Robotics

Miao Li

Fall 2023, Wuhan University
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Sponsor

智元机器人

Course Info

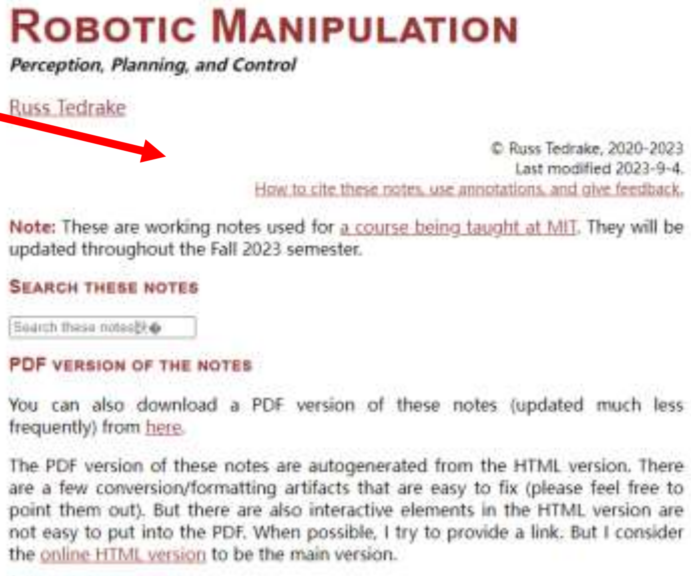
- **Instructor: Prof. Miao Li (李淼)**
    - **HUST, EPFL with Prof Aude Billard**
    - **Robotic grasping and manipulation, imitation learning**
    - **Co-Chair IEEE TC (CAFM)**
    - **Email: limiao712@gmail.com**
- **TA: Mengde Li （李梦德， 博士生）**
    - **Micro-robots with medical applications**
    - **Email: limengde@whu.edu.cn**
- **Read/comment on the lecture notes and we don’t have specific handout.**
- **If YOU have any questions, please feel free to ask.**

Course Info

- **This course will cover a range of topics in robotics, including design, perception, planning and control.　(13 weeks for teaching + 4 weeks for project)**
- **Mainly focusing on robotic manipulation.**
- **Paper reading: Each group will read at least one or two paper and share it with presentation.**
- **Project-based: Each group will spend at least 4 weeks to do some fun mini-projects.**
- **Exam: 20% paper reading + 50% project + 30% exam.**
- **# You can learn robots only when you can move them.**
- **# Have fun!**

Course Info

- **This course will use material from the following books and handouts.**
- **Mark Spong, Robot Modelling and Control**
- **Russ Tedrake, MIT 6.4210/6.4212 Robotic Manipulation (Fall 2022)**
  - **https://groups.csail.mit.edu/locomotion/russt.html**
  - **This course also have a very nice video lecture on YouTube**



ROBOTIC MANIPULATION

Perception, Planning, and Control

Russ Tedrake

© Russ Tedrake, 2020-2023
Last modified 2023-9-4.
How to cite these notes, use annotations, and give feedback.

Note: These are working notes used for a course being taught at MIT. They will be updated throughout the Fall 2023 semester.

SEARCH THESE NOTES

PDF VERSION OF THE NOTES

You can also download a PDF version of these notes (updated much less frequently) from here.

The PDF version of these notes are autogenerated from the HTML version. There are a few conversion/formatting artifacts that are easy to fix (please feel free to point them out). But there are also interactive elements in the HTML version are not easy to put into the PDF. When possible, I try to provide a link. But I consider the online HTML version to be the main version.

Why do we study robotics?

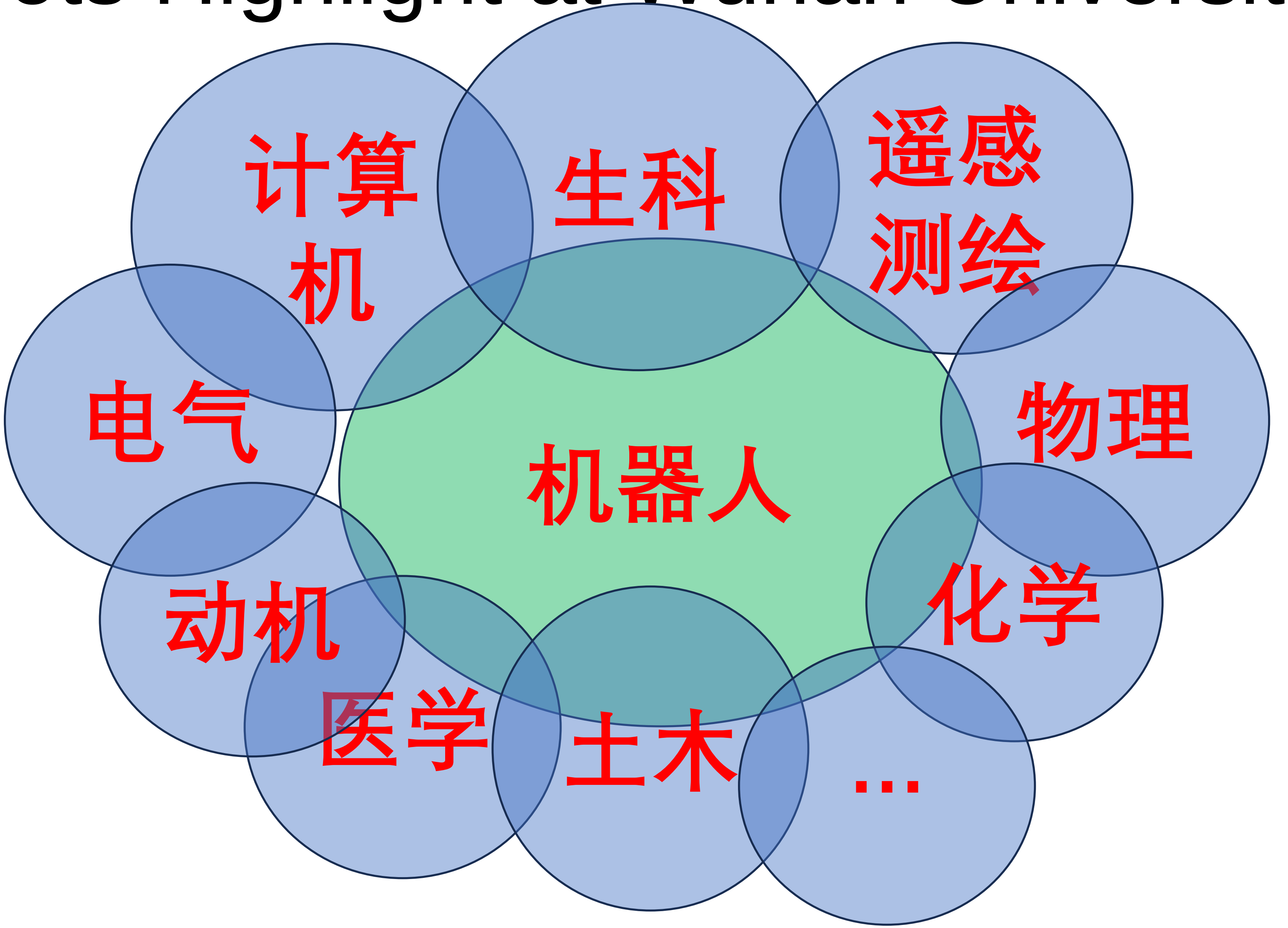
- **A different perspective to understand human beings**
- **A good way to interact with the world physically**
- **A promising way to make avatar of ourselves**
- **A testbed for many scientific researches**
- **Industrial workforce**
- **Household service**
- **Medical application**
- **OutSpace exploration**
- **….**

Super difficult for robots even today!

Today

- **Basics of robots with examples**
- **Different perspectives of robots**
- **Goal for the course**
- **Paper reading**
- **Project list intro**

Robots Highlight at Wuhan University



机器人

计算机

生科

遥感测绘

电气

物理

动机

化学

医学

土木

...

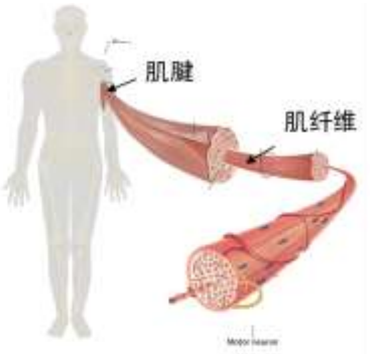
高爆发仿生与人形机器人

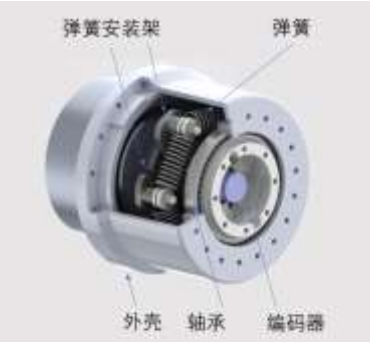
首次构建了面向极限动作的人体神经-肌肉-骨骼生物力学模型，突破了高爆发刚柔耦合仿生一体化关节设计技术，实现了仿人机器人变步长规划与稳定性控制。

人体肌肉骨骼生物力学模型

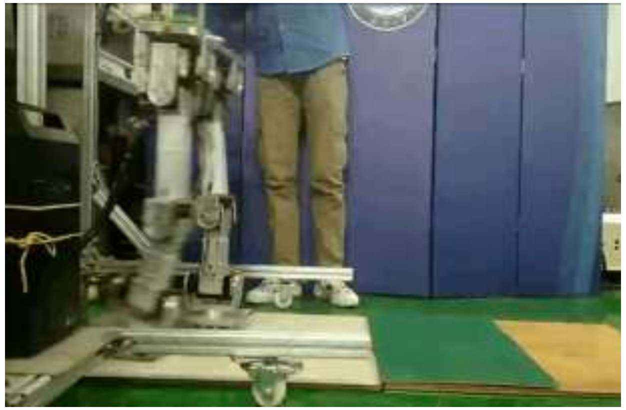
跳跃动作模拟

高爆发一体化驱动关节





仿人机器人稳定性控制

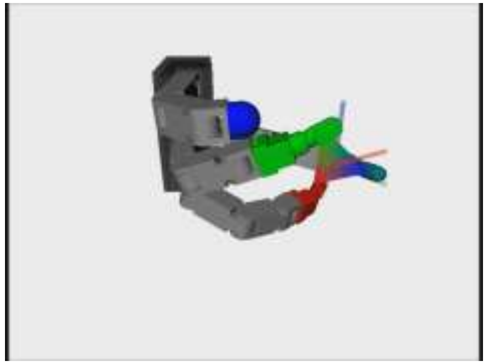


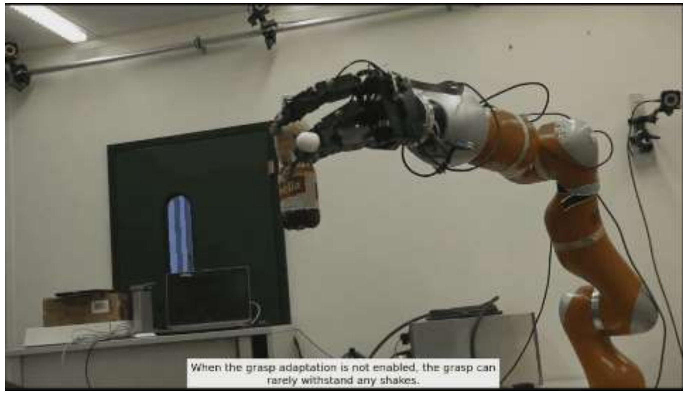
SCI论文： [1] ***IEEE/ASME Transaction on Mechatronics***, 2018, 23(5): 2121-2131. [2] ***Mechanism and Machine Theory***, 2018, 130: 123-136.

机器人操作手与多模态技能学习

首次提出机器人动态抓取自适应理论，荣获瑞士ABB全球自动化奖（唯一华人获得者）

动态抓取自适应





When the grasp adaptation is not enabled, the grasp can rarely withstand any shakes.

多模态技能学习

OpenAI

Industry	Artificial intelligence
Founded	December 11, 2015; 5 years ago
Founders	Elon Musk • Sam Altman • Ilya Sutskever • Greg Brockman • Wojciech Zaremba • John Schulman
Headquarters	Pioneer Building, San Francisco, California, US[1][2]
Key people	Ilya Sutskever • Greg Brockman
Products	DALL-E, GPT-3, GPT-2, OpenAI Gym
Number of employees	>120 (as of 2020)[2]
Website	openai.com

Article

Learning dexterous in-hand manipulation

The International Journal of Robotics Research
2020, Vol. 39(1) 3–20
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sagepub.com/journals-permissions
DOI: 10.1177/0278364919887447
journals.sagepub.com/home/ijr
SAGE

OpenAI: Marcin Andrychowicz, Bowen Baker, Maciek Chociej, Rafal Józefowicz, Bob McGrew, Jakub Pachocki, Arthur Petron, Matthias Plappert, Glenn Powell, Alex Ray, Jonas Schneider, Szymon Sidor, Josh Tobin, Peter Welinder, Lilian Weng and Wojciech Zaremba

- □ **全世界排名前三的AI实验室（DeepMind、OpenAI、FAIR）OpenAI 2019年在机器人领域排名第一的杂志IJRR撰文评价此工作“采用一种闭环的灵巧操作策略并在执行过程根据传感反馈来修正错误”。**

SCI论文： [1] ***IEEE Transactions on Robotics,*** 2016, 32 (4), 960-972. [2] ***Robotics and Autonomous Systems***, 2016, 75, 352-364. [3] ***IEEE Robotics and Automation Letters***, 2021, 6(3): 5048-5055

机器人操作手与多模态技能学习

首次提出基于深度模仿学习的多模态技能建模表达与泛化方法，力控精度从~2N提高到~0.3N，提高6.7倍。

机器人模仿学习

多模态技能学习

L'École Polytechnique Fédérale de Lausanne
sur proposition de la Commission de recherche

décerne le

Prix Asea Brown Boveri Ltd. (ABB)

DYNAMIC GRASP ADAPTATION – FROM HUMANS TO ROBOTS

à Monsieur

Miao Li

Pour ses contributions exceptionnelles à la robotique, par le développement de nouvelles techniques pour la préhension habile d'objets complexes, et pour le transfert fructueux de cette technologie à la manipulation industrielle à large échelle.

For his exceptional contributions to robotics, via the development of robust algorithms for dexterous manipulation of complex objects, and for the highly successful transfer of this technology to real-world industrial manipulation.

Vice-président pour la recherche
Andreas Mortensen

ABB
Stéphane [illegible]

Directrice de thèse :
Aude Billard

Délivré à Lausanne le 5 octobre 2016

For his exceptional contribution to robotics, via the development of robust algorithms, for dexterous manipulation of complex objects, and for the highly successful transfer of this technology to real-world industrial manipulation

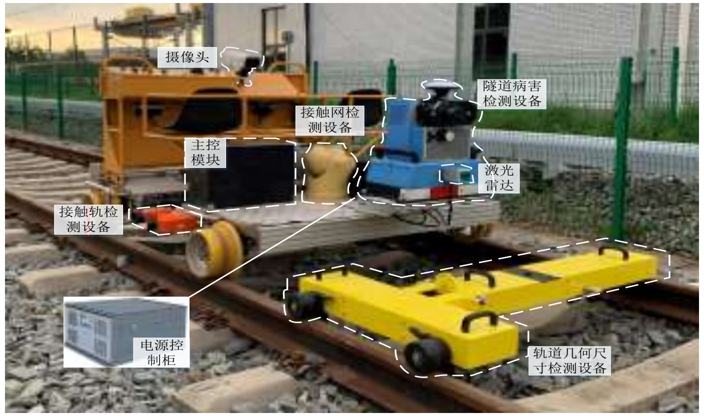
ABB Award首位中国学者获得者，因为研发了“复杂物体灵巧操作的鲁棒性算法以及成功应用于现实世界的机器人操作问题”

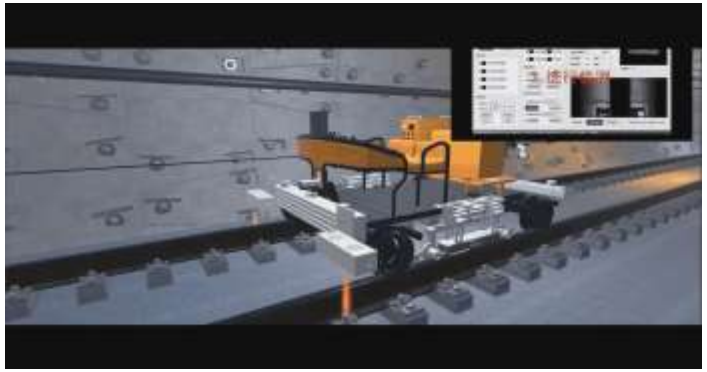
SCI论文： [1] ***IEEE Transactions on Robotics,*** 2016, 32 (4), 960-972. [2]***SCIENCE CHINA Information Sciences***, 2022, 65, Article number: 184201

特种环境作业机器人

针对轨道交通、电力行业等特殊场景的自动化需求，研制了轨道巡检、管道攀爬等特种环境作业机器人，解决了人工效率低、工作环境差等行业痛点。

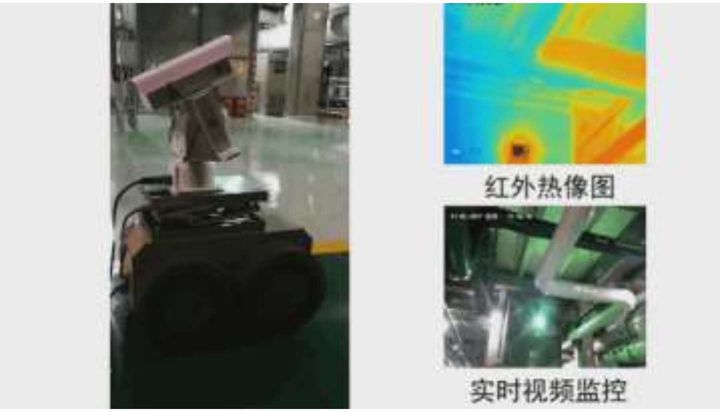
轨道交通巡检机器人



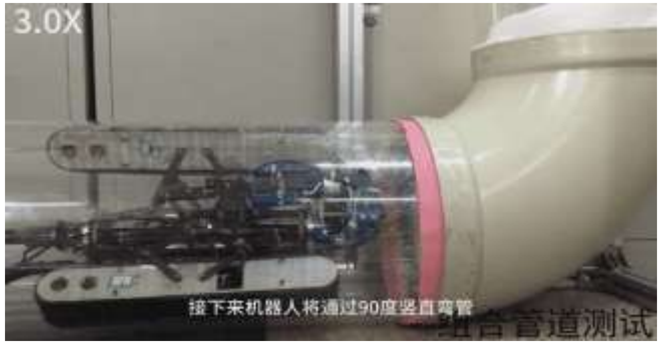


锅炉管道攀爬机器人

厂房智能巡检机器人



管道内检测机器人



SCI论文： [1] ***IEEE/ASME Transaction on Mechatronics***, 2018, 23(5): 2121-2131. [2] ***Mechanism and Machine Theory***, 2018, 130: 123-136. [3] ***Mechanism and Machine Theory***, 2022, 176: 104970

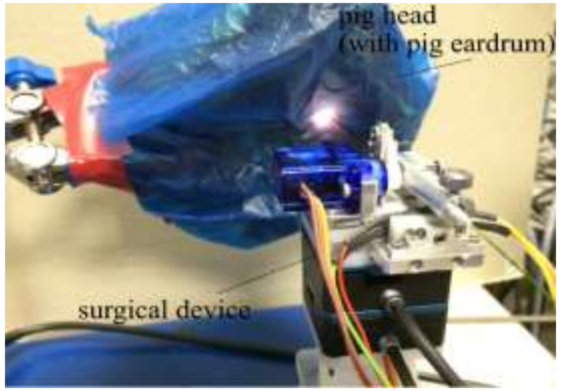
医疗机器人与人工智能

研制了上/下肢柔性外骨骼康复机器人、遥操作超声机器人、压电驱动手术机器人等医疗机器人，开展了AI辅助的机器人控制与临床应用。

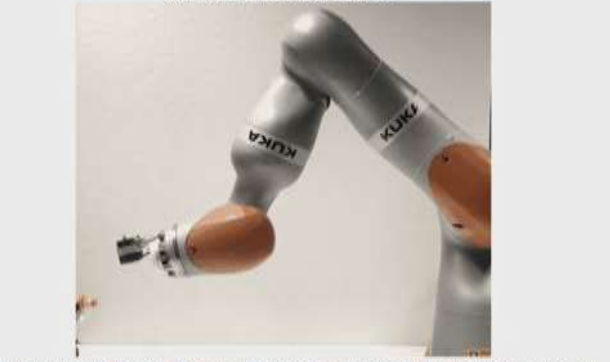
外骨骼康复机器人

遥操作超声机器人

鼓膜切开置管手术机器人



Medical application



Manipulator moves the end-effector to approach the mock membrane

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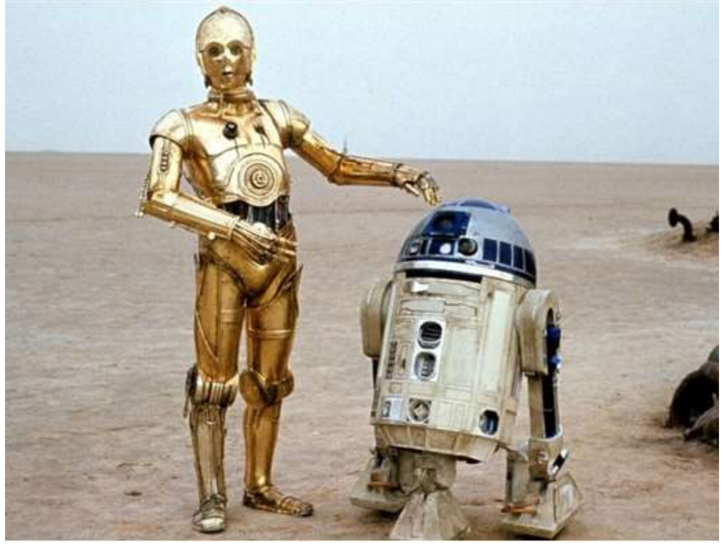
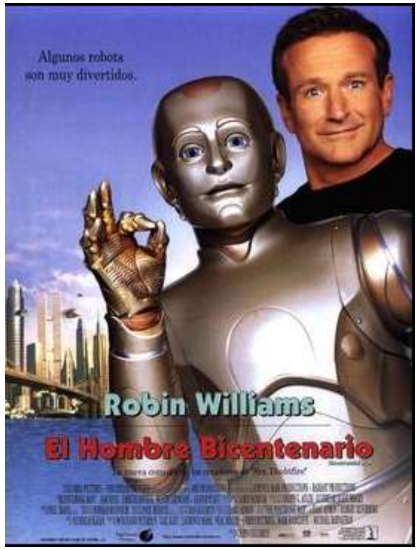
SCI论文： [1] ***IEEE/ASME Transaction on Mechatronics***, 2023, 28(3): 1730 - 1741. [2]***SCIENCE CHINA Information Sciences***, 2022, 65, Article number: 184201. [3] ***IEEE/ASME Transaction on Mechatronics***, 2021, 27(3): 1784 - 1795.

Robots in Sci-Fi



星球大战



机器人管家

我机器人

异形

Any other movies?

Robots in Sci-Fi

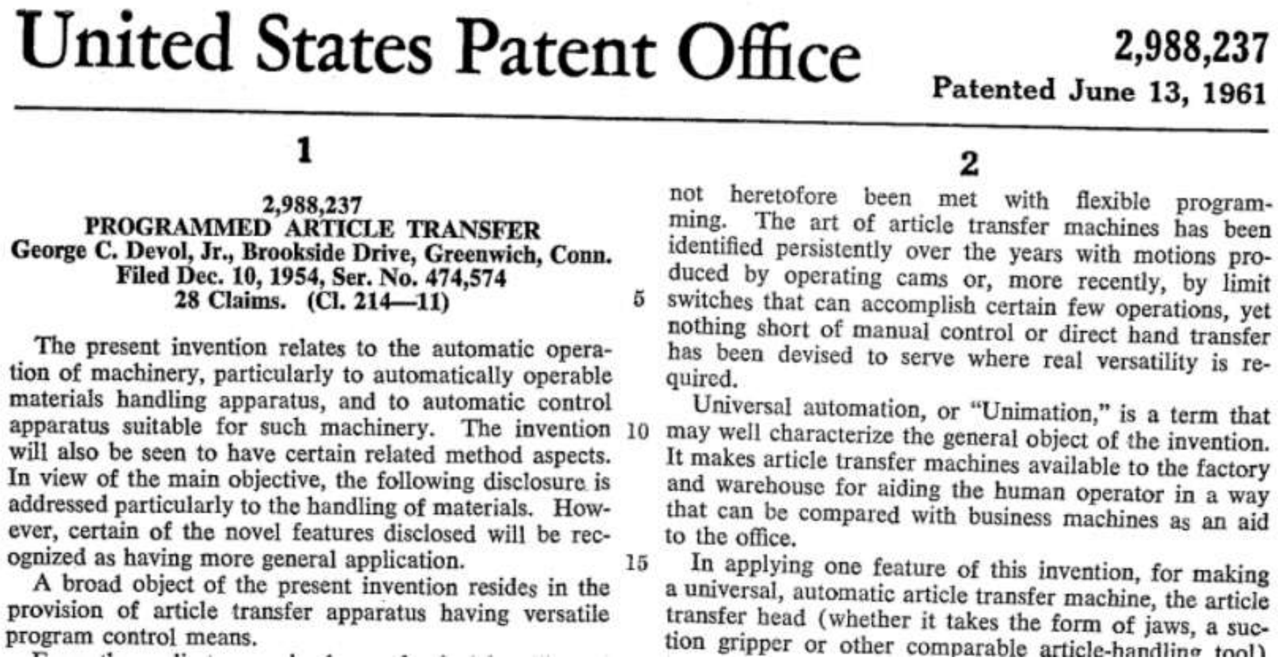
(video ~10mins)

https://www.youtube.com/watch?v=mtZNB9ksPd4&ab_channel=%E4%B8%80%E8%AF%AD%E9%81%93%E7%A0%B4%E7%94%B5%E5%BD%B1

Robots in Reality

A long time ago in a galaxy far away……

1954 George Devol designs the first programmable robot



United States Patent Office

2,988,237

Patented June 13, 1961

1

2,988,237
PROGRAMMED ARTICLE TRANSFER
George C. Devol, Jr., Brookside Drive, Greenwich, Conn.
Filed Dec. 10, 1954, Ser. No. 474,574
28 Claims. (Cl. 214—11)

The present invention relates to the automatic operation of machinery, particularly to automatically operable materials handling apparatus, and to automatic control apparatus suitable for such machinery. The invention will also be seen to have certain related method aspects. In view of the main objective, the following disclosure is addressed particularly to the handling of materials. However, certain of the novel features disclosed will be recognized as having more general application.

A broad object of the present invention resides in the provision of article transfer apparatus having versatile program control means.

2

not heretofore been met with flexible programming. The art of article transfer machines has been identified persistently over the years with motions produced by operating cams or, more recently, by limit switches that can accomplish certain few operations, yet nothing short of manual control or direct hand transfer has been devised to serve where real versatility is required.

Universal automation, or "Unimation," is a term that may well characterize the general object of the invention. It makes article transfer machines available to the factory and warehouse for aiding the human operator in a way that can be compared with business machines as an aid to the office.

In applying one feature of this invention, for making a universal, automatic article transfer machine, the article transfer head (whether it takes the form of jaws, a suction gripper or other comparable article-handling tool)

Devol had already applied for a patent an industrial robotic arm in 1954; U.S. Patent 2,988,237 was issued in 1961

https://www.google.com/patents/US2988237

Robots in Reality

1956 Joseph Engelberger, a Columbia University physics student, buys the rights to Devol's robot and founds the Unimation Company

1961 the first Unimate robot is installed in a Trenton, New Jersey plant of General Motors to tend a die casting machine

Joseph Engelberger

At a **cocktail party** in 1956, **Joseph Engelberger** met inventor George Devol and the two got to talking about George's latest invention - his **Programmed Article Transfer** device. "Sounds like a robot to me," exclaimed Engelberger, who had a deep fascination with robots as a result of his love for writer Isaac Asimov's science fiction stories.

After almost two years in development, Engelberger and Devol produced a prototype - the **Unimate #001**
Source: https://www.robotics.org/joseph-engelberger/unimate.cfm

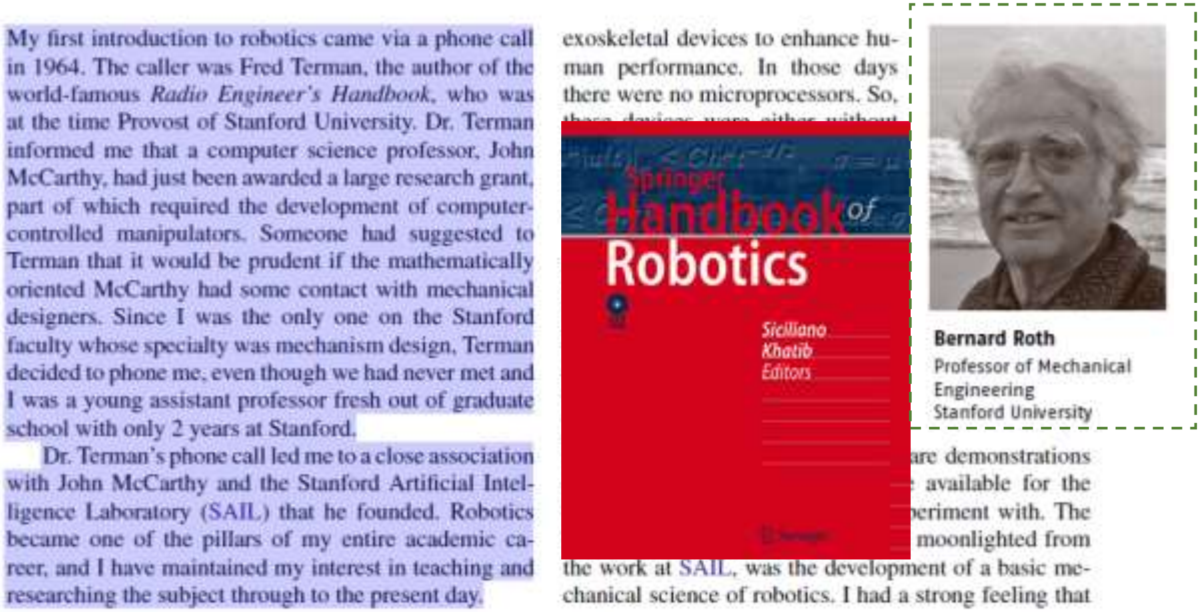
Robots in Reality

1961 the first robot incorporating force feedback is develop

1963 the first robot vision system is developed

1971 the Stanford Arm is developed at Stanford University

Stanford Arm



My first introduction to robotics came via a phone call in 1964. The caller was Fred Terman, the author of the world-famous *Radio Engineer's Handbook*, who was at the time Provost of Stanford University. Dr. Terman informed me that a computer science professor, John McCarthy, had just been awarded a large research grant, part of which required the development of computer-controlled manipulators. Someone had suggested to Terman that it would be prudent if the mathematically oriented McCarthy had some contact with mechanical designers. Since I was the only one on the Stanford faculty whose specialty was mechanism design, Terman decided to phone me, even though we had never met and I was a young assistant professor fresh out of graduate school with only 2 years at Stanford.

Dr. Terman's phone call led me to a close association with John McCarthy and the Stanford Artificial Intelligence Laboratory (SAIL) that he founded. Robotics became one of the pillars of my entire academic career, and I have maintained my interest in teaching and researching the subject through to the present day.

exoskeletal devices to enhance human performance. In those days there were no microprocessors. So,

are demonstrations

available for the

periment with. The

moonlighted from

the work at SAIL, was the development of a basic mechanical science of robotics. I had a strong feeling that

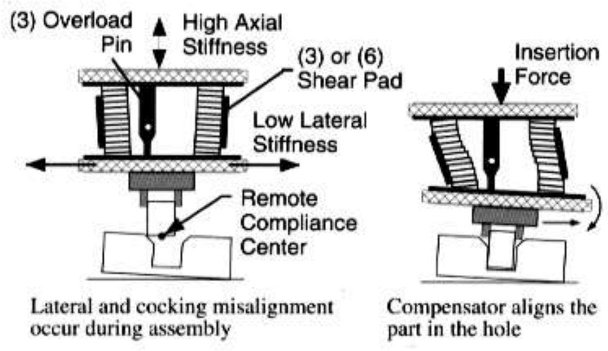
Bernard Roth
Professor of Mechanical Engineering
Stanford University

Robots in Reality

1973 the first robot programming language (WAVE) is developed at Stanford

1976 the Remote Center Compliance (RCC) device for part insertion in assembly is developed at Draper Labs in Boston

1978 Unimation introduces the **PUMA**（**P**rogrammable **U**niversal **M**achine for **A**ssembly），based on designs from General Motors



Source: http://www.ati-ia.com/products/compliance/assembly_compliance_device.aspx

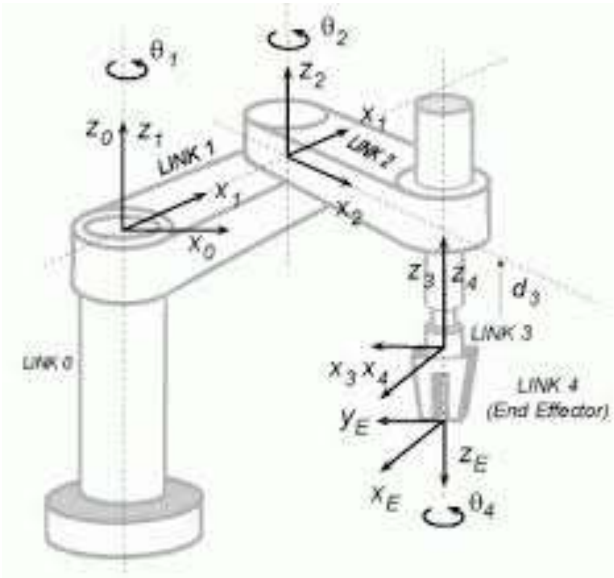
拍摄于南开大学

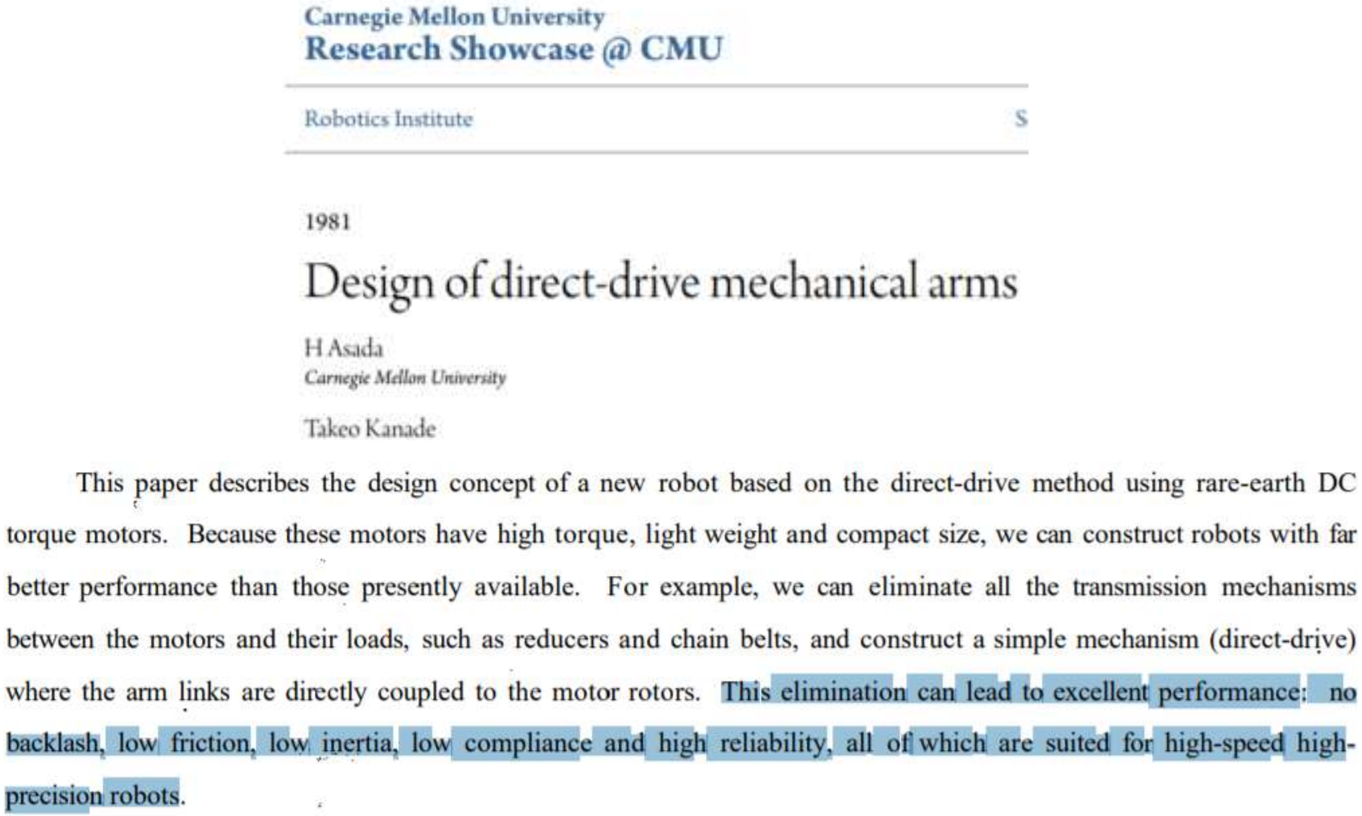
Unimation produced PUMAs for years until being purchased by Westinghouse (ca. 1980), and later by Swiss company Stäubli (1988). Nokia Robotics manufactured about 1500 PUMA robots during the 1980s, the Puma-650 being their most popular model with customers. Nokia sold their Robotics division in 1990.

Robots in Reality

1979 the SCARA(Selective Compliance Assembly Robot Arm) is introduced in Japan

1981 the first direct-drive robot is developed at Carnegie-Mellon University




Carnegie Mellon University
Research Showcase @ CMU

Robotics Institute S

1981

Design of direct-drive mechanical arms

H Asada
Carnegie Mellon University

Takeo Kanade

This paper describes the design concept of a new robot based on the direct-drive method using rare-earth DC torque motors. Because these motors have high torque, light weight and compact size, we can construct robots with far better performance than those presently available. For example, we can eliminate all the transmission mechanisms between the motors and their loads, such as reducers and chain belts, and construct a simple mechanism (direct-drive) where the arm links are directly coupled to the motor rotors. This elimination can lead to excellent performance: no backlash, low friction, low inertia, low compliance and high reliability, all of which are suited for high-speed high-precision robots.

Robots in Reality

1982 **Salisbury hand** was designed at Stanford University

1982 Fanuc of Japan and General Motors form GM Fanuc to market robots in North America

1983 Adept Technology is founded and successfully markets the direct drive robot



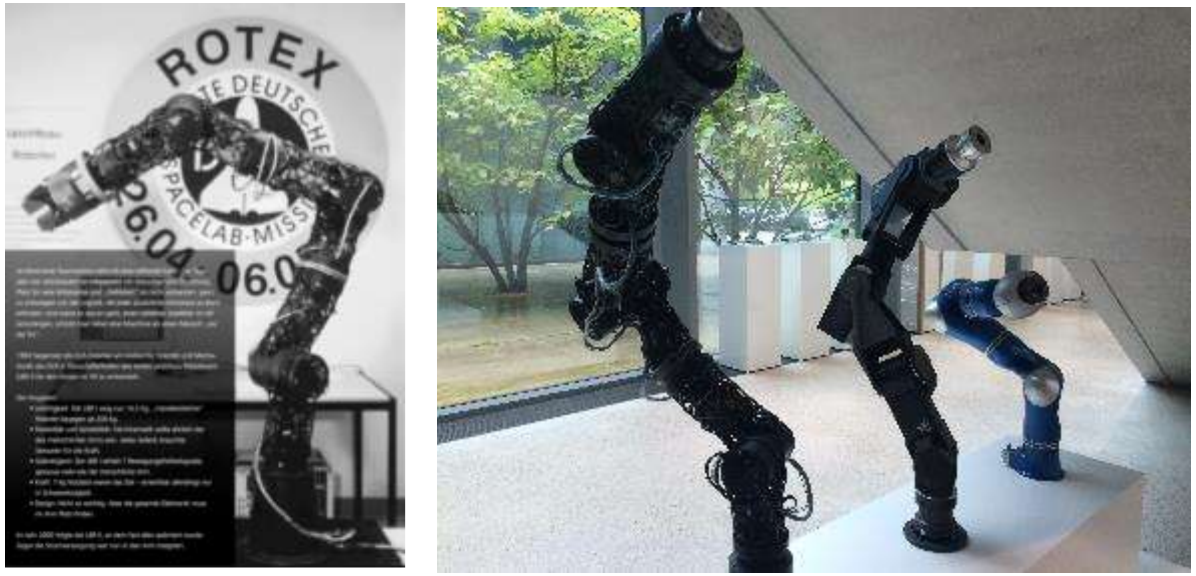

https://www.youtube.com/watch?v=Q2z8pJMN1dM

Robots in Reality

1988 Staubli Group purchases Unimation from Westinghouse

1988 the IEEE Robotics and Automation Society is formed

1993 the experimental robot, ROTEX, of the German Aerospace Agency (DLR) was flown aboard the space shuttle Columbia and performed a variety of tasks under both teleoperated and sensor-based offline programmed modes



拍摄于DLR

Aude Billard will serve as RAS President Elect in 2022-2023. The RAS Administrative Committee elected Billard to serve as President Elect under President, Frank Park & to assume the Society presidency in Jan 2023

ieee-ras.org/about-ras/late…

Robots in Reality

1996 Honda unveils its Humanoid robot; a project begun in secret in 1986

1997 the first robot soccer competition, RoboCup-97, is held in Nagoya

1997 the Sojourner mobile robot travels to Mars

2001 Sony begins to mass produce the first household robot, a robot dog named Aibo

https://en.wikipedia.org/wiki/AIBO

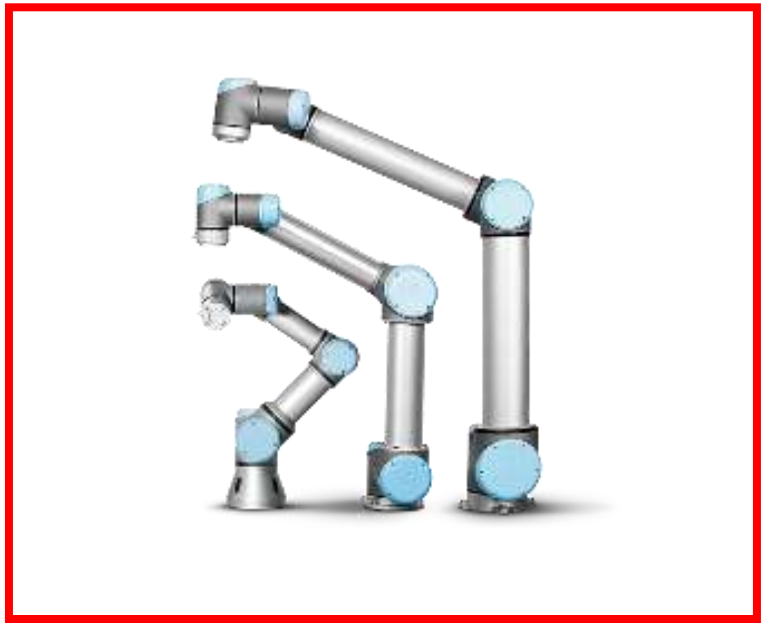
Robots in Reality

2001 the first telesurgery was performed

2002 Honda’s Humanoid Robot ASIMO rings the opening bell at the New York Stock Exchange

2005 **Universal Robots** was founded

2008 **UR5** was introduced for small and medium sized companies



Robots in Reality

2012 Baxter robot was introduced

2015 YuMi was officially introduced to the market at the Hannover Messe

2015 KUKA iiwa was introduced

Baxter

YuMi

iiwa

Robots in Reality

2015 AUBO Robotics is a national high-tech enterprise specialized in the research & development, production and sale of collaborative robots.

2016 Franka Emika is a Munich-based robotics company founded in 2016 by Sami Haddadin and his brother Simon together with a long-standing team of experts.

2016 Elite, JAKA, DOBOT …… Many new robot arms have been produced!

Aubo

Franka

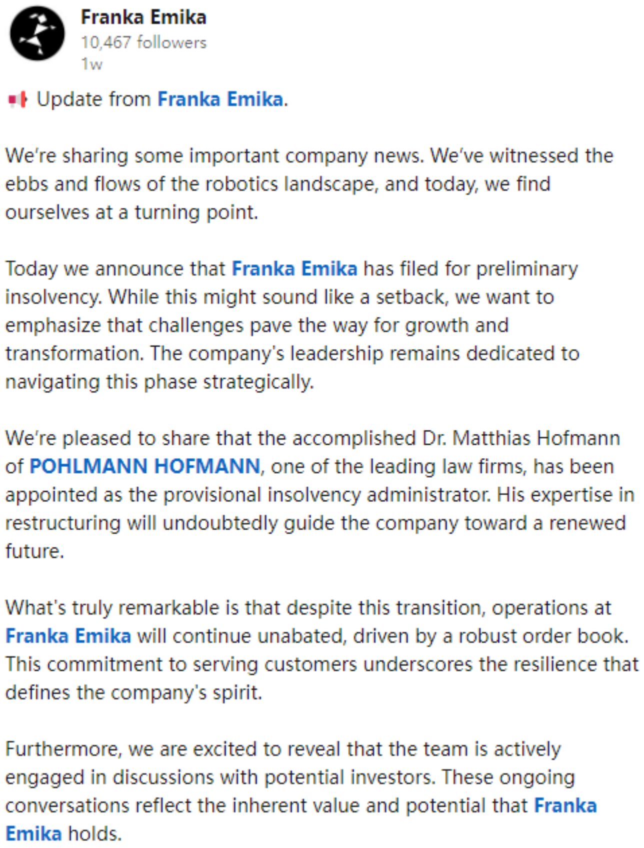
Elite

Robots in Reality

2023 Franka files for insolvency

Cobot arm maker Franka Emika files for insolvency

By Steve Crowe | September 1, 2023



Update from **Franka Emika**.

We're sharing some important company news. We've witnessed the ebbs and flows of the robotics landscape, and today, we find ourselves at a turning point.

Today we announce that **Franka Emika** has filed for preliminary insolvency. While this might sound like a setback, we want to emphasize that challenges pave the way for growth and transformation. The company's leadership remains dedicated to navigating this phase strategically.

We're pleased to share that the accomplished Dr. Matthias Hofmann of **POHLMANN HOFMANN**, one of the leading law firms, has been appointed as the provisional insolvency administrator. His expertise in restructuring will undoubtedly guide the company toward a renewed future.

What's truly remarkable is that despite this transition, operations at **Franka Emika** will continue unabated, driven by a robust order book. This commitment to serving customers underscores the resilience that defines the company's spirit.

Furthermore, we are excited to reveal that the team is actively engaged in discussions with potential investors. These ongoing conversations reflect the inherent value and potential that **Franka Emika** holds.

Robots in Reality

2016-2023 Many **new AI algorithms** have been developed and integrated with robots.

Robots in Reality

2023 PaLM-E

PaLM-E: An Embodied Multimodal Language Model

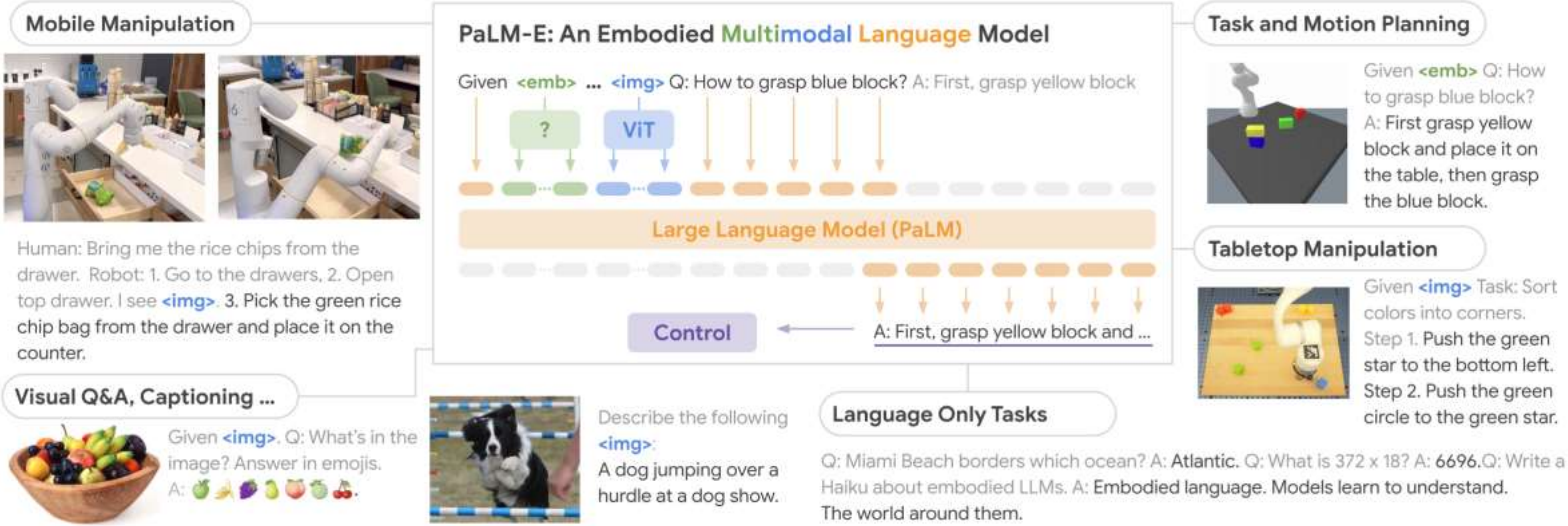
Danny Driess[1,2] Fei Xia[1] Mehdi S. M. Sajjadi[3] Corey Lynch[1] Aakanksha Chowdhery[3]
Brian Ichter[1] Ayzaan Wahid[1] Jonathan Tompson[1] Quan Vuong[1] Tianhe Yu[1] Wenlong Huang[1]
Yevgen Chebotar[1] Pierre Sermanet[1] Daniel Duckworth[3] Sergey Levine[1] Vincent Vanhoucke[1]
Karol Hausman[1] Marc Toussaint[2] Klaus Greff[3] Andy Zeng[1] Igor Mordatch[3] Pete Florence[1]

[1] Robotics at Google [2] Technische Universität Berlin [3] Google Research

The main architectural idea of PaLM-E is to inject continuous, embodied observations such as images, state estimates, or other sensor modalities into the language embedding space of a pre-trained language model. This is realized by encoding the continuous observations into a sequence of vectors with the same dimension as the embedding space of the language tokens. The continuous information is hence injected into the language model in an analogous way to language tokens. PaLM-E is a decoder-only LLM that generates textual completions autoregressively given a prefix or prompt. We call our model PaLM-E, since we use PaLM (Chowdhery et al., 2022) as the pre-trained language model, and make it Embodied.

https://palm-e.github.io/

Robots in Reality



Human: Bring me the rice chips from the drawer. Robot: 1. Go to the drawers, 2. Open top drawer. I see <img>. 3. Pick the green rice chip bag from the drawer and place it on the counter.

Given <emb> Q: How to grasp blue block? A: First grasp yellow block and place it on the table, then grasp the blue block.

Given <img> Task: Sort colors into corners. Step 1. Push the green star to the bottom left. Step 2. Push the green circle to the green star.

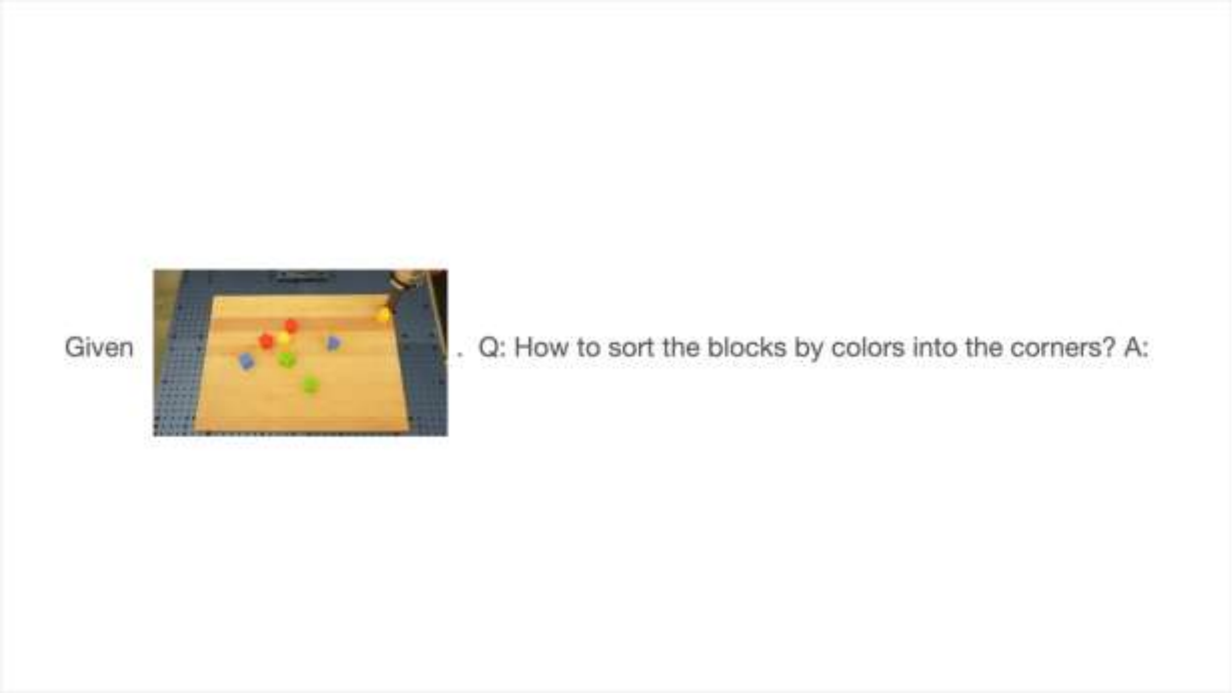
Given <img>. Q: What's in the image? Answer in emojis. A: 🍏🍌🍇🍐🍑🍏🍒.

Describe the following <img>: A dog jumping over a hurdle at a dog show.

Q: Miami Beach borders which ocean? A: Atlantic. Q: What is 372 x 18? A: 6696.Q: Write a Haiku about embodied LLMs. A: Embodied language. Models learn to understand. The world around them.

https://palm-e.github.io/

Robots in Reality

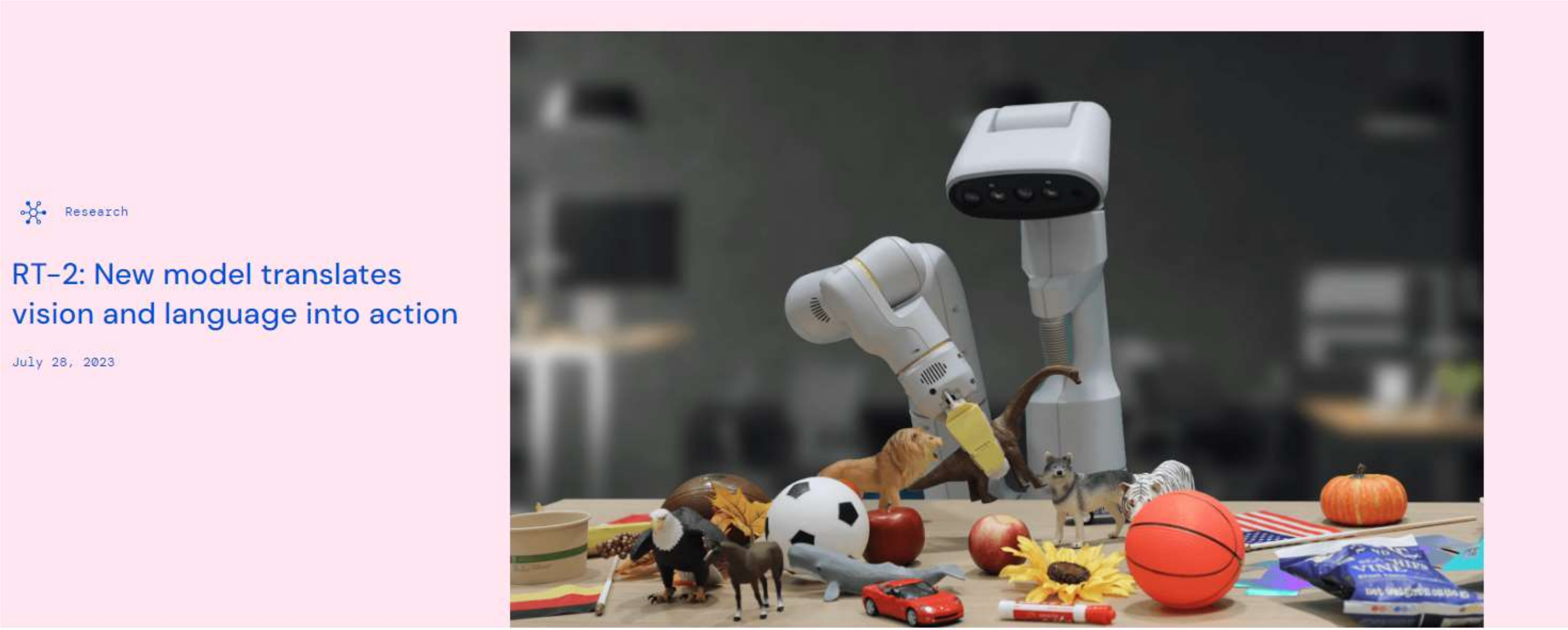


Given . Q: How to sort the blocks by colors into the corners? A:

https://palm-e.github.io/

Robots in Reality

2023 Robotic Transformer 2 (RT-2) is a novel vision-language-action (VLA) model that learns from both web and robotics data, and translates this knowledge into generalised instructions for robotic control.



Research

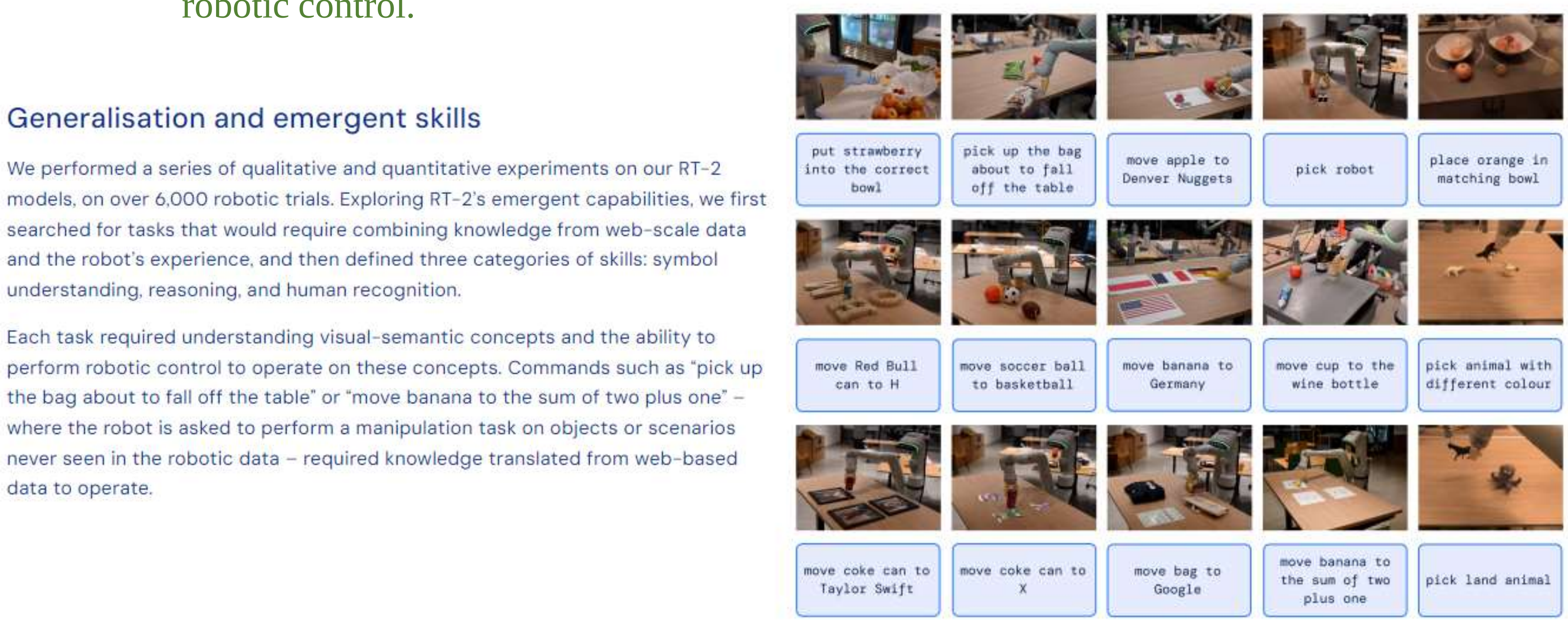
RT-2: New model translates vision and language into action

July 28, 2023

https://www.deepmind.com/blog/rt-2-new-model-translates-vision-and-language-into-action

Robots in Reality

2023 **Robotic Transformer 2** (RT-2) is a novel vision-language-action (VLA) model that learns from both web and robotics data, and translates this knowledge into generalised instructions for robotic control.



Generalisation and emergent skills

We performed a series of qualitative and quantitative experiments on our RT-2 models, on over 6,000 robotic trials. Exploring RT-2's emergent capabilities, we first searched for tasks that would require combining knowledge from web-scale data and the robot's experience, and then defined three categories of skills: symbol understanding, reasoning, and human recognition.

Each task required understanding visual-semantic concepts and the ability to perform robotic control to operate on these concepts. Commands such as "pick up the bag about to fall off the table" or "move banana to the sum of two plus one" – where the robot is asked to perform a manipulation task on objects or scenarios never seen in the robotic data – required knowledge translated from web-based data to operate.

https://www.deepmind.com/blog/rt-2-new-model-translates-vision-and-language-into-action

Application: Industry Robots

Tesla 生产车间

宝马生产车间

SME robot

The European Initiative for
Strengthening the Competitiveness
of SMEs in Manufacturing

Application: Medical Robots

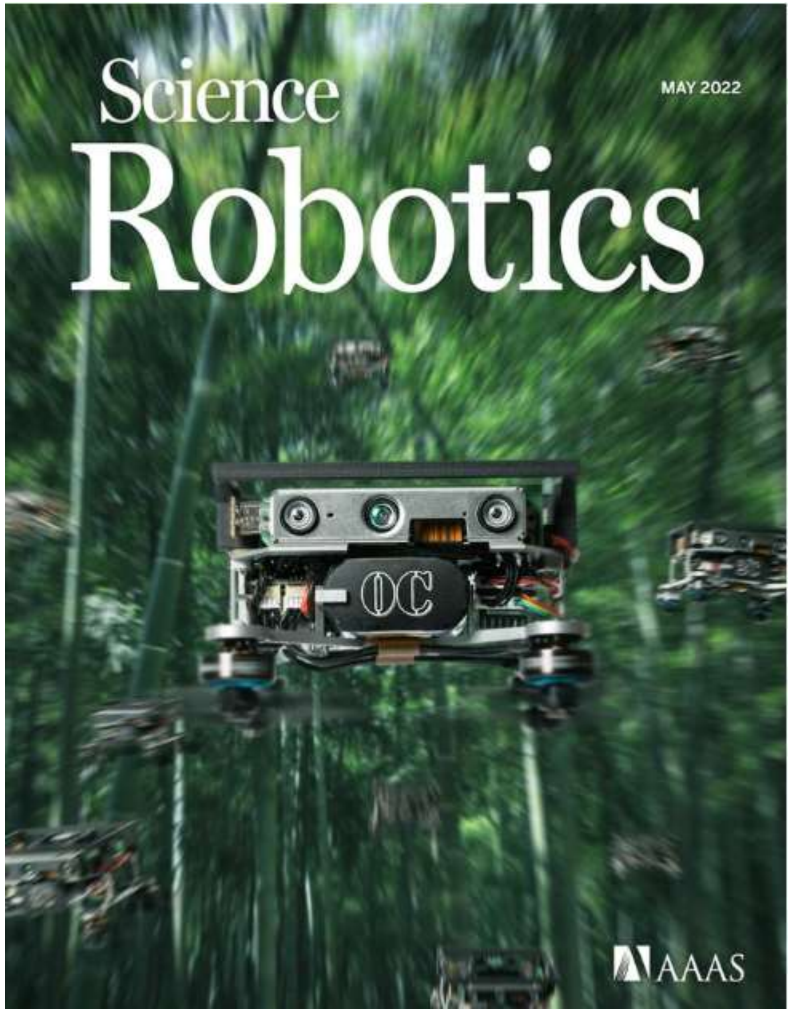
Application: Care Support Robots

Baymax

RIBA

Source: https://www.youtube.com/watch?v=wOzw71j4b78&t=11s

Application: Aerial Robots



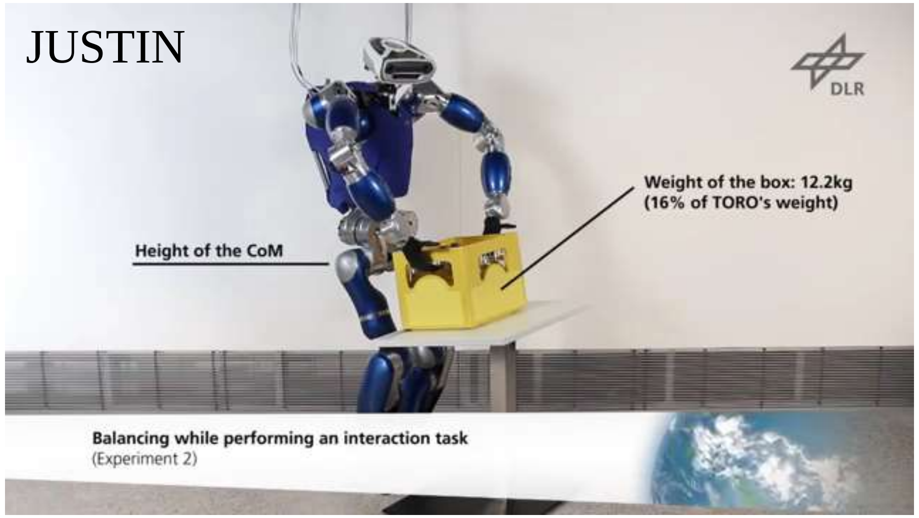
Source: https://www.youtube.com/watch?v=ge3--1hOm1s

Application: Humanoids

DARPA Challenge

ASIMO

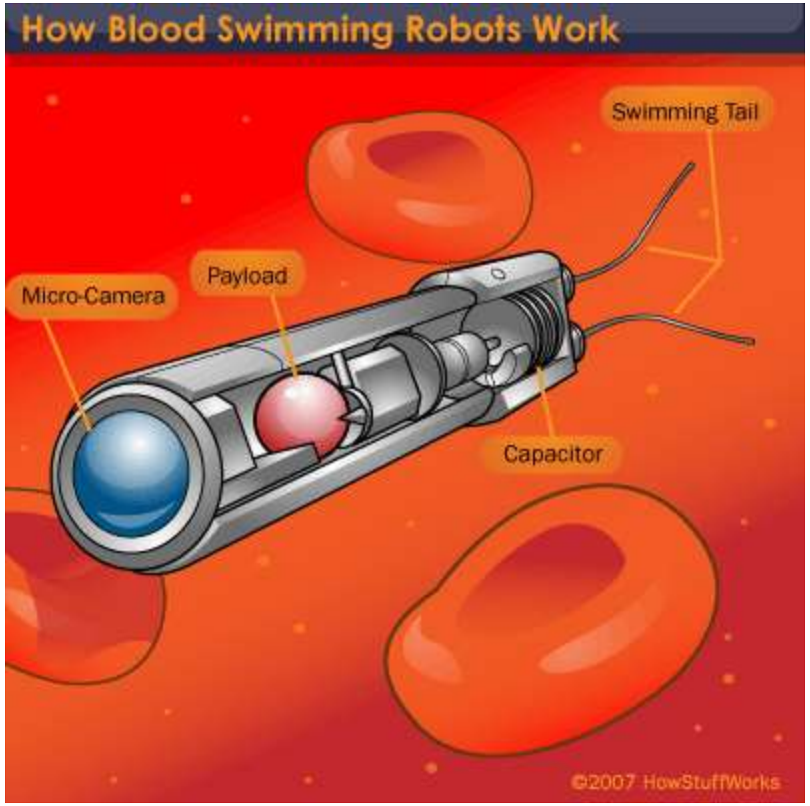
JUSTIN



Application: Humanoids

Application: Underwater Robots

Application: Micro-Robots



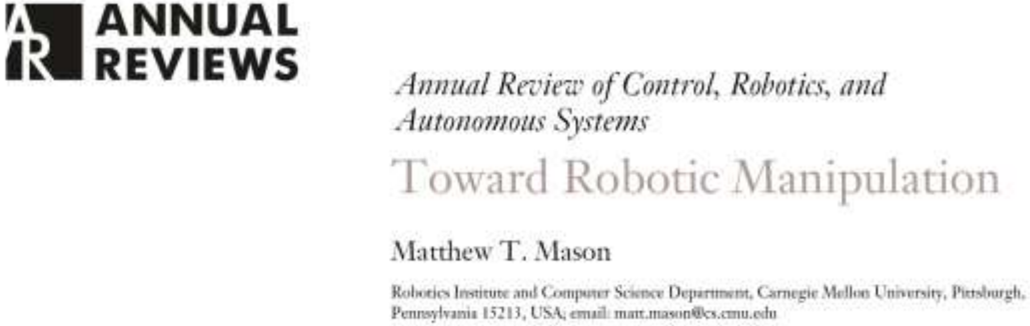

MASCE(Magnetically Actuated Soft-Capsule Endoscope)

A new tetherless miniature mobile robot for diagnostic and therapeutic medical application

Source: https://www.youtube.com/watch?v=ayteOA5VDRI

Different perspectives of robots

> “The ultimate goal of robotics is to understand the relation between real-world tasks and systems that solve them – to understand the relation so thoroughly that we can readily identify robotic solutions to novel real-world tasks”
>
> **- Matt Mason**



ANNUAL REVIEWS

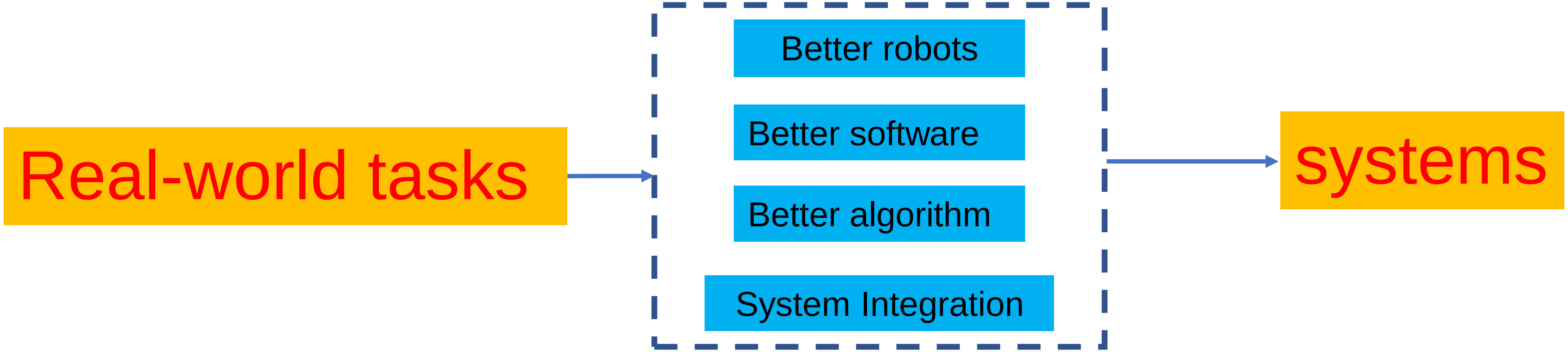
Annual Review of Control, Robotics, and Autonomous Systems

Toward Robotic Manipulation

Matthew T. Mason

Robotics Institute and Computer Science Department, Carnegie Mellon University, Pittsburgh, Pennsylvania 15213, USA; email: matt.mason@cs.cmu.edu

Different perspectives of robots



Real-world tasks

Better robots

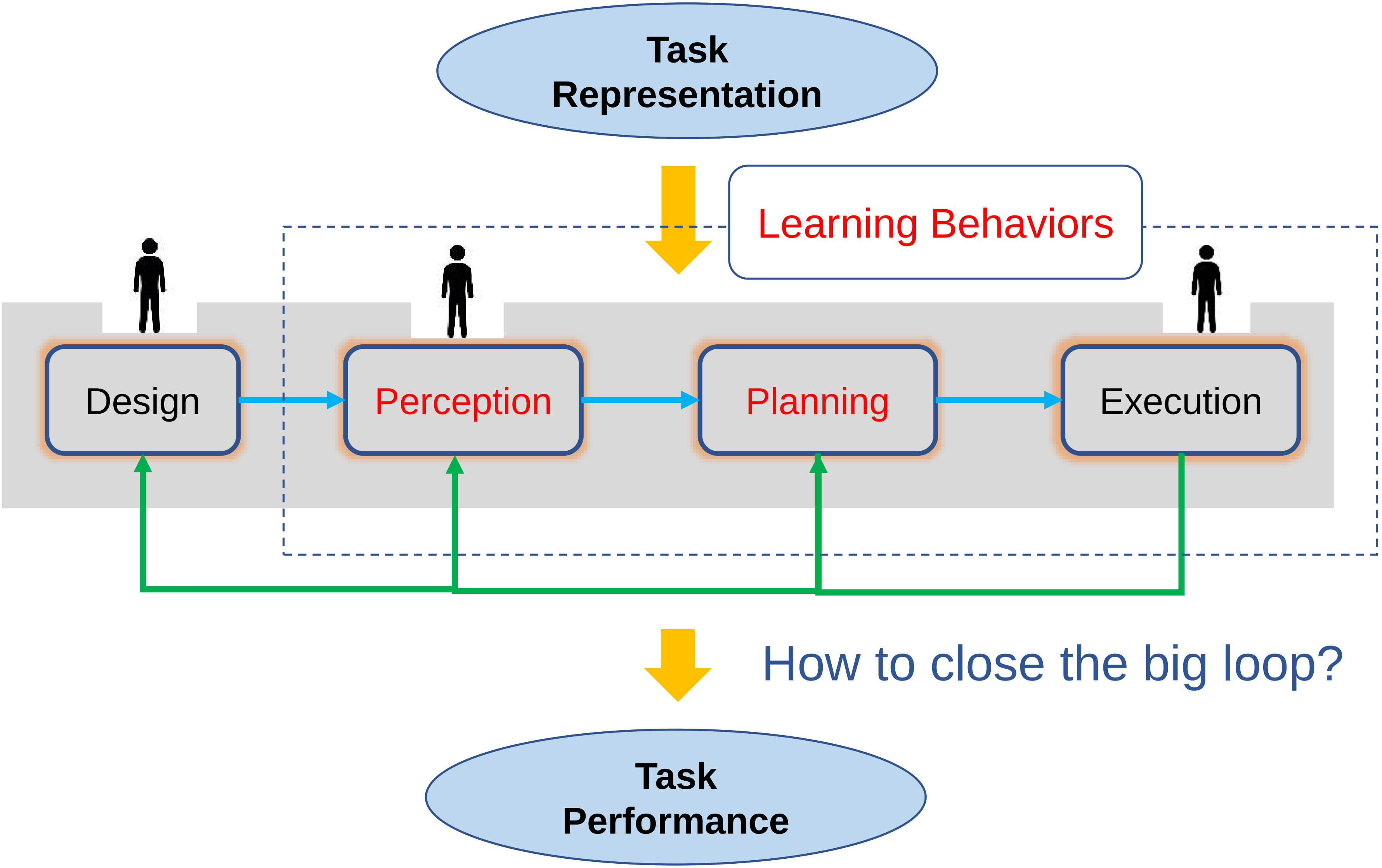
Better software

Better algorithm

System Integration

systems

Different perspectives of robots


Task Representation

Learning Behaviors

Design

Perception

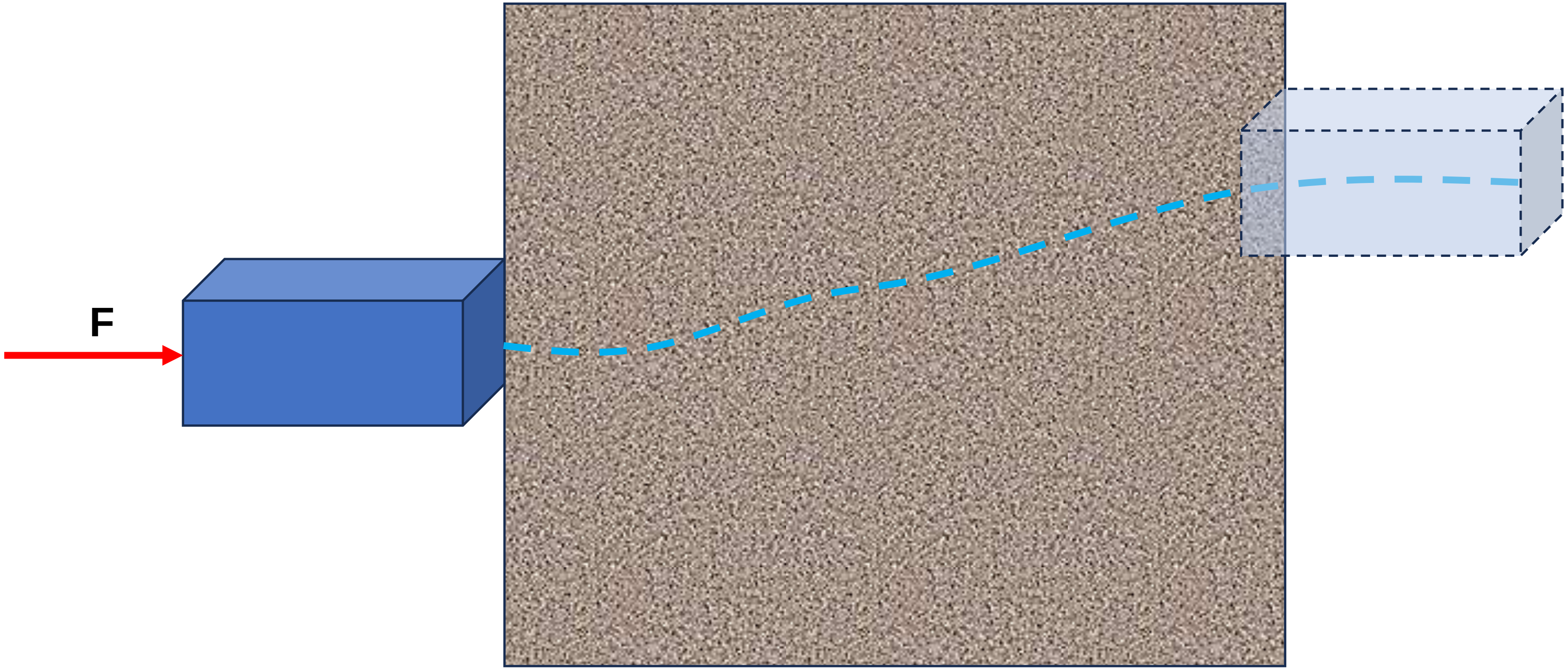
Planning

Execution

How to close the big loop?

Task Performance

Different perspectives of robots



Design

Perception

Planning

Control

Different perspectives of robots

Aerial Robotics and Unmanned Aerial Vehicles
Agricultural Robotics and Automation
Algorithms for Planning and Control of Robot Motion
Automation in Health Care Management
Automation in Logistics
Autonomous Ground Vehicles and Intelligent Transportation Systems
Bio Robotics
Cognitive Robotics
Computer & Robot Vision
Cyborg & Bionic Systems
Energy, Environment, and Safety Issues in Robotics and Automation
Haptics
Human Movement Understanding
Human-Robot Interaction & Coordination
Humanoid Robotics
Marine Robotics
Mechanisms and Design
Micro/Nano Robotics and Automation
Mobile Manipulation
Model-Based Optimization for Robotics
Multi-Robot Systems
Neuro-Robotics Systems
Performance Evaluation & Benchmarking of Robotic and Automation Systems
Rehabilitation and Assistive Robotics
RoboCup
Robot Ethics
Robot Learning
Robotic Hands, Grasping and Manipulation
Robotics and Automation in Nuclear Facilities
Safety, Security and Rescue Robotics
Semiconductor Manufacturing Automation
Smart Buildings
Soft Robotics
Software Engineering for Robotics and Automation
Space Robotics
Surgical Robotics
Sustainable Production Automation
Telerobotics
Wearable Robotics
Whole-Body Control

http://www.ieee-ras.org/technical-committees

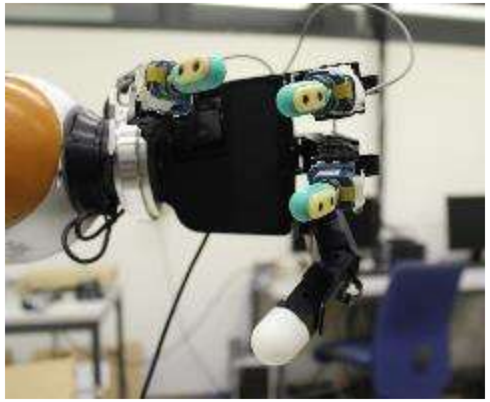
Different perspectives of robots

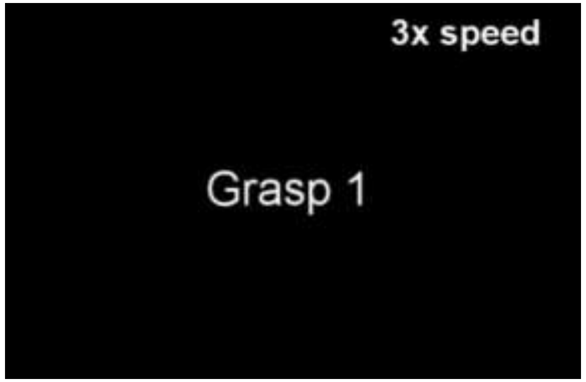
Robotic Hands, Grasping and Manipulation

SCOPE:

Priority areas for the technical committee include:

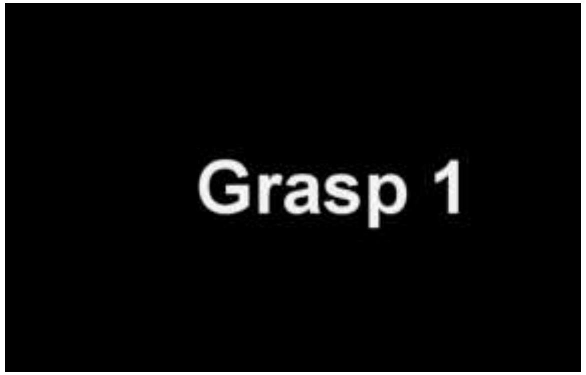
- Multi-finger robotic hand design
- Hand sensor and actuator design
- Force and tactile sensing
- Grasping force control
- Multimodal sensing
- Sensor-based control
- Grasping planning
- Grasp contact modeling
- Grasp quality measure
- Dexterous manipulation
- Human grasping and manipulation modeling and learning
- Under-actuated hand design
- Under-actuated grasping
- Caging
- Whole-body grasping
- Grasp synergies
- Grasping with uncertainties
- Task-oriented grasping
- In-hand manipulation
- Learning and cognitive development of grasping and manipulation





3x speed

Grasp 1

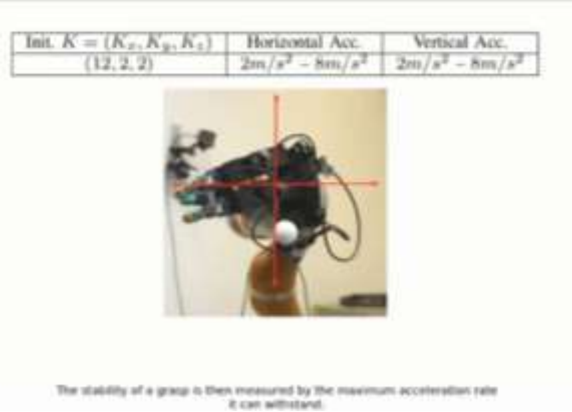


Grasp 1

Learning of Grasp Adaptation through
Experience and Tactile Sensing

Miao Li, Yasemin Bekiroglu,
Danica Kragic and Aude Billard

IROS 2014



Init. $K = (K_x, K_y, K_z)$	Horizontal Acc.	Vertical Acc.
$(12, 2, 2)$	$2m/s^2 - 8m/s^2$	$2m/s^2 - 8m/s^2$

The stability of a grasp is then measured by the maximum acceleration rate it can withstand.

Different perspectives of robots

Robotic Hands, Grasping and Manipulation

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- In-hand manipulation
- Learning and cognitive development of grasping and manipulation

Learning Hand-Eye Coordination for Robotic Grasping with Deep Learning and Large-Scale Data Collection

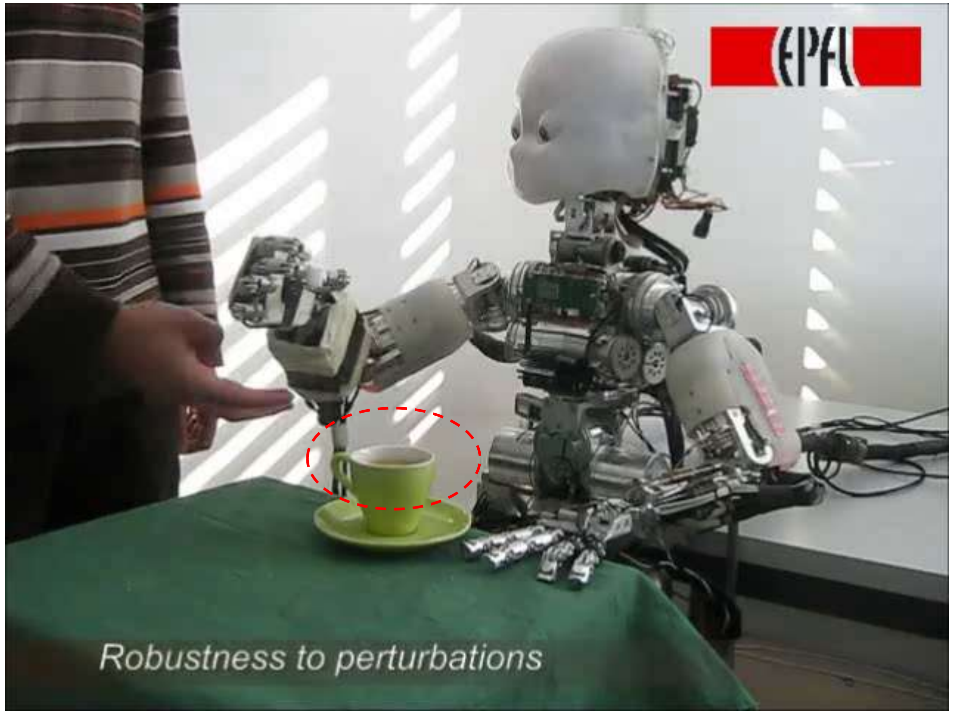
Abstract

Different perspectives of robots

Algorithms for Planning and Control of Robot Motion

Priority areas for the technical committee include:

- consideration of sensing modalities and uncertainty in planning and control algorithms;
- development of representations and motion strategies capable of incorporating feedback signals;
- motion subject to constraints, arising from kinematics, dynamics, and nonholonomic systems;
- addressing the characteristics of dynamic environments;
- developing control and planning algorithms for hybrid systems;
- understanding the complexity of algorithmic problems in control and motion planning;
- encouraging the application of planning algorithms in novel application area.



LASA@EPFL

Different perspectives of robots

Robot Learning

- **Robot learning** is a research field at the intersection of machine learning and robotics. It studies techniques allowing a robot to **acquire novel skills or adapt to its environment through learning algorithms**.
- Example of skills that are targeted by learning algorithms include sensorimotor skills such as locomotion, grasping, active object categorization, as well as interactive skills such as joint manipulation of an object with a human peer, and linguistic skills such as the grounded and situated meaning of human language. Learning can happen either through **autonomous self-exploration or through guidance from a human teacher**, like for example in robot learning by imitation.
- Robot learning can be closely related to adaptive control, reinforcement learning as well as developmental robotics which considers the problem of autonomous lifelong acquisition of repertoires of skills. While machine learning is frequently used by computer vision algorithms employed in the context of robotics, these applications are usually not referred to as "robot learning".

Source: https://en.wikipedia.org/wiki/Robot_learning

Catching Objects in Flight

Seungsu Kim, Ashwini Shukla and Aude Billard

LASA, EPFL

March 22, 2013

Different perspectives of robots

Soft Robotics

Priority areas for the technical committee include:

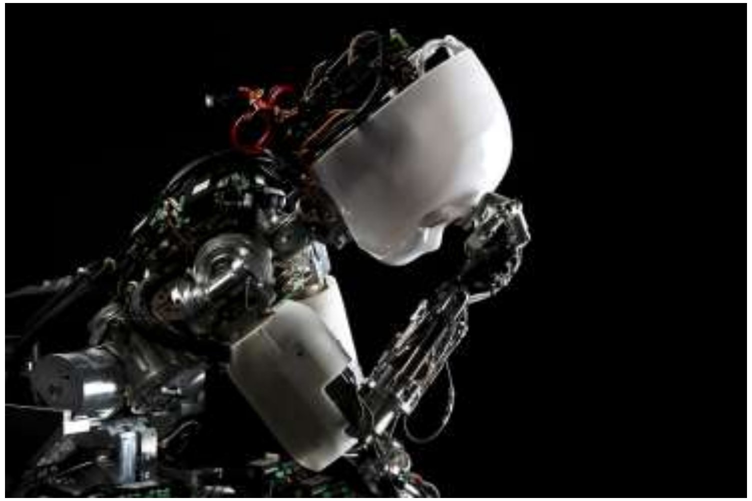
- **scientific problems related with soft-bodied robots**
- **soft materials for robots**
- **modeling and simulation techniques of soft bodies**
- **fabrication and control of soft bodies**
- **interdisciplinary interactions with biological/medical sciences, material sciences and chemistry**
- **soft robotics application**

Goal for this course

- **Design：soft hand design x1**
- **Perception: vision, point cloud, tactile, force/torque x1**
- **Planning: sampling-based, optimization-based, learning-based x3**
- **Control: feedback, multi-modal x2**
- **Learning: imitation learning, RL x2**
- **Simulation tool (pybullet, matlab, OpenRAVE, Issac Nvidia, Gazebo)**
- **How to get a robot moving!**

Paper Reading

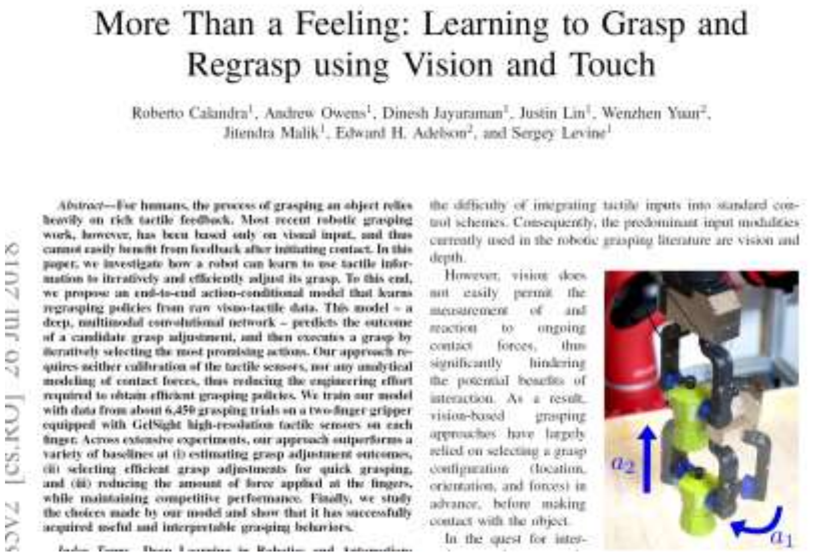
- **Robot paper reading and writing (Advanced Intelligent System, RAL, TRO, soft robots, science robot, ICRA, IROS) x2**
- **Understand the novelty and contribution of a Robot Paper**
- **Technical method, theory, experiments design, result analysis**
- **Any critical comments? Why is good or not good?**



REVIEW SUMMARY

ROBOTICS

Trends and challenges in robot manipulation



More Than a Feeling: Learning to Grasp and Regrasp using Vision and Touch

Roberto Calandra[1], Andrew Owens[1], Dinesh Jayaraman[1], Justin Lin[1], Wenzhen Yuan[2], Jitendra Malik[1], Edward H. Adelson[2], and Sergey Levine[1]

v2 [cs.RO] 20 Jul 2018

Abstract—For humans, the process of grasping an object relies heavily on rich tactile feedback. Most recent robotic grasping work, however, has been based only on visual input, and thus cannot easily benefit from feedback after initiating contact. In this paper, we investigate how a robot can learn to use tactile information to iteratively and efficiently adjust its grasp. To this end, we propose an end-to-end action-conditional model that learns regrasping policies from raw visuo-tactile data. This model – a deep, multimodal convolutional network – predicts the outcome of a candidate grasp adjustment, and then executes a grasp by iteratively selecting the most promising actions. Our approach requires neither calibration of the tactile sensors, nor any analytical modeling of contact forces, thus reducing the engineering effort required to obtain efficient grasping policies. We train our model with data from about 6,450 grasping trials on a two-finger gripper equipped with GelSight high-resolution tactile sensors on each finger. Across extensive experiments, our approach outperforms a variety of baselines at (i) estimating grasp adjustment outcomes, (ii) selecting efficient grasp adjustments for quick grasping, and (iii) reducing the amount of force applied at the fingers, while maintaining competitive performance. Finally, we study the choices made by our model and show that it has successfully acquired useful and interpretable grasping behaviors.

the difficulty of integrating tactile inputs into standard control schemes. Consequently, the predominant input modalities currently used in the robotic grasping literature are vision and depth.

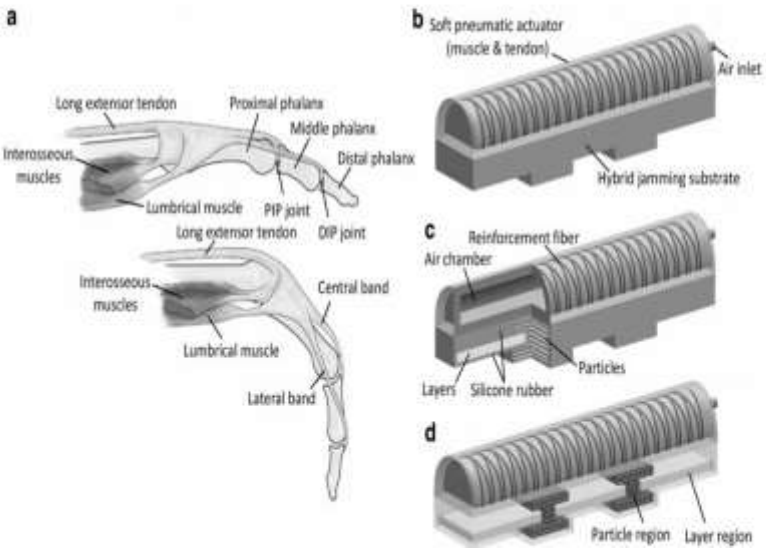
However, vision does not easily permit the measurement of and reaction to ongoing contact forces, thus significantly hindering the potential benefits of interaction. As a result, vision-based grasping approaches have largely relied on selecting a grasp configuration (location, orientation, and forces) in advance, before making contact with the object.

In the quest for inter-

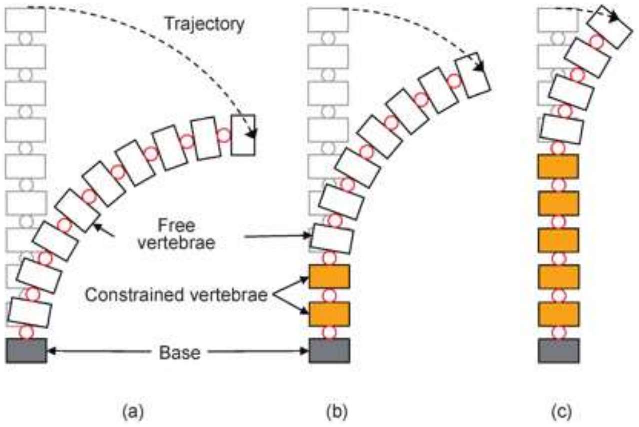
Project

- **Project: please contact the TA as soon as possible to choose the proper project. No later than the 8th week.**
- **Please discuss with us to make sure the project plan is feasible in terms of technical support. Bonus will be given to project with novel idea.**
- **Expected outcome: technical report 50% (paper, patent), presentation 30%, video 20%.**
- **# If you have further interest, please contact the TA to join in the lab for an internship.**

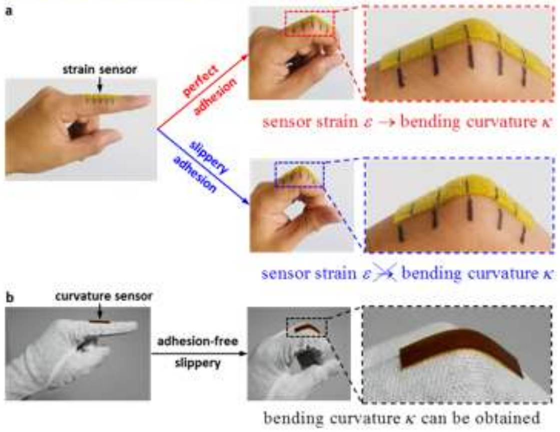
Project 1: Soft hand design



材料与结构设计



运动学与刚度分析



柔性传感技术

Project 1: Soft hand design

✓ 柔性灵巧手的设计与研究旨在克服传统刚性关节机械手缺乏柔顺性、控制复杂以及造假高昂等缺点，主要通过柔性材料与结构设计等来实现仿人手抓取功能。以下是柔性灵巧手的主要研究内容：

a. 仿生机理研究

柔性灵巧手的仿生机理综合了材料、结构、驱动控制、运动学分析、可变刚度接触、传感器技术等多个学科在内的全方位的仿生理论和技术，对其仿生机理的研究是设计柔性灵巧手的理论基础和关键。

b. 运动学建模分析

柔性灵巧手大多采取欠驱动的方式以减少零部件数量与结构复杂性，柔性材料的选择、手指关节数目与截面结构设计等的不同都会改变柔性灵巧手的刚度与运动学特征。因此如何对灵巧手进行运动学建模以及获得期望的刚度曲线是研究的重要内容。

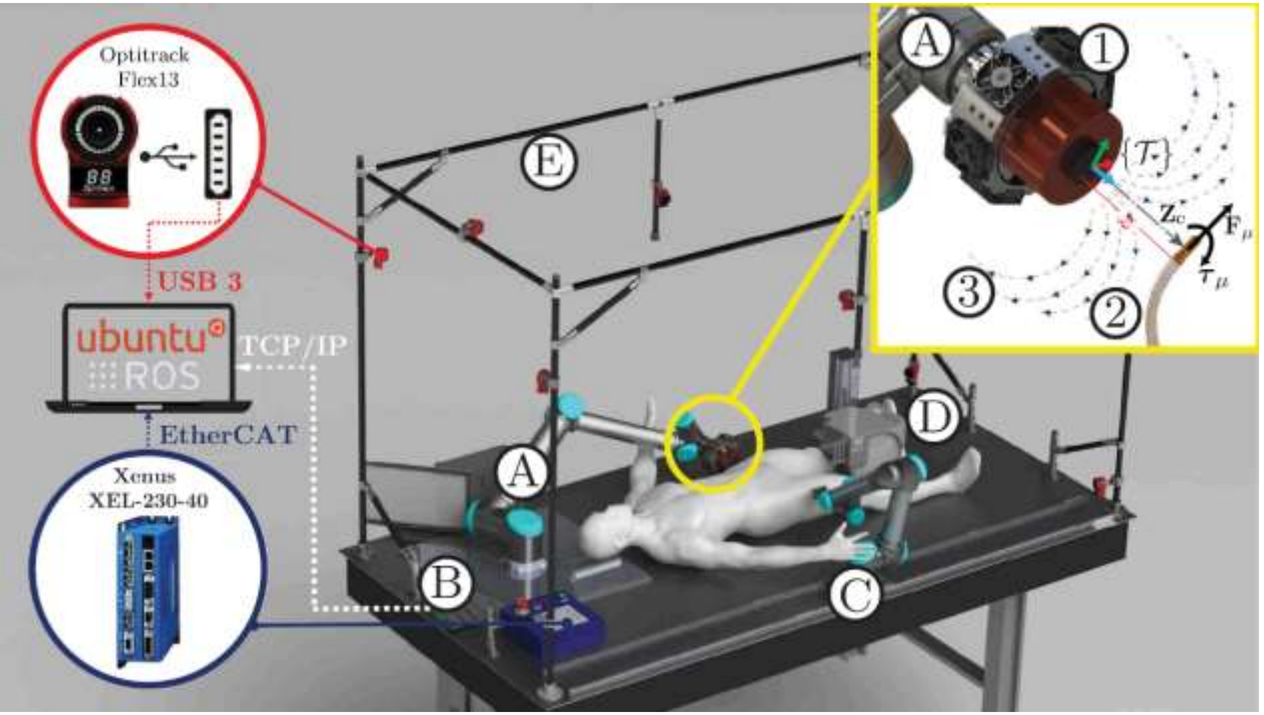
c. 驱动与控制技术研究

柔性灵巧手的运动控制可以结合机器视觉、传感器等技术实现精细操作，如何在有限的驱动和传动空间内协同控制诸多的驱动器实现仿人的运动和动作，也是研究中的一个巨大挑战。

d. 柔性传感技术研究

灵巧操作要求灵巧手能够准确地反馈自己的状态并感知周围环境，因此需要结合灵巧手内部与外部的感知传感器来获取手指运动姿态、物体接触信息和环境的物理特征等信息。如何实现柔性传感器的高集成度、多功能、广覆盖，以及将触觉数据处理方法与自主控制算法相结合进行基于触觉的灵巧操作也是重要的研究内容。

Project 2: Micro-Robots



✓ 磁控微型机器人

a. 磁控微型机器人操控技术的改进：

磁场建模与仿真：开发精确的磁场模型，优化磁场配置以实现更精准的微型机器人操控。

控制算法：研究高效的基于学习的控制算法，实现微型机器人在三维空间内的精准操控。

b. 微型机器人设计与制造：

磁性材料选择：研究不同磁性材料的性能，以满足微型机器人在特定应用中的要求。

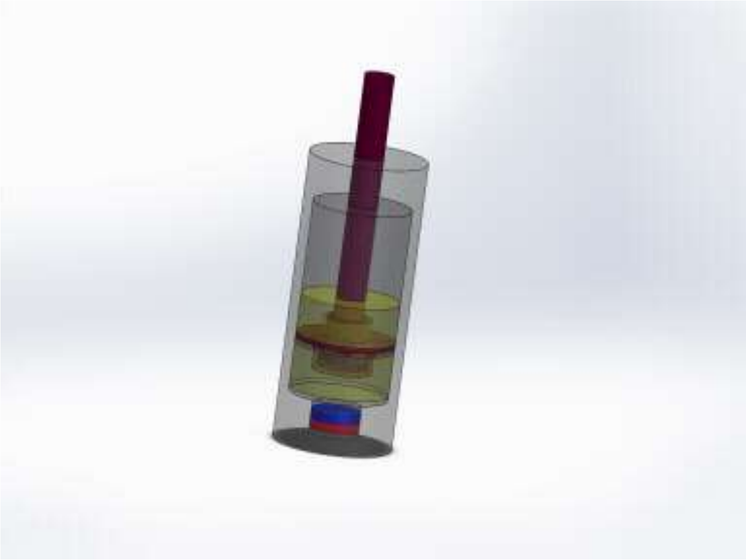
制造技术：开发高精度制造技术，生产出尺寸微小但性能卓越的微型机器人。

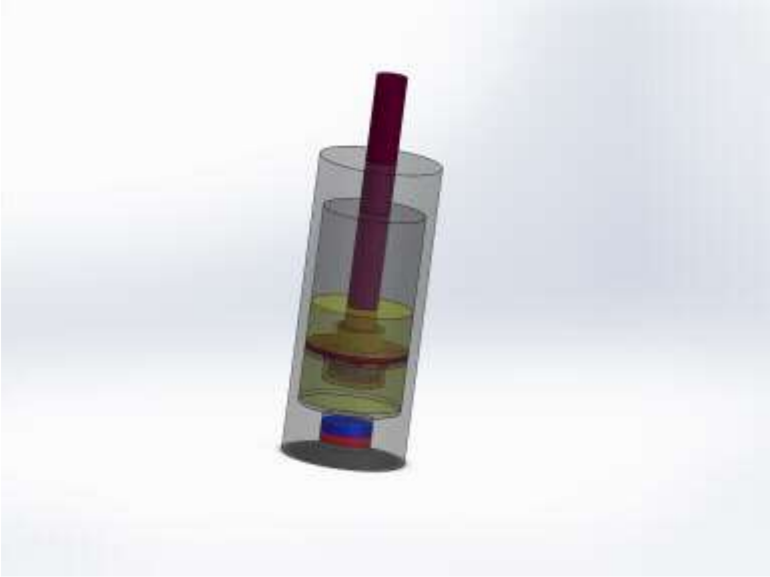
c. 生物医学应用：

肿瘤治疗：探索磁控微型机器人在肿瘤内部的定向输送和治疗应用，如药物传递或局部热疗。

微创手术：研究微型机器人在微创手术中的应用，提高手术精确度和恢复速度。

Project 3: Modelling

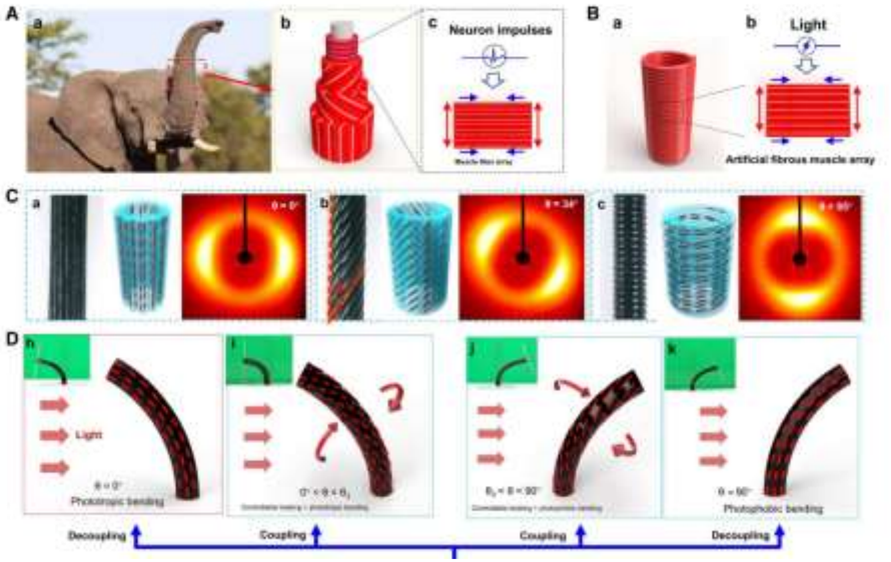




- ✓ **基于ansys的通电螺线管式电磁铁温升控制**

首先，对于通电螺线管式电磁铁，温升是不可避免的，对于特定的有间隔的通电断电应用场景来说，间隔时间影响着最大温升。研究温度传感器实时监测温升并通过ansys maxwell软件建模分析温度场随通电时间的交替变化情况，并程序控制在温升过高情况下，强制停止通电，并在降低后允许通电。

Project 4: Modelling and simulation

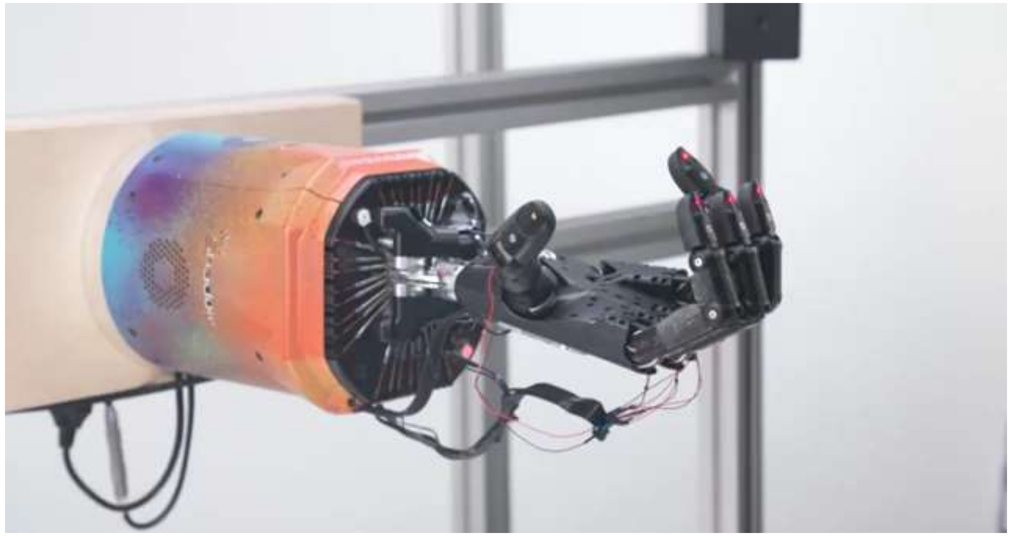


- ✓ **一种仿生弹跳腿模型构建与运动分析**

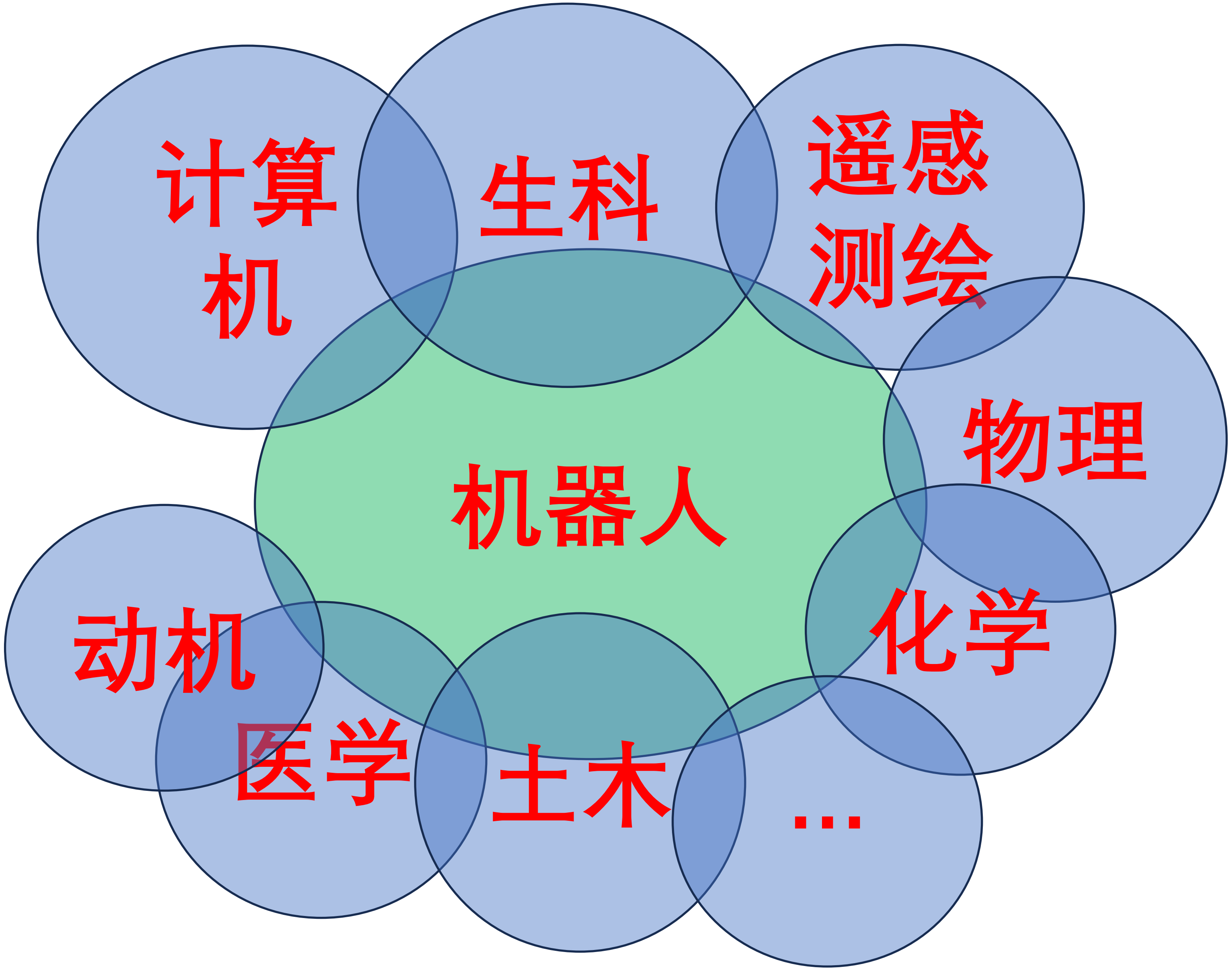
建立仿生弹跳腿模型，由于力量越大，腿部爆发速度越快，但是响应时间减短，总的力的冲量变化不明显，这就造成速度变化率不明显，而增大力的作用距离可增大力的总响应时间(持续走完整个行程，行程越长力作用时间越长）。所以研究在一定爆发力范围情况下，腿长(决定着爆发力作用于腿的行程)与爆发力之间的关系，寻找在一定质量或者体积下，合适的爆发力与行程之间的比值。可以通过三维建模，然后理论进行运动方程的建模，然后仿真软件界定边界条件，比如爆发力过大材料承受能力，或者弹性形变范围等等，最后根据理论得出最佳力距比，仿真验证理论。

Project 5: Dexterous manipulation

- ✓ Dexterous manipulation: learning dexterous manipulation from human teaching or from simulation.
    - ✓ Hand kinematics (data-driven)
    - ✓ Control policy (imitation learning, RL, hard-coded, rule-based)
    - ✓ Taks representation (2D camera, tactile sensing, …)



Project 6: X



机器人

计算机

生科

遥感测绘

物理

化学

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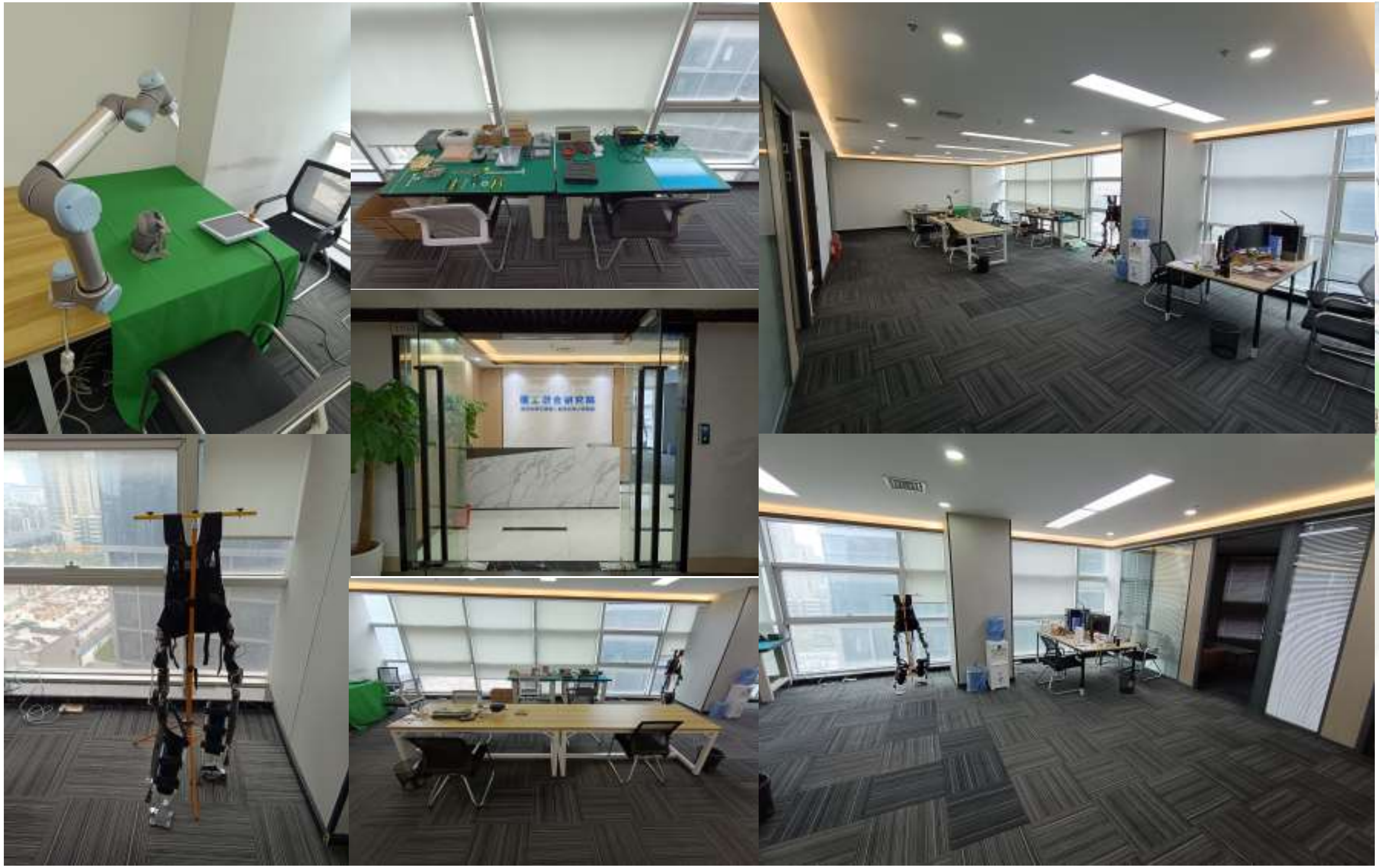
土木

医学

动机

Hardware support



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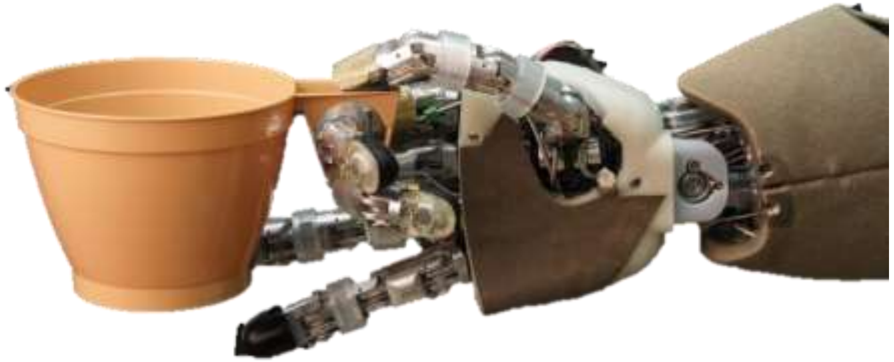
Next Course

- **Design and Modelling of typical robotic arm**
- **DH parameters**
- **Kinematics, IK, Jacobian**
- **Simulation tool introduction**
- **Group list**



Any questions?