳）	吴伟仁 马广富
51.	李 志	基于全驱系统方法的预设时间控制及应用	哈尔滨工业大学（深圳）	张 颖
52.	王 艺	高阶全驱网络系统的全局同步牵制控制	哈尔滨工业大学（深圳）	赵 毅
53.	王一峰	基于深度全驱系统方法的惯性导航与定位技术研究	哈尔滨工业大学（深圳）	赵 毅

全驱系统理论与应用青年研究基金

为了支持国内控制理论界青年学者在全驱系统控制理论方向做出优秀成果,段广仁院士依托其负责的国家自然科学基金基础科学中心项目和黑龙江省头雁计划项目,设立了全驱系统理论与应用青年基金。该基金针对教师项目的资助额度为20万元/人,针对博士生项目的资助额度为2万元/人。

受资助单位	年份	教师	博士生	金额 (万元)
哈尔滨工业大学	2022	7	6	152
	2023	13	18	296
	2024	5	2	104
燕山大学	2021	4	1	82
	2022	7	6	152
	2023	4	6	92
哈尔滨工业大学 (深圳)	2022	/	4	8
	2023	8	3	166
	2024	2	4	48
南京航空航天大学	2022	6	/	120
	2023	3	/	60
山东大学	2022	4	4	88
	2023	4	/	80
上海交通大学	2022	5	/	100
	2023	2	/	40
聊城大学	2023	1	/	20
曲阜师范大学	2023	1	/	20
辽宁科技大学	2023	1	/	20
中山大学	2025	1	/	20
东北大学秦皇岛分校	2025	1	/	20
合计		79	54	1688



全驱系统理论与应用青年基金获得者合影 2024年5月 深圳

四、应用篇

代表性应用论文

截至2025年6月，FAS方法已在多个领域中得到广泛应用，共发表相关应用论文140余篇。这里仅列举其中具有代表性的100篇，涵盖航天器控制、无人机控制、机器人控制以及其他控制领域，其中标注“*”的为带有实验验证的FAS控制应用论文。

航天器控制代表性论文（34篇）

[1] *Kai-Xin Cui, Guang-Ren Duan, and Yang Cui, “Discrete-time high-order **fully actuated** robust stabilization control for a type of combined spacecraft subject to uncertainties,” *Asian J. Control*, 2025, doi: 10.1002/asjc.3574.

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其他应用方面代表性论文（27 篇）

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非完整系统

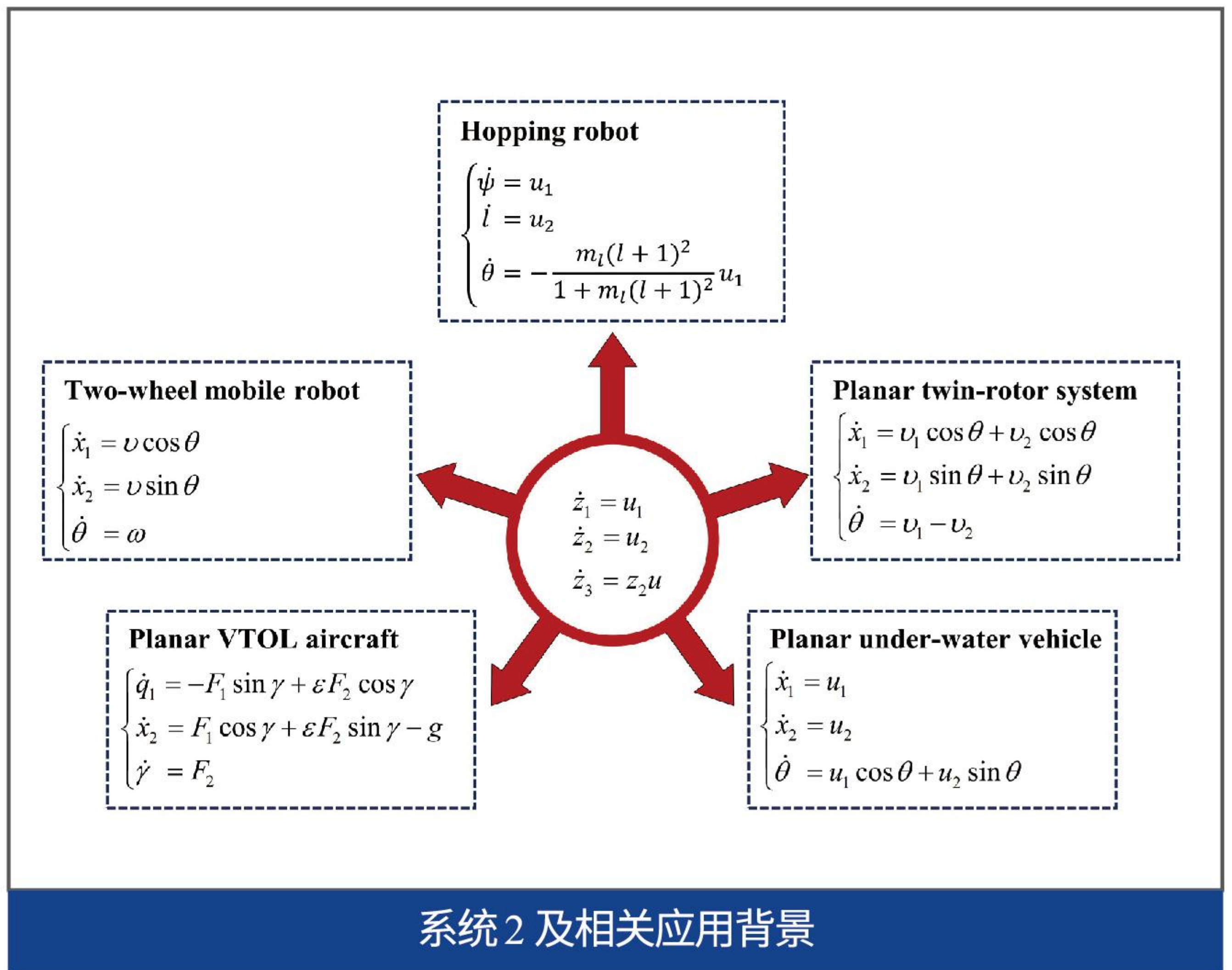
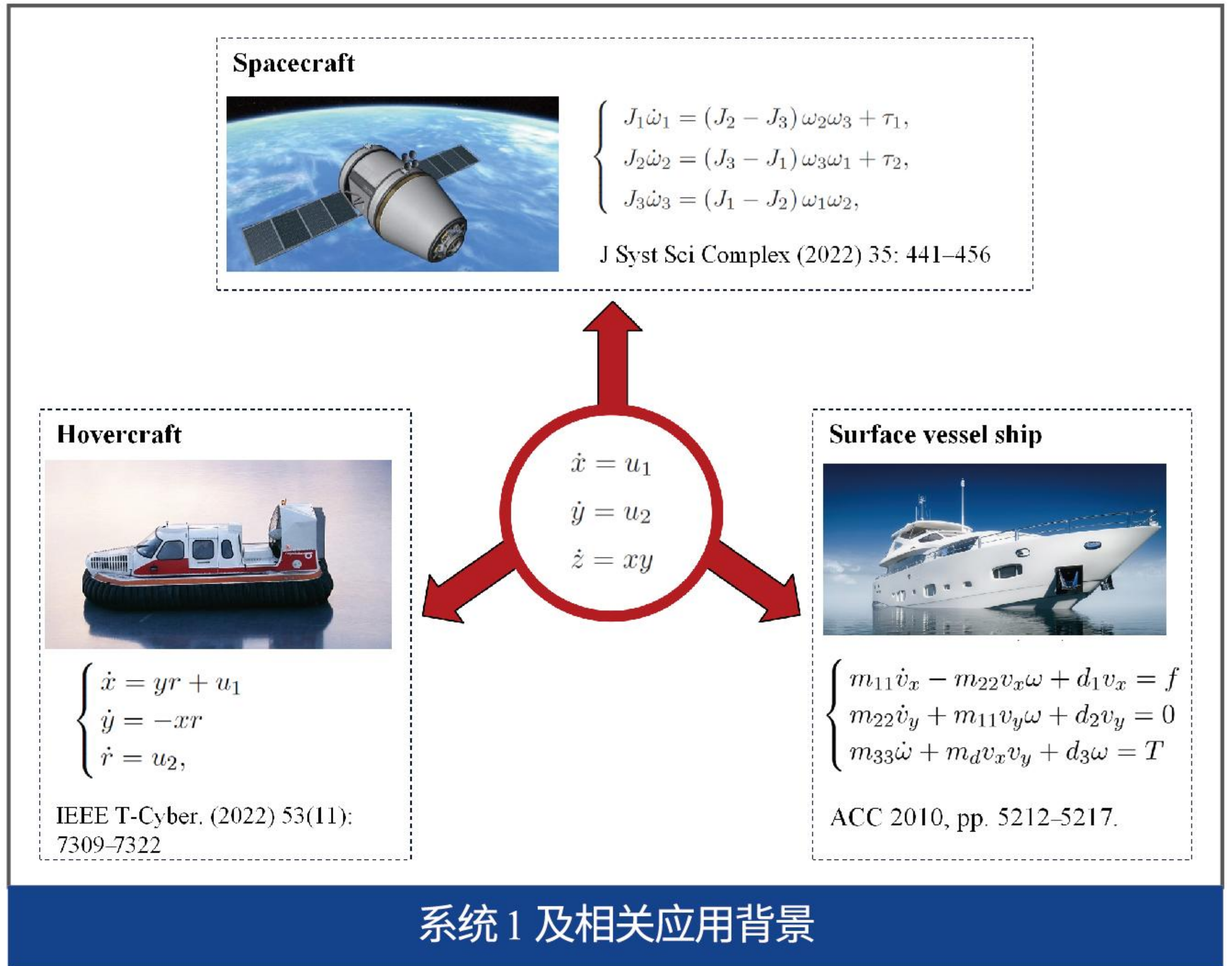
■ 著名非线性理论科学家Roger W.

Brockett于1983年在其题为“Asymptotic stability and feedback stabilization”的论文讨论了两个典型的非线性系统, 引发了人们后续关于非完整系统的热烈探讨。

■ 虽然两个系统描述都极其简单, 但却都有多方面应用背景。

由于其非完整特性, 他们被称之为“deceivingly simple looking”、“tough and thorny”, 不存在光滑甚至连续的时不变反馈控制律。

■ 基于全驱系统方法, 这两个典型系统的镇定问题得到圆满解决, 其结果亦被推广到带有时滞的更加一般的时变非完整系统上。



非完整系统方面的代表性论文

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航天器控制应用

单体/编队卫星的姿轨控制

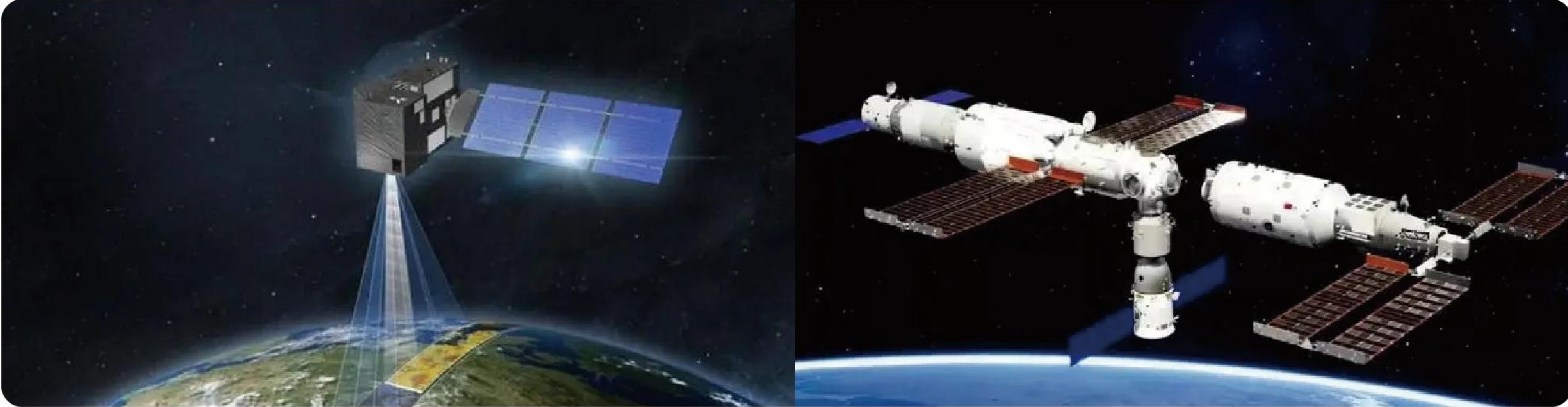
针对时变转动惯量、执行机构饱和、姿态指向约束等复杂情形,基于欧拉角、四元数、姿态旋转矩阵、修正罗德里格斯参数等航天器运动学模型,研究了基于全驱系统理论的刚体、充液、挠性、编队卫星的姿态机动控制、姿态跟踪控制、最优控制、预设性能控制等问题[8],[15]。

航天器交会对接姿轨一体化控制

针对空间航天器在轨操控中的交会、绕飞、对接等关键任务,考虑空间干扰力矩、执行机构饱和、非合作目标、无线网络通讯等复杂约束,研究了基于全驱系统理论的航天器交会对接过程中姿轨耦合情形下的扰动观测器、预设时间控制、预测控制、自适应预设性能控制、自适应迭代学习控制等问题[6]。

组合体航天器姿轨一体化控制

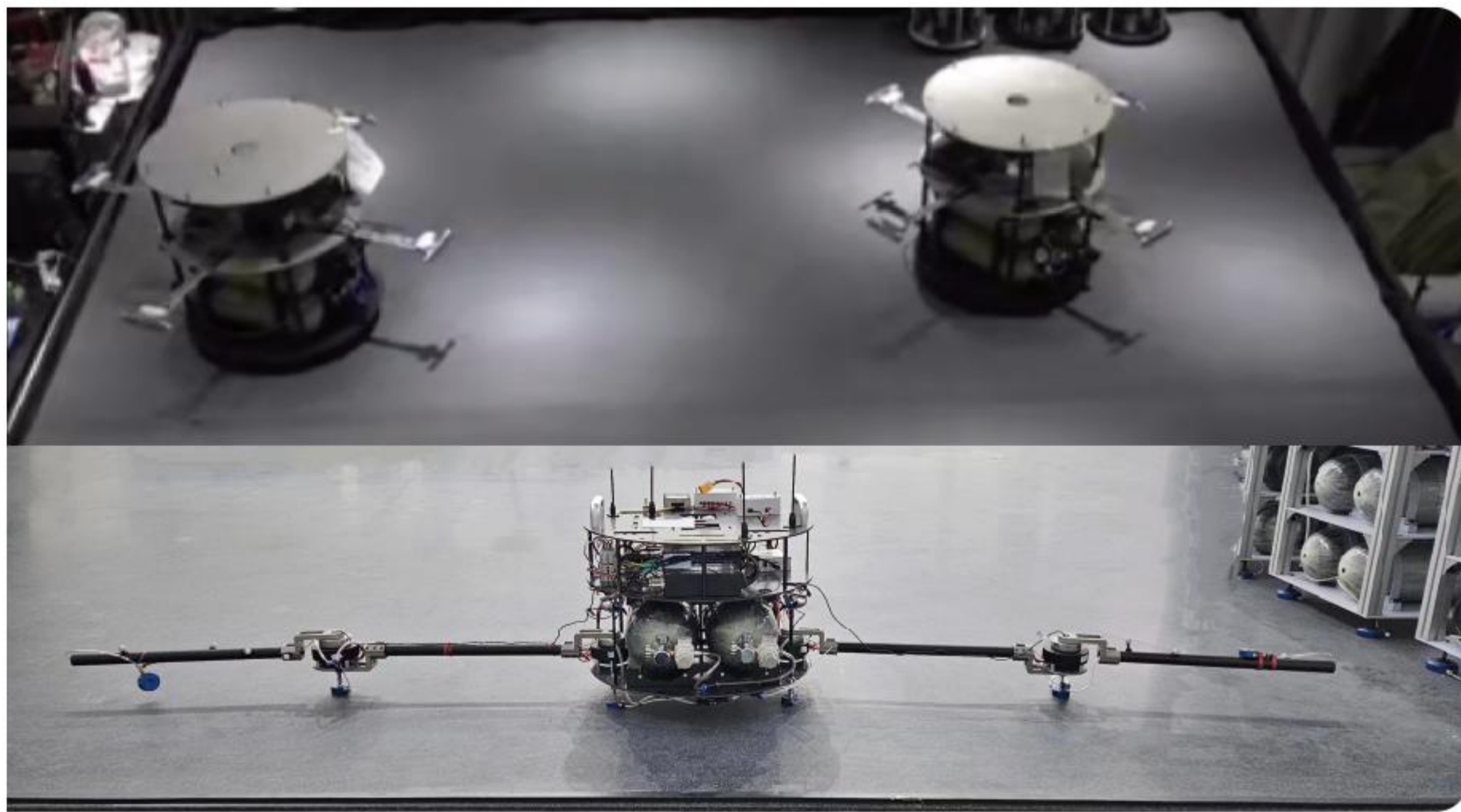
针对存在未知模型参数、空间干扰力矩等影响的组合航天器的位置和姿态控制问题,考虑其由于航天器组合导致的复杂运动学约束以及未知模型参数,分别在连续和离散时间域内研究了基于全驱系统理论的位姿耦合一体化控制、最优控制、预设性能控制、抗干扰控制以及制导律设计等问题[1],[3]。



高速飞行器全驱系统控制方法及综合仿真验证
航天三院魏毅寅院士团队:针对高速飞行器在宽域飞行状态下的强非线性、强耦合性,进而超出传统控制系统边界的问题,开展了基于全驱系统理论的高速飞行器姿态二阶全驱系统模型建立、全驱姿态控制方法设计等研究工作,并为下一步的工程应用奠定了良好的理论基础。



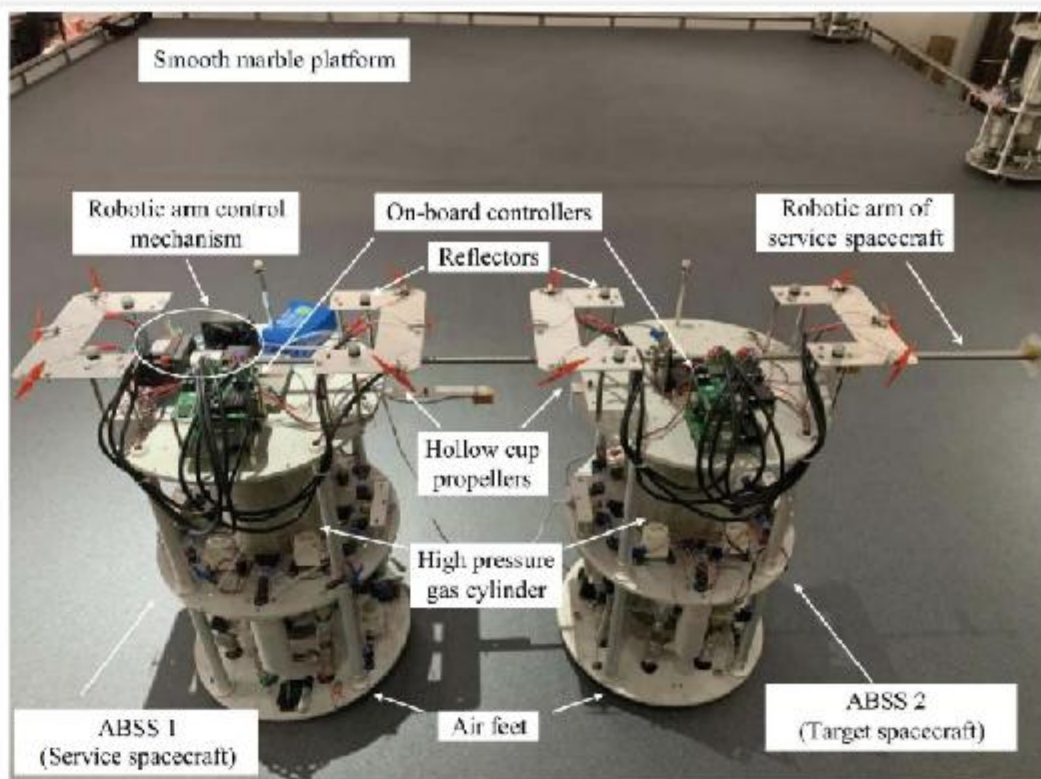
基于气浮台的编队卫星、空间机械臂半物理仿真验证
哈工大曹喜滨院士团队:搭建了多气浮台卫星模拟器编队、双臂空间机械臂的半物理仿真演示验证系统,开展了基于全驱系统理论的卫星轨道协同控制算法、空间双臂机械臂位姿控制算法的仿真验证工作,充分展示了全驱系统控制理论在航天器中的应用性和有效性。



航天器模拟器控制实验

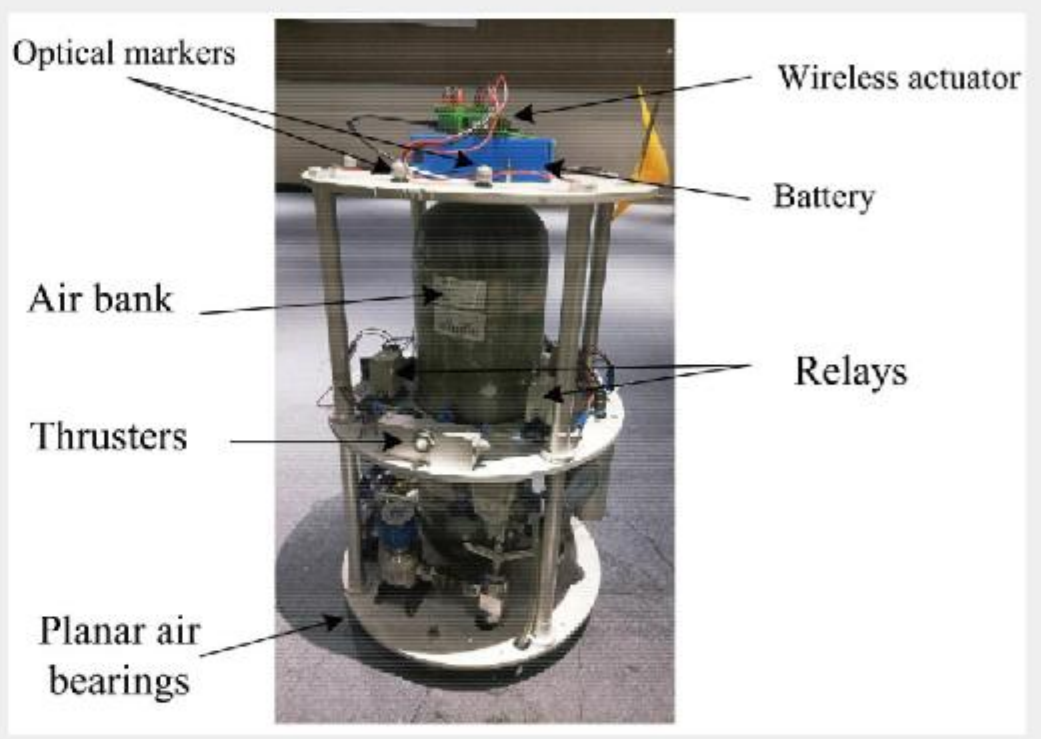
组合航天器模型参考跟踪控制

针对一类具有扰动的组合航天器模拟器的模型参考跟踪控制问题,提出了基于全驱系统模型的离散时间参考跟踪控制方法,该方法不仅可以很好地处理组合航天器的非线性项,得到特征结构可任意配置的线性闭环系统,而且还提供了简单直观和数值稳定的控制器完全参数化设计方法[2]。



航天器多智能体安全预测控制

针对网络化多智能体系统在DoS攻击下的输出跟踪控制问题,提出了基于全驱系统模型和Diophantine方程的安全预测控制方法。该方法通过多步输出预测实现了跟踪性能的优化和随机DoS攻击造成的随机数据丢失和混乱的补偿,其可行性通过气浮台航天器模拟器的跟踪控制实验得到了验证[26]。



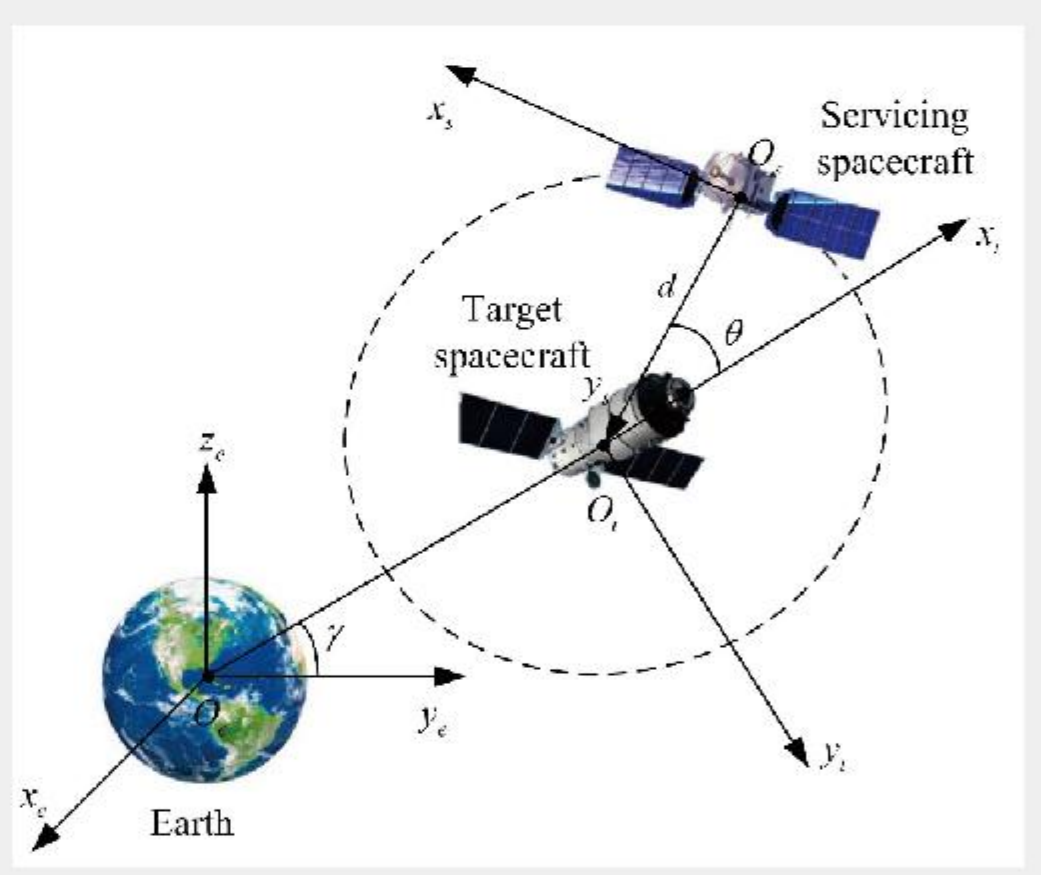
航天器多智能体协同控制

针对具有通信延迟的网络化高阶全驱多智能体系统的协同控制问题,提出了一种比例积分预测控制方案。该方案利用基于Diophantine方程建立增量高阶全驱预测模型而不是降阶的预测模型,通过多步输出预测完成考虑协作性能的成本函数优化和通信延迟补偿,从而构造最优协同控制器。为验证所提算法的有效性,应用到了气浮台航天器模拟器的协同控制实验中[30]。



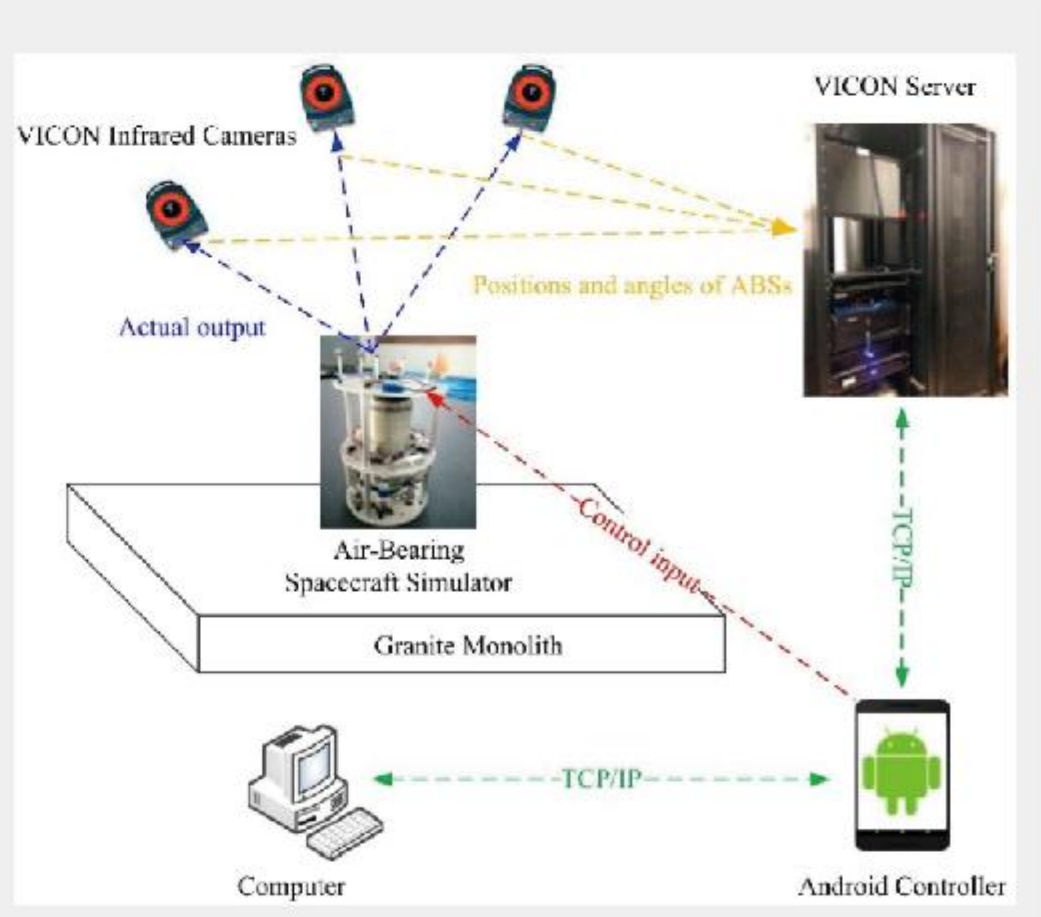
航天器绕地飞行预测控制

针对航天器在视点坐标系下绕地飞行控制问题,提出了一种基于高阶全驱系统方法和Diophantine方程的控制方案,应用非线性高阶全驱系统模型建立航天器绕地飞行的相对动力学,实现了多步超前预测,优化了跟踪控制性能,保证了给定绕地飞行任务的实现,开展了基于气浮台航天器模拟器绕地飞行的验证实验[22]。



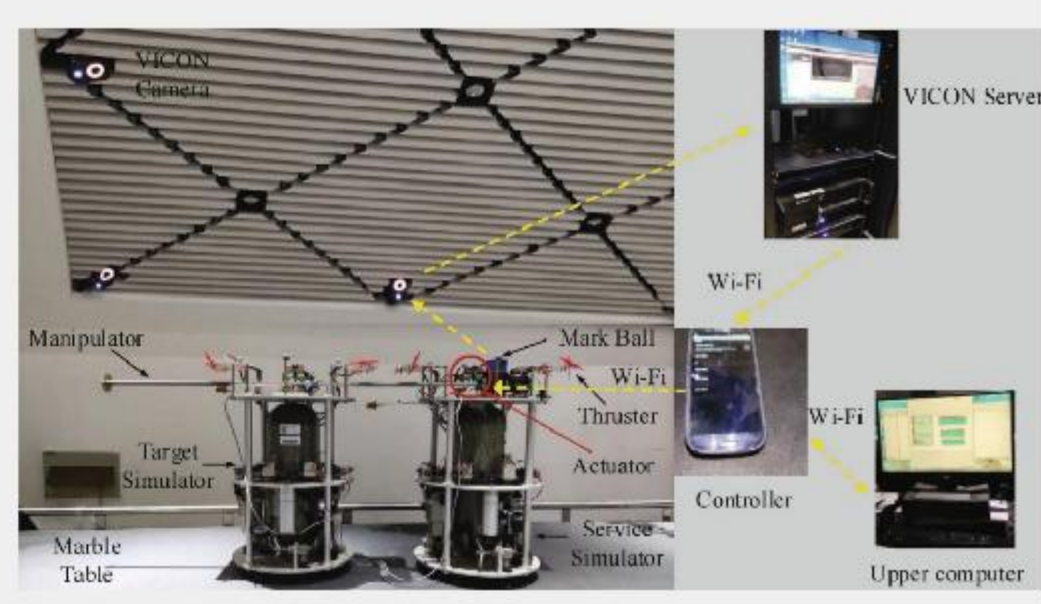
航天器离散时间预测控制

针对离散时间系统的输出跟踪控制问题,提出了基于高阶全驱系统方法的预测控制策略。该策略采用Diophantine方程构建了增量高阶全驱预测模型来代替降阶预测模型,并利用多步超前输出预测最小化跟踪性能的成本函数,实现了最优跟踪控制性能,开展了基于气浮台航天器模拟器的可行性验证实验[29]。



组合航天器姿轨最优控制

针对不具备自主控制能力的目标航天器被服务航天器捕获后形成的组合航天器,研究了其姿态和轨道控制问题,提出了基于全驱系统方法的组合航天器姿态镇定和轨道镇定的最优控制器,开展了基于联合航天器模拟器的物理实验,验证了所提方法的有效性和实用性[5]。



无人机控制应用

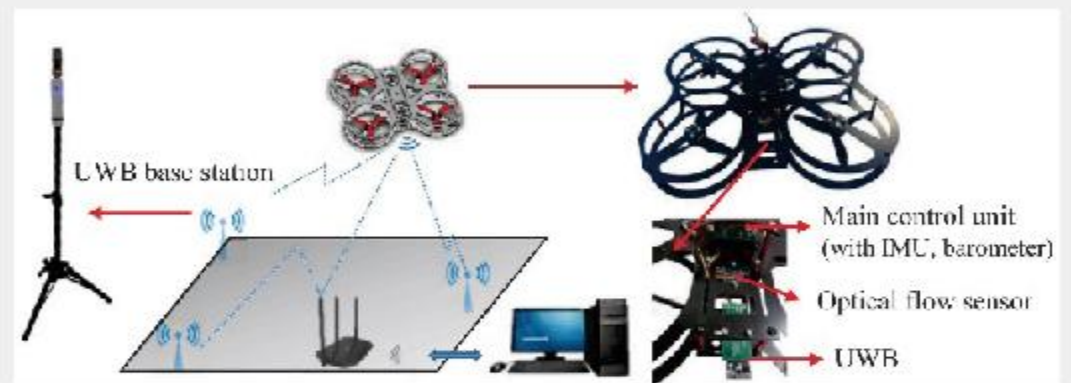
无人机机械臂捕获控制

哈尔滨工业大学高会军团队:针对飞行器机械臂系统的不确定性和扰动的控制问题,提出了基于高阶全驱系统方法的固定时间控制器和固定时间干扰观测器的控制策略,利用隐式Lyapunov函数确保了控制系统的有限时间收敛性,并在飞行实验中验证了该系统的6-DOF轨迹跟踪、抗干扰、抓取和放置未知质量物体的能力[40]。



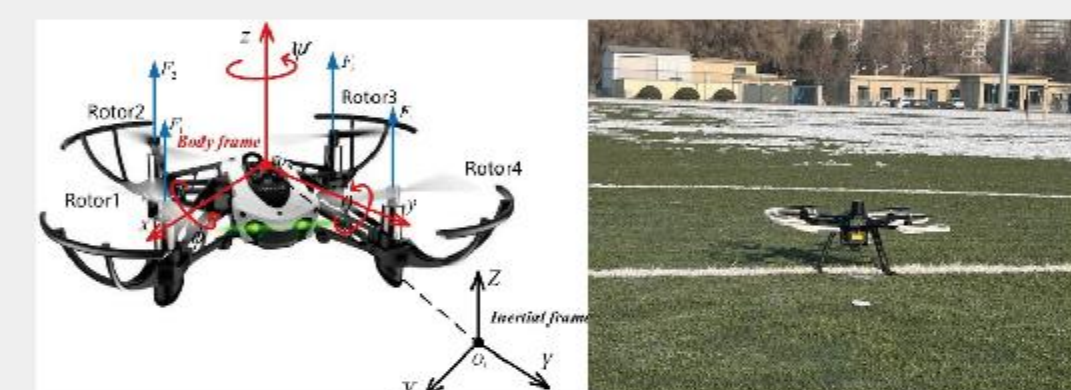
四旋翼无人机跟踪控制

针对混合约束下欠驱动四旋翼无人机的最优跟踪问题,提出了一种新的重构模型和全驱系统方法的预测控制方案,将具有混合约束的复杂非线性优化问题转化为具有线性约束的多个解耦线性优化问题,从根本上减少了非线性优化的计算量,保证了四旋翼无人机控制系统的稳定性和实时性[52]。



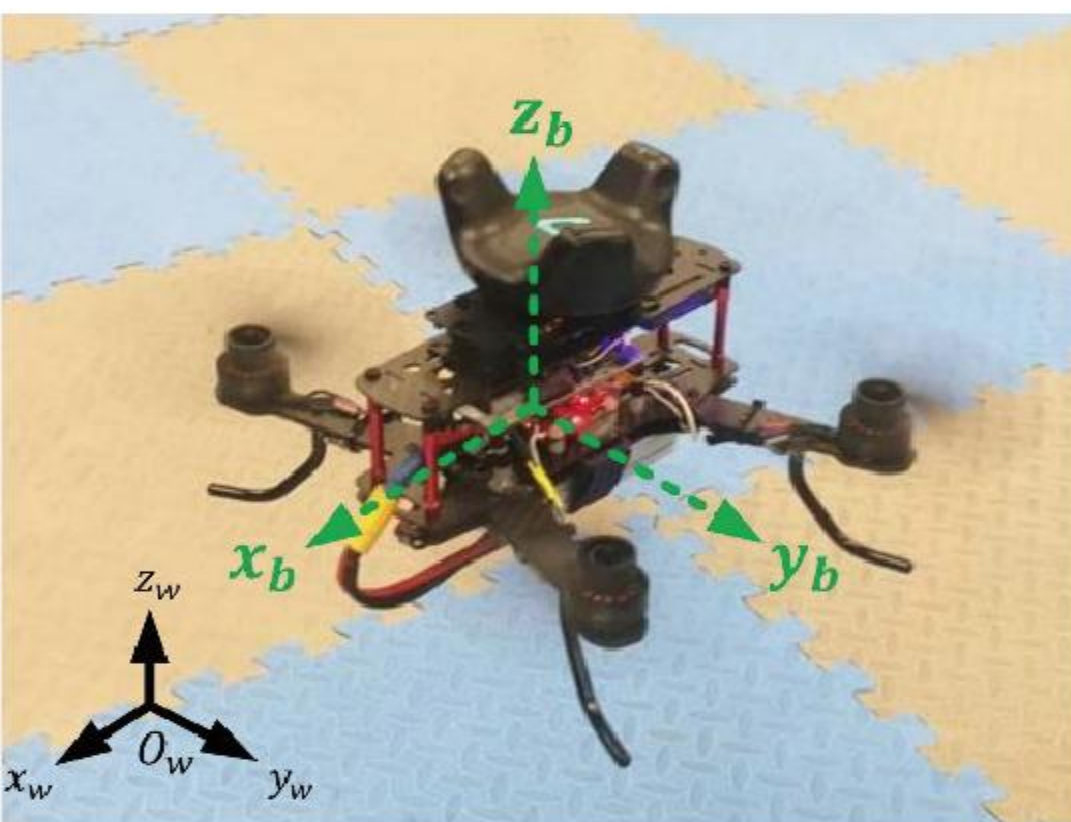
四旋翼无人机位姿控制

针对四旋翼无人机的位置和姿态控制问题,提出了基于张量积模型变换和部分全驱系统理论的双环控制器设计方法。该方法充分利用了全驱特性,具有简单,任意极点放置,易于参数设计和测试验证等一系列优点。在Parrot Mambo迷你无人机MFP450上开展了实验研究,验证了所提算法的有效性[35]。



四旋翼无人机平面运动控制

针对一类不能直接转换为伪严格反馈形式的无人机非线性系统,提出了一种改进的高阶全驱系统方法,克服了状态空间方法和Lyapunov函数无法完全解决无人机分层控制的难题,应用到了3-DOF四旋翼无人机的平面运动控制器设计问题中,实现了可任意特征结构配置的线性系统动态响应[45]。



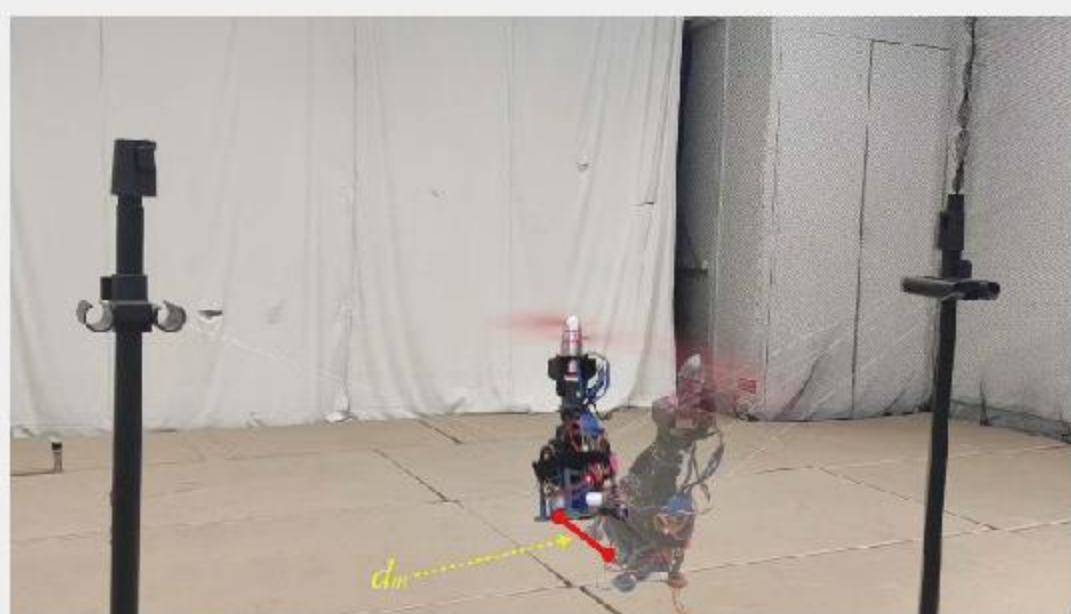
直升机容错编队控制

南京航空航天大学姜斌团队:针对多架直升机编队控制问题,提出了基于增量全驱系统方法的预设时间容错编队控制策略,以同时应对传感器故障和桨盘支杆执行器故障。此外,提出了一种“任务-故障”双驱动的预设时间参数调度机制,用于快速激活预设时间功能。基于 Lyapunov 稳定性理论,证明了该控制方案具有预设时间收敛性[51]。



共轴双桨无人机位置控制

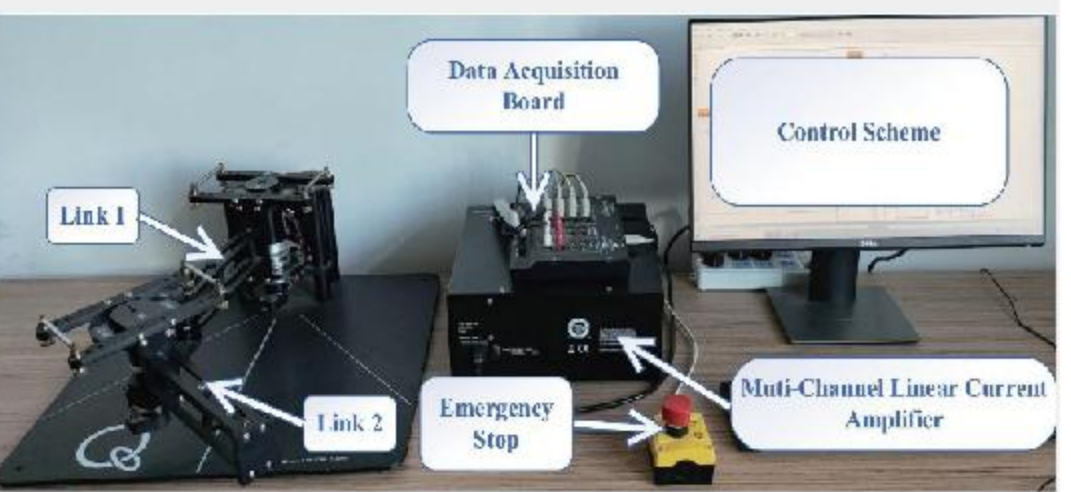
针对带有两个对转螺旋桨的共轴双桨无人机,提出一种基于全驱系统方法的位置和姿态控制向量分配和控制器设计方法,可产生期望的力矩来实现无人机位置变量和偏航角的期望控制目标,通过数值仿真和物理实验,验证了无人机设计、所建立的模型和所提出的控制策略的有效性[36]。



机器人控制应用

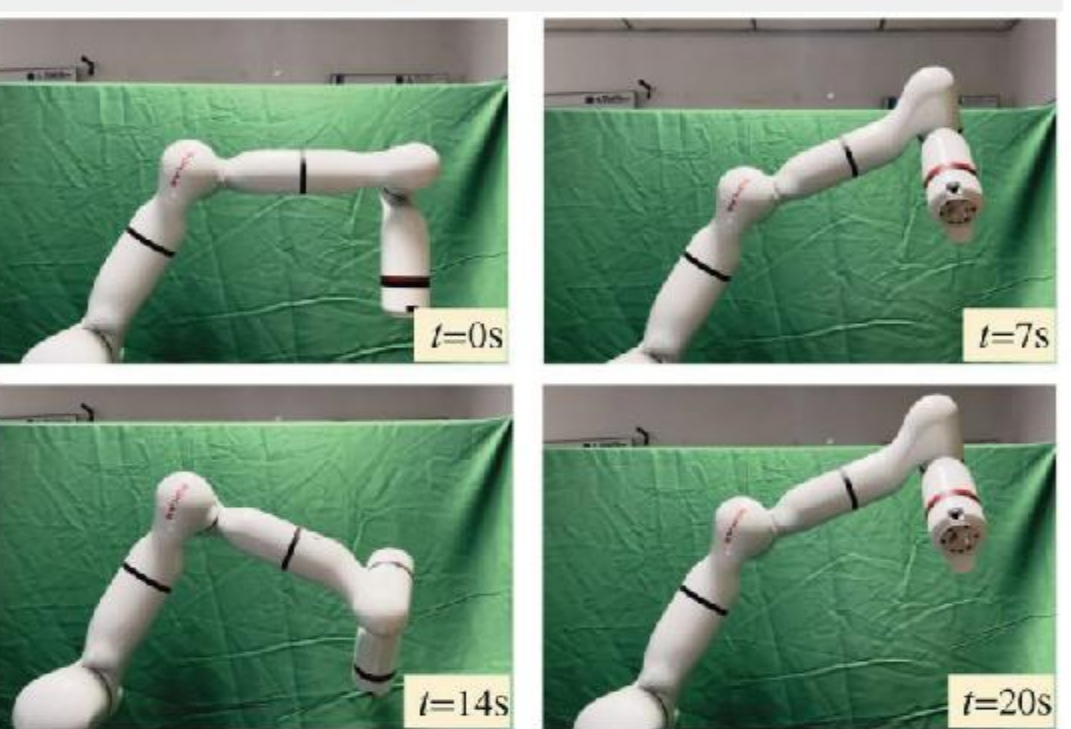
柔性关节机器人

韩国科学院院士Ju H. Park团队:考虑动态时间触发通信、暂态性能约束等影响,提出了基于全驱系统理论的柔性关节机器人事件触发控制方法,降低了柔性关节机器人控制系统设计的计算复杂度,有效地克服了传统反步法的缺陷,在Quanser二连杆柔性机器人平台上开展了实验研究,验证了所提控制策略的可行性和优越性[68]。



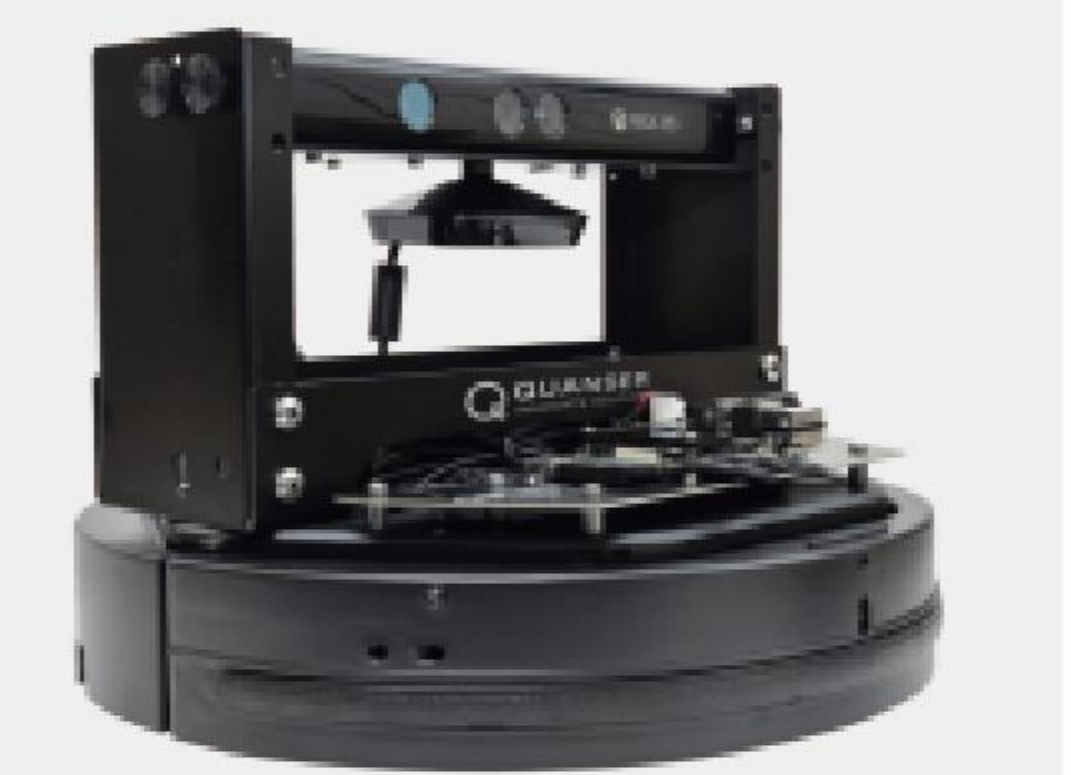
工业机械臂

中科院自动化所乔红院士团队:考虑状态约束、不确定模型动态等复杂情形,提出了基于全驱系统理论的工业机械臂管式滑模预测控制方法,采用神经网络对系统未知动态部分进行补偿,保证了系统状态估计误差在一个管状不变集内变化,在xMate7 Pro工业机械臂上开展了对比实验研究,验证了所提控制方法的有效性[58]。



轮式机器人

针对存在扰动和模型不确定性的链式非完整系统的控制问题,提出了一种基于全驱系统模型的镇定控制方法,设计了基于傅里叶变换技术的观测器来估计系统状态和扰动,利用输出反馈控制和基于继电器开关特性的控制,实现了系统状态的指数收敛或渐近稳定,并应用到了Qbot2e轮式机器人的控制系统设计问题中[56]。



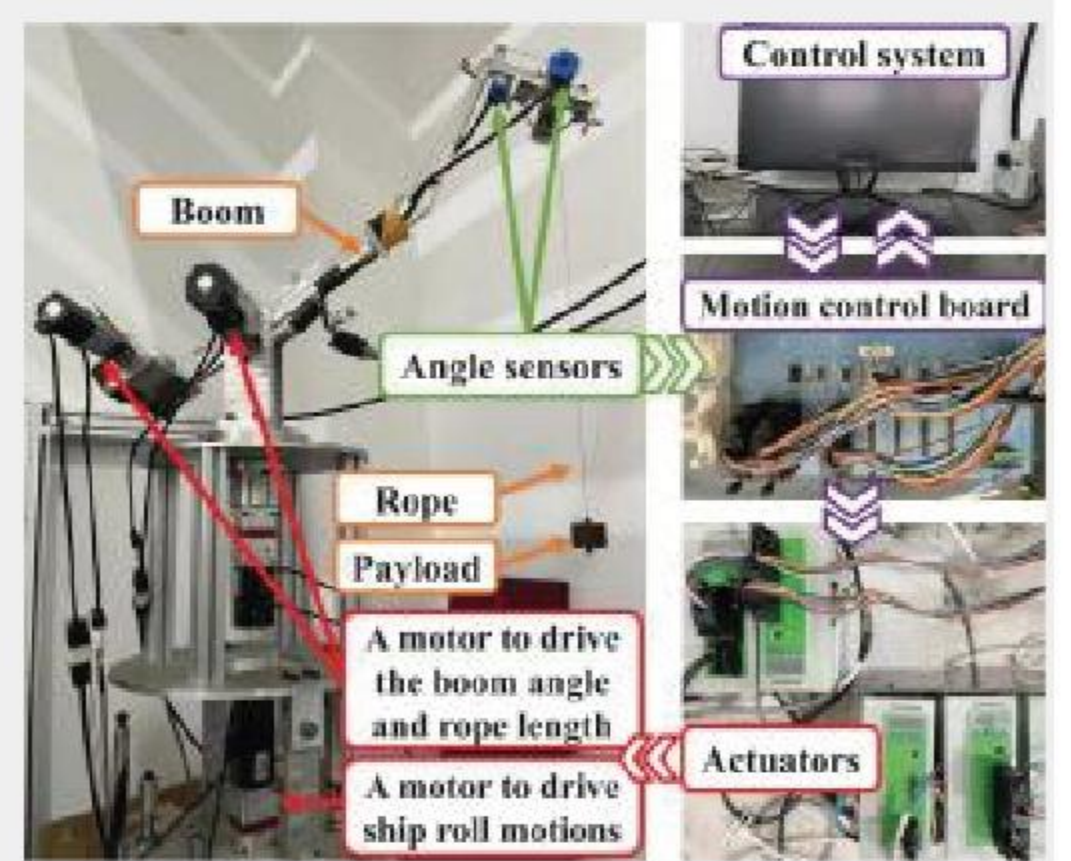
柔性关节机械臂

针对一类不确定柔性关节机械臂(FJM)系统,提出了一种基于高阶全驱系统方法的预设时间复合模糊自适应轨迹跟踪控制。相较于传统基于反步法的状态空间方法,应用于FJM系统的高阶全驱系统方法减轻了计算负担,提升了系统的运行效率。此外,创新性地提出了一种复合模糊自适应控制方案,通过引入预设时间非奇异积分滑模控制律,不仅提升了瞬态响应速度,也极大地提高了稳态跟踪精度[57]。



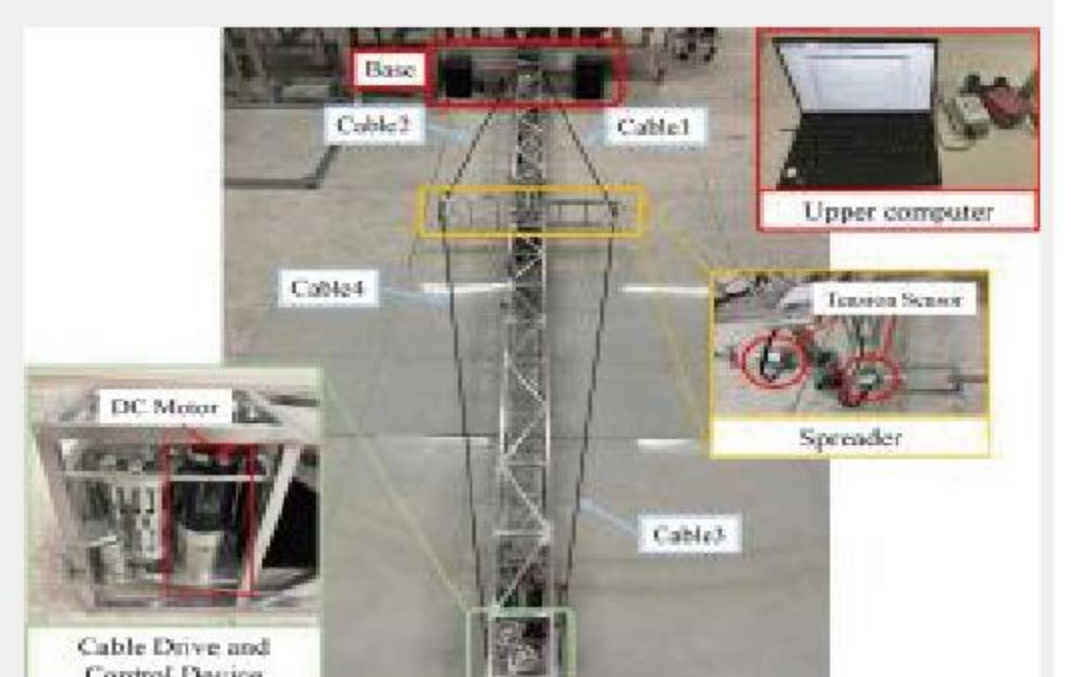
欠驱动机器人

针对欠驱动机器人的状态估计和延迟,提出了一种基于全驱系统方法的神经自适应控制器。首先,设计了一组高阶辅助变量,将非线性欠驱动系统重构为高阶线性全驱系统;然后,利用全驱系统固有的特性与优势,提出了一种适用于一类欠驱动机器人的连续自适应控制器;最后,提供了理论分析和若干实验验证结果,证明了所提方法的有效性[69]。



空间机械臂

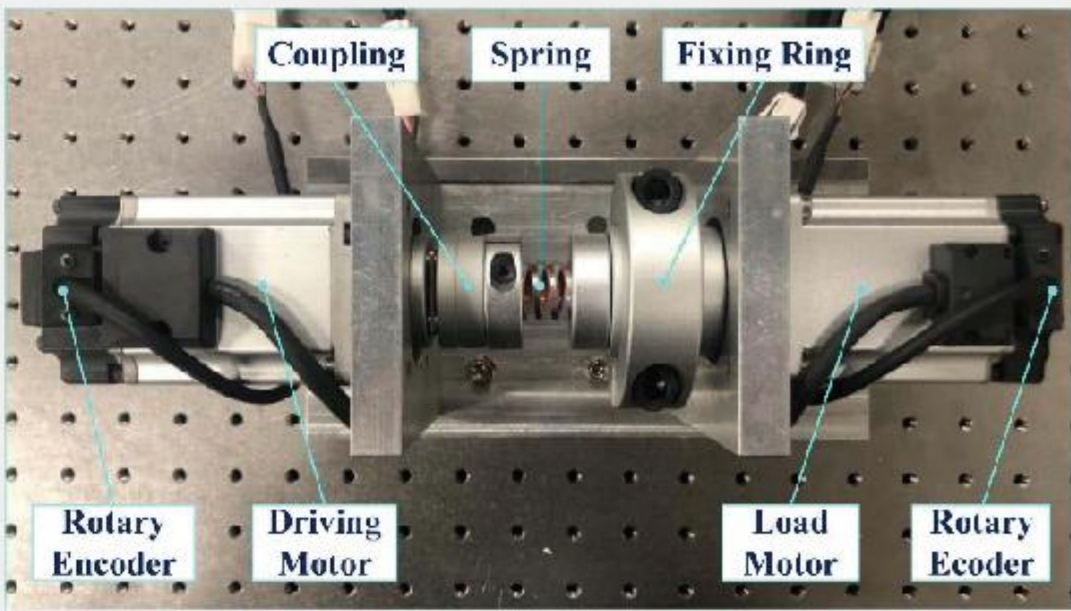
柔索驱动的空间机械臂在大范围操作会导致结构变形,针对这一情况,提出了一种基于全驱系统方法的新型预设时间控制。首先,通过全驱动系统方法将非线性系统控制问题转化为线性系统控制问题,从而实现高精度跟踪;其次,利用预设时间控制技术,实现了快速轨迹跟踪。最后,通过数值仿真和物理实验验证了所提控制方法的有效性和优越性[72]。



其他方面的控制应用

柔性伺服系统

针对柔性伺服系统在未知扰动和不确定性下的控制问题,提出了基于高阶全驱系统方法和奇异扰动模型的自抗扰控制策略,其工程应用价值在于,一个欠驱动机械系统可以基于多时间尺度特性转化为多个全驱系统进行控制器设计与分析,具有简单、直观、高效等优点,在永磁同步伺服电机驱动的柔性伺服系统上开展了验证实验研究[79-82]。



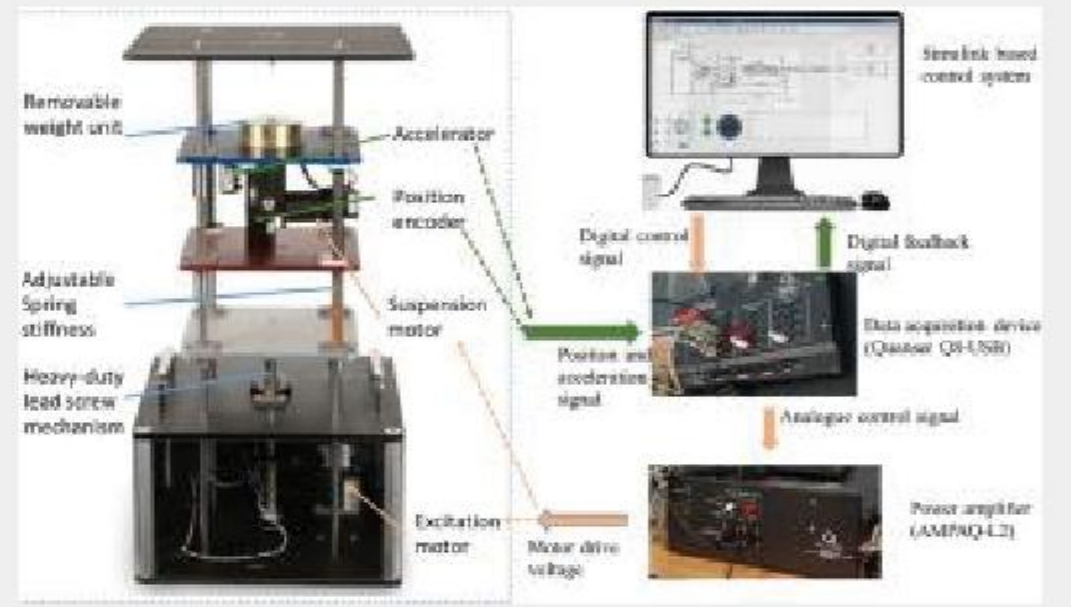
微电网系统

针对微电网的电力耦合对分布式次级控制器的设计带来的阻碍,提出了基于高阶全驱系统方法和直流微电网解耦模型的次级预测控制策略。所得到的解耦全驱微电网模型不仅能全面地刻画直流微电网的电力拓扑信息及实际电气特性,而且还具有非常简单的、便于次级控制器设计的结构。为验证所提算法的有效性,开展了太阳能电池板直流微电网系统控制实验[93-96]。



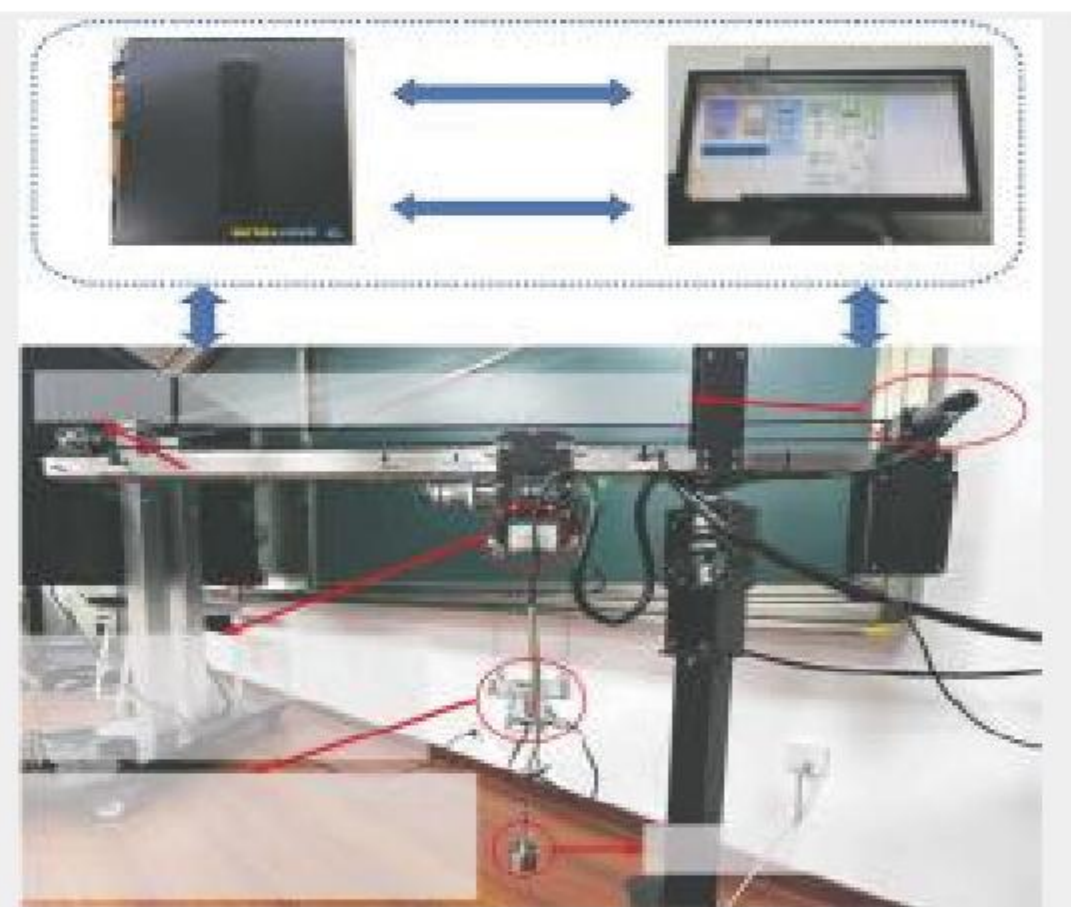
主动悬架系统

针对汽车主动悬架系统不确定性和输入死区约束等问题,提出了一种基于仿生参考模型和全驱系统方法的神经自适应控制方法。相比于传统的状态空间方法,全驱系统方法减少了系统变换所需的计算量,降低了控制器设计的难度。特别地,该系统的状态能够渐近收敛至零。此外,所设计的控制方法能够有效应对系统不确定性和输入死区问题,因而具备较强的鲁棒性[97]。



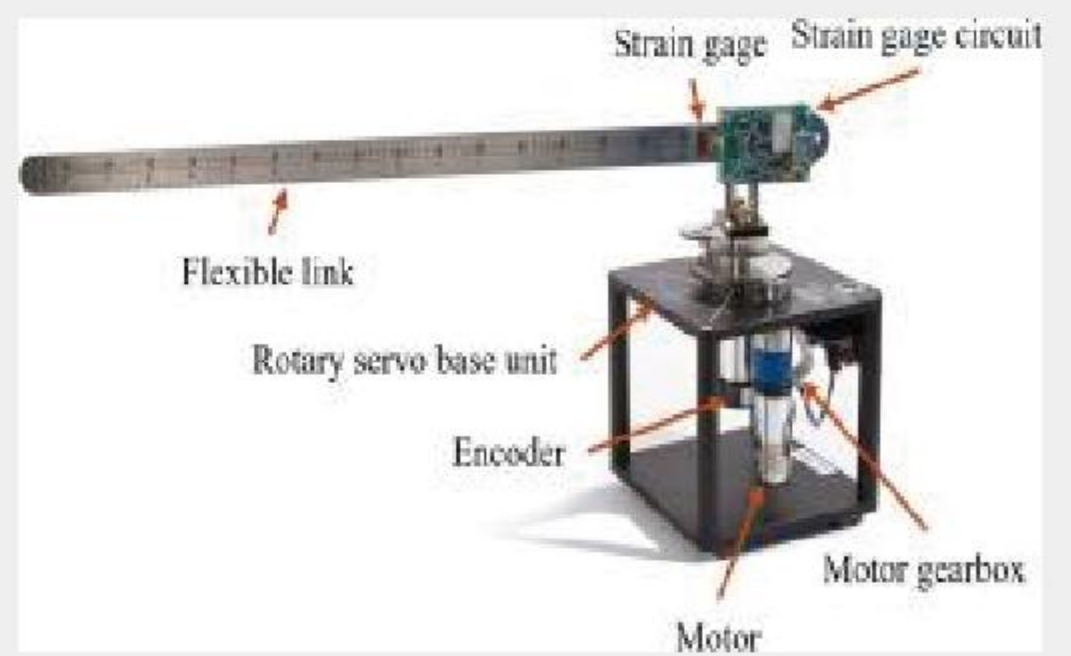
桥式起重机

针对具有双摆效应的桥式起重机动力系统,研究了其定位与摆动抑制这两个控制难题。首先将欠驱动的桥式起重机系统转化为数学意义上的全驱系统,然后在全驱系统方法框架下,通过引入一个设计良好的动态项,增强了摆动抑制效果。此外,还扩展讨论了具有不确定性和输入饱和情况下的控制问题。所提方案不仅实现了高精度定位和防摆控制方案,还为起重机系统控制提供了全新视角[75]。



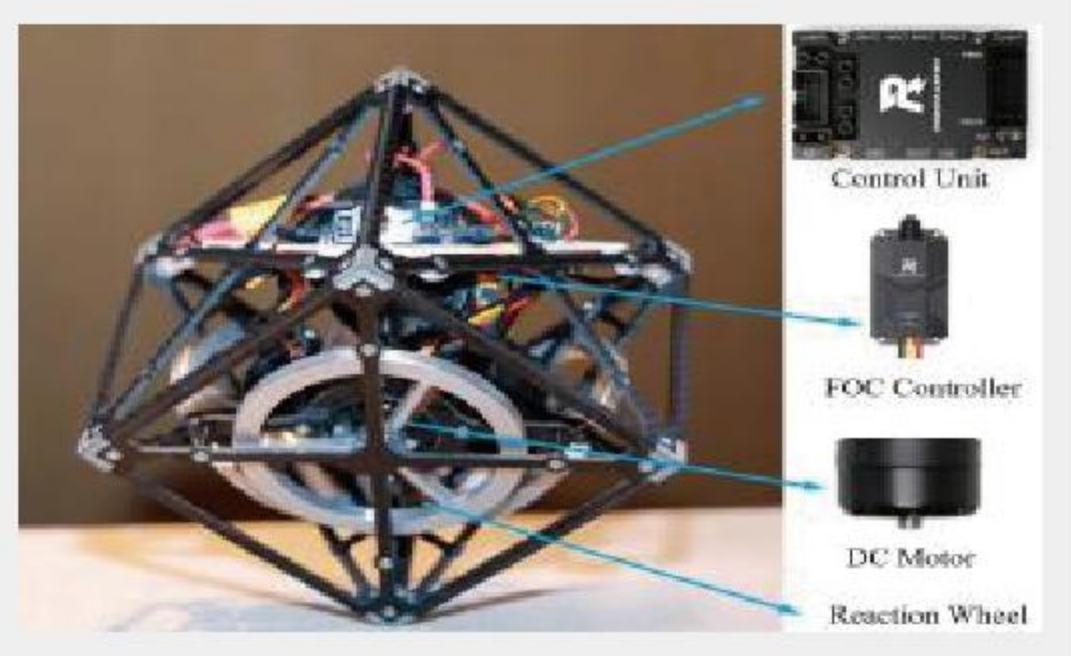
旋转柔性尺系统

针对旋转柔尺系统,提出了一种基于集合的执行器故障检测器和基于全驱系统方法的容错控制策略。该检测器采用全驱系统镇定控制生成的闭环系统构建,采用Gershgorin圆定理进行策略极点配置,能够避开敏感区域或实现极点隔离,实现了灵活的极点配置。在Quanser设备上的实验结果表明,该方法在保持系统稳定性和控制性能的同时,能够有效地减轻致动器故障[87]。



三维Cubli平衡机构

针对三维Cubli姿态控制问题,提出了一种基于高阶全驱系统方法的抗扰控制策略。首先,采用全驱系统理论的概念和工具,将Cubli的系统模型转化为高阶全驱模型。其次,基于全驱特性设计了一个基线控制器,以消除系统固有的非线性特征。此外,开发了一种非线性观测器,用于实时估计系统的加性扰动,以提升基线控制器的抗扰效果。数值仿真和实验结果表明,该方案在性能上优于基于线性化的LQR方法和反步法[84]。



五、成长篇

全驱系统控制理论的诞生与成长



在短短四年的时间里, 全驱系统理论体系走过了“从无到有、从小到大、由弱到 强”的发展历程, 当前在众多国内外控制界同仁的呵护下, 正在飞速发展!

Fully Actuated System Approach for Control: An Overview

Guang-Ren Duan¹, Fellow, IEEE

Abstract—Fully actuated system (FAS) approach was proposed in 2020 and 2021 as a general framework for control system analysis and design based on a newly discovered general type of fully actuated models for dynamical systems. Due to its great advantages and power in dealing with complicated nonlinear time-varying and time-delay systems with possibly nonholonomic features, it has attracted much attention in the control community immediately since its birth. By now, numerous results have been produced for analysis and control of various types of complicated systems, which cover the topics of adaptive control, robust control, predictive control and fault-tolerant control, and involve time-varying and time-delay systems, discrete-time systems, stochastic systems and even impulsive systems. Meanwhile, a large number of applications have also been carried out. These include spacecraft control, aircraft and quadrotor control, robot control and control of power electronic systems and servo systems. In this article, an overview of the FAS approach is presented, ranging from models, basic theories, and control techniques to applications.

Index Terms—Applications, fully actuated system (FAS) approach, nonholonomic systems, nonlinear systems, stabilization and control, strict-feedback systems (SFSs).

I. INTRODUCTION

A. State-Space Approach

STATE-SPACE models are not the original forms used to handle control problems. In fact, state-space models are a set of first-order differential equations, or, in the case of discrete-time systems, a set of difference equations. The introduction of FAS as a general approach based on a new type of fully-actuated models for dynamical systems is intriguing and holds substantial promise for handling complex nonlinear, time-varying, time-delay, and possibly nonholonomic systems. State-space models do have found success in controlling linear systems, but largely because linear systems are straightforward to handle.

If state-space models are not the ideal choice, could there be a better model for managing control tasks?

described in a survey paper [1] by Casti that seeking a completely general theory of nonlinear systems is somewhat akin to the search for the Holy Grail: a relatively harmless activity full of many pleasant surprises and mild disappointments, but ultimately unrewarding. It was also claimed by Alberto Isidori at an open talk in Korea that from the mid 1990s, the study of problems of feedback design for MIMO nonlinear systems came to a (almost complete) stall. He then asked: Why was this the case? Was the study of these problems irrelevant? Or was it too difficult? Eventually, these observations have become widely acknowledged in the last decades, and many control theorists have turned to application topics.

Why is this the case? Isidori's question is certainly worth serious consideration.

As a matter of fact, the reason lies in that state-space models, despite their dominance in modern control theory for centuries, are not necessarily the best suited for control tasks. This reason can be difficult to accept, especially for those who frequently utilize state-space models. Indeed, the state-space models serve well in tackling problems directly tied to the states. This is evident from the application of linear state-space models, first proposed by Euler in early 1750 to solve high-order linear differential equations (giving the state responses), and of nonlinear models, used by Lyapunov in 1892 to analyze the limit behavior of states. They were not originally proposed to solve control problems. State-space models do have found success in controlling linear systems, but largely because linear systems are straightforward to handle.

If state-space models are not the ideal choice, could there be a better model for managing control tasks?

B. Fully Actuated System Approach

There is no doubt that a model which permits the control vector to be explicitly solved will provide great convenience for its controller design, and will simultaneously optimize control performance. Do such models exist? Indeed, they are not only existent, but also have been widely applied. Our substantial reliance on the state-

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The author is with the Center for Control Theory and Guidance Technology, Harbin Institute of Technology, Harbin 150001, China, and also with the Center for Control Science and Technology, Southern University of Science and Technology, Shenzhen 518055, China (e-mail: g.r.duan@hit.edu.cn).

Color versions of one or more figures in this article are available at <https://doi.org/10.1109/TCYB.2024.3457584>.

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Reviewer 2:

This paper summarizes a fully-actuated system (FAS) approach for control, ranging from models, basic theories, control techniques, and applications, which is a general approach for control system analysis and design based on a newly discovered general type of fully-actuated models for dynamical systems. Furthermore, this approach has been extended to diverse domains including discrete-time systems, time-delay systems, stochastic systems, and impulsive systems. This paper is an excellent one overall.

Reviewer 3:

The topic surveyed here is very interesting. Furthermore, this is a concise paper that I enjoyed reading. The recent main advancements on FAS are well conveyed and the paper is very well written.

黑龙江省自然科学特等奖 (2023)

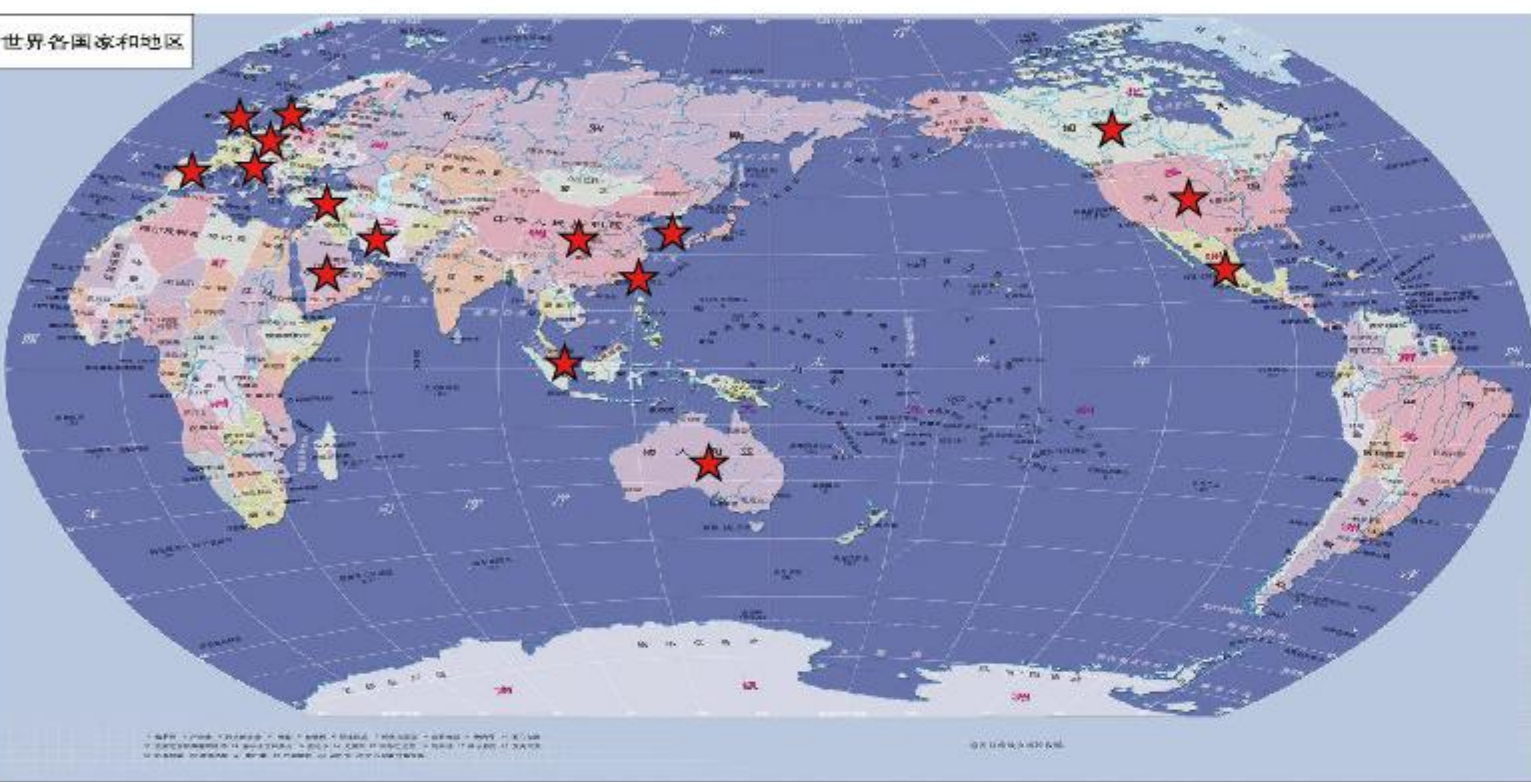
项目名称:控制理论的全驱系统方法体系

奖励类型:黑龙江省自然科学奖

奖励等级:特等奖

完 成 人:段广仁

发现了描述一般动态系统的全驱系统模型,进而提出了全驱系统理论的基本思想,并建立了控制理论的一个全新的全驱系统理论体系框架,打破了当前控制理论的发展困境,“对控制理论与工程产生深远的影响”。



1	High-order fully actuated system approaches: Part I. Models and basic procedure	364 Citations
	Duan, GR Jan 25 2021 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 52 (2), pp.422-435	38 References
2	High-order fully-actuated system approaches: - part II. Generalized strict-feedback systems	226 Citations
	Duan, GR Feb 17 2021 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 52 (3), pp.437-454	29 References
3	High-order fully actuated system approaches: Part III. Robust control and high-order backstepping	229 Citations
	Duan, GR Apr 4 2021 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 52 (5), pp.952-971	33 References
4	High-order fully actuated system approaches: Part IV. Adaptive control and high-order backstepping	203 Citations
	Duan, GR Apr 4 2021 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 52 (5), pp.972-989	51 References
5	High-order fully actuated system approaches: Part V. Robust adaptive control	143 Citations
	Duan, GR Jul 27 2021 INTERNATIONAL JOURNAL OF SYSTEMS SCIENCE 52 (10), pp.2129-2143	27 References

首都前沿学术成果

(THU安全控制 2024年12月02日)

近日, 经过北京自动化学会推荐和北京市科学技术协会组织的评审, 清华大学安全控制技术研究中心师生在控制领域顶级期刊Automatica上发表的长文An active fault tolerance framework for uncertain nonlinear high-order fully-actuated systems入选“首都前沿学术成果”。



【论文简介】自段广仁院士开创全驱系统理论以来, 这一中国原创的控制理论在非线性系统领域展现出独特的参数化设计优势, 得到了国内外控制理论学者的广泛关注。考虑到动态系统的运行安全, 清华大学安全控制技术研究团队针对系统存在不确定性和大幅值故障的情形, 给出了一类高阶全驱系统容错控制器的设计框架, 提高了系统对大幅值故障的补偿速度, 扩大了全驱系统理论的应用范畴。该成果是全驱系统理论领域的全球首篇Automatica长文, 加深了中国原创理论的国际化传播程度。

【奖项介绍】“首都前沿学术成果”是由北京市科学技术协会牵头, 依据中国科学院文献情报中心的定量分析结果, 重点关注期刊影响力和文章影响力等因素, 最终评选出具有重大国际影响力和原创性的科技论文或科研成果, 为北京国际科技创新中心建设凝智聚力。【作者及项目支持】清华大学自动化系博士生蔡苗为论文第一作者, 清华大学安全控制中心周东华教授为论文通讯作者。该研究得到了国家自然科学基金、山东省泰山学者人才计划等项目支持。

【论文链接】<https://doi.org/10.1016/j.automatica.2023.110969>



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An active fault tolerance framework for uncertain nonlinear high-order fully-actuated systems^{*}

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ABSTRACT

This paper presents a novel active fault tolerance framework for uncertain high-order fully-actuated systems (HOFASs). Starting from the uncertain faulty HOFAS model with nonlinear measurement, the advantages of this description are revealed via Lie Derivatives. A HOFAS adaptive observer and controller integration is established and further a closed-loop HOFAS dynamic data modeling structure is derived. This structure uncovers the dynamic characteristics including fault features, and naturally yields a fault detectability condition. Based on the fault information from the dynamic data model, an active fault tolerant control strategy for HOFASs is proposed, which enriches HOFAS control theory. The uniformly bounded stability of the HOFAS model is proved theoretically and illustrated experimentally.
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1. Introduction

In the past decades, nonlinear control has been a hot topic due to its various theoretical bottlenecks (Chen, Shao, & Jiang,

to be put into practice. In order to overcome the above dilemmas, Duan originally proposed the high-order fully-actuated system (HOFAS) theory (Duan, 2020a, 2020b, 2020c, 2021a, 2021b, 2021c, 2021d, 2021e, 2021f, 2021g, 2022a, 2022b, 2022c). light-

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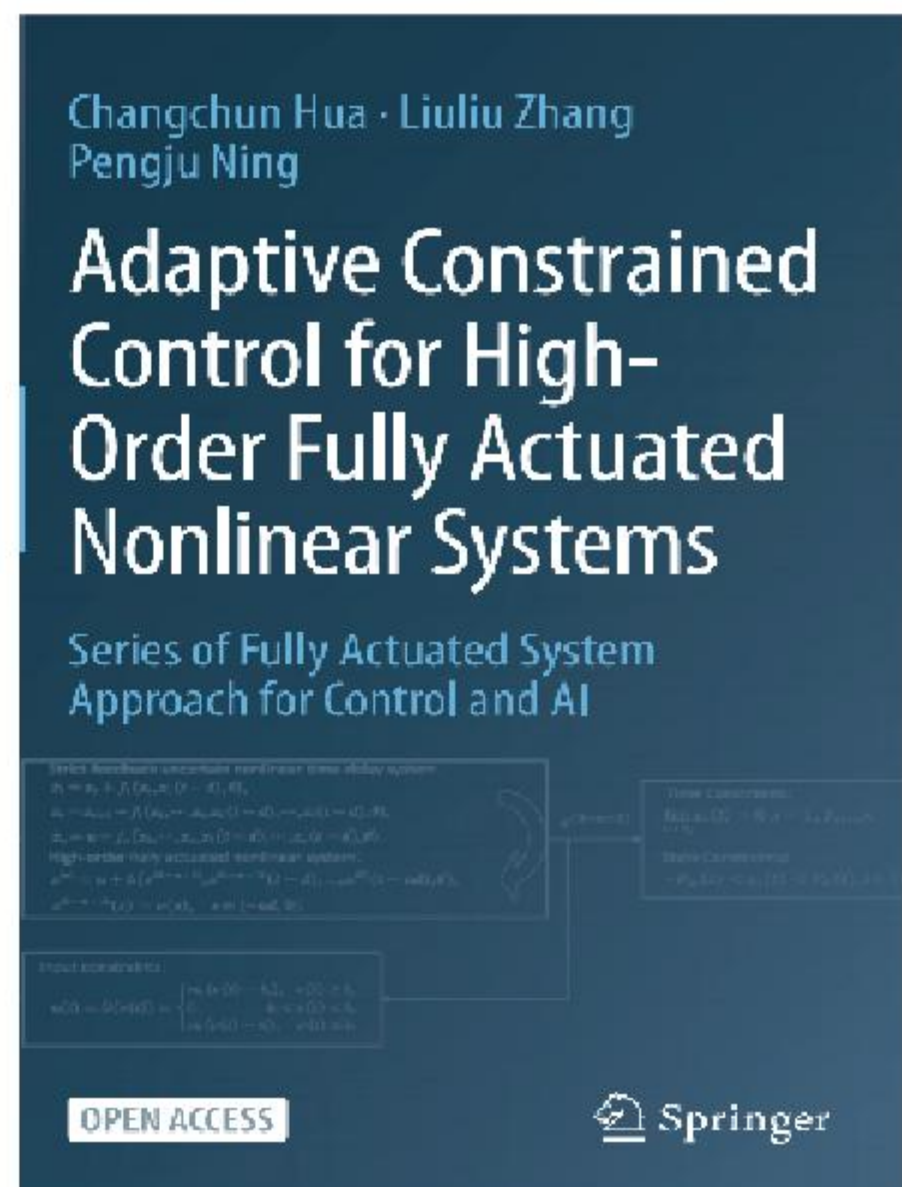
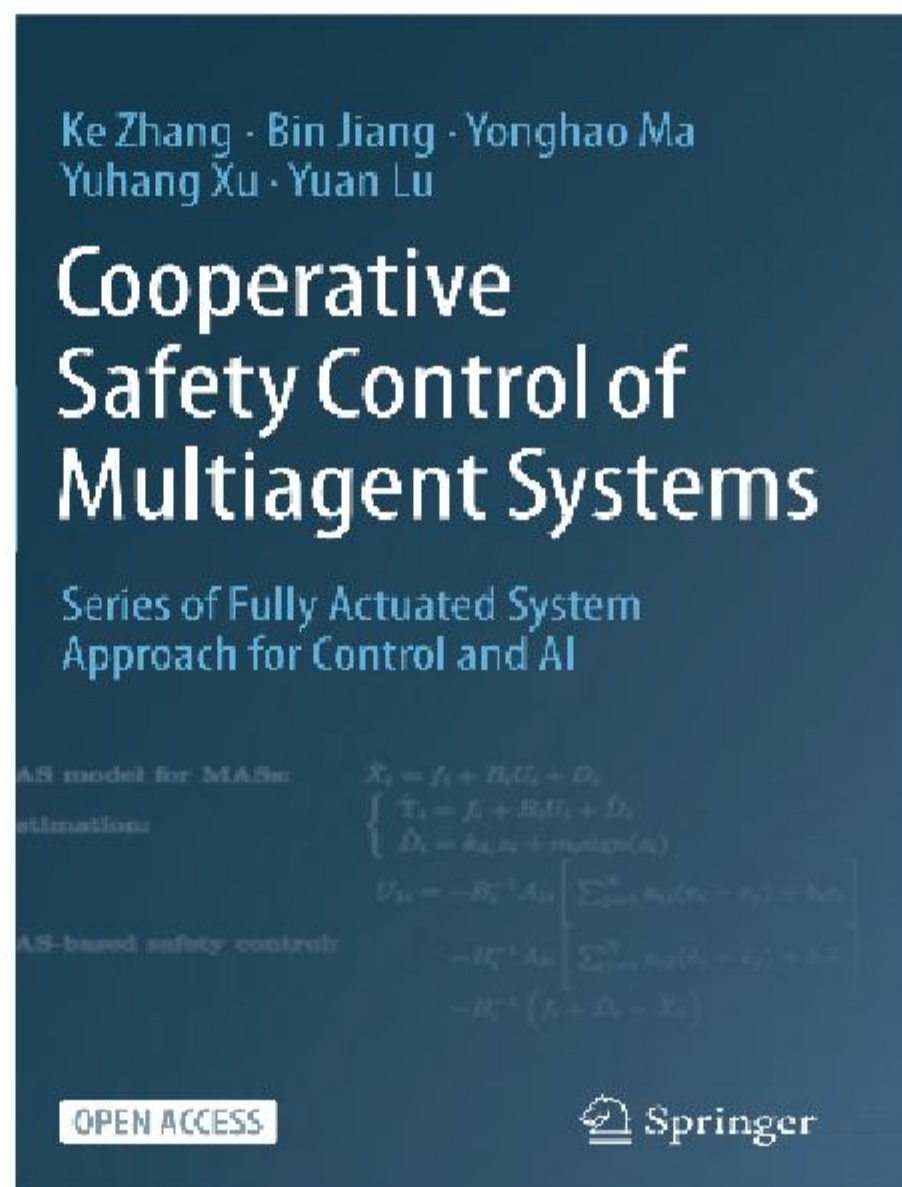
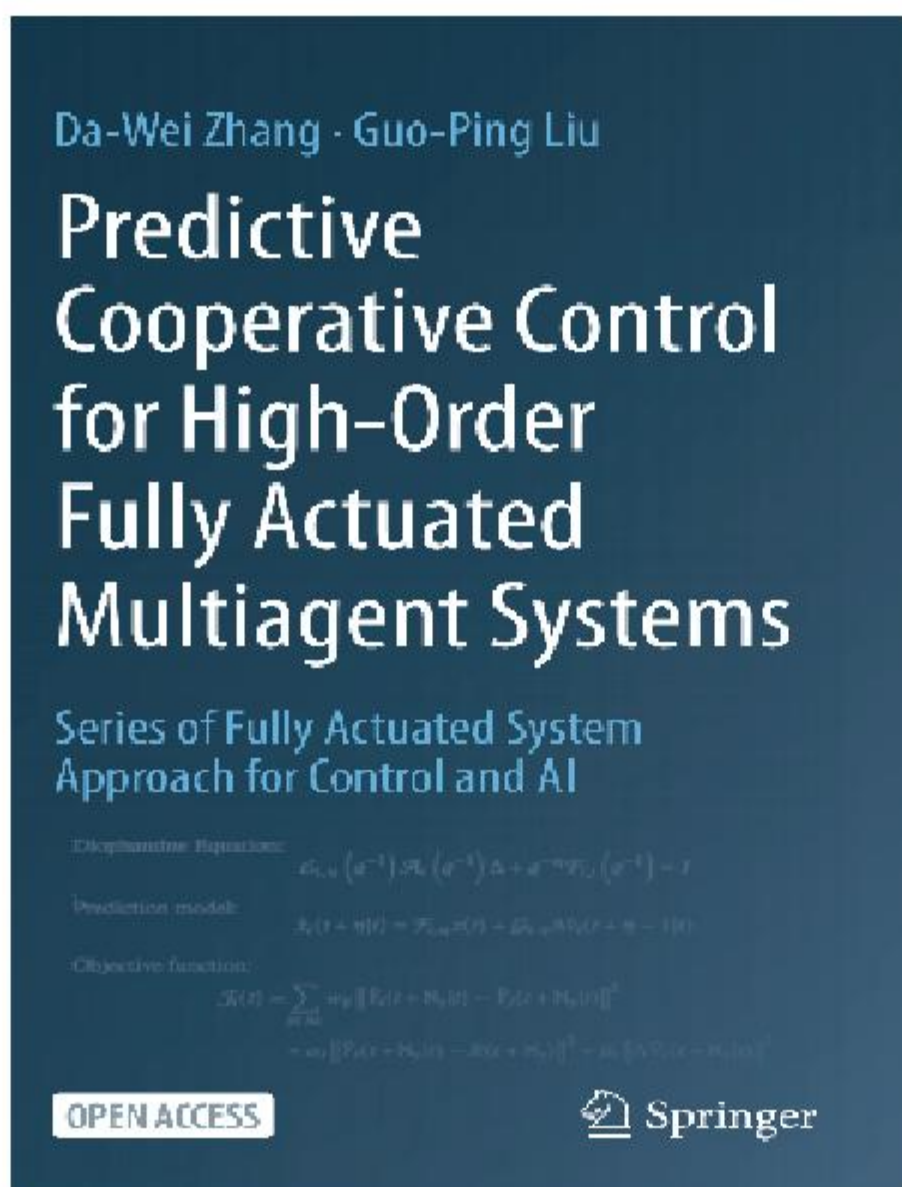
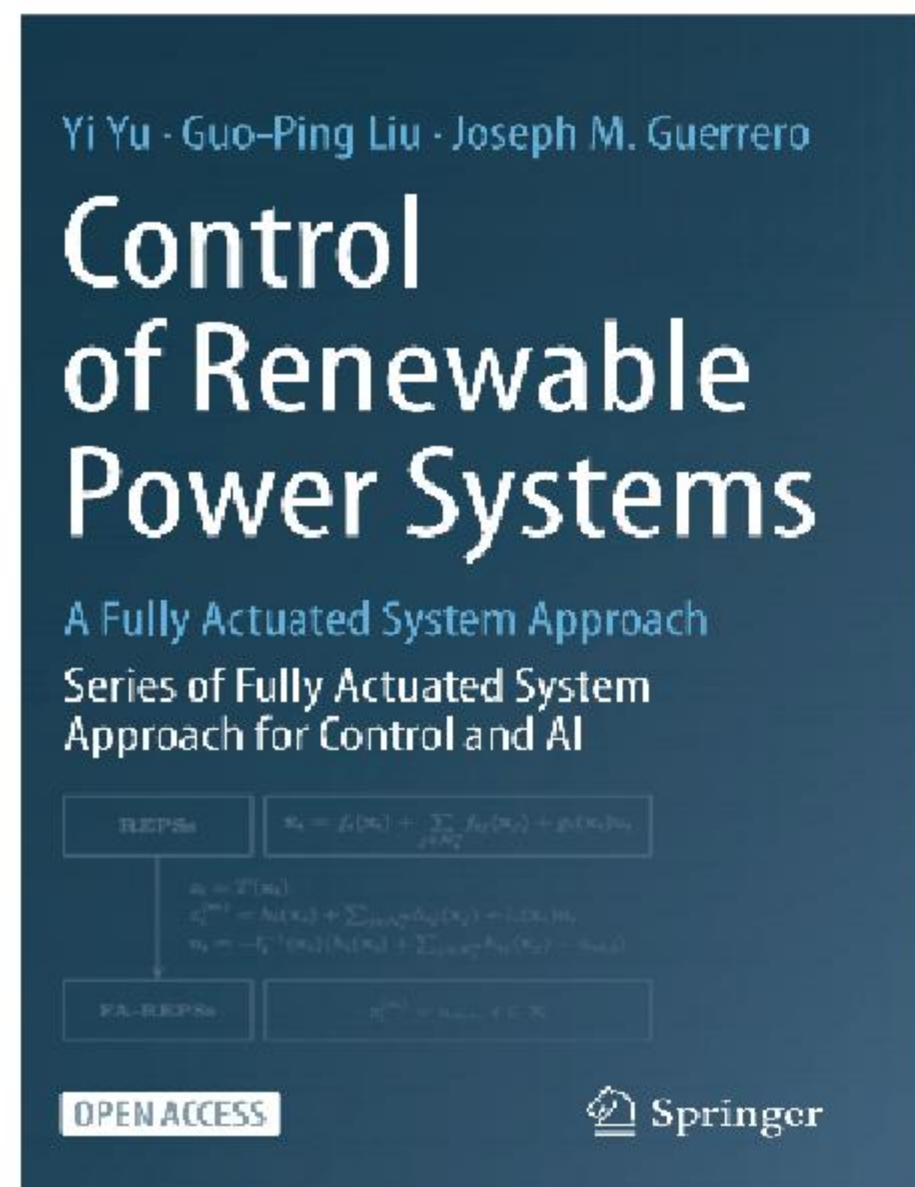
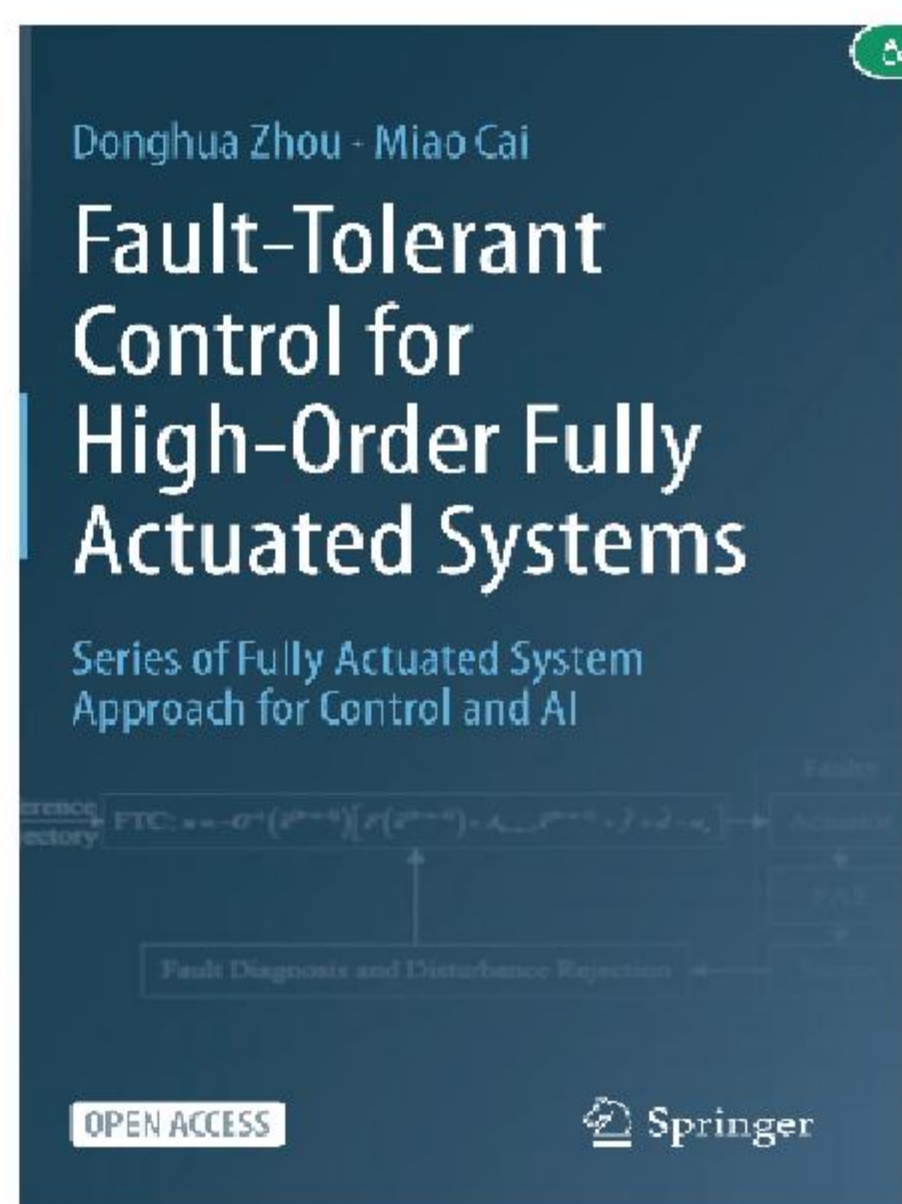
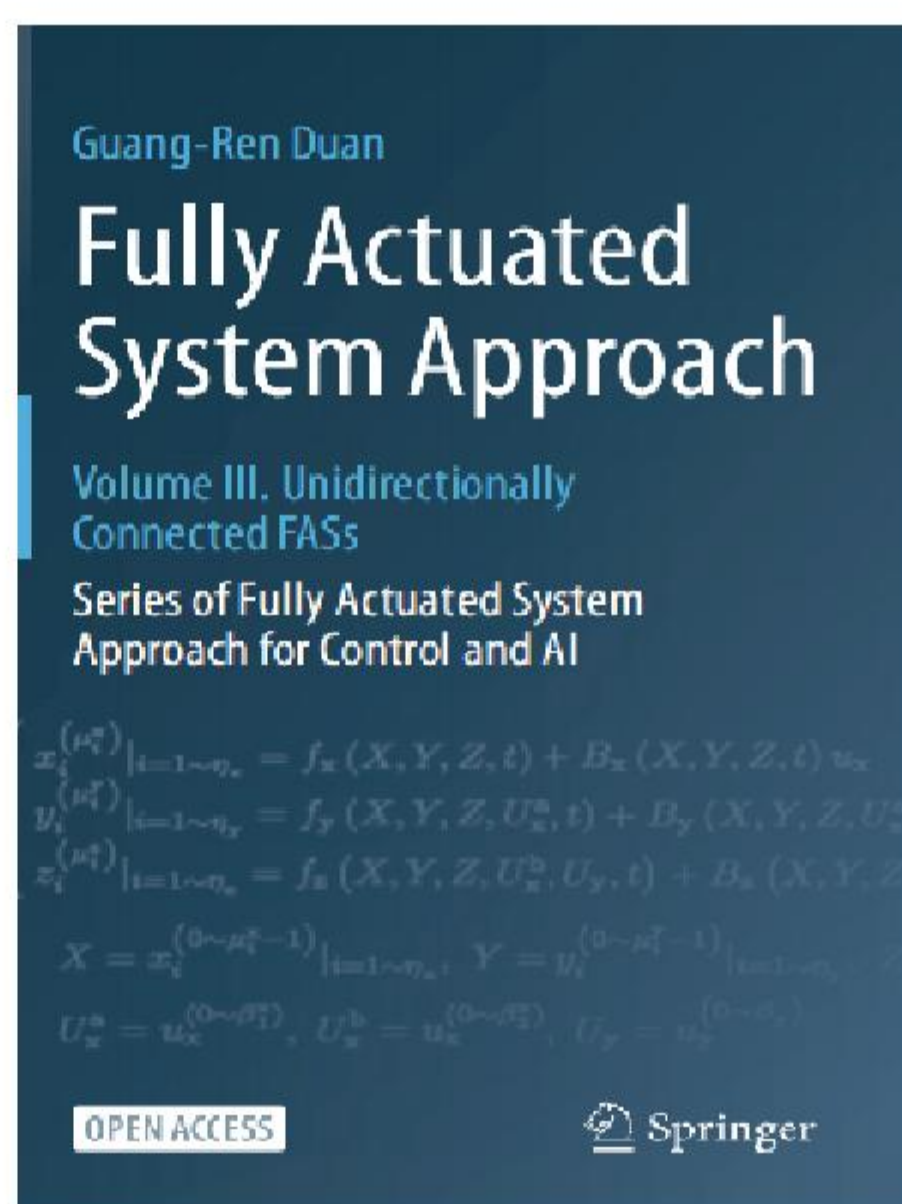
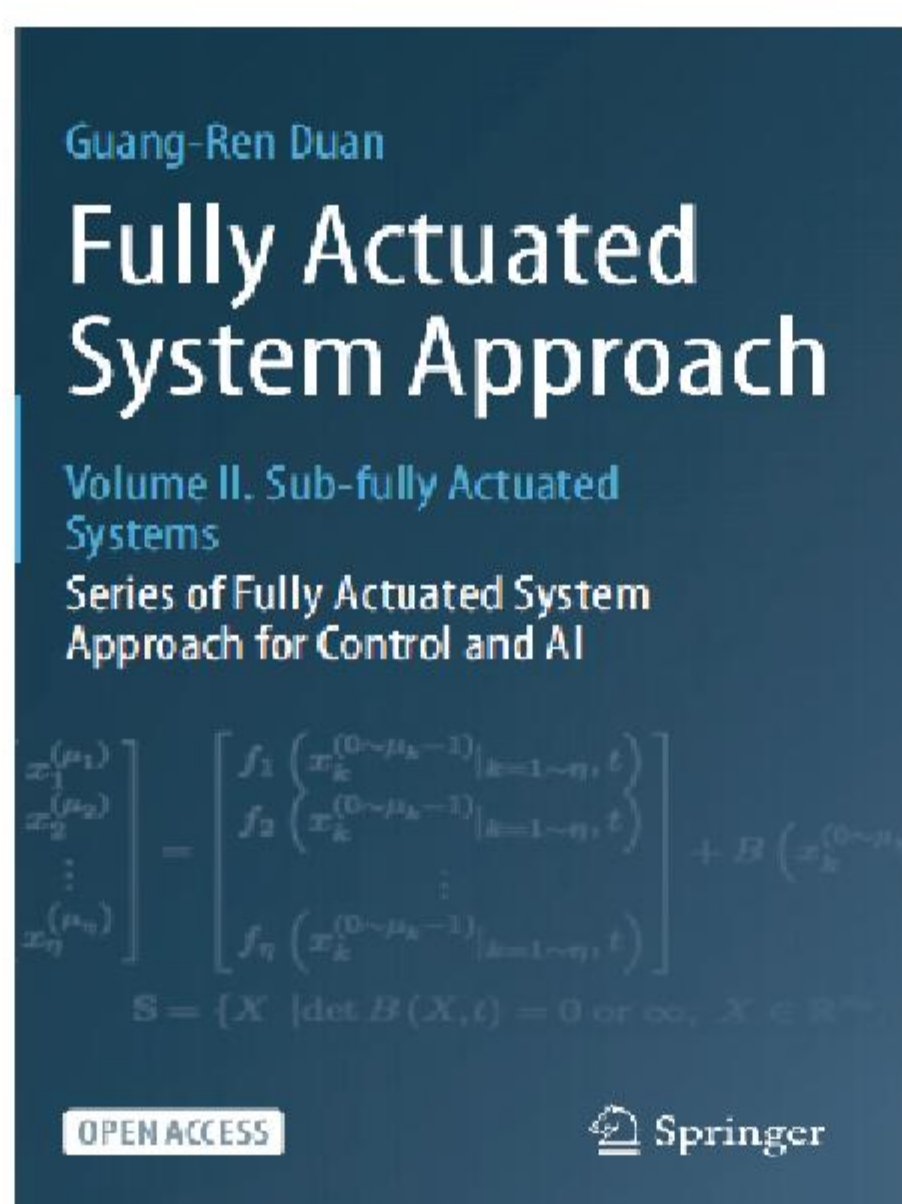
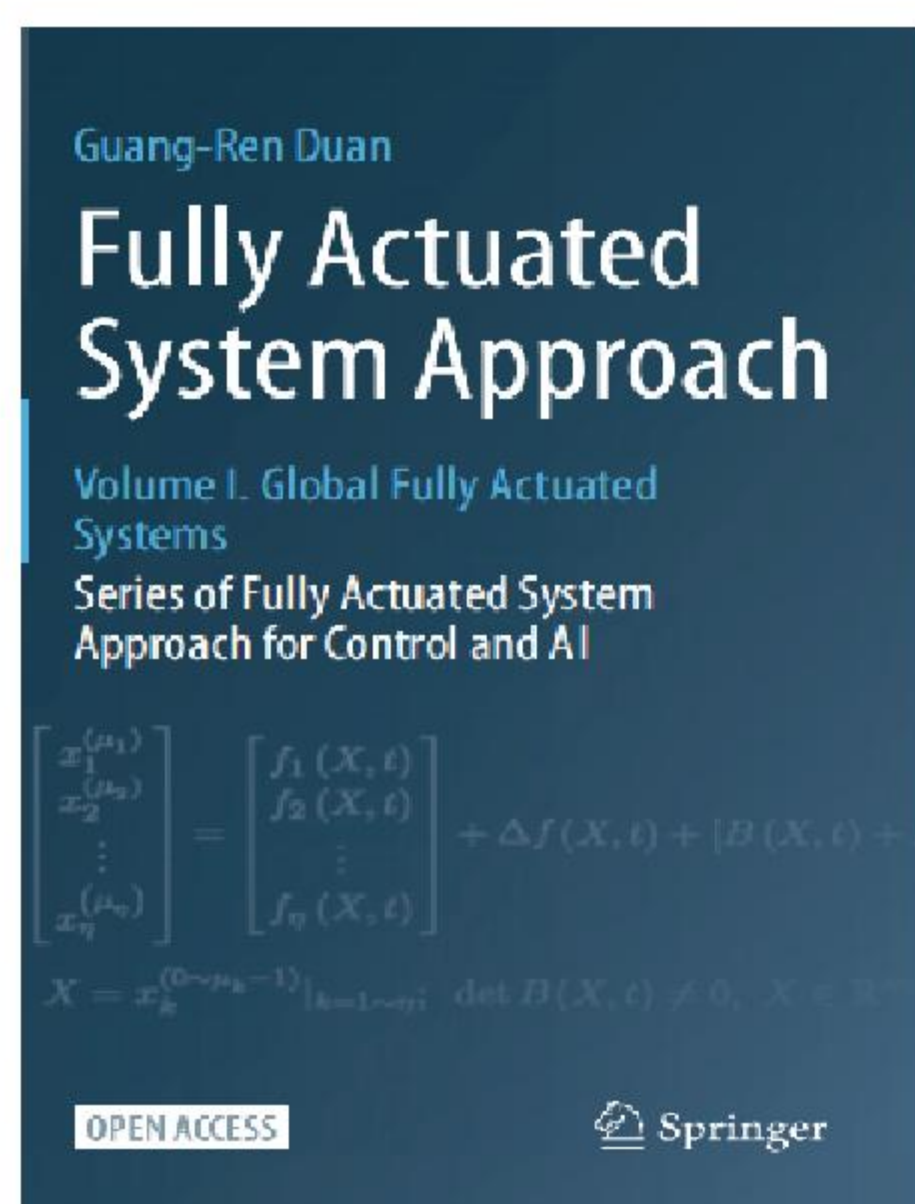
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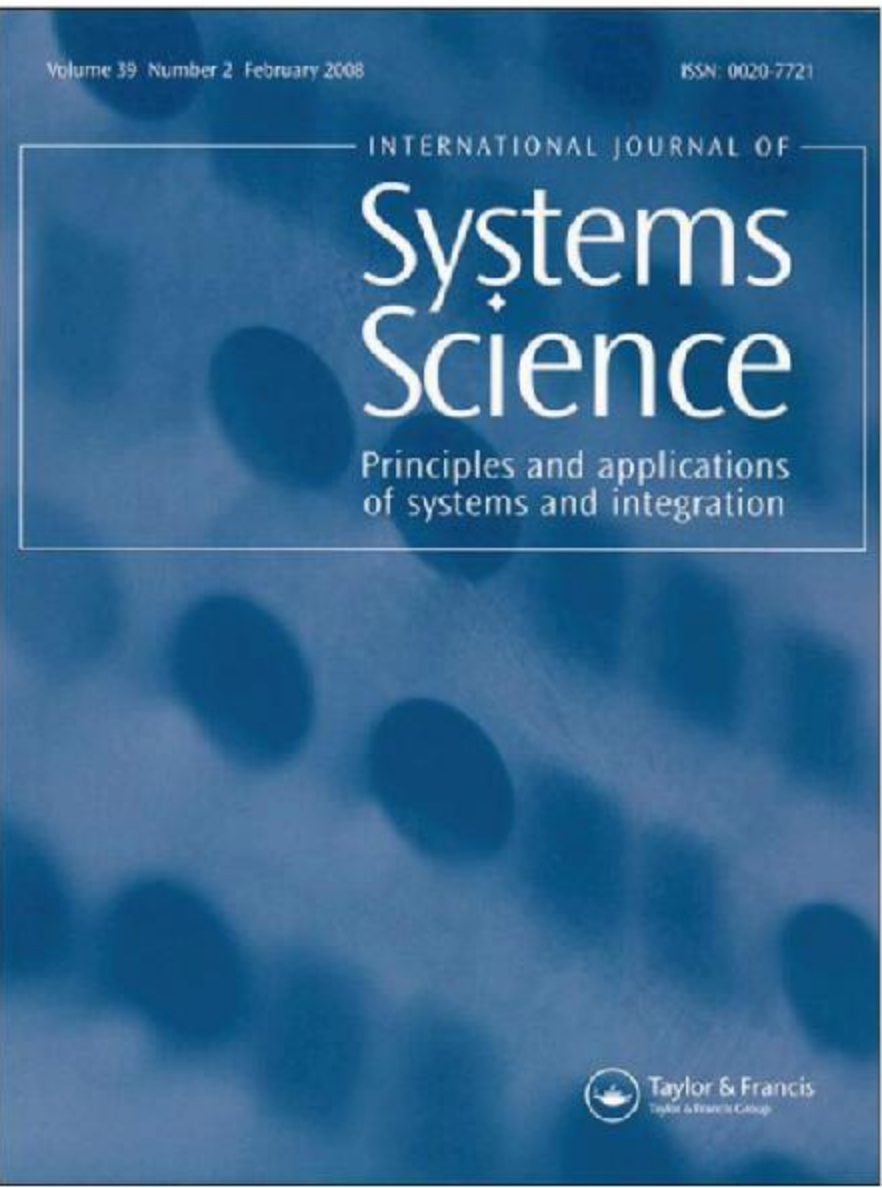
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2025年计划出版书目



全驱系统理论与应用专刊

Int. J. Systems Science — officially affiliated journal of FASTA conference



As the official journal of the FASTA conferences, *Int. J. Systems Sciences* (IJSS) publishes a special issue on Fully Actuated System Theory and Applications each year after that year’s FASTA conference, with most papers selected from the solid ones accepted by the conference, to highlight recent advances and remarkable developments on many facets. IJSS was launched in 1970 and is a world leading journal in the field of systems engineering complexity, with a strong focus on emerging topics such as intelligence and autonomy.

Int. J. Systems Science 专刊简介

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第 45 卷 第 1 期 (半月刊) 2024 年 1 月 15 日	
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2024年Int. J. Systems Science 专刊

Submit a Manuscript to the Journal

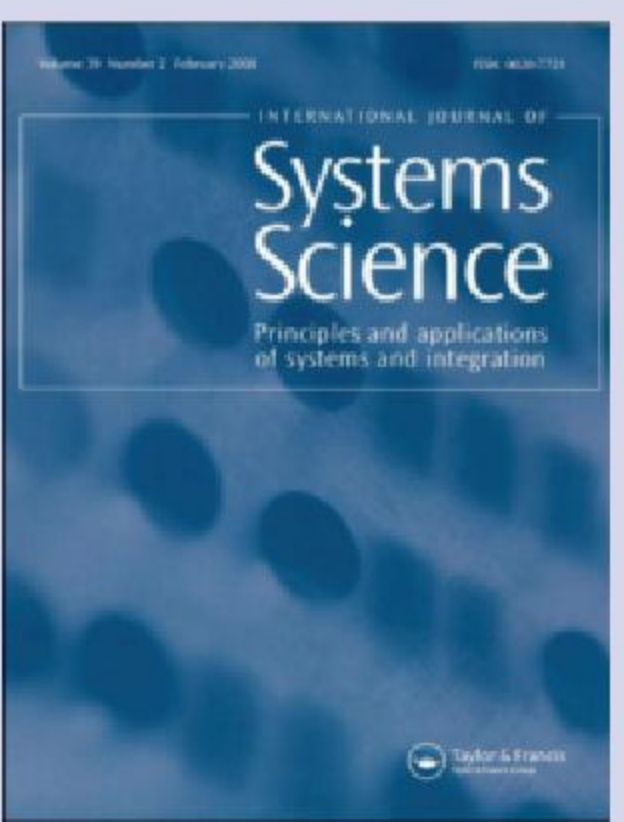
International Journal of Systems Science

For a Special Issue on

Fully Actuated System Theory and Applications: New Developments in 2025

Manuscript deadline

30 November 2025



Special Issue Editor(s)

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VISIT JOURNAL

ARTICLES

In recent years, the high-order fully actuated system (HOFAS) framework has been introduced to address control design challenges in nonlinear systems. The idea of HOFAS originates from second-order mechanical systems. Initially, it was believed that compared to underactuated systems, fully actuated systems were only a minor part of the set of control systems. However, recent research findings indicate that when this concept is mathematically generalized, a HOFAS becomes a general model for control systems. Similar to the system's state-space model, a HOFAS is a representation form of a control system, and a model designed for control system. Owing to its distinct advantages, the fully actuated system (FAS) approach has garnered increasing attention.

Due to the demands of the control community, the fourth annual conference on fully actuated system theory and applications (FASTA) was held in Nanjing on 4-6 July, 2025, with over 1040 participants. Through a strict review process, 589 papers were accepted to be presented on this conference.

To further promote FASTA research, this special issue is dedicated to publishing outstanding papers presented at the fourth annual conference on FASTA. Papers that were not presented on this conference but are related to the topic of this special issue are recommended to be submitted directly as regular submissions for this journal.

2025年Int. J. Systems Science 专刊征稿

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Menu

Call for papers

12 November 2024

Development and Applications of High-order Fully Actuated System Theory

Submission deadline: 31 August 2025

It is well-known that physical fully actuated systems (FASs) are a perfect type of systems in the sense that their controllers can be easily designed and the resulted closed-loop systems can often be made globally constant linear. A non-FAS is a system that is either a physical under-actuated system (UAS) or a system that cannot be classified into a FAS or UAS. If, by any chance, a non-FAS can be converted into a FAS, then the control design of all non-FASs can be systematically solved. However, under physical restrictions, this goal is not practical and achievable.

However, a recently significant achievement on the discovery of the mathematically generalized FAS model of dynamical systems made an important milestone toward this goal. Namely, although a non-FAS cannot be converted into a physical FAS, it can be converted into a mathematically generalized FAS. Moreover, like a physical FAS, the control of a mathematically generalized FAS can also be easily realized. Such facts and logic naturally produce the so-called FAS approach that solves control systems design based on generalized FAS models.

The FAS approach was systematically proposed and discussed recently for different topics and applications (see <https://www.tandfonline.com/journals/tsys20/collections/HOFA>). Due to its great advantages, it has attracted many attentions ever since its emergence. By now, there are many papers published on the FAS approach about both FAS theory development and corresponding practical control applications, including but not limited to unmanned aerial vehicles (UAVs), aerospace vehicles, industrial robots and manipulators, and high speed trains.

Guest editors:

- Prof. Michael V. Basin, The Autonomous University of Nuevo Leon, Mexico
- Prof. Yan Chen, Arizona State University, USA
- Prof. Guoxiang Gu, Louisiana State University, USA
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- Prof. Jinjun Shan, York University, Canada

<https://www.sciencedirect.com/special-issue/316681/development-and-applications-of-high-order-fully-actuated-system-theory>

2025 年 *Controlle Engineering Practice* 专刊征稿

As a Journal of IFAC, *control engineering practice* (CEP) strives to meet the needs of industrial practitioners and industrially related academics and researchers. It publishes papers which illustrate the direct application of control theory and its supporting tools in all possible areas of automation. It is normally expected that practical results should be included, but where simulation only studies are available, it is necessary to demonstrate that the simulation model is representative of a genuine application.

2023年度“中国高等学校十大科技进展”入选项目

项目名称:全驱系统控制理论

打破了控制系统领域中全驱系统和欠驱系统的传统界限，发现了描述动态系统的面向控制的全驱系统模型，进而创立了控制理论的一个全新的全驱系统方法体系，引领了全球54所高校的88个团队在该方向上发表论文350余篇。主要贡献包括：

- ◆ **时滞非线性时变系统控制的全驱系统方法**：针对带有时滞的非线性时变系统，提出了全驱系统控制方法，克服了系统中的时变性、时滞特性、非光滑性以及非完整性所带来的各种困难；
- ◆ **网络化高阶全驱系统的预测控制**：针对网络攻击和外部干扰的网络化系统，提出了网络化高阶全驱预测控制方法，克服了系统中的随机欺骗攻击、拒绝服务攻击、通信受限等所带来的各种困难，解决了多智能体系统的安全协同控制问题和网络化系统的跟踪控制问题；
- ◆ **不确定高阶全驱系统的容错控制**：针对存在故障的不确定高阶全驱系统，提出了主动容错控制、自适应容错控制、自愈容错控制方法，丰富了全驱系统理论；
- ◆ **不确定高阶全驱系统的自适应跟踪控制**：针对不确定高阶非线性系统，提出了基于全驱系统框架的自适应跟踪控制方法，克服了系统中的未建模动态、执行器故障等带来的困难，并解决了系统性能受约束、未知参数的高精度在线估计等问题；
- ◆ **全驱系统方法的应用**：基于全驱系统方法解决了一些应用对象的控制问题，包括吸气式飞行器的预测控制和协同控制、无人机轨迹跟踪控制以及空间飞行器轨迹-姿态一体化控制。

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华长春
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教育部司局函件

教技委〔2024〕1号

教育部科学技术委员会关于公布 2023 年度“中国高等学校十大科技进展” 入选项目的通知

有关高等学校：
2023 年度“中国高等学校十大科技进展”评审工作已经结束，现将入选名单予以公布（名单附后）。
入选项目名单按负责人姓名拼音排序，排名不分先后。
联系人及电话：
附件：2023 年度“中国高等学校十大科技进展”入选项目名单

教育部科学技术委员会
2024 年 7 月 12 日

附件：
2023 年度“中国高等学校十大科技进展”
入选项目名单

序号	负责人	项目名称	申报学校	合作单位
1	段宝岩	逐日工程--世界首个全链路全系统空间太阳能电站地面验证系统	西安电子科技大学	无
2	段广仁	全驱系统控制理论	哈尔滨工业大学	南方科技大学、清华大学、燕山大学、南京航空航天大学、同济大学、东北大学
3	巩金龙	高能致化学链丙烷氧化脱氢制丙烯关键技术	天津大学	无
4	姜长涛	肠道菌源宿主同工酶是干预代谢性疾病的新靶点	北京大学	北京大学第三医院、首都医科大学附属朝阳医院
5	李德仁	通导遥一体化智能光学与雷达遥感卫星（珞珈系列卫星）	武汉大学	航天东方红卫星有限公司、中国空间技术研究院
6	刘宏	空间站实验舱机械臂	哈尔滨工业大学	无
7	彭练矛	超越硅极限的弹道二维晶体管	北京大学	无
8	舒歌群	自然工质 CO ₂ 循环理论与技术	天津大学	中国科学技术大学
9	孙金鹏	碳碳双键和嗅觉分子的感知机制	山东大学	浙江大学、上海交通大学
10	吴建平	1.2T 超高速下一代互联网主干通路	清华大学	中国移动通信集团有限公司、华为技术有限公司、赛尔网络有限公司

注：按负责人姓名拼音排序，排名不分先后

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