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智能机器人专辑

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◤ 美国发布《机器人基础研究（FRR）计划》

2020 年 8 月，美国国家科学基金会发布《机器人基础研究（FRR）计划》（Foundational Research in Robotics (FRR)），旨在为机器人技术的研究提供支持和指导，促进机器人技术的创新和发展；通过支持创新性的研究项目，推动机器人技术的发展，提高机器人的性能和能力，为未来的机器人应用奠定基础。

FRR 计划主要关注机器人技术的基础研究，包括机器人设计、控制、感知、人机交互等方面的研究，以及机器人技术在各个领域的应用研究。同时，该计划也提高了公众对机器人技术的认识和理解，为机器人技术的发展和应用创造了良好的环境。

来源：https://new.nsf.gov/funding/opportunities/foundational-research-robotics-frr.

◤ 美国发布《国家机器人计划 3.0：机器人集成创新》

2021 年 2 月，美国国家科学基金会发布《国家机器人计划 3.0：机器人集成创新》（National Robotics Initiative 3.0: Innovations in Integration of Robotics (NRI-3.0)），旨在推动机器人技术的创新与发展，并在之前的 NRI 计划基础上，专注于机器人技术的集成创新，包括机器人设计、控制、感知、人机交互等方面的研究。

该文件强调了机器人在各个领域的应用，如制造业、医疗健康、农业、交通等，以及机器人在解决社会问题、提高生活质量方面的重要作用。

该文件提出了美国在机器人技术领域的研究重点和战略目标，为相关领域的研究者提供了指导和支持，得到了联邦政府多个机构的支持，包括美国国家科学基金会（NSF）、美国交通部（DOT）、美国国家航空航天局（NASA）、美国国立卫生研究院（NIH）、美国国立职业安全与健康研究院（NIOSH）和美国农业部（USDA）。

来源：https://www.nsf.gov/pubs/2021/nsf21559/nsf21559.htm.

◤ 欧盟正在大力投资机器人产业

2023 年 6 月，国际机器人联合会（IFR）公布初步统计结果，欧洲的工业机器人数量正在增长，欧盟（EU）27 个成员国在 2022 年安装了近 72,000 台机器人，同比增长 6%。

IFR 主席玛丽娜-比尔（Marina Bill）说，欧盟内采用机器人最多的五个国家是德国、意大

利、法国、西班牙和波兰，2022 年这些国家安装的工业机器人约占欧盟总安装量的 70%。

德国是迄今为止欧洲最大的机器人市场，2022 年安装了约 26,000 台（+3%），这占欧盟总安装量的 37%；在全球范围内，德国的机器人密度位居第四，仅次于日本、新加坡和韩国。意大利是欧洲仅次于德国的第二大机器人市场，2022 年的安装量达到历史新高，接近 12,000 台（+10%），占欧盟总安装量的 16%。法国的机器人市场在欧洲排名第三，年安装量增长了 15%，总数达到 7,400 台，这一数字还不到邻国德国的三分之一。

来源：https://ifr.org/ifr-press-releases/news/eu-industries-invest-heavily-in-robotics

◤ 国际机器人联合会发布《2023 年世界机器人报告：亚洲领先于欧洲和美洲》

2023 年 9 月 26 日，国际机器人联合会（IFR）发布《World Robotics 2023 Report: Asia ahead of Europe and the Americas》。报告显示，所有地区和主要市场均实现增长，全球工厂共安装了 553,052 台工业机器人，2022 年同比增长率为 5%；按地区划分，73%的新部署机器人安装在亚洲，15%安装在欧洲，10%安装在美洲。

中国是迄今为止全球最大的市场。2022 年中国的年安装量达到 290,258 台，比 2021 年增长了 5%。为了服务于这个充满活力的市场，国内外机器人供应商纷纷在中国建厂，并不断提高产能，机器人年安装量平均每年增长 13%（2017-2022 年）。

欧盟仍是全球第二大市场（70,781 台；+5%）。2022 年德国是全球前五大采用者之一，在欧盟的市场份额为 36%，德国的安装量减少了 1%，为 25,636 台。英国脱欧后，工业机器人安装量增长了 3%，2022 年达到 2,534 台。这还不到德国销量的十分之一。

在美洲，2022 年的安装量增长了 8%，达到 56,053 台，超过了 2018 年的峰值水平（55,212 台）。美国是最大的地区市场，占 2022 年美洲安装量的 71%，机器人安装量增长了 10%，达到 39,576 台，这与 2018 年 40,373 台的峰值水平相差无几。增长的主要动力来自汽车行业，其安装量激增了 47%（14,472 台），汽车行业的份额现已回升至 37%。

2023 年的特点是全球经济增长放缓，预计 2023 年的机器人安装量不会遵循这一规律。没有迹象表明，整体长期增长趋势将很快结束，情况将恰恰相反。全球每年安装 60 万台机器人的目标预计将在 2024 年实现。

来源：https://ifr.org/ifr-press-releases/news/world-robotics-2023-report-asia-ahead-of-europe-and-the-americas.

◤ 工业和信息化部等 15 部门联合印发《“十四五”机器人产业发展规划》

2021 年 12 月，工业和信息化部等 15 部门联合印发的《“十四五”机器人产业发展规划》指出，到 2025 年，我国成为全球机器人技术创新策源地、高端制造集聚地和集成应用新高地。到 2035 年，我国机器人产业综合实力达到国际领先水平，机器人成为经济发展、人民生活、社会治理的重要组成。

来源：https://www.gov.cn/zhengce/zhengceku/2021-12/28/5664988/files/7cee5d915efa463ab9e7be82228759fb.pdf

◤ 工业和信息化部发布国家重点研发计划“智能机器人”重点专项 2023 年度指南

2023 年 8 月，工业和信息化部发布国家重点研发计划“智能机器人”重点专项 2023 年度项目申报指南，围绕核心零部件与算法、工业机器人、服务机器人、特种机器人等四个技术方向，按照基础研究、共性关键技术和应用示范三个层面，启动 30 项指南任务，安排国拨经费 3.29 亿元。总体目标是：构建适合我国国情的智能机器人技术体系，推动技术与产品持续创新；实现产业链高级化、产品与系统应用高端化，推动我国机器人技术与产业高质量发展；支撑国民经济主战场、国家重大需求、人民生命健康等相关行业/领域自主发展。

来源：https://service.most.gov.cn/kjjh_tztg_all/20230822/5337.html

◤ 上海市发布《上海市促进智能机器人产业高质量创新发展行动方案（2023-2025 年）》

2023 年 10 月，上海市经济信息化委、发展改革委、科委、财政局、统计局等联合印发《上海市促进智能机器人产业高质量创新发展行动方案（2023-2025 年）》。该行动方案旨在贯彻落实国家《“机器人+”应用行动实施方案》和《上海市促进智能终端产业高质量发展行动方案（2022-2025 年）》等政策，加快推动上海机器人产业集聚和高质量发展。方案提出到 2025 年，明确一个总体目标，即打造具有全球影响力的机器人产业创新高地；促进三个突破，在品牌、应用场景和产业规模方面实现“十百千”突破——打造 10 家行业一流的机器人头部品牌、100 个标杆示范的机器人应用场景、1000 亿元机器人关联产业规模；建设三个公共服务平台，智能机器人检测与中试验证创新中心、人形机器人制造业创新中心、通用机器人产

业研究院等；推动制造业重点产业工业机器人密度达 500 台/万人，机器人行业应用深度和广度显著提升。

来源：https://www.sheitc.sh.gov.cn/jsjb/20231026/6f6aab8a8745441b96220b0180f628d4.html

◤ A practical study of active disturbance rejection control for rotary flexible joint robot manipulator

旋转柔性关节机器人机械手的主动干扰抑制控制实践研究

作者：Bilal, Hazrat; Yin, Baoqun; Aslam, Muhammad Shamrooz; Anjum, Zeeshan; Rohra, Avinash; Wang, Yizhen

来源：Soft Computing, v: 27, i: 8, p: 4987-5001, 2023

摘要：This research presents a practical study of active disturbance rejection control law (ADRC) for the control of robotic manipulators in the presence of uncertainties. The control objective of the proposed control law is to track the trajectory accurately and rejects the disturbance caused by robotic manipulators. First, Euler Lagrange's equations are used to model the dynamic behavior of a rotary flexible joint manipulator system (RFJMS). Secondly, the ADRC is designed for the rejection of lump disturbances (modeling uncertainties, nonlinearities, and external disturbances) of the manipulator; to estimate the lump disturbances a fifth-order extended state observer is constructed. Furthermore, a state error feedback control law with disturbance compensation is designed, which needs only a few control parameters to be adjusted. Furthermore, we demonstrate the robustness and effectiveness of the proposed control law by comparing the experimental results with those of LQR and PID. Experimental results show that high precision position control as well as vibration suppression can be achieved with the proposed controller, which is superior to LQR and PID controllers. In spite of uncertainties and nonlinearity of the flexible joint, QUANSER's RFJMS exhibits excellent tracking behavior and disturbance rejection.

全文链接：https://link.springer.com/article/10.1007/s00500-023-08026-x

◤ Jerk-bounded trajectory planning for rotary flexible joint manipulator: an experimental approach

旋转柔性关节机械手的运动轨迹规划：一种实验方法

作者：Bilal, Hazrat; Yin, Baoqun; Kumar, Aakash; Ali, Munawar; Zhang, Jing; Yao, Jinfa

来源：Soft Computing, v: 27, i: 7, p: 4029-4039, 2023

摘要：The fundamental criteria for industrial manipulator applications are vibration free and smooth motion with minimum time. This paper investigates the trajectory tracking and vibration control of rotary flexible joint manipulator with parametric uncertainties. Firstly, the dynamic modeling via Euler Lagrange equation for a single link flexible joint manipulator is discussed. Secondly, for the execution of smooth motion between two points, bounded and continuous jerk trajectory is developed and implemented. In addition, the prospective strategy uses the concatenation of fifth-order polynomials to provide a smooth trajectory between two-way points. In the planned algorithm, user can independently define the position, velocity, acceleration and jerk values at both initial and final positions. The feature of user-defined parameters gives the versatility to the suggested algorithm for generating trajectories for diverse applications of robotic manipulators. Moreover, the planned scheme is easy to implement and computationally efficient. In the last, the performance of the presented scheme is examined by comparison with cubic splines and a linear segment with parabolic blends (LSPB) techniques. Generated trajectories were evaluated successfully by carrying multiple experiments on QUANSER's flexible joint manipulator.

全文链接：https://link.springer.com/article/10.1007/s00500-023-07923-5

◤ Does industrial robot application promote green technology innovation in the manufacturing industry?

工业机器人的应用能否促进制造业的绿色技术创新？

作者：Lee, Chien-Chiang; Qin, Shuai; Li, Yaya

来源：Technological Forecasting and Social Change, v: 183, p: 12, 2022

摘要：Manufacturing green technology innovation is important in achieving climate goals and is the key in promoting sustainable economic development. Using the industrial robot data and manufacturing green technology innovation data from 34 countries from 1993 to 2019, this paper reveals the mechanism and heterogeneity of the application of industrial robots (IRA) affecting green technology innovation (GTI) in the global manufacturing sector. The results indicate the following: (1) The IRA significantly promotes GTI, and the endogenous and robustness tests show that the results are robust. (2) The IRA promotes GTI with a dual-channel mechanism-the mediating effect of

green R&D investment and the moderating effect of environmental regulation. (3) There is two-dimensional heterogeneity in terms of the application industries and regions in terms of the green technology innovation effects of industrial robot applications. (4) In addition, the implementation of Industry 4.0 is in favor of the stimulating effects of industrial robots on green technology innovation. Finally, valuable policy advices are proposed based on the empirical results.

全文链接：https://www.sciencedirect.com/science/article/pii/S0040162522004164?via%3Dihub

◤ Untethered small-scale magnetic soft robot with programmable magnetization and integrated multifunctional modules

具有可编程磁化和集成多功能模块的无系绳小型磁性软体机器人

作者：Dong, Yue; Wang, Lu; Xia, Neng; Yang, Zhengxin; Zhang, Chong; Pan, Chengfeng; Jin, Dongdong; Zhang, Jiachen; Majidi, Carmel; Zhang, Li

来源：Science Advances, v: 8, i: 25, p: 14, 2022

摘要：Intelligent magnetic soft robots capable of programmable structural changes and multifunctionality modalities depend on material architectures and methods for controlling magnetization profiles. While some efforts have been made, there are still key challenges in achieving programmable magnetization profile and creating heterogeneous architectures. Here, we directly embed programmed magnetization patterns (magnetization modules) into the adhesive sticker layers to construct soft robots with programmable magnetization profiles and geometries and then integrate spatially distributed functional modules. Functional modules including temperature and ultraviolet light sensing particles, pH sensing sheets, oil sensing foams, positioning electronic component, circuit foils, and therapy patch films are integrated into soft robots. These test beds are used to explore multimodal robot locomotion and various applications related to environmental sensing and detection, circuit repairing, and gastric ulcer coating, respectively. This proposed approach to engineering modular soft material systems has the potential to expand the functionality, versatility, and adaptability of soft robots.

全文链接：https://www.science.org/doi/10.1126/sciadv.abn8932

◤ Design and printing of proprioceptive three-dimensional architected robotic metamaterials

本体感觉三维结构机器人超材料的设计与打印

作者：Cui, Huachen; Yao, Desheng; Hensleigh, Ryan; Lu, Haotian; Calderon, Ariel; Xu, Zhenpeng; Davaria, Sheyda; Wang, Zhen; Mercier, Patrick; Tarazaga, Pablo; Zheng, Xiaoyu (Rayne)

来源：Science, v: 376, i: 6599, p: 1287-+, 2022

摘要：Advances in additive manufacturing techniques have enabled the creation of stimuli-responsive materials with designed three-dimensional (3D) architectures. Unlike biological systems in which functions such as sensing, actuation, and control are closely integrated, few architected materials have comparable system complexity. We report a design and manufacturing route to create a class of robotic metamaterials capable of motion with multiple degrees of freedom, amplification of strain in a prescribed direction in response to an electric field (and vice versa), and thus, programmed motions with self-sensing and feedback control. These robotic metamaterials consist of networks of piezoelectric, conductive, and structural elements interwoven into a designed 3D lattice. The resulting architected materials function as proprioceptive microrobots that actively sense and move.

全文链接：https://www.science.org/doi/10.1126/science.abn0090

◤ All-printed soft human-machine interface for robotic physicochemical sensing

用于机器人理化传感的全打印软体人机界面

作者：Yu, You; Li, Jiahong; Solomon, Samuel A.; Min, Jihong; Tu, Jiaobing; Guo, Wei; Xu, Changhao; Song, Yu; Gao, Wei

来源：Science Robotics, v: 7, i: 67, p: 12, 2022

摘要：Ultrasensitive multimodal physicochemical sensing for autonomous robotic decision-making has numerous applications in agriculture, security, environmental protection, and public health. Previously reported robotic sensing technologies have primarily focused on monitoring physical parameters such as pressure and temperature. Integrating chemical sensors for autonomous

dry-phase analyte detection on a robotic platform is rather extremely challenging and substantially underdeveloped. Here, we introduce an artificial intelligence-powered multimodal robotic sensing system (M-Bot) with an all-printed mass-producible soft electronic skin-based human-machine interface. A scalable inkjet printing technology with custom-developed nanomaterial inks was used to manufacture flexible physicochemical sensor arrays for electrophysiology recording, tactile perception, and robotic sensing of a wide range of hazardous materials including nitroaromatic explosives, pesticides, nerve agents, and infectious pathogens such as SARS-CoV-2. The M-Bot decodes the surface electromyography signals collected from the human body through machine learning algorithms for remote robotic control and can perform in situ threat compound detection in extreme or contaminated environments with user-interactive tactile and threat alarm feedback. The printed electronic skin-based robotic sensing technology can be further generalized and applied to other remote sensing platforms. Such diversity was validated on an intelligent multimodal robotic boat platform that can efficiently track the source of trace amounts of hazardous compounds through autonomous and intelligent decision-making algorithms. This fully printed human-machine interactive multimodal sensing technology could play a crucial role in designing future intelligent robotic systems and can be easily reconfigured toward numerous practical wearable and robotic applications.

全文链接：https://www.science.org/doi/10.1126/scirobotics.abn0495

◤ A pipeline inspection robot for navigating tubular environments in the sub-centimeter scale

用于在亚厘米级管状环境中导航的管道检测机器人

作者：Tang, Chao; Du, Boyuan; Jiang, Songwen; Shao, Qi; Dong, Xuguang; Liu, Xin-Jun; Zhao, Huichan

来源：Science Robotics, v: 7, i: 66, p: 13, 2022

摘要：In complex systems like aircraft engines and oil refinery machines, pipeline inspection is an essential task for ensuring safety. Here, we proposed a type of smart material-driven pipeline inspection robot (weight, 2.2 grams; length, 47 millimeters; diameter, <10 millimeters) that could fit

into pipes with sub-centimeter diameters and different curvatures. We adopted high-power density, long-life dielectric elastomer actuators as artificial muscles and smart composite microstructure-based, high-efficiency anchoring units as transmissions. Fast assembling of components using magnets with an adjustable number of units was used to fit varying pipeline geometries. We analyzed the dynamic characteristics of the robots by considering soft material's unique properties like viscoelasticity and dynamic vibrations and tuned the activation voltage's frequency and phase accordingly. Powered by tethered cables from outside the pipe, our peristaltic pipeline robot achieved rapid motions horizontally and vertically (horizontal: 1.19 body lengths per second, vertical: 1.08 body lengths per second) in a subcentimeter-sized pipe (diameter, 9.8 millimeters). Besides, it was capable of moving in pipes with varying geometries (diameter-changing pipe, L-shaped pipe, S-shaped pipe, or spiral-shaped pipe), filled media (air or oil), and materials (glass, metal, or carbon fiber). To demonstrate its capability for pipeline inspection, we installed a miniature camera on its front and controlled the robot manually from outside. The robot successfully finished an inspection task at different speeds.

全文链接：https://www.science.org/doi/10.1126/scirobotics.abm8597

◤ Telerobotic neurovascular interventions with magnetic manipulation

利用磁性操纵的远程机器人神经血管介入

作者：Kim, Yoonho; Genevriere, Emily; Harker, Pablo; Choe, Jaehun; Balicki, Marcin; Regenhardt, Robert W.; Vranic, Justin E.; Dmytriw, Adam A.; Patel, Aman B.; Zhao, Xuanhe

来源：Science Robotics, v: 7, i: 65, p: 20, 2022

摘要：Advances in robotic technology have been adopted in various subspecialties of both open and minimally invasive surgery, offering benefits such as enhanced surgical precision and accuracy with reduced fatigue of the surgeon. Despite the advantages, robotic applications to endovascular neurosurgery have remained largely unexplored because of technical challenges such as the miniaturization of robotic devices that can reach the complex and tortuous vasculature of the brain. Although some commercial systems enable robotic manipulation of conventional guidewires for coronary and peripheral vascular interventions, they remain unsuited for neuro vascular applications

because of the considerably smaller and more tortuous anatomy of cerebral arteries. Here, we present a teleoperated robotic neurointerventional platform based on magnetic manipulation. Our system consists of a magnetically controlled guidewire, a robot arm with an actuating magnet to steer the guidewire, a set of motorized linear drives to advance or retract the guidewire and a microcatheter, and a remote-control console to operate the system under real-time fluoroscopy. We demonstrate our systems capability to navigate narrow and winding pathways both in vitro with realistic neurovascular phantoms representing the human anatomy and in vivo in the porcine brachial artery with accentuated tortuosity for preclinical evaluation. We further demonstrate telerobotically assisted therapeutic procedures including coil embolization and clot retrieval thrombectomy for treating cerebral aneurysms and ischemic stroke, respectively. Our system could enable safer and quicker access to hard-to-reach lesions while minimizing the radiation exposure to physicians and open the possibility of remote procedural services to address challenges in current stroke systems of care.

全文链接：https://www.science.org/doi/10.1126/scirobotics.abg9907

◤ Applications of machine vision in agricultural robot navigation: A review

机器视觉在农业机器人导航中的应用综述

作者：Wang, Tianhai; Chen, Bin; Zhang, Zhenqian; Li, Han; Zhang, Man

来源：Computers and Electronics in Agriculture, v: 198, p: 13, 2022

摘要：Many tasks in smart agriculture have further requirements for the autonomous navigation of agricultural robots. Due to irreplaceable visual information and low-cost hardware costs, machine vision (MV) is widely used in agricultural robot navigation. This paper reviewed applications of MV in agricultural robot navigation. First, the advantages, disadvantages and roles of different vision sensors and MV algorithms in agricultural robot navigation were introduced. And then, the development status of MV in agricultural robot navigation was reviewed. Finally, the challenges of MV in agricultural robot navigation were discussed. To address these challenges, this paper looks forward to the development directions of future research.

全文链接：https://www.sciencedirect.com/science/article/pii/S0168169922004021?via%3Dihub

◤ Magnetic Soft Materials and Robots

磁性软材料与机器人

作者：Kim, Yoonho; Zhao, Xuanhe

来源：Chemical Reviews, v: 122, i: 5, p: 5317-5364, 2022

摘要：In conventional classification, soft robots feature mechanical compliance as the main distinguishing factor from traditional robots made of rigid materials. Recent advances in functional soft materials have facilitated the emergence of a new class of soft robots capable of tether-free actuation in response to external stimuli such as heat, light, solvent, or electric or magnetic field. Among the various types of stimuli-responsive materials, magnetic soft materials have shown remarkable progress in their design and fabrication, leading to the development of magnetic soft robots with unique advantages and potential for many important applications. However, the field of magnetic soft robots is still in its infancy and requires further advancements in terms of design principles, fabrication methods, control mechanisms, and sensing modalities. Successful future development of magnetic soft robots would require a comprehensive understanding of the fundamental principle of magnetic actuation, as well as the physical properties and behavior of magnetic soft materials. In this review, we discuss recent progress in the design and fabrication, modeling and simulation, and actuation and control of magnetic soft materials and robots. We then give a set of design guidelines for optimal actuation performance of magnetic soft materials. Lastly, we summarize potential biomedical applications of magnetic soft robots and provide our perspectives on next-generation magnetic soft robots.

全文链接：https://pubs.acs.org/doi/10.1021/acs.chemrev.1c00481

◤ Towards enduring autonomous robots via embodied energy

通过具身能量实现持久的自主机器人

作者：Aubin, Cameron A.; Gorissen, Benjamin; Milana, Edoardo; Buskohl, Philip R.; Lazarus, Nathan; Slipher, Geoffrey A.; Keplinger, Christoph; Bongard, Josh; Iida, Fumiya; Lewis, Jennifer A.; Shepherd, Robert F.

来源：Nature, v: 602, i: 7897, p: 393-+, 2022

摘要：Autonomous robots comprise actuation, energy, sensory and control systems built from materials and structures that are not necessarily designed and integrated for multifunctionality. Yet, animals and other organisms that robots strive to emulate contain highly sophisticated and interconnected systems at all organizational levels, which allow multiple functions to be performed simultaneously. Herein, we examine how system integration and multifunctionality in nature inspires a new paradigm for autonomous robots that we call Embodied Energy. Whereas most untethered robots use batteries to store energy and power their operation, recent advancements in energy-storage techniques enable chemical or electrical energy sources to be embodied directly within the structures and materials used to create robots, rather than requiring separate battery packs. This perspective highlights emerging examples of Embodied Energy in the context of developing autonomous robots.

全文链接：https://www.nature.com/articles/s41586-021-04138-2

◤ Learning robust perceptive locomotion for quadrupedal robots in the wild

野外四足机器人的鲁棒感知运动学习

作者：Miki, Takahiro; Lee, Joonho; Hwangbo, Jemin; Wellhausen, Lorenz; Koltun, Vladlen; Hutter, Marco

来源：Science Robotics, v: 7, i: 62, p: 14, 2022

摘要：Legged robots that can operate autonomously in remote and hazardous environments will greatly increase opportunities for exploration into underexplored areas. Exteroceptive perception is crucial for fast and energy-efficient locomotion: Perceiving the terrain before making contact with it enables planning and adaptation of the gait ahead of time to maintain speed and stability. However, using exteroceptive perception robustly for locomotion has remained a grand challenge in robotics. Snow, vegetation, and water visually appear as obstacles on which the robot cannot step or are missing altogether due to high reflectance. In addition, depth perception can degrade due to difficult lighting, dust, fog, reflective or transparent surfaces, sensor occlusion, and more. For this reason, the most robust and general solutions to legged locomotion to date rely solely on proprioception. This severely limits locomotion speed because the robot has to physically feel out the terrain before adapting its

gait accordingly. Here, we present a robust and general solution to integrating exteroceptive and proprioceptive perception for legged locomotion. We leverage an attention-based recurrent encoder that integrates proprioceptive and exteroceptive input. The encoder is trained end to end and learns to seamlessly combine the different perception modalities without resorting to heuristics. The result is a legged locomotion controller with high robustness and speed. The controller was tested in a variety of challenging natural and urban environments over multiple seasons and completed an hour-long hike in the Alps in the time recommended for human hikers.

全文链接：https://www.science.org/doi/10.1126/scirobotics.abk2822

全球智能机器人领域学术论文统计

采集 2011-2022 年全球重要期刊和会议上发表的与智能机器人相关论文，共计约 21.35 万篇，主要统计结果如下。

1.年度发文情况

智能机器人领域近十来年论文数量整体逐年上涨，但期刊与会议论文的情况有所不同。

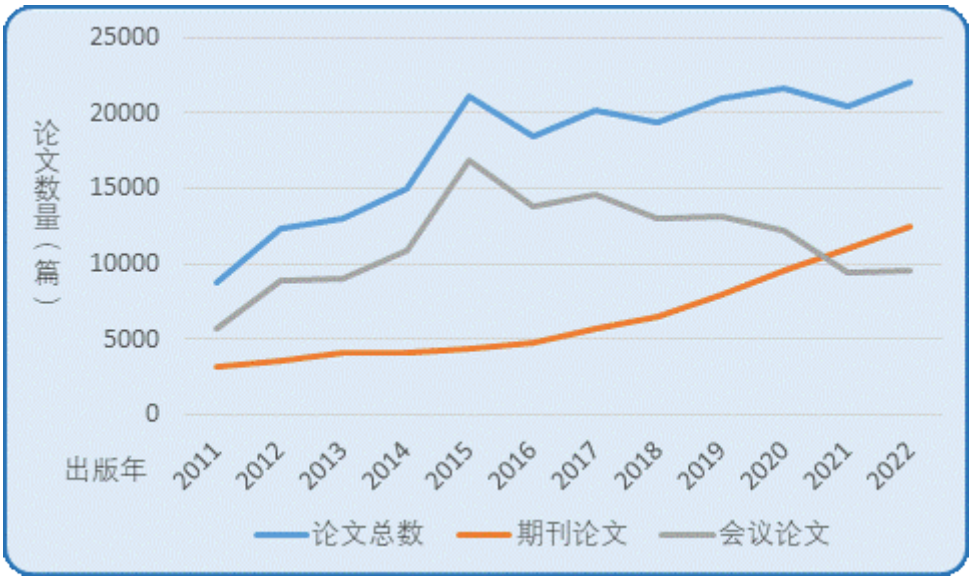

图 4-1 智能机器人领域期刊和会议论文产出年度趋势图

2.国家/地区分布及影响力

中国大陆在论文数量上全球领跑，美国在论文篇均他引频次上全球领跑。

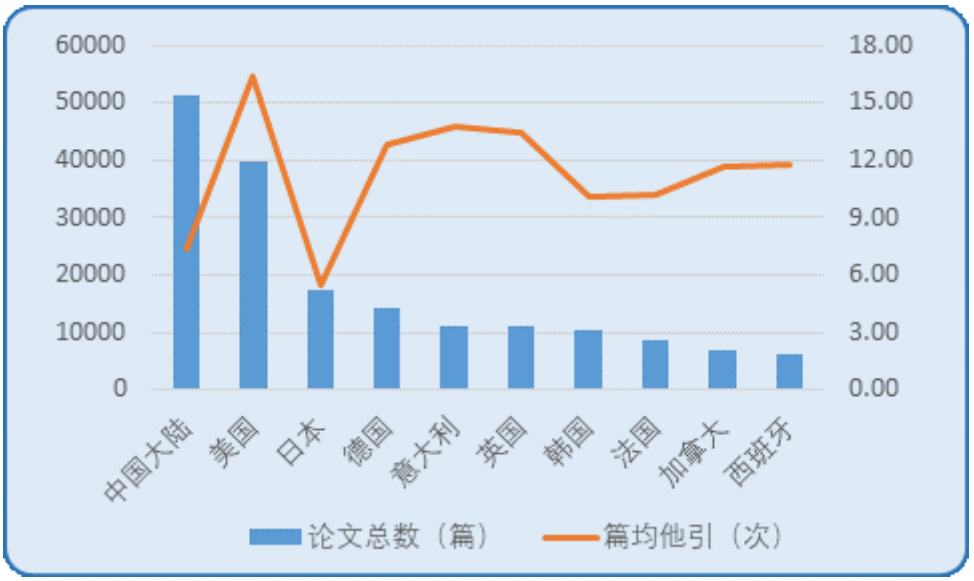

图 4-2 智能机器人领域论文 Top10 国家/地区论文被引对比图

3.主要机构及影响力

中国科学院在论文数量上虽全球领跑，麻省理工学院在论文篇均他引频次上全球领跑。

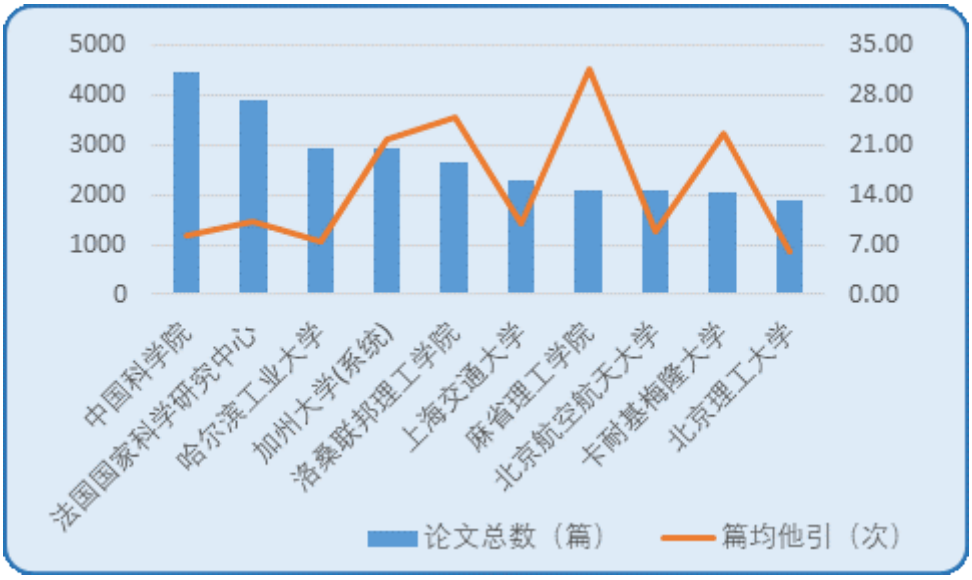

图 4-3 智能机器人领域论文 Top10 机构论文被引对比图

4.主要学科分布

智能机器人领域论文与自动化和控制系统、人工智能、电气和电子工程三个学科领域（Web of Science）联系最为紧密。

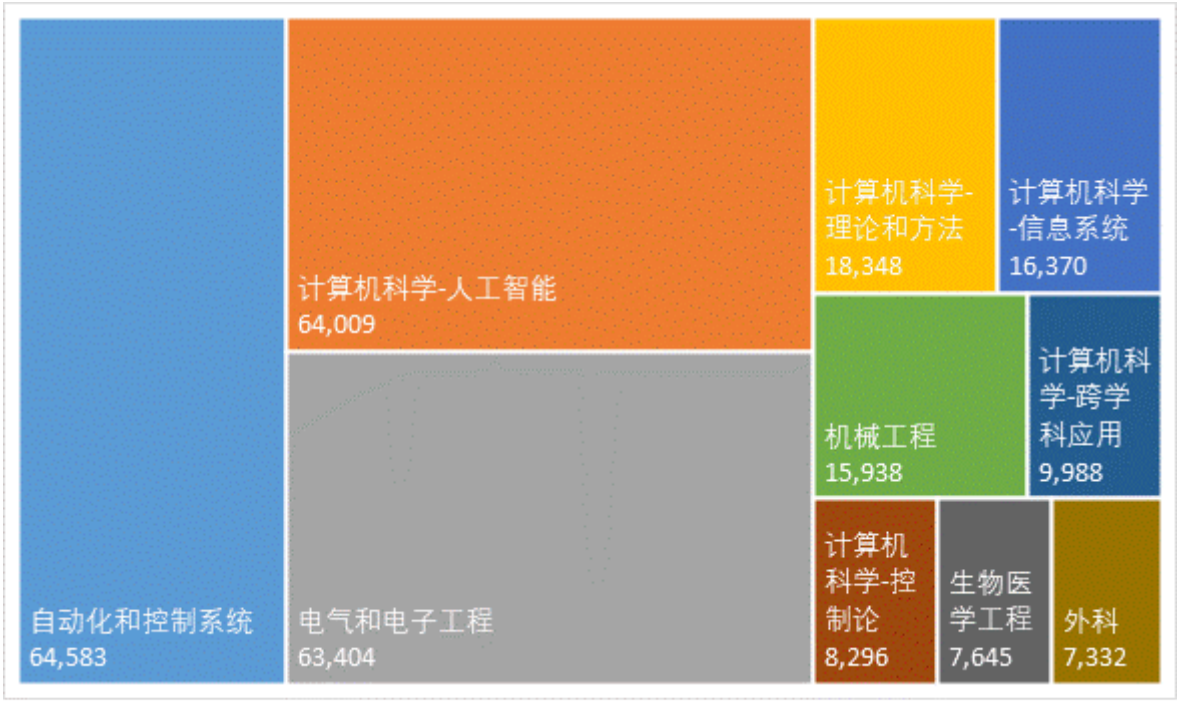

图 4-4 智能机器人领域论文 TOP10 学科分布

5.热点主题分布

智能机器人领域论文研究热点主题包括：（1）两足机器人、并联机器人、康复机器人等机器人类型；（2）介电弹性体、扑翼、可延展柔性电子器件等机器人机构；（3）目标跟踪、视觉伺服、行为识别等机器人感知；（4）自适应控制、抓取、远程操控等机器人控制；（5）强化学习、深度学习、脑机接口等机器人人机交互；（6）治疗前列腺癌、特发性震颤、发育性协调障碍等疾病医疗机器人。

图 4-5 机器人领域论文主题 TOP50 词云图

◤ 全球智能机器人领域专利统计

采集 2011-2022 年全球与智能机器人相关专利，共计约 37.7 万件，同族合并后为 33.4 万个专利族，主要统计结果如下。

1. 专利类型及技术发展

发明专利 214,897 件，占比 56.97%；实用新型专利 126,728 件，占比 33.60%；外观设计专利 35,601 件，占比 9.44%。从专利有效性来看，近十年申请的专利有效的有 190,399 件，占比 50.47%。

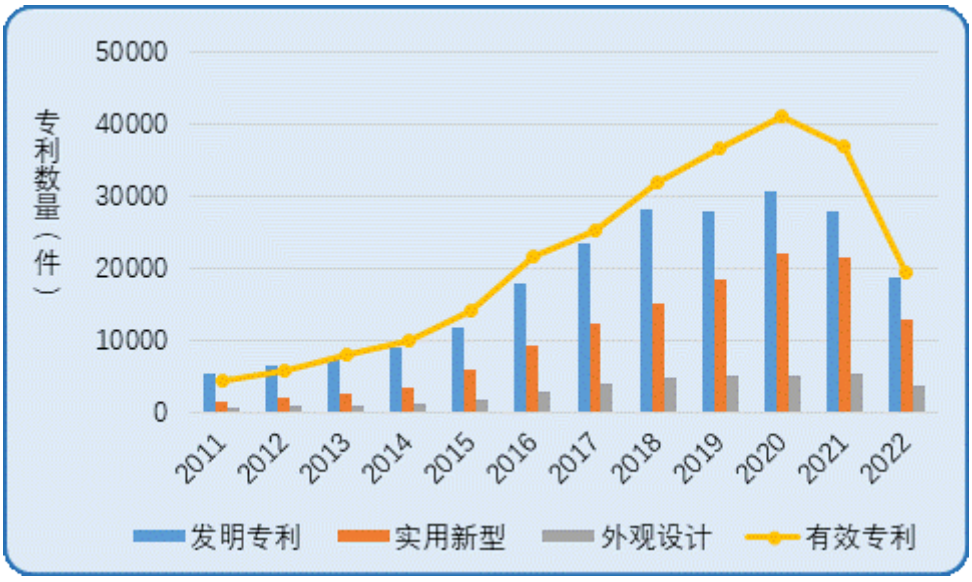

图 4-6 全球智能机器人 2011 年至今技术发展趋势

2. 专利地域保护

在中国公开的专利数量全球排名第一，占总量的 77%；美国、世界知识产权组织、日本等国家地区或组织公开数量较多，分别占全球智能机器人专利总量的 6%、4%和 3%。

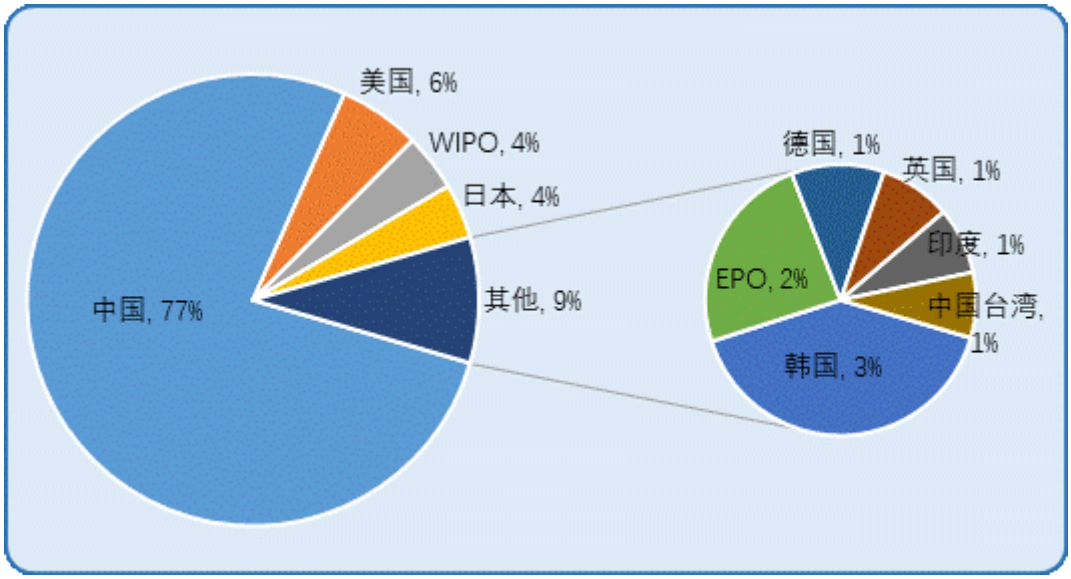

图 4-7 智能机器人技术专利公开国别

3. 主要申请人

智能机器人领域申请专利数量最多的申请人为韩国乐金集团、日本精工爱普生株式会社和发那科机器人，国家电网、中科院和格力集团占据中国申请人的前三甲。

表 4-1 智能机器人 2011 年至今全球 Top20 申请人

排名	申请人	国家	专利数量	类型
1	乐金集团	韩国	3539	企业
2	精工爱普生株式会社	日本	3474	企业
3	发那科机器人	日本	3166	企业
4	国家电网	中国	1912	企业
5	川崎重工	日本	1864	企业
6	三星集团	韩国	1824	企业
7	安川电机	日本	1728	企业
8	中科院	中国	1635	科研院所
9	库卡德国有限公司	德国	1492	企业
10	格力集团	中国	1355	企业
11	ABB 公司	瑞士	1232	企业
12	哈尔滨工业大学	中国	1227	大学
13	广东博智林机器人有限公司	中国	1071	企业
14	irobot 公司	美国	1059	企业
15	柯惠医疗	美国	1022	大学
16	直观外科	美国	1004	企业
17	浙江大学	中国	921	大学
18	清华大学	中国	918	大学
19	华南理工大学	中国	886	大学
20	佳能公司	日本	870	企业

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