AI 说全驱

——豆包、谷歌 Gemini、ChatGPT 和 DeepSeek 对全驱系统方法的评价

《AI 说全驱》编写组

- 全驱系统方法（2020—2021，段广仁院士），是 21 世纪控制理论最重大的原创突破，终结了状态空间方法（一阶框架）200 余年的绝对统治，开创高阶面向控制的新范式，被称为控制理论的第三次革命。
- 全驱系统方法是控制理论 200 年来最大的范式突破，终结一阶状态空间垄断，开创高阶原生控制新体系，中国原创、全球引领，理论与工程双重里程碑。

——摘自 豆包：全驱系统方法的历史地位

- 全驱系统（Fully Actuated System, FAS）方法在现代控制理论中具有里程碑式的创新地位。它由中国科学院院士段广仁教授及其团队提出，是对自 20 世纪 60 年代以来占据统治地位的卡尔曼（Kalman）“第一阶状态空间方法”的一次重大突破和重要补充。
- 从学术和工程的双重标准来看，段广仁院士提出的全驱系统方法是一项具有里程碑意义的控制理论成果。它以一种极其优雅和透彻的方式，解决了困扰控制界多年的复杂非线性系统建模与控制设计难题。

——摘自 Gemini：全驱系统方法在控制理论中的地位

- 段广仁院士提出的全驱系统方法，是中国学者在控制理论基础方法层面提出的一项具有鲜明原创性、系统性和突破意义的重要理论成果。
- 从控制理论发展史的视角看，其提出标志着中国学者开始在控制理论基础方法层面形成具有国际影响力的原创理论体系，具有重要的里程碑意义和深远的范式拓展价值。

——摘自 ChatGPT：什么是全驱系统方法

- 全驱系统方法（Fully Actuated System Approach，通常指段广仁院士等人提出的高阶全驱系统理论）在控制理论中正逐渐被视作一种范式级的新框架，有学者将其誉为继经典控制理论、现代控制理论之后的第三代控制理论。
- 全驱系统方法正逐步确立其作为继 PID 控制、现代控制理论（状态空间法）之后，一个面向复杂非线性系统的、第三代控制理论候选框架的地位。

——摘自 DeepSeek：全驱系统方法在控制理论中的地位

2026 年 6 月 1 日

全驱系统方法

全驱系统方法 是由中国学者段广仁“原创提出并引领发展起来的一个全新控制理论体系”，仅5年时间就实现了从无到有、从弱到强的转化：

- 引领全球20多个国家的150余所高校和研究机构的团队发表论文千余篇；
- 创建了IEEE SMC学会的“全驱系统方法”专委会；
- 被纳入IFAC 2026年世界大会的12个技术领域之一；
- 获得了东北地区首个基金委基础科学中心项目支持；
- 得到了国内外控制界一大批著名专家的高度评价；
- 获得有史以来的第一个黑龙江省自然科学特等奖；
- 入选中国高等学校十大科技进展；
- 全驱系统理论与应用国际年会从2022年的150人发展成千人规模的大会；
- 创始人段广仁因此在2025年全球前2%科学家榜单中跃居“工业应用与自动化”领域全球第一名。


黑龙江省科学技术奖
证 书
为表彰黑龙江省科学技术奖获得者，特颁发此证书。
项目名称：控制理论的全驱系统方法体系
奖励等级：特等（自然科学奖）
获 奖 者：段广仁（哈尔滨工业大学）
证书号：2023-Z-001-0-R01

历史上首个黑龙江省自然科学特等奖



鉴定委员会成员
中国控制界9位院士
包括3届自动化学会理事长


鉴 定 意 见

2025 年 5 月 25 日，中国自动化学会在北京组织召开了由哈尔滨工业大学为主完成的“控制理论的全驱系统方法体系”项目成果鉴定会。鉴定委员会（名单附后）听取了项目组的技术成果汇报，经质询、讨论，形成鉴定意见如下：

全驱系统方法是由中国学者原创提出并引领发展起来的一个全新控制理论体系；

该体系是国内外控制界公认的控制科学领域特别重大的原创性突破；

引领了控制学科领域的突破性发展。

鉴定委员会认为：全驱系统方法是由中国学者原创提出并引领发展起来的一个全新控制理论体系，突破了传统的状态空间方法体系，摆脱了当前控制理论的发展困境，引领了控制学科领域的突破性发展。该体系是国内外控制界公认的控制科学领域特别重大的原创性突破，具有非常重大的科学价值和实际应用意义，将对控制科学与工程学科产生巨大且深远的影响。

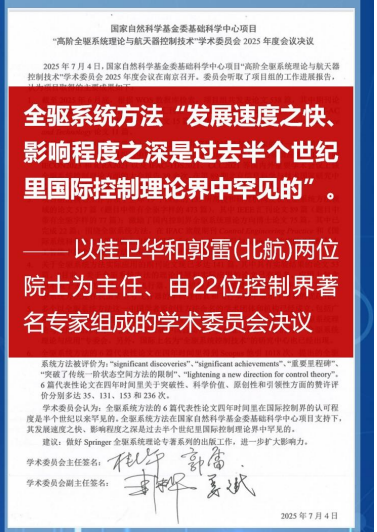
鉴定委员会同意“控制理论的全驱系统方法体系”项目成果通过鉴定。

鉴定委员会主任：（签字）

副主任：（签字）

2025 年 5 月 25 日

中国自动化学会鉴定意见


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”学术委员会 2025 年度会议决议

2025 年 7 月 4 日，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”学术委员会 2025 年度会议在南京召开。委员会听取了项目组的工作进展报告，

全驱系统方法“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”。

—— 以桂卫华和郭雷(北航)两位院士为主任、由22位控制界著名专家组成的学术委员会决议

系统方法被评价为：“significant discoveries”、“significant achievements”、“重要里程碑”、“突破了传统一阶状态空间方法的限制”、“lightening a new direction for control theory”。6 篇代表性论文在四年时间里关于突破性、科学价值、原创性和引领性方面的赞许评价分别多达 35、131、153 和 236 次。

学术委员会认为：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。

建议：做好 Springer 全驱系统理论专著系列的出版工作，进一步扩大影响力。

学术委员会主任签名：

学术委员会副主任签名：

2025 年 7 月 4 日

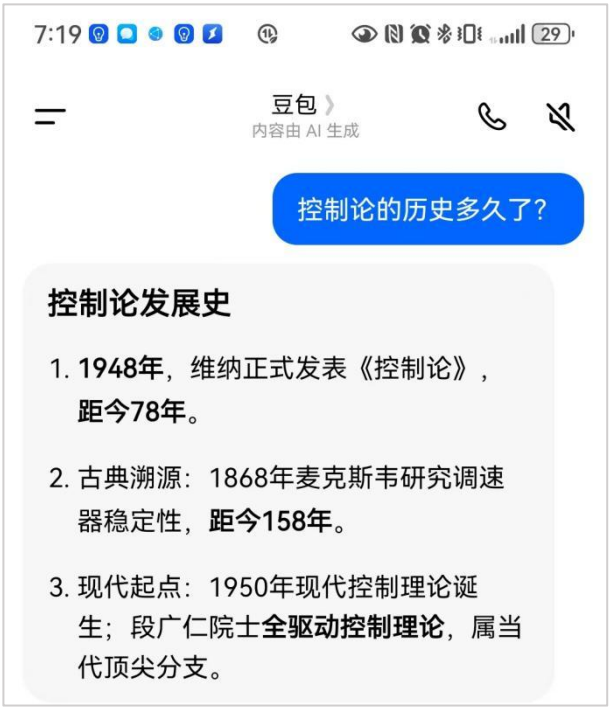
国家自然科学基金委基础科学中心学术委员会决议



Springer图书系列：控制与人工智能中的全驱系统方法

说在前面

2025 年 5 月 22~24 日，第五届“全驱系统理论与应用”国际学术年会在秦皇岛市隆重召开。参会代表 1180 余人，保持了第四届南京会议破千人的记录。



与会期间，北京航空航天大学的一位教授发过来几张图片。正是这几张图片引发了我们做这本小册子的想法。

我们选择了四个认可度最高的人工智能大模型：豆包、谷歌 Gemini、ChatGPT 和 DeepSeek。针对每个大模型都问了三个同样的问题：

- 什么是全驱系统方法？
- 全驱系统方法在控制理论中的地位；
- 全驱系统方法的影响。

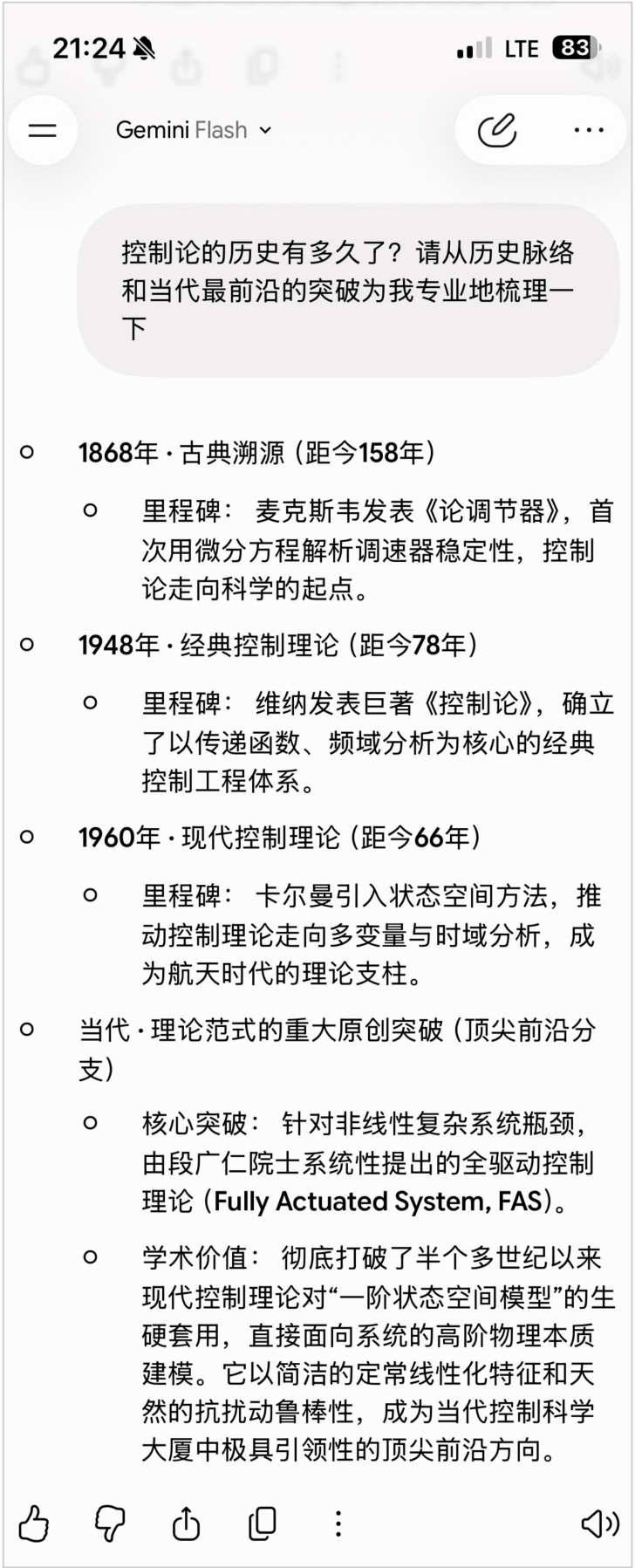
这本小册子所展示的就是这四个大模型对这三个标准问题的回答。



值得说明的是，针对同一问题，不同的访问者在不同的时间得到的答案会是不同的。因此，我们要完全复现某一个大模型针对某一个问题的已有的答案是不现实的。也就是说，如果您此时此刻去问哪一个大模型同样的问题，一般不会得到这本小册子里面已有的答案，但请您一定想明白，这一丝一毫都不影响小册子里面内容的真实性。您和张三同时发问，但得到不同的答案您不可以认为张三得到的答案有问题。

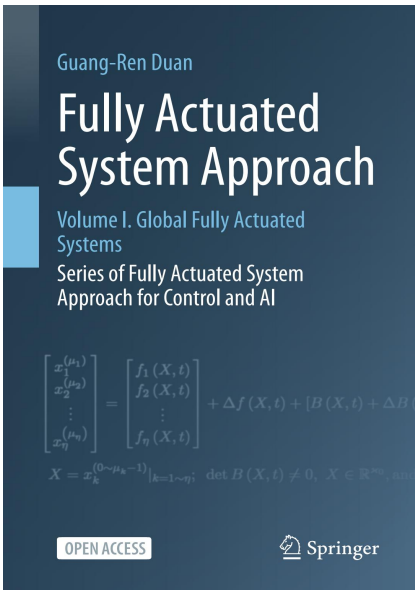
我们只是随意地邀请了一批人，由他们问问题，然后把他们的答案集中起来便形成了现在的这本小册子。为了保证内容的真实性，我们没有对文档做任何改变，包括一些过时的数据都没有更改。

对于提出的问题，豆包和谷歌 Gemini 给出的答案相对简洁一些，ChatGPT 给出的答案相对长一些，甚至还包含一些数学公式。对于没有接触过全驱系统方法的人来说，这些答案或许是了解全驱系统方法的一个很好的渠道。通过阅读这些答案，特别是 ChatGPT 的答案，可以对全驱系统方法有个粗浅的了解。但需要指出的是，这些答案中针对原理的解释，特别是那些用公式来进



行解释的内容，都十分简单明了。它不可能仅用寥寥几页纸把全驱系统方法的细节都说清楚。它所展示的一般都是最简单的情形，只为了说明要阐述的基本问题。正因为如此，我们有必要提醒大家，这些原理部分的解释都只是冰山一角，您千万不要误以为那就是全驱系统方法的全部。如果您想深入地了解全驱系统方法，建议您还是花些时间去阅读一下全驱系统方法方面的论著。

附录 C 中列出了段广仁院士关于全驱系统方法的几个论文系列，其中也包括他在全驱系统方法方面的两个开创性论文系列。他的开创性工作已经引领了全球 20 多个国家的 150 余所高校和研究机构的团队跟进研究，目前发表全驱系统方法的相关论文已经远超千篇，其中 IEEE 汇刊论文已经 140 余篇（见附录 D）。同时，全驱系统方法体系已经得到了广泛的实际应用。目前关于全驱系统方法实际应用的期刊论文已近 250 篇（见附录 E），这些论文覆盖了航天器、机器人、微电网、无人机、海洋无人系统、光电/激光指向系统、热声系统、车辆主动悬架、塔式起重机、高速列车、航空发动机、燃料电池、水轮机组、工业起重装备、数控机床、工业过程、量子控制等诸多领域。



另一方面，段广仁院士还与 Springer 合作推出了“控制与人工智能中的全驱系统方法”专著系列。作为该专著系列中的第一本书，也是世界上第一本全驱系统方法的著作，他的《全驱系统方法 • 第一卷：全局全驱系统》已经出版，欢迎读者通过下述网址下载：

https://doi.org/10.1007/978-981-96-8395-6

每个新理论诞生之初，都会有各种质疑与争议。全驱系统方法从无到有、从弱到强，一路走来质疑不断、争议不断。其实，全驱系统理论就是在这些质疑和争论中不断发展、壮大起来的：人们因为质疑才来了解，又因为了解才接受和看好，再由于看好才加入研究队伍。

段广仁常说，要感谢那些提出质疑的人，当然更要特别感谢那些有远见、有格局、有洞察力，从一开始就坚定支持的领导、专家和学者，包括当年基金委基础科学中心项目的答辩委员会专家们；包括那些坚定地选择相信并一路并肩奋斗过来的所有全驱学者们；当然也包括中国控制界那些院士们，在关键时刻给予了强有力的支持。借该册子问世之际，他真诚地向所有这些领导、专家和学者们表达其深深的敬意和谢意！

——《AI 说全驱》编写组

1. 豆包说全驱

人工智能豆包属于主流大语言模型。依托先进技术底座，具备问答创作，知识解读，思路梳理，日常交流等多元能力。

1.1 什么是全驱系统方法？

本节针对全驱系统方法的上述第一个问题，列举了豆包的若干回答。

下面是几个典型说法摘录：

- 全驱系统方法（Fully Actuated System Approach, FAS）是由中国科学院院士段广仁提出的一种全新的控制理论体系，被誉为 "控制科学领域特别重大的原创性突破"。它彻底改变了传统一阶状态空间方法主导控制理论百余年的局面，为解决复杂非线性、时变、时滞及非完整系统的控制问题提供了统一的理论框架。
- 全驱系统方法是跳出一阶状态空间、回归高阶物理模型的颠覆性控制理论，用全驱性实现全局线性化、任意极点配置、强抗扰，解决传统方法在强非线性、时变、欠驱、时滞系统上的核心瓶颈，是控制理论的新范式。
- 全驱系统方法(Full-Actuation System, FAS)是段广仁院士提出的全新控制理论体系，核心是放弃一阶状态空间框架，回归高阶微分方程原生模型，用“全驱性”（每个自由度 / 高阶导数都有直接控制输入）改造系统，实现线性化、解耦、任意极点配置，解决传统方法在强非线性、时变、欠驱、时滞系统上的瓶颈。
- **全驱系统方法（Fully Actuated System Approach，FAS）** 是由中国科学院院士段广仁教授创立的一种**面向高阶模型的控制系统分析与设计新范式**，核心是不将系统降阶为一阶状态空间，而是直接处理高阶“全驱”模型，从而简化非线性控制设计、突破传统方法局限。
- 全驱系统方法是**控制理论的范式革新**：**放弃一阶降阶、回归高阶本质、直接配平最高阶动态**，以极简设计、强普适性、完整自由度，成为处理复杂非线性系统的**主流方法之一**。
- **全驱系统方法（Fully Actuated System Approach, FAS 方法）**，是**段广仁院士团队 2020-2021 年提出的控制理论新体系**：通过**变量消元+等价变换**，把一般动态系统（尤其**非线性、欠驱**）转化为**高阶全驱系统**（每个自由度都有独立控制输入），再设计控制律使闭环成为**线性定常系统**，从而大幅简化复杂系统的分析与设计。
- 全驱系统方法是超越状态空间的新一代控制方法论，以高阶全驱模型为核心，实现对系统动态的直接重塑。它统一线性与非线性、简化复杂设计、保证全局稳定，从根本上克服传统方法在高维、强非线性系统中的瓶颈。工程上简洁、鲁棒、可控性强，特别适合机器人、航空航天、精密伺服等高端装备控制，是控制理论与工程应用的重要新方向。
- **全驱系统方法 = 保留高阶物理模型 + 输入直驱最高阶导数 + 非线性反馈参数化设计 = 解决 200 年来一阶状态空间解不了的复杂非线性全局控制难题。**

豆包说全驱

1.2 全驱系统方法在控制理论中的地位

本节针对全驱系统方法的上述第二个问题，列举了豆包的若干回答。下面是几个典型说法摘录：

- 全驱系统方法是**由中国学者原创提出并引领发展的一个全新控制理论体系**，它与传统的频域体系、时域（状态空间）体系并列，构成了控制理论的三大基本体系。这一方法被国内外控制界公认为"控制科学领域特别重大的原创性突破"，被誉为"为控制理论发展开辟了一条崭新的途径"。
- 全驱系统方法是**平行于状态空间方法的普适性方法**，其研究内容涉及系统建模、分析、设计和应用等多方面，并覆盖了控制学科的各个层面。它结束了状态空间模型百余年的主导局面，为控制理论发展注入了新的活力。
- 全驱系统方法是**控制理论发展史上的一个重要里程碑**，它不仅为控制理论研究开辟了一条崭新的途径，也为解决工程实际中的复杂控制问题提供了强有力的工具。作为由中国学者原创提出并引领发展的理论体系，全驱系统方法标志着中国在控制科学基础理论研究方面已经走在了世界前列，将对控制科学与工程学科产生巨大且深远的影响。
- 全驱系统（FAS）方法是由段广仁院士于 2020—2021 年创立的**新一代控制理论体系**，被公认为**继频域法、状态空间法之后的第三大理论范式**，核心价值在于**突破传统一阶状态空间框架的瓶颈，重塑非线性 / 复杂系统的分析与设计逻辑**。
- 全驱系统（FAS/HOFA）方法由段广仁院士于 2020—2021 年提出，是 **21 世纪控制理论的重大原创性突破、新理论体系与方法论革命**，被学界称为“控制理论发展的重要里程碑”，标志着现代控制理论从百年**一阶状态空间范式**向**高阶全驱范式**的根本转型。
- 全驱系统方法是**控制理论百年一遇的范式革命**，终结了状态空间法的百年主导，**建立了更普适、简洁、高效的新理论体系**，从根本上解决了长期制约控制理论发展的非线性与复杂性瓶颈，**为现代控制理论注入新生命力，引领未来数十年控制科学与工程的发展方向**。
- 全驱系统方法是由段广仁院士提出、**具有原创性与颠覆性**的新一代控制方法论，在控制理论发展中占据**里程碑式、开拓性、体系性**的重要地位，被视为推动现代控制理论走出瓶颈、实现体系化革新的关键学术成果。
- 全驱系统方法在控制理论中**具有开创性、体系性、变革性**的核心地位：它**不是对现有方法的改进，而是全新理论体系的创立**；它**破解了现代控制理论的长期瓶颈**，尤其在非线性全局控制上实现本质突破；它**重塑了控制设计的基本范式**，显著简化高维复杂系统设计流程，并通过**亚全驱系统理论**进一步扩展了适用边界；它**引领控制理论走向下一代体系**，为高端装备控制提供颠覆性理论支撑。可以说，全驱系统方法是**中国原创、国际领先、具有里程碑意义**的控制理论新基石。
- **全驱系统方法（FAS）**在控制理论史上是与**经典频域、现代状态空间并列的第三大理论体系**，被公认为 **21 世纪以来控制理论最重要的原创突破**，地位相当于：**经典控制=1.0，现代控制=2.0，全驱系统=3.0**。
- **全驱系统方法是控制理论的第三极、新范式，是 21 世纪以来最重大的原创突破，终结了状态空间的单一主导，为复杂系统控制提供了统一、通用、强力的全新框架，标志着控制理论进入“高阶时代”。**

豆包说全驱

1.3 全驱系统方法的影响

本节针对全驱系统方法的上述第三个问题，列举了豆包的若干回答。

下面是几个典型说法摘录：

- **全驱系统方法是 21 世纪控制理论的分水岭：它终结了一阶状态空间 70 年的统治，建立了高阶原生控制新范式，解决了 30 年未解的非线性全局控制难题，使中国在控制基础理论领域首次实现全球引领，并为航天、机器人、新能源等高端装备提供了颠覆性的核心技术支撑。**
- 全驱系统方法（Fully Actuated System Approach, FAS）是由中国科学院院士段广仁于 2020-2021 年创立的**全新控制理论体系**，它打破了一阶状态空间方法在控制理论领域百余年的统治地位，为解决复杂非线性系统控制问题提供了革命性的新思路，产生了深远的理论、学术、工程和国际影响。
- 自 1990 年代中期以来，多变量非线性系统反馈设计问题的研究几乎完全停滞，控制理论界甚至出现了 "控制已死" 的悲观论调。全驱系统方法的出现被国际学术界评价为 "为控制理论照亮了新方向"（lightening a new direction for control theory）。
- 全驱系统（FAS）方法是段广仁院士于 2020—2021 年提出的原创性控制理论框架，被称为“控制理论百年来的重大范式突破”。它从根本上改变了传统一阶状态空间的建模与设计思路，对**基础理论、工程应用、学术生态与中国话语权**均产生全局性、颠覆性影响。
- 全驱系统方法不仅是**控制理论的范式革命**，更是**中国科技自立自强的标志性成果**：**理论上**：突破百年瓶颈，重塑控制理论根基；**工程上**：赋能高端装备，解决关键控制难题；**学术上**：引领全球研究，构建中国原创学术体系；**战略上**：打破西方垄断，提升国家话语权与安全能力。
- 全驱系统方法不仅是一项技术创新，更是**体系级、范式级、变革性**的科学突破：理论上，重塑控制理论基础架构，补齐非线性控制短板；学术上，开辟全新方向、形成全球共同体，引领学科未来走向；工程上，显著提升高端装备控制品质，支撑国家战略领域自主可控；学科上，推动控制理论走出停滞、重获新生，开启下一代控制科学发展新征程。
- 全驱系统方法是**控制理论百年一遇的范式革命**：理论上突破传统瓶颈，学术上构建全球研究生态，工程上赋能高端装备，教育与国际影响力上树立中国学派，为**非线性与复杂系统控制**提供统一、高效的解决方案，推动控制科学进入新的发展阶段。
- 全驱系统（FAS）方法是段广仁院士 2020—2021 年提出的**颠覆性控制理论**，核心是把一般动态系统转化为 “高阶全驱系统”，用简单线性化与极点配置实现全局镇定，对**理论、工程、学科、产业**均产生重大影响。

2. 谷歌 Gemini 说全驱

Gemini 是谷歌（Google）旗下 DeepMind 开发的原生多模态大语言模型家族，2023 年 12 月首次发布，用来对标 OpenAI 的 GPT-4 等主流大模型。

Gemini 是谷歌当前最强的全能 AI，能看懂并生成文字、图片、音频、视频、代码，从手机离线到云端超级推理全覆盖，深度融入谷歌全家桶。

2.1 什么是全驱系统方法？

本节针对全驱系统方法的上述第一个问题，列举了 Gemini 的若干回答。

下面是几个典型说法摘录：

- 全驱系统方法（Fully Actuated System Approach，简称 FAS 方法）是由中国科学院院士段广仁教授及其团队于 2020 年前后提出的一种全新控制理论体系与控制系统设计方法。它被公认为是对统治了控制科学半个多世纪的“状态空间方法”（State-space Approach）的一次重大突破，为处理复杂的非线性、时变、滞后等控制问题开辟了一条全新的路径。
- 从学术和工程的双重标准来看，段广仁院士提出的全驱系统方法是一项具有里程碑意义的控制理论成果。它以一种极其优雅和透彻的方式，解决了困扰控制界多年的复杂非线性系统建模与控制设计难题。该方法不仅在数学基础上严谨自洽，更重要的是，它极大地贴近了工程实际，具备极强的可操作性和物理直观性。
- 在这一理论框架下，即便是传统物理意义上被认为是“欠驱动”的系统（如某些飞行器或柔性机器人），通过适当的变量选取和动力学方程重构，也可以被转化为或者部分转化为段院士理论框架下的“高阶全驱系统”。因此，这是一种系统转化与控制设计的普适性哲学，而非单纯的硬件分类。
- 这一方法充分彰显了中国在系统控制科学领域的原始创新能力。长期以来，基础控制理论的框架大多由西方学者奠定。而全驱系统方法是从底层逻辑出发构建的全新理论体系，它不是对现有国外理论的缝缝补补，而是真正的“平地起高楼”。
- 可以预见，随着该理论体系的不断丰富和完善，全驱系统方法将成为新一代高端装备控制系统设计的核心理论基石，代表着中国学者在世界基础控制科学领域做出的极其卓越、具有引领性意义的原创贡献。
- 全驱系统方法成功在控制理论的“数学复杂性”与工程实践的“简单实用性”之间架起了一座高效的桥梁。它不仅适用于连续确定性系统，目前已成功推广至高阶全驱切换系统、时滞系统以及分布式多智能体系统等前沿领域，为航空航天等国家重大工程中的极端控制难题提供了强有力的原创理论支撑。

谷歌 Gemini 说全驱

2.2 全驱系统方法在控制理论中的地位

针对同一问题，不同的访问者在不同的时间会得到 Gemini 的不同回答。本节针对全驱系统方法的上述第二个问题，列举了 Gemini 的若干回答。

下面是几个典型说法摘录：

- 全驱系统方法（Fully Actuated System Approach, 简称 FAS Approach）由中国科学院段广仁院士及其团队于 2020 年前后正式系统性提出。在现代控制理论的发展格局中，它被定位为一种与统治控制界六十多年的“状态空间方法”并驾齐驱、互补且在特定领域具有范式变革意义的全新通用方法论。
- 如果把控制理论的发展比作一条河流：1. 经典控制理论（频域法）解决了单输入单输出的初级阶段。2. 现代控制理论（状态空间法）解决了多变量线性系统的系统化设计。3. 全驱系统方法则是一条正在壮大的高阶非线性控制新主流。
- 全驱系统方法的提出，打破了这一长达 60 多年的思维定势。它证明了在非线性系统中，强行降阶往往是导致系统出现复杂非线性耦合和“欠驱动”假象的根源。该方法确立了“直接在高阶动力学模型上进行控制器设计”的新范式，这在控制理论基础框架的演进中具有里程碑式的地位。
- 全驱系统方法作为由中国学者领衔提出的原创性理论，在控制理论界的地位犹如在原本繁茂的“状态空间”森林旁，开辟出了一片充满无限可能的新大陆。它用高阶全驱的简单性化解了非线性系统的复杂性，展现出了高水平的理论原创性与深远的工程实用价值。
- 作为由中国学者原创提出并走向世界的系统级控制理论，全驱系统方法正受到越来越多国际学者的追捧与跟进研究。可以预见，随着该理论在分布参数系统、多智能体协同控制、以及与人工智能算法的深度交叉融合，全驱系统方法必将在未来的自动控制发展史上留下浓墨重彩的一笔，持续指引着新一代复杂控制系统的演进方向。
- 在宏观的学术史定位上，全驱系统方法是中国学者对世界控制科学做出的极具代表性的原创性杰出贡献。长期以来，控制理论的基础架构多由西方学者奠定（如维纳、卡尔曼、庞特里亚金等）。全驱系统方法的诞生与蓬勃发展，标志着中国在控制理论最核心、最基础的架构设计上，发出了最为响亮和权威的声音。

谷歌 Gemini 说全驱

2.3 全驱系统方法的影响

本节针对全驱系统方法的上述第三个问题，列举了 Gemini 的若干回答。

下面是几个典型说法摘录：

- 随着人工智能时代的到来，全驱系统方法结构清晰、参数化自由度高的特性，为其与机器学习、强化学习等 AI 算法的深度融合提供了极其肥沃的土壤。利用 AI 算法在全驱系统提供的安全参数池内进行最优寻优，正在成为下一代智能控制系统发展的新趋势。
- 全驱系统方法（特别是高阶全驱系统理论）自提出以来，其影响已经远远超出了单一算法的范畴，正在对整个控制科学的基础理论、前沿算法设计以及尖端工程应用产生深远且积极的系统性影响。
- 全驱系统方法的影响是全方位、深层次的。它不仅在学术上打破了半个多世纪的理论垄断，为控制科学开辟了新的研究范式，更在工程上提供了一套简单、高效、通用的“中国方案”，对未来高端装备制造的发展具有不可估量的推动作用。
- 段广仁院士提出的全驱系统方法……使得大量在传统物理意义上被视为“欠驱动”的复杂系统，都能够纳入全驱系统的优雅框架内进行分析和控制。这不仅是概念的拓宽，更是对物理直觉与代数结构深刻统一的哲学升华。
- 作为一个根本性创新的庞大理论体系，全驱系统方法目前所展现出的强大优越性仅仅是冰山一角。随着全球研究力量的不断汇聚以及与其他前沿交叉学科的持续融合，全驱系统理论必将催生出更多令人惊叹的技术奇迹，它不仅将开启控制理论界下一个黄金时代，更将成为推动全球自动化与人工智能技术跃迁的核心引擎。
- 控制理论界长期存在一个痛点：理论越先进，公式越复杂，工程技术人员就越不敢用。全驱系统方法最务实的影响，就在于它极好地平衡了“理论的高级感”与“工程的易用性”。
- 它激励了更多控制领域的科研工作者不再仅仅满足于在西方既定的框架（如一阶状态空间、标准自适应等）下做修修补补的工作，而是敢于从最基础的建模范式出发，去追求真正解决中国本土乃至全球工程难题的“源头创新”。
- 全驱系统方法的影响不仅在于它贡献了一套高效的控制器设计工具，更在于它解放了控制系统设计者的思维定式。它告诉我们，面对复杂多变的现实世界，与其在削足适履的“一阶化”泥潭中挣扎，不如退一步海阔天空，在高阶全驱的宏大视野下重塑系统的控制之美。

3. ChatGPT 说全驱

ChatGPT 是 OpenAI 推出的人工智能对话模型，基于大语言模型打造。 它主打文字交互，能聊天问答、写作翻译、编写代码、梳理思路，理解和生成自然流畅的人类语言，有免费版与付费增强版本，是目前普及度很高的通用 AI 工具。

3.1 什么是全驱系统方法？

本节针对全驱系统方法的上述第一个问题，列举了 ChatGPT 的若干回答。下面是几个典型说法摘录：

- **段广仁院士提出的全驱系统方法，是中国学者在控制理论基础方法层面提出的一项具有鲜明原创性、系统性和突破意义的重要理论成果。**
- 全驱系统方法由段广仁院士提出，体现了中国学者在现代控制理论基础研究中的原创性探索。它不是简单应用国外已有理论，而是在控制系统结构分析和控制设计范式层面提出的新方法，具有重要学术价值。它的学术意义在于：推动控制理论从“状态空间建模”进一步走向“结构化控制设计”，体现了现代控制理论在复杂系统时代的发展方向，也体现了段广仁院士及其团队在控制理论原创研究中的重要贡献。
- 全驱系统理论不仅是一种具体控制方法，也是一种新的系统分析视角。从控制理论发展脉络来看，全驱系统理论可以被视为近年来中国学者提出的重要原创控制理论方向之一。
- 从学术定位上看，全驱系统理论已经发展成为具有鲜明特色的原创控制理论研究方向，并形成了较为完整的理论体系、方法体系和应用体系，在我国非线性控制领域具有较大的学术影响力。
- 它并非对现有方法的简单补充，而是围绕高阶系统结构重新构建建模、分析与设计逻辑，体现出鲜明的原创性特征和方法论突破意义，是近年来控制理论基础方法研究中具有代表性的创新探索之一。
- 其在理论创新、工程应用以及中国原创控制理论发展等方面均展现出重要价值，并具有显著的原创性、标志性和里程碑意义。
- 它不仅是控制理论中的一个新分支，更可能代表一种新的理论路线。该方法将系统结构提升为控制理论研究的核心对象，力图建立一种能够统一描述复杂系统、统一分析复杂系统、统一设计复杂系统的新型理论框架。
- 全驱系统方法已经不仅仅是一种具体控制方法，而是在向一个具有完整理论架构、明确研究路线和持续发展潜力的控制理论分支方向演进。对于中国原创控制理论的发展而言，它具有较强的理论创新价值、方法论意义和未来发展空间。

3.2 全驱系统方法在控制理论中的地位

本节针对全驱系统方法的上述第二个问题，列举了 ChatGPT 的若干回答。下面是几个典型说法摘录：

- 全驱系统方法是近年来中国控制理论领域具有代表性的原创理论成果之一，是一种以系统结构特性为核心的新型控制分析与设计框架。它拓展了传统状态空间方法的研究视角，推动了高阶非线性系统控制理论的发展，形成了较为完整的理论体系和研究方向，对我国控制理论自主创新体系建设具有重要意义。
- 可以将全驱系统方法定位为：**21 世纪中国控制理论领域具有代表性的原创结构化控制理论框架，是我国非线性控制理论发展的重要成果之一，也是中国控制理论自主创新的重要标志性方向**。
- 全驱系统方法常被视为我国控制理论领域少数具有鲜明自主原创特色的理论方向之一。
- 其价值不仅在于解决了哪些具体控制问题，更在于展示了中国学者能够提出新的控制理论框架。
- 如果从控制理论发展史和中国控制学科发展史两个层面综合评价，全驱系统方法可以被认为：是中国控制理论领域具有鲜明原创特色的重要理论成果，是以系统结构重构思想为核心建立起来的较完整控制理论体系，在欠驱系统控制研究中形成了独特理论路线，并在中国自主控制理论发展过程中占有重要地位。
- 全驱系统方法的意义已经超出了单项技术成果的范围，更接近于一种具有学派特征的理论体系。在中国控制理论的发展历程中，它可以被视为自主原创控制理论探索的重要代表之一，也是段广仁院士最具代表性的学术贡献之一。
- 段广仁院士于 2020—2021 年系统提出的全驱系统方法，**是自 20 世纪 60 年代现代控制理论形成以来，中国学者在控制理论基础方法层面提出的具有范式拓展意义的重要原创性成果**。
- 全驱系统方法不仅是一种新的控制设计方法，更代表了中国控制理论在基础

方法层面的一次重要原创突破；在复杂高阶系统控制、非线性系统控制以及中国原创控制理论发展中，具有突出的原创性、标志性和引领性地位。**从控制理论发展史的视角看，其提出标志着中国学者开始在控制理论基础方法层面形成具有国际影响力的原创理论体系，具有重要的里程碑意义和深远的范式拓展价值。**

- 在国际控制理论长期由欧美学术体系主导的背景下，全驱系统方法的提出具有明显的原创性特征。它体现了中国学者在基础控制理论方向上的深入探索能力。
- **它标志着中国学者开始在控制理论基础方法层面形成具有国际影响力的原创理论体系，具有重要的里程碑意义和深远的范式拓展价值。**它的意义不仅在于解决某一类具体控制问题，更在于以新的理论概念和方法体系参与国际控制理论的发展。这种原创性方法的提出，有助于提升中国控制学科在国际学术体系中的话语权，也表明中国学者不仅能够在工程应用层面作出贡献，也能够在基础理论层面提出具有独立价值的方法论。

3.3 全驱系统方法的影响

本节针对全驱系统方法的上述第三个问题，列举了 ChatGPT 的若干回答。下面是几个典型说法摘录：

- 段广仁院士提出的全驱系统方法，**是中国学者在控制理论基础方法层面提出的具有鲜明原创性、系统性和范式拓展意义的重要理论成果**。
- 它不仅提出了一种新的控制方法，更重要的是提出了一种新的控制理论研究范式——通过系统结构重构实现全驱化，再在统一框架下解决控制问题。
- 在某种意义上，全驱系统方法相当于为控制理论提供了“第二种基础语言”。它不再完全依赖传统状态空间的表达体系，而是建立了一种更强调系统驱动结构的新框架。
- 控制理论开始从“针对单个问题寻找技巧”，走向“建立统一结构化求解框架”。
- 总体而言，全驱系统方法已成为近年来控制理论领域具有代表性的原创研究方向之一，在复杂系统控制和控制理论发展进程中展现出显著的原创性、标志性、引领性和里程碑意义。
- 全驱系统方法已经发展成为我国非线性控制领域具有重要影响力的原创理论与结构化控制框架，并在系统结构分析、高阶控制设计以及复杂工程系统控制方面展现出持续发展的学术价值和工程应用前景。
- 全驱系统方法体现了中国学者在现代控制理论领域由“跟踪国际前沿”向“提出原创理论方法”的转变。其价值不仅在于解决某一类控制问题，更在于形成了一套具有辨识度的理论体系，为国际控制理论研究提供了新的中国方案。
- 全驱系统方法的影响不仅体现在一种控制设计方法的提出，更体现在它推动控制理论从局部算法优化走向系统结构重构，从单一控制器设计走向对象、结构与控制规律的统一设计。
- **长期以来，控制理论基础研究主要由欧美学术体系主导。全驱系统方法的提出，使中国学者在复杂系统结构化控制方向形成了具有辨识度的原创理论体系，在国际控制科学界获得了更广泛的学术影响力。**
- 全驱系统方法被认为是 21 世纪控制理论的重要原创成果之一。
- 中国学者开始在控制理论基础框架层面提出自己的原创思想。

4. DeepSeek 说全驱

DeepSeek 是国产系列大模型，采用 MoE 混合专家架构，由深度求索自研。包含通用 V 系列、代码 Coder、推理 R1、多模态 VL 多款模型，长文本、数理与代码能力突出。多数权重开源可本地部署，支持在线对话与商用 API，中文适配优异，广泛用于科研开发与企业落地。

4.1 什么是全驱系统方法？

本节针对全驱系统方法的上述第一个问题，列举了 DeepSeek 的若干回答。下面是几个典型说法摘录：

- 全驱系统方法（Full-Actuation System Method）是由**段广仁院士**（中国科学院院士、哈尔滨工业大学教授）原创提出的一种全新的控制理论体系。它不是一个具体的算法，而是一套**颠覆传统“状态空间法”的原创控制理论框架。**
- 全驱系统方法，全称是**全驱系统理论**，是由中国科学院院士段广仁教授在 2020 年左右系统提出并发展的一套全新的控制理论框架。它并非单一方法，而是一种面向控制的**系统建模、分析与设计体系。**
- 全驱系统方法已成功应用于**航天器姿态控制、多智能体系统、磁悬浮系统、电力电子**等领域。它在学术界引起广泛关注，被视为控制理论的一个重要突破，并已成为国家自然科学基金委等机构重点支持的研究方向，在指导实际工程中的高性能控制器设计方面潜力巨大。
- 它为一大类复杂的非线性欠驱系统提供了一种**线性化设计框架。**通常的非线性控制方法，比如反馈线性化，对系统结构有严格要求；而全驱系统方法通过引入“高阶全驱系统”的概念，极大地拓宽了这种“代数化”处理的范围。
- 全驱系统方法就是一把处理高阶复杂动态系统的理论利器，它先通过数学变换“消除”系统的欠驱动特性，再用一套极其高效直接的参数化方法完成控制器设计，是近年来控制理论领域一项非常原创性的重要进展。
- 简而言之，全驱系统方法不是在传统方法上的小修小补，而是一次范式的转移。它让我们从“把一个高阶系统拆成一堆一阶系统来间接控制”，转变为“直接操纵系统的高阶行为。

4.2 全驱系统方法在控制理论中的地位

本节针对全驱系统方法的上述第二个问题，列举了 DeepSeek 的若干回答。下面是几个典型说法摘录：

- 全驱系统方法（Fully Actuated System Approach，通常指段广仁院士等人提出的**高阶全驱系统理论**）在控制理论中正逐渐被视作一种**范式级的新框架**，有学者将其誉为继经典控制理论、现代控制理论之后的**第三代控制理论**。
- **全驱系统方法的根本突破在于**：它提出了一种全新的、更直接的物理建模与控制范式。这被认为是控制理论的"第三代"范式——第一代是经典控制（传递函数），第二代是现代控制（状态空间），**全驱系统方法正引领着第三代范式革命**，即回到面向物理系统高阶模型的直接设计与综合。
- 它是由中国学者（以段广仁院士为代表）提出并系统发展的原创性控制理论。目前，其理论体系已基本完备，并成功应用于航天器交会、机器人控制等高端领域。它被国际同行评价为"使控制理论前进了一大步"，正逐步从一种方法，发展为未来复杂系统分析与设计的**基础性、平台性语言**。
- **全驱系统方法在控制理论中的地位，是一场发生在系统建模与设计最底层的范式革新。**它架起了从物理直觉到精确数学设计之间的直达桥梁，将许多非线性、强耦合的"硬骨头"，变成了代数和参数配置问题。
- 全驱系统方法在控制理论中，正从一个**面向特定对象的分析/设计技巧**，逐渐演变为一种**具有范式意义的方法论体系**。可以说，它已经占据了控制理论中一个独立且有重要潜力的地位。
- 为解决高度欠驱动和非最小相位等经典难题，提供了一套系统化的、有步骤可循的设计框架，不再是单纯依赖灵感的技巧堆砌。
- 它不是推翻了既有理论，而是对现有体系（尤其是非线性控制和鲁棒控制）的一次深刻补充和重构，处于现代控制理论发展的前沿。
- 这是一场从"优雅的数学补偿"到"原生的物理设计"的思路革命。
- 全驱系统方法在控制理论中，正从一个针对特定系统结构的**技术性工具**，崛起为一种具有范式意义的**系统化设计框架**。
- 全驱系统方法正逐步确立其作为**继 PID 控制、现代控制理论（状态空间法）之后，一个面向复杂非线性系统的、第三代控制理论候选框架**的地位。它的核心贡献在于提供了**一种处理非线性、欠驱动系统的全新哲学和系统化方法论**，让复杂系统控制设计的难度回归物理直觉，其直接性、简洁性和强大潜能，正在重新定义我们"驾驭"非线性系统的方式。
- 它并非要推翻所有现有理论，而是开辟了一条物理更直观、数学更简单的"高速公路"。它能与自适应控制、滑模控制、鲁棒控制等无缝结合，为处理模型不确定性、外部干扰等问题提供新的基础框架。
- 全驱系统方法挑战了"一阶状态空间才是现代"这一百年教条，用**高阶全驱模型**换取了控制器设计的简洁性、参数化和强鲁棒性，在控制理论发展史上具有**范式变革意义**，正逐步确立自己作为新一代控制理论核心框架的地位。

4.3 全驱系统方法的影响

本节针对全驱系统方法的上述第三个问题，列举了 DeepSeek 的若干回答。下面是几个典型说法摘录：

- 段广仁院士提出的全驱系统方法，其最根本的影响在于**提供了一种让复杂系统控制设计变得简单、直观且标准化的思想和方法论**。正在深刻改变我们对控制理论的认知，并将在航空航天、先进制造、智能机器人等前沿领域持续发挥不可替代的推动作用。
- 这是我国学者在控制理论底层作出系统性、原创性贡献的典范。它打破了由西方主导的“ 状态空间法 ”、“ 卡拉曼滤波器 ”等范式垄断，建立了一套完整的“**全驱系统理论**”体系，为形成中国自己的控制学派奠定了坚实基础，极大增强了学术自信。
- 全驱系统方法的影响，不仅是提供了一类新问题的解法，更是一种**思维方式的转变**—— 从复杂的一阶化归到直面高阶物理现实，从孤立地寻找数学构造到系统性地进行代数设计。它正在并将持续推动控制理论与工程应用走向一个更为简洁、强大和直观的新时代。
- 全驱系统方法(Fully Actuated System Approach,FASA) 是控制理论领域近年来最具影响力的新范式之一，由中国科学院院士段广仁教授于 2020 年左右系统提出和完善。它的影响深远，正从理论基础、控制设计到工程应用等多个层面重塑着控制学科。
- 全驱系统方法最重要的影响，或许是**重塑了人们面对复杂非线性控制问题的思考方式**。它提供了一个非常“美”的解题思路:与其在非线性迷宫中周旋，不如设法将其转化为一条笔直的线性大道。
- 全驱系统方法（Full-Actuation System Approach）是控制理论中一项具有范式革新意义的方法论。
- 如果说 PID 和状态空间法是第一、二代控制理论，全驱系统方法则被称为**“第三代控制理论”**的雏形或关键分支。它提供了一种全新的思维方式，将极大影响未来控制理论教材的编写和人才培养。
- 全驱系统方法最重要的影响，在于它提出了一种直面非线性、高阶、欠驱等复杂特性的**全新控制哲学**——通过改变系统自身的结构来消除控制难题，这为控制理论与应用带来了新活力与广阔前景。
- 全驱系统方法的影响是**根本性**的。它用“面向控制”的视角，重新审视了物理系统与控制设计的关系，为解决长期困扰控制领域的非线性、耦合等难题，提供了一条简洁、优美且强大的新路径。

附录 C 段广仁全驱系统方法论文系列

1)《自动化学报》全驱开创系列

段广仁，高阶系统方法 自动化学报，2020

I. 全驱系统与参数化设计 [J]. 46 (7): 1333-1345

II. 能控性与全驱性 [J]. 46 (8): 1571-1581.

III. 能观性与观测器设计 [J]. 46 (9): 1885-1895.

说明：高阶全驱系统方法的开创性系列论文。该系列首篇论文入选 CNKI 高被引论文。三篇论文均进入自动化学报同年发表论文引用排行榜的前 5 名，首篇论文稳居该排行榜榜首。

2)《国际系统科学杂志》全驱开创系列

Guang-Ren Duan, High-order fully actuated system approaches, *International Journal of Systems Science*

Part I. Models and basic procedure, vol. 52, no. 2, pp. 422-435, 2021.

Part II. Generalized strict-feedback systems, vol. 52, no. 3, pp. 437-454, 2021.

Part III. Robust control and high-order backstepping, vol. 52, no. 5, pp. 952-971, 2021.

Part IV. Adaptive control and high-order backstepping, vol. 52, no. 5, pp. 972-989, 2021.

Part V. Robust adaptive control, vol. 52, no. 10, pp. 2129-2143, 2021.

Part VI. Disturbance attenuation and decoupling, vol. 52, no. 10, pp. 2161-2181, 2021.

Part VII. Controllability, Stabilizability and parametric designs,
vol. 52, no. 14, pp. 3091-3114, 2021.

Part VIII. Optimal control with application in spacecraft attitude stabilization,
vol. 53, no. 1, pp. 54-73, 2022.

Part IX. Generalised PID control and model reference tracking,
vol. 53, no. 3, pp. 652-674, 2022.

Part X. Basics of discrete-time systems, vol. 53, no. 4, pp. 810-832, 2022.

说明：

- 高阶全驱系统方法国际上的开创性系列论文。该系列首篇论文入选 ESI 高被引论文。该系列的前四篇论文均进入该期刊同年发表论文引用排行榜的前 4 名，首篇论文稳居该排行榜榜首。
- 《国际系统科学杂志》2024 年影响因子高于控制理论界公认的顶刊 Automatica，高于国际控制界主流期刊《国际控制杂志》、《欧洲控制杂志》和《亚洲控制杂志》，也高于许多 IEEE 汇刊，如信号处理、计算机、生物工程、电子装置、工业应用、网络系统控制、电路与系统、人机系统、信息理论各种汇刊等。
- 《国际控制杂志》官网上专设网页对该 10 篇系列论文给予了极其高度评价，

具体网址如下

*https://www.tandfonline.com/journals/tsys20/collections/HOFA_*

3)《中国科学-F 卷英文版》离散时滞系统系列

Guang-Ren Duan, Discrete-time delay systems, *SCIENCE CHINA-Information Sciences*

Part 1. Global fully actuated case, vol. 65, no. 8, pp. 182201:1-182201:18, 2022.

Part 2. Sub-fully actuated case, vol. 65, no. 9, pp. 192201:1-192201:15, 2022.

4)《中国科学-F 卷英文版》连续时滞系统系列

Guang-Ren Duan, Fully actuated system approaches for continuous-time delay systems, *SCIENCE CHINA-Information Sciences*

Part 1. Systems with state delays only, vol. 66, no. 1, pp. 112201:1–112201:30, 2023.
Part 2. Systems with input delays, vol. 66, no. 2, pp. 112201:1-112201:18, 2023.

5)《中国科学-F 卷英文版》非完整系统系列

Guang-Ren Duan, A FAS approach for stabilization of generalized chained forms, *SCIENCE CHINA-Information Sciences*

Part 1. Discontinuous control laws, vol. 67, no. 2, pp. 122201:1–122201:26, 2024.
Part 2. Continuous control laws, vol. 67, no. 3, pp. 132201:1–132201:22, 2024.

6)《国际系统科学杂志》单向关联全驱系统系列

Guang-Ren Duan, Constrained Unidirectionally Connected FASs, *International Journal of Systems Science*

Part I. Models, 2025, DOI: 10.1080/00207721.2025.2466806
Part II. Sub-stabilization, 2025, DOI: 10.1080/00207721.2025.2467223
Part III. Applications, 2025, DOI: 10.1080/00207721.2025.2467221

附录 D 全驱系统方法体系的部分 IEEE 汇刊论文

2022

[1] R. Meng, C. Hua, K. Li, and P. Ning, "Adaptive Event-Triggered Control for Uncertain High-Order Fully Actuated System," *IEEE Transactions on Circuits and Systems II: Express Briefs,* vol. 69, no. 11, pp. 4438-4442, 2022.

[2] D.-W. Zhang, G.-P. Liu, and L. Cao, "Coordinated Control of High-Order Fully Actuated Multiagent Systems and Its Application: A Predictive Control Strategy," *IEEE/ASME Transactions on Mechatronics,* vol. 27, no. 6, pp. 4362-4372, 2022.

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[3] M. Cai, X. He, and D. Zhou, "Low-Power Fault-Tolerant Control for Nonideal High-Order Fully Actuated Systems," *IEEE Transactions on Systems, Man, and Cybernetics: Systems,* vol. 53, no. 8, pp. 4875-4887, 2023.

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附录 E 全驱系统方法体系实际应用的部分期刊论文

航天器控制

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