NANYANG TECHNOLOGICAL UNIVERSITY

School of Mechanical and Aerospace Engineering

Design, Machine, Control, Intelligence

Invited Talk

大知识库模型

KnowNet:
A Large Knowledge Model

Ming XIE, PhD (France)

http://personal.ntu.edu.sg/mmxie

Xie M., (2014), 基于自然语言的人机对话系统 Human-Machine Dialogue Systems Based on Understanding of Texts in Natural Languages, ZL2009 1 0040170.1, 授权日期: 2014.02.12, Granted on 12 February 2014, Filed on 2009.6.11

ABOUT NTU

Vision and Mission

A great global university founded on science and technology, nurturing leaders and creating societal impact through interdisciplinary education and research.

Leadership

Professor Ho Teck Hua
President and Distinguished University Professor

Professor Christian Wolfrum
Deputy President and Provost

Ranked Among the Best in the World

3rd
Nature Index
Young University Rankings

1st
Times Higher Education
Young University Rankings

3rd
US News and World Report
Best Global Universities in Asia

4th
Times Higher Education
Asia University Rankings

15th
QS World University Rankings

4th
QS Asia University Rankings

27th
US News and World Report
Best Global University Rankings

30th
Times Higher Education
World University Rankings

10th
QS World's Most Photogenic Universities

Ranked Among the Best in the World

NTU 2025 Strategic Plan

NTU 2025 reinforces NTU's strong commitment to the four core pillars of the University:

- Education
- Research
- Innovation
- Community

Addressing humanity's grand challenges:

- Mitigating our impact on the environment
- Harnessing the science, art and technology of learning
- Addressing technology's impact on humanity;
- Responding to the needs and challenges of healthy living and ageing

15-Year Sustainability Manifesto

Solidifying the University's position as a global leader in sustainability

- NTU's sustainability manifesto goals: carbon neutrality by 2035, halve net energy utilisation and new sustainability courses
- First university in the world to launch a sustainability-linked bond with an Aaa credit rating from Moody's
- Sustainable campus with eight zero-energy buildings, the most amongst organisations in Singapore
- Home to two of Asia's largest wooden buildings, Gaia and The Wave
- Winner of ISCN's Whole Systems Approach Excellence Award in recognition of sustainable practices in the areas of research, education, community engagement, and infrastructure developments

Main Campus

200 hectares

State-of-the-art-facilities

25 halls of residence

The NTU Smart Campus is a living testbed of tomorrow's technologies and frequently named among the most beautiful campuses in the world.

Medical Campus

School of Medicine

Learning and research

Sports and recreation

Home to the Lee Kong Chian School of Medicine in Novena, Singapore's healthcare district. The school aims to be a model for innovative medical education and a centre for transformative research.

At a Glance

35,400 students

24,800 undergraduates
10,600 postgraduates

8,000

faculty, researchers and staff from 73 countries

300,900 alumni

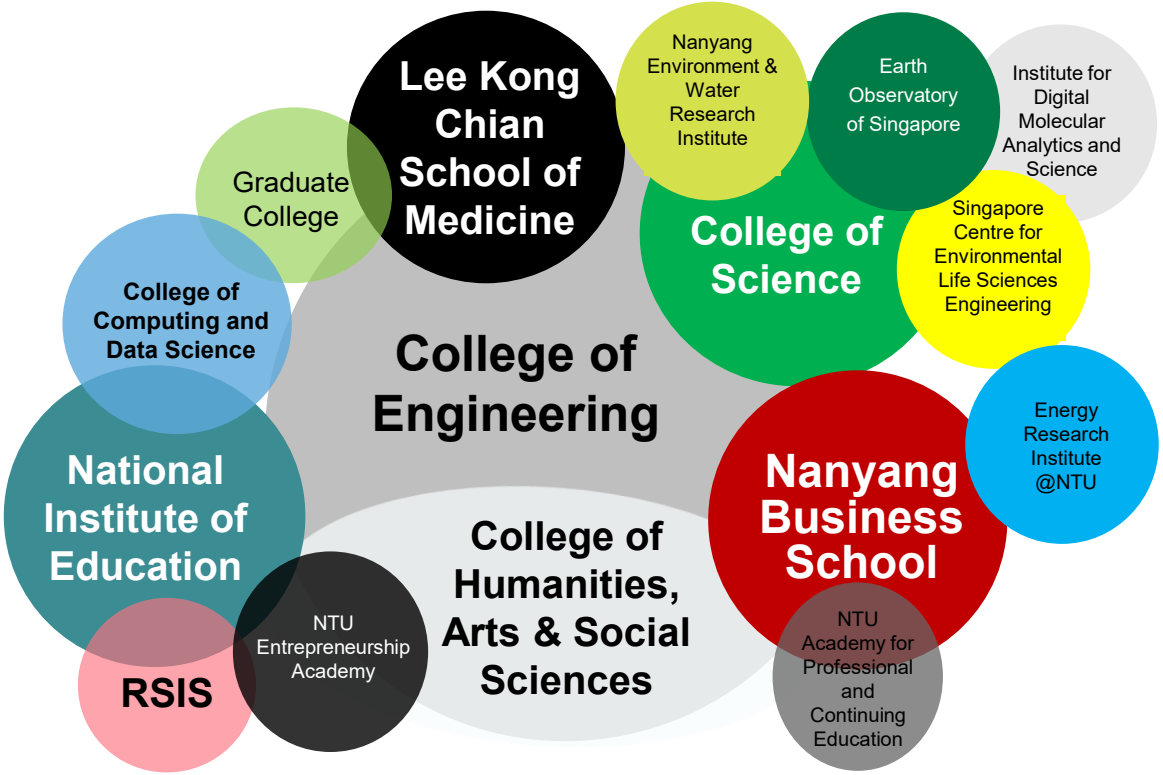
representing 172 nationalities

At a Glance

6
Colleges

15
Schools

World-class institutes & research centres



NTU Academy for Professional and Continuing Education

- Consolidates continuing education and training capabilities and expertise within the University
- Enriches the lifelong learning experience of adult learners, including the University's alumni, making it easier for them to take charge of their own continuing education
- The FlexiMasters programme for continuing education at the Master's degree level, launched in 2020, has grown to more than 35 curricular offerings from all parts of the University

Global Alliance of Industries @ NTU

- Catalysing new university-industry partnerships through multiple consortia, corporate laboratories, multidisciplinary institutes and technology invention disclosures
- Over 250 industry partners and 20 corporate and joint labs with global entities such as Alibaba, Continental, Hewlett-Packard, Nanofilm Technologies, Rolls-Royce and Schaeffler

Top Industry Partners

Top Academic Partners


UC Berkeley

Northeastern University


Australian National University


University of British Columbia


Imperial College London

Karolinska Institute


TUM


Seoul National University


Indian Institute of Technology, Madras


University of Toronto


Tsinghua University


University of Pennsylvania

NANYANG TECHNOLOGICAL UNIVERSITY

School of Mechanical and Aerospace Engineering

Design, Machine, Control, Intelligence

Welcome You to NTU

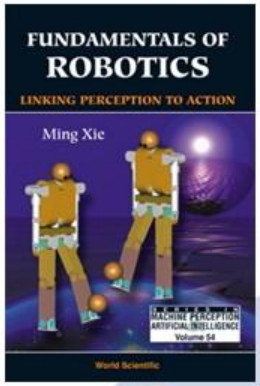
ABOUT SPEAKER

Xie Ming as Scientist and Educator in Authentic AI, Humanoid Robotics and Autonomous Driving

Recipient of Chinese Government's Overseas Scholarship (1984 - 1989)

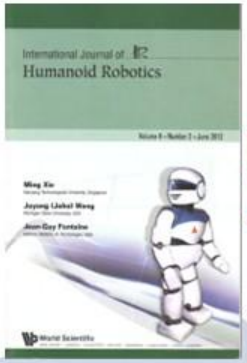
1984: BEng (China)
1986: MSc (France)
1989: PhD (France)

2003

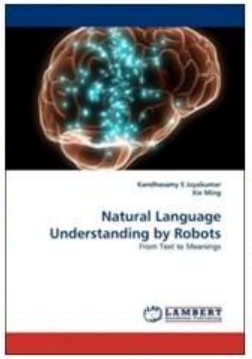


2008

2004



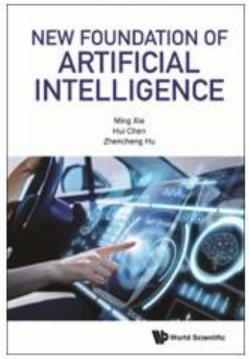
2010



2010

RSS
Robotics Society of Singapore

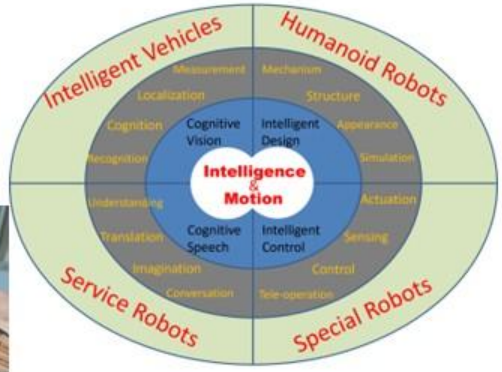
2021



Service

Enterprising

Research / Innovation



Teaching Portfolio

1. Sensors
2. Robotics
3. Microprocessors
4. Machine Intelligence

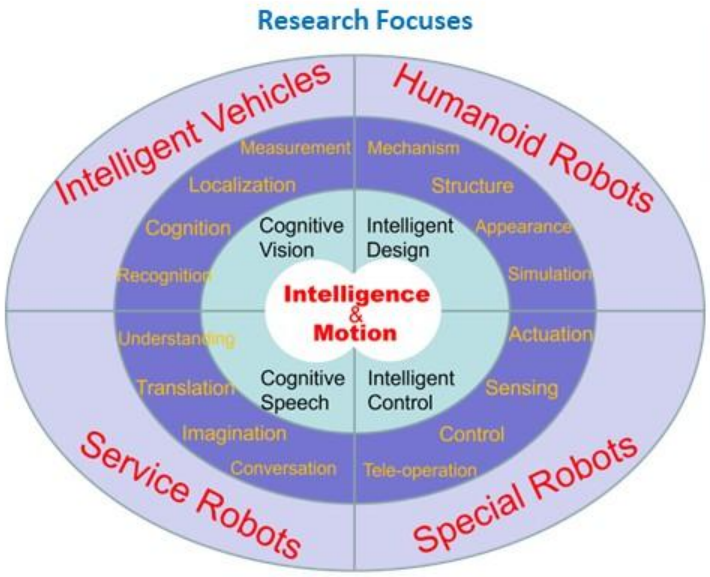
2023

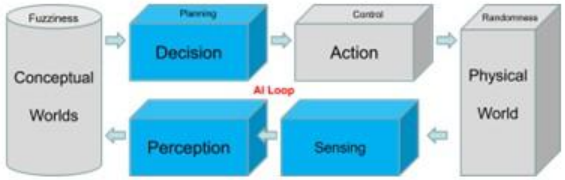
2024

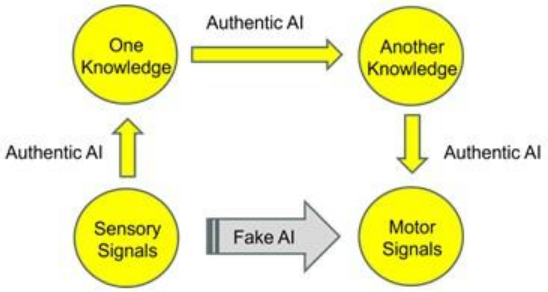
Associate Professor
Ming XIE
http://xieming.robotics.sg

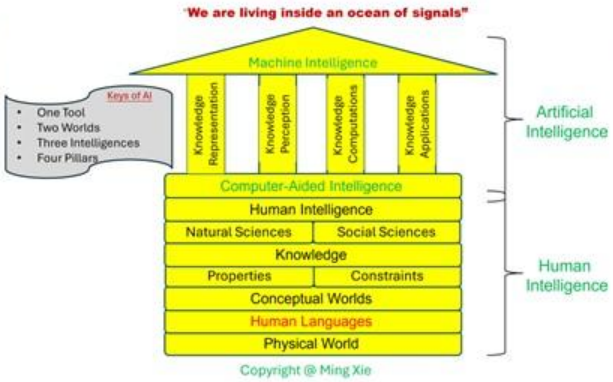
(Learning, Teaching) <o> (Research, Innovation) <o> (Leadership, Service)

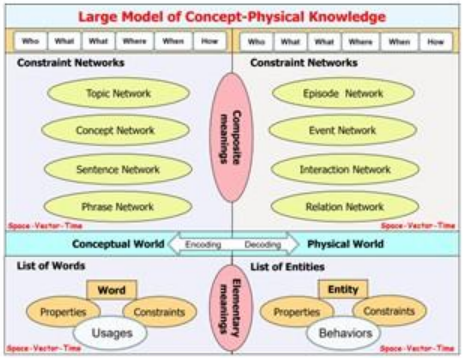
Artificial Intelligence Research Leading to Science of Mind

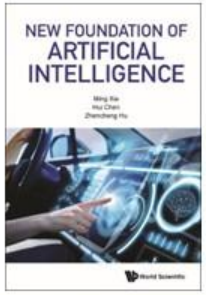


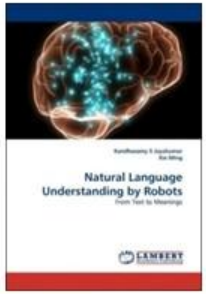


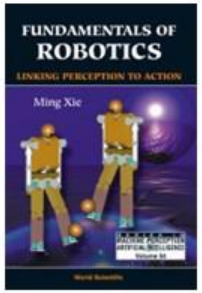












1. **Xie M** and Wang X. H., 2025, Biomimetic Digital Twin of Future Embodied Internet for Advancing Autonomous Vehicles and Robots, Open Access Journal of Biomimetics.
2. **Xie M**, Wang X. H. and Li J. H., 2025, A Hybrid Strategy for Achieving Robust Matching Inside the Binocular Vision of a Humanoid Robot, Open Access Journal of Mathematics.
3. **Xie M.**, Fang Yuhui and Lai Tingfeng, 2025, New Solution to 3D Projection in Human-like Binocular Vision, International Journal of Humanoid Robotics.
4. **Xie M.**, 2024, Top-down Design of Human-like Teachable Mind, Special Issue in Celebrating IJHR's 20th-Year Anniversary, International Journal of Humanoid Robotics.
5. **Xie M**. Lai Tingfeng, and Fang Yuhui, 2023, A New Principle Toward Robust Matching in Human-like Stereovision, Open Access Journal of Biomimetics.

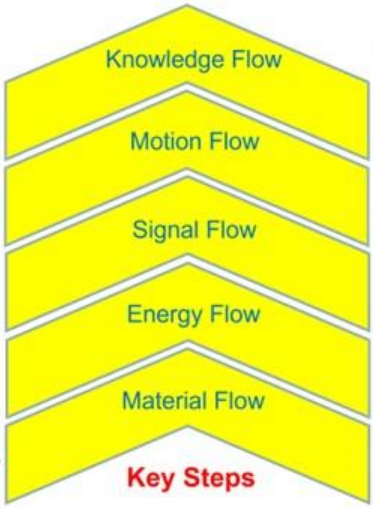
Associate Professor
Ming XIE
http://xieming.robotics.sg

Humanoid Robotics Research

Research Focuses

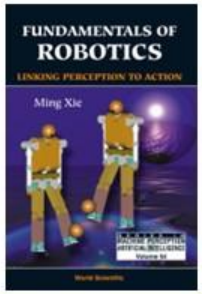
Miomir Vukobratovic
(1931-2012)
Discovery of ZMP

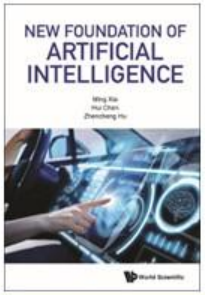
Any smart dynamic system has a physical body and brain



- Cognition
- Recognition
- Interaction
- Perception
- Planning
- Control
- Motion Kinematics
- Motion Dynamics
- Position Sensors
- Velocity Sensors
- Force/Torque Sensors
- Visual/Acoustic Sensors
- Power Suppliers
- Actuators and Controllers
- Appearance
- Structure
- Mechanism
- Computing
- Memory

In-House Developed Prototypes of Humanoid Robots

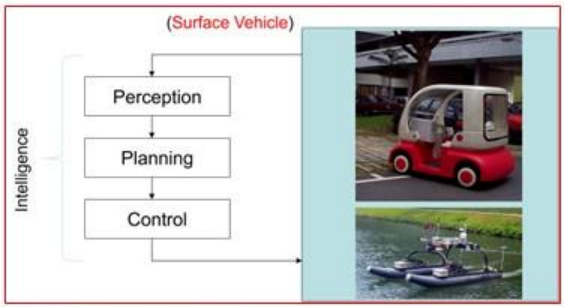


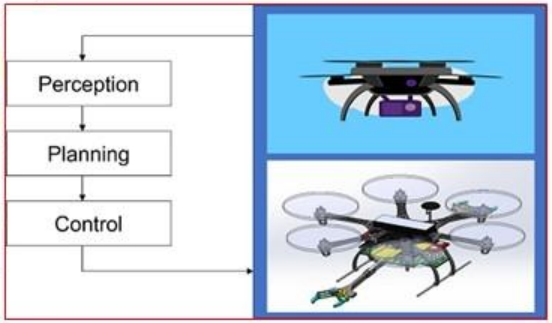


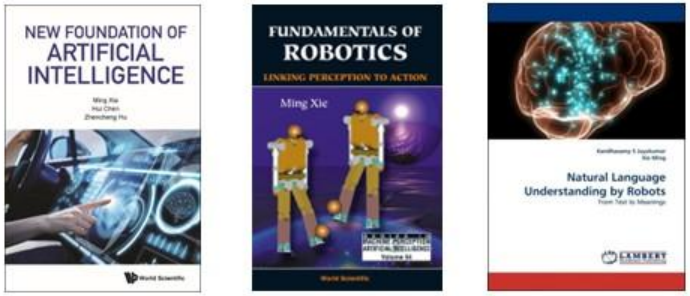
1. **Xie M** and Wang X. H., 2025, Biomimetic Digital Twin of Future Embodied Internet for Advancing Autonomous Vehicles and Robots, Open Access Journal of Biomimetics.
2. **Xie M**, Wang X. H. and Li J. H., 2025, A Hybrid Strategy for Achieving Robust Matching Inside the Binocular Vision of a Humanoid Robot, Open Access Journal of Mathematics.
3. **Xie M.**, Fang Yuhui and Lai Tingfeng, 2025, New Solution to 3D Projection in Human-like Binocular Vision, International Journal of Humanoid Robotics.
4. **Xie M.**, 2024, Top-down Design of Human-like Teachable Mind, Special Issue in Celebrating IJHR's 20th-Year Anniversary, International Journal of Humanoid Robotics.
5. **Xie M**. Lai Tingfeng, and Fang Yuhui, 2023, A New Principle Toward Robust Matching in Human-like Stereovision, Open Access Journal of Biomimetics.

Associate Professor
Ming XIE
http://xieming.robotics.sg

Research on Autonomous Driving with Embedded Driver or Robot Driver



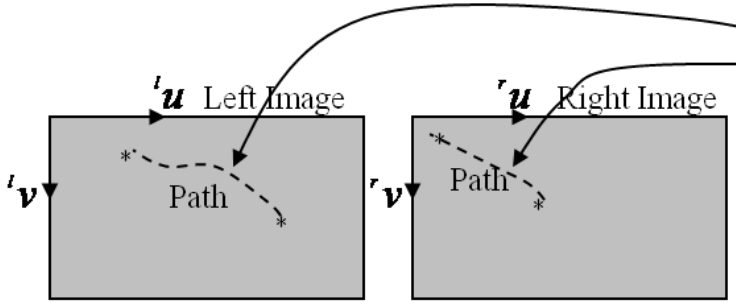




1. **Xie M** and Wang X. H., 2025, Biomimetic Digital Twin of Future Embodied Internet for Advancing Autonomous Vehicles and Robots, Open Access Journal of Biomimetics.
2. **Xie M**, Wang X. H. and Li J. H., 2025, A Hybrid Strategy for Achieving Robust Matching Inside the Binocular Vision of a Humanoid Robot, Open Access Journal of Mathematics.
3. **Xie M**., Fang Yuhui and Lai Tingfeng, 2025, New Solution to 3D Projection in Human-like Binocular Vision, International Journal of Humanoid Robotics.
4. **Xie M**., 2024, Top-down Design of Human-like Teachable Mind, Special Issue in Celebrating UHR's 20th-Year Anniversary, International Journal of Humanoid Robotics.
5. **Xie M**. Lai Tingfeng, and Fang Yuhui, 2023, A New Principle Toward Robust Matching in Human-like Stereovision, Open Access Journal of Biomimetics.

Associate Professor
Ming XIE
http://xieming.robotics.sg

Key Breakthrough No.1: X-Eye Coordination



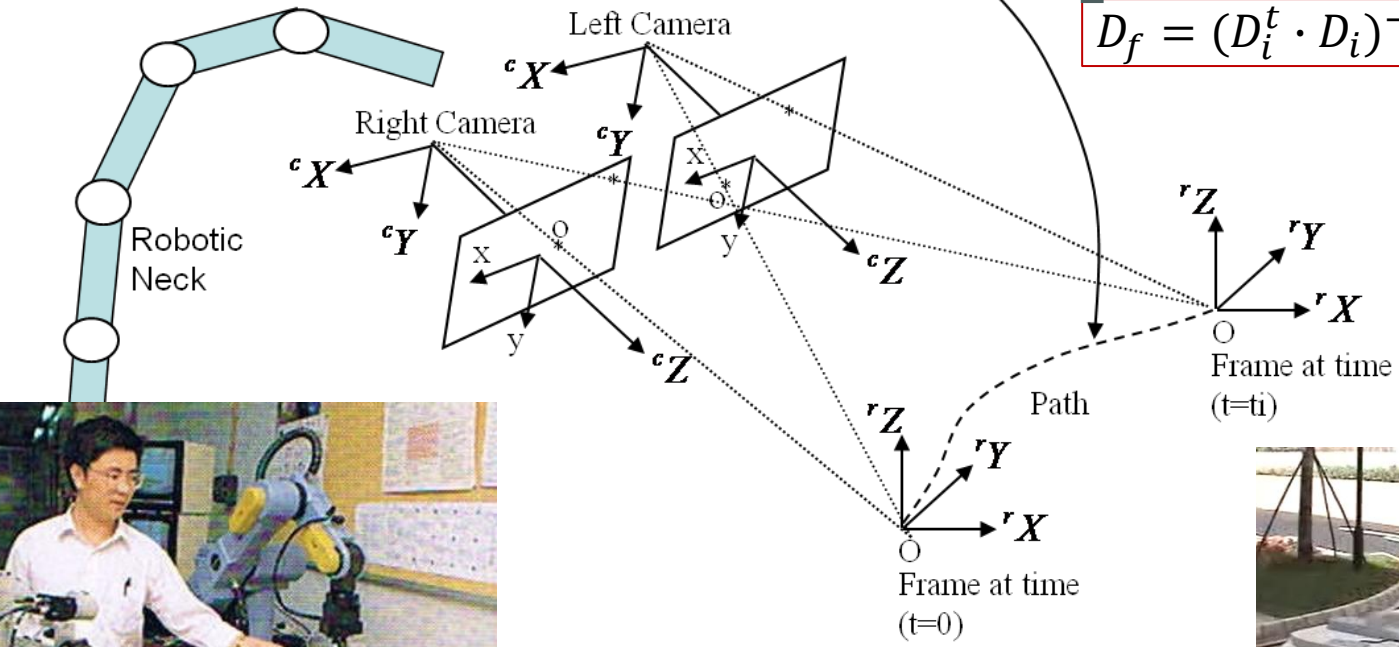
3D Forward Projection

$$\begin{bmatrix}\Delta u_l \\ \Delta v_l \\ \Delta u_r \\ \Delta v_r\end{bmatrix} = D_f \cdot \begin{bmatrix}\Delta X \\ \Delta Y \\ \Delta Z\end{bmatrix}$$

3D Inverse Projection

$$\begin{bmatrix}\Delta X \\ \Delta Y \\ \Delta Z\end{bmatrix} = D_i \cdot \begin{bmatrix}\Delta u_l \\ \Delta v_l \\ \Delta u_r \\ \Delta v_r\end{bmatrix}$$

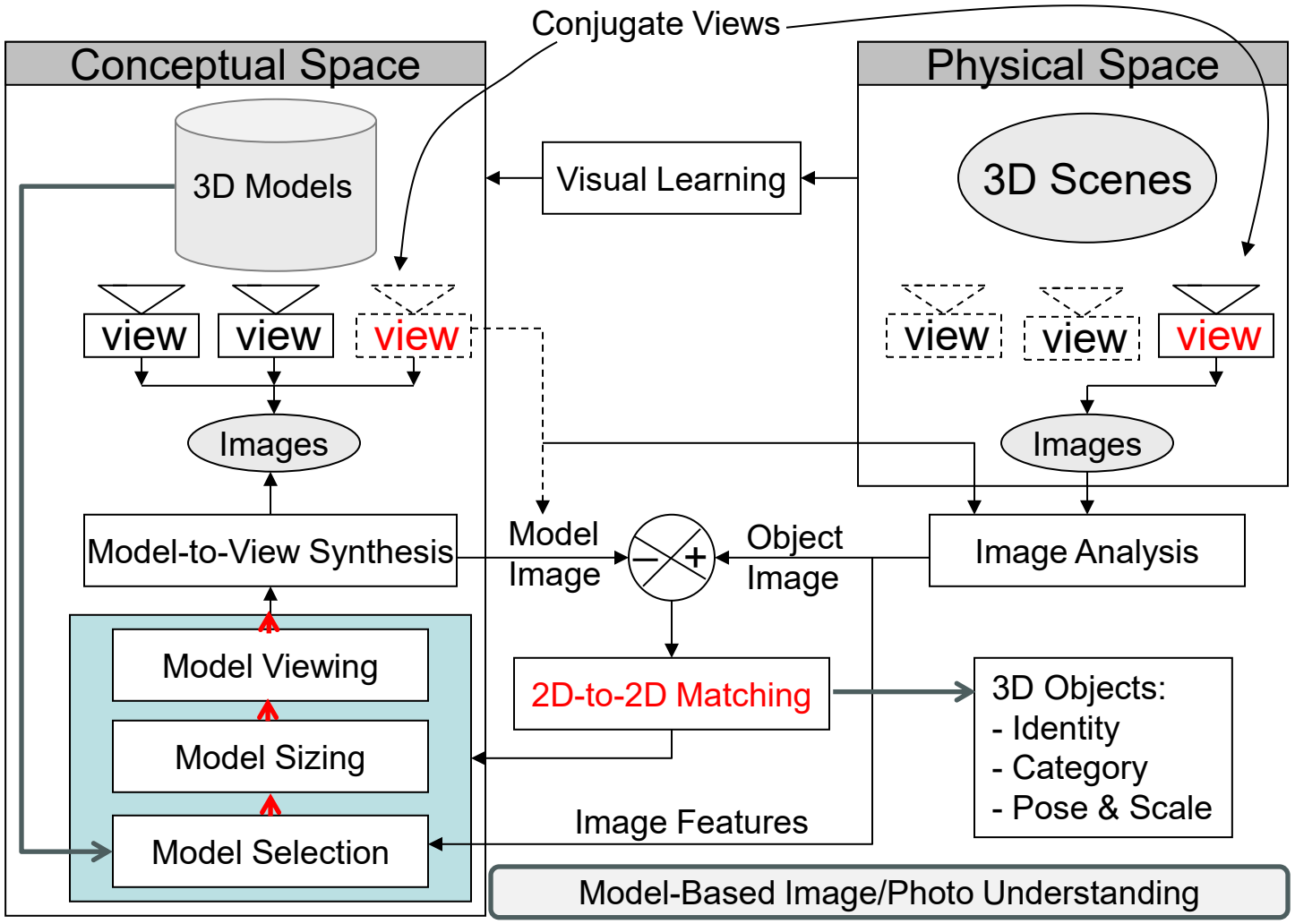
$$D_f = (D_i^t \cdot D_i)^{-1} \cdot D_i^t$$



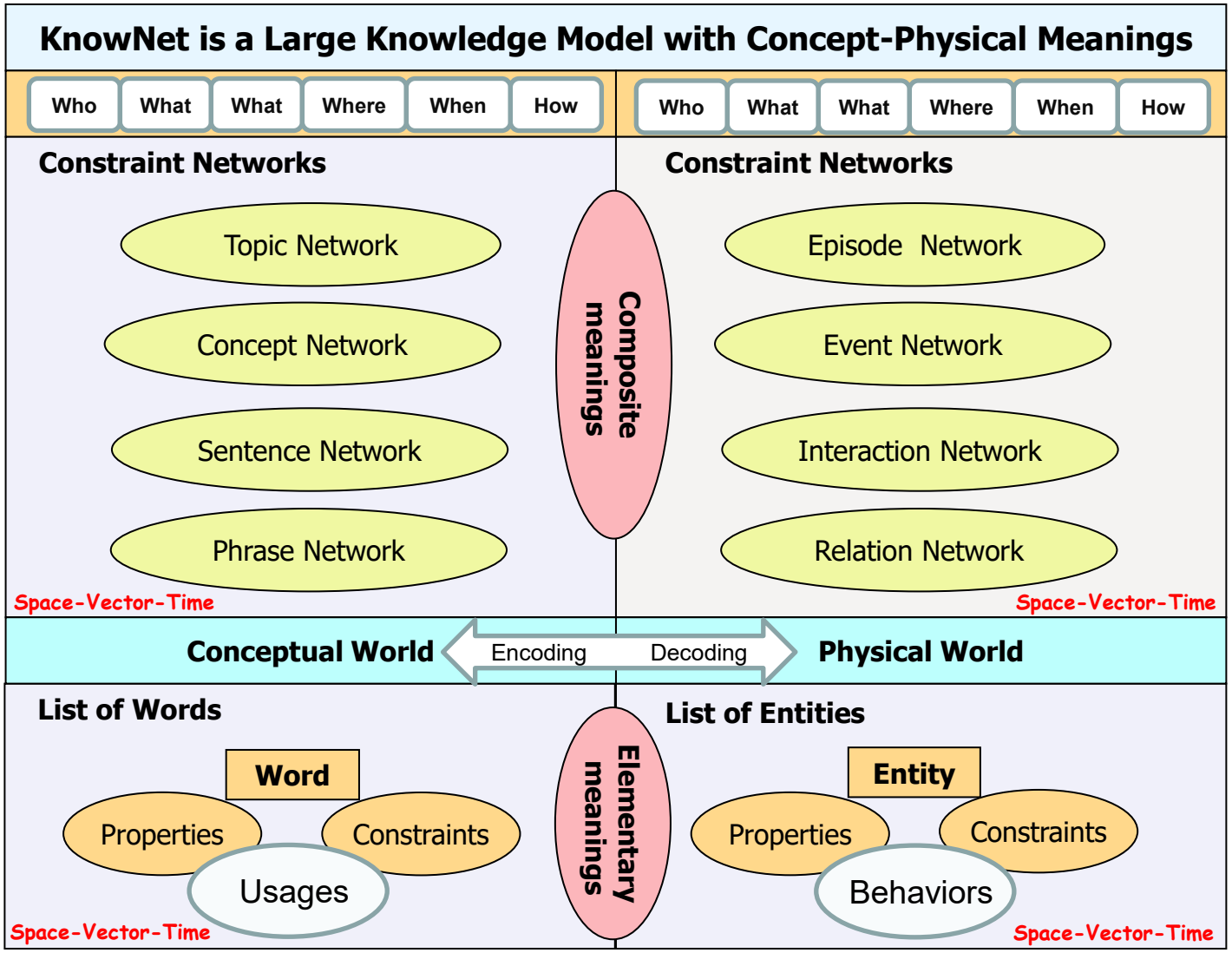
Hand-Eye Coordination

Head-Eye Coordination

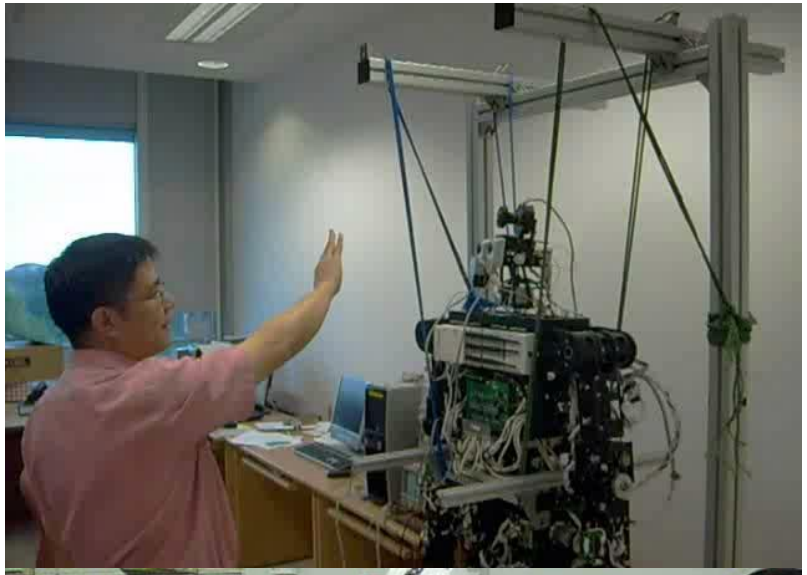
Key Breakthrough No.2: Model-Based Vision

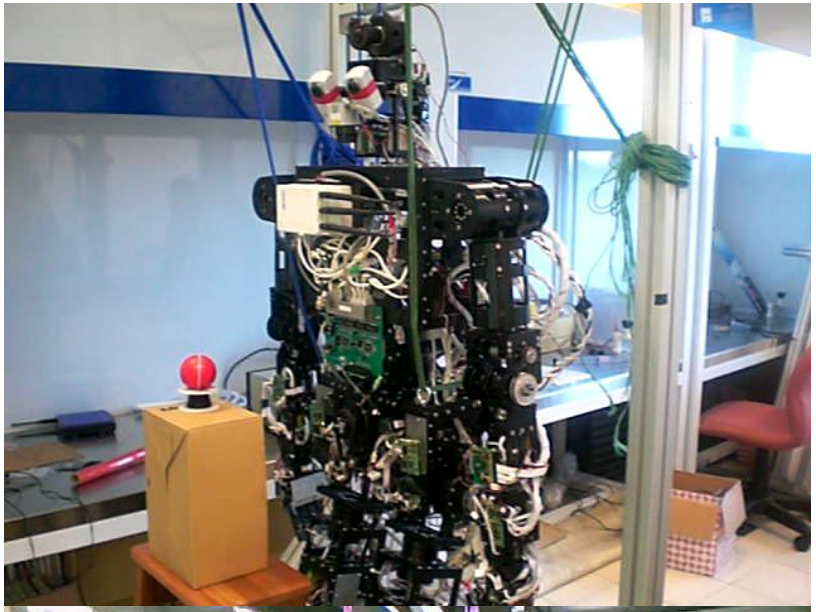


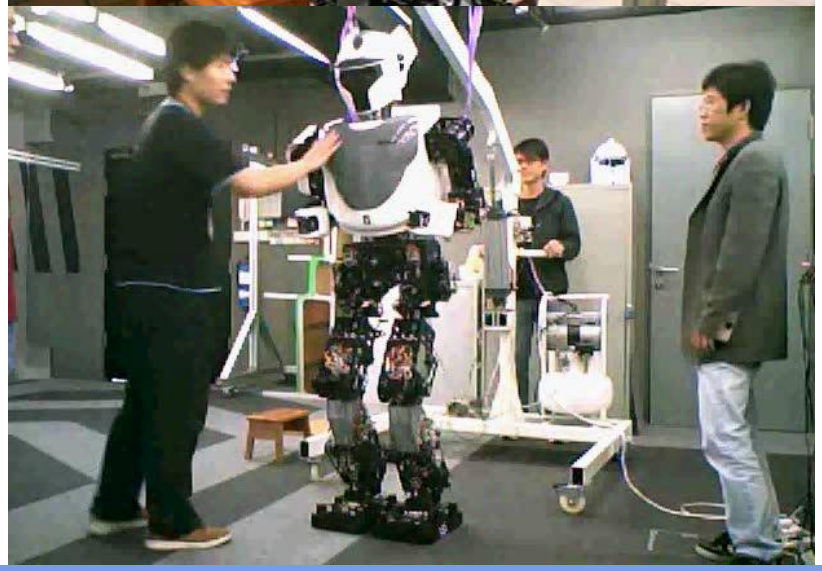
Key Breakthrough No.3: Large Knowledge Models



Some Demonstrations ...








CCTV 新闻
重播

WARM-UP QUESTIONS

Warm-Up Question 1

- Which one of the following two systems is the generator of Artificial Intelligence?

  (人工智能? 人工心智?)

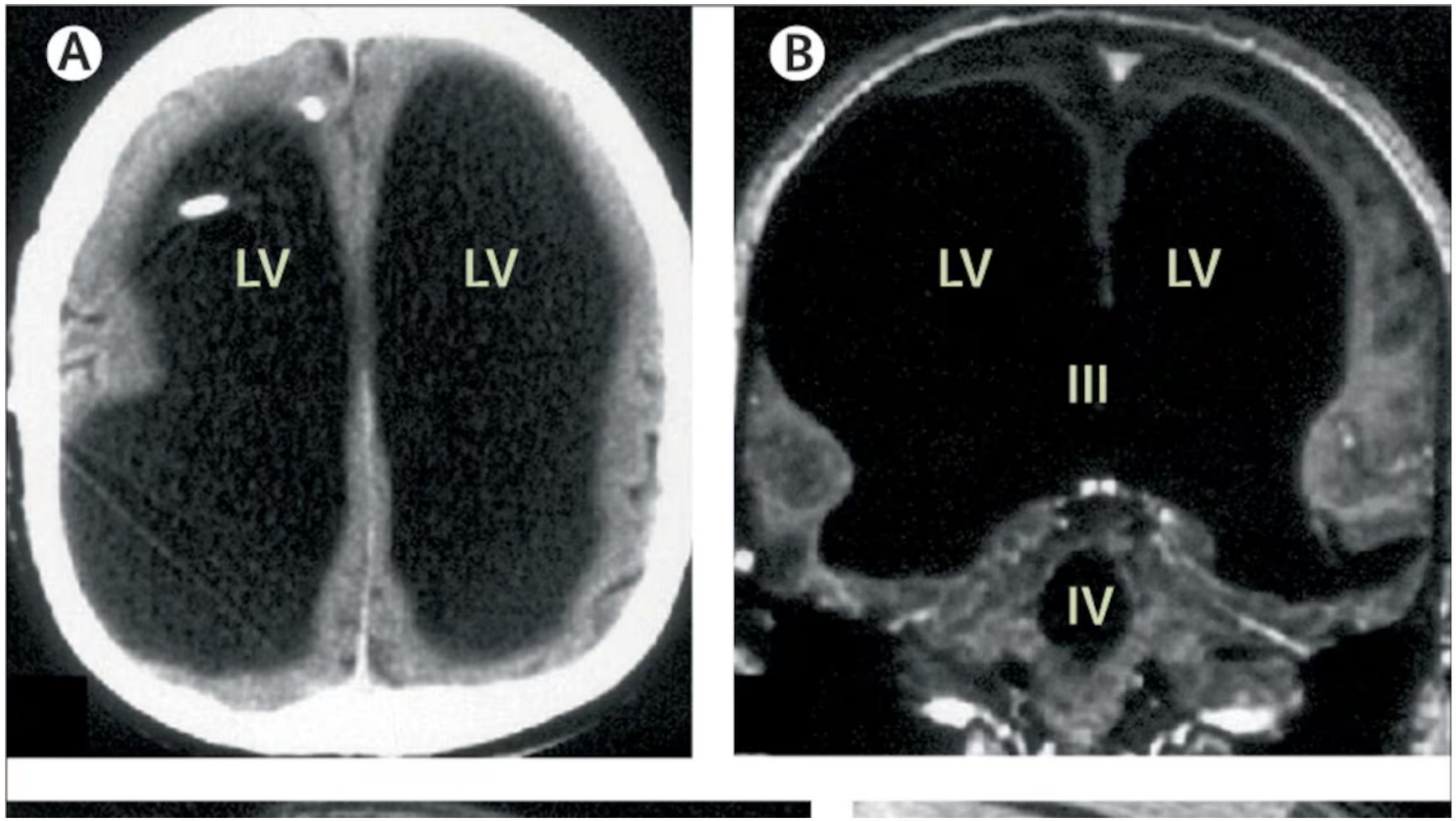
  – A) Artificial Brain 人工大脑

  – B) Artificial Mind 人工识觉

Evidence ...

Scientists research man missing 90% of his brain who leads a normal life

CBC Radio · Posted: Jul 14, 2016 5:27 PM EDT | Last Updated: April 17, 2023



These scans of a French man's brain were published in The Lancet in 2007. Since then, this case has puzzled researchers, including cognitive psychologist Axel Cleeremans. (Feuillet et al/The Lancet)

Many Other Evidences …

▸ J Undergrad Neurosci Educ. 2016 Apr 15;15(1):C1–C3.

The Woman Born Without a Cerebellum: A Real-Life Case Adapted for Use in an Undergraduate Developmental and Systems Neuroscience Course

Jennifer Brielmaier [1,✉]

▸ Author information ▸ Article notes ▸ Copyright and License information

PMCID: PMC5105972 PMID: 27980478

Abstract

In 2014, the case of a 24-year-old woman who had just discovered she was born without a cerebellum made headlines around the world. The details of this case were combined with

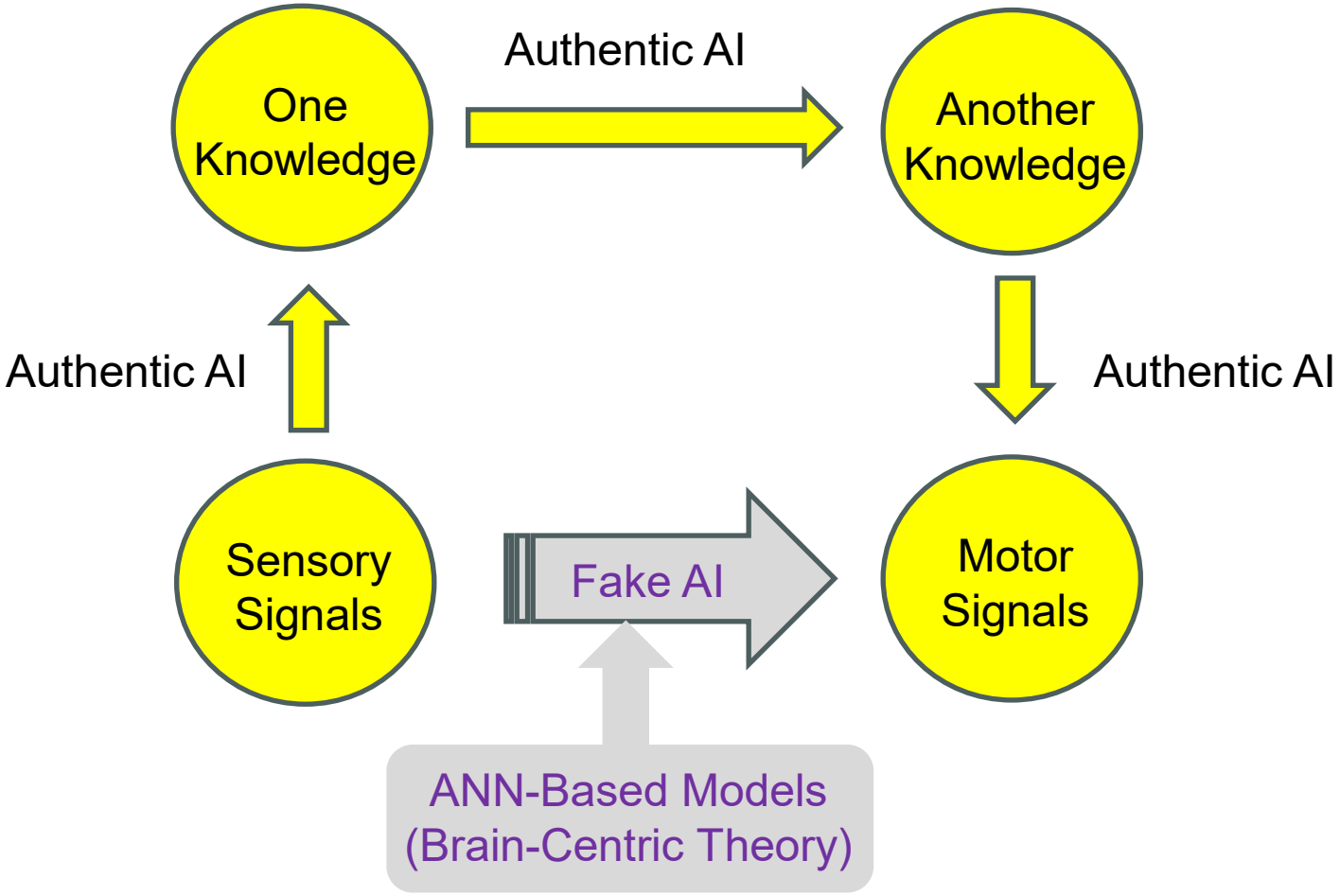
Warm-Up Question 2

- Which one of the following four terminologies is a synonym for Learning?
  - A) Cognition
  - B) Optimization
  - C) Tuning
  - D) Calibration

Warm-Up Question 3

- Which one of the following four transformations is not a process of Authentic AI?
  - A) Signal to Signal
  - B) Signal to Knowledge
  - C) Knowledge to Knowledge
  - D) Knowledge to Signal

Authentic AI versus Fake AI



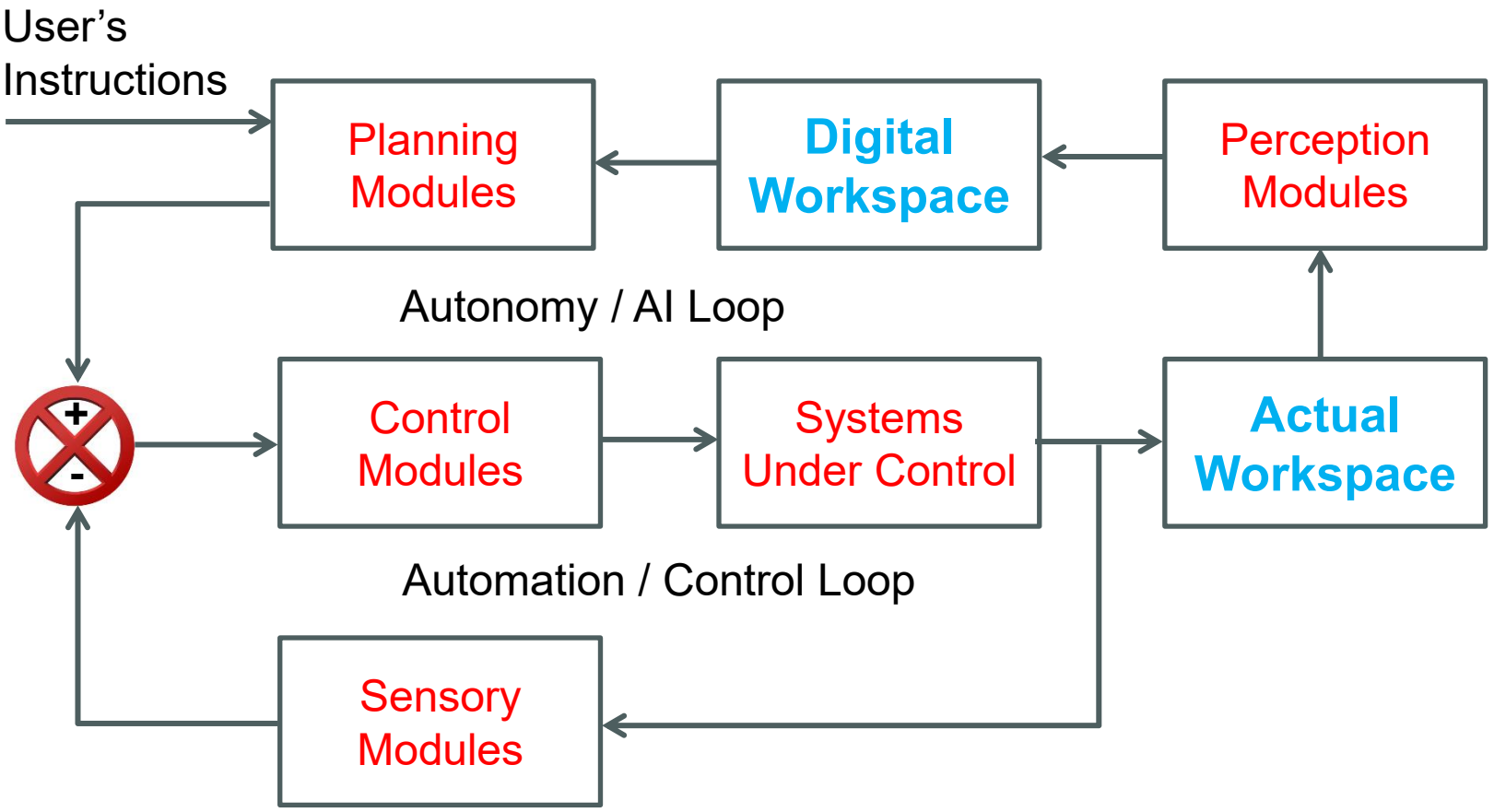
Warm-Up Question 4

- Which one of the following two theories empowers the achievement of Automation?
  - A) Control Theory
  - B) Mind Theory (or AI Theory)

Warm-Up Question 5

- Which one of the following two theories empowers the achievement of Autonomy?
  - A) Control Theory
  - B) Mind Theory (or AI Theory)

Automation versus Autonomy



Outline of Today's Talk

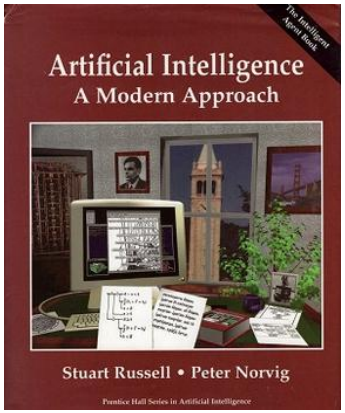
- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

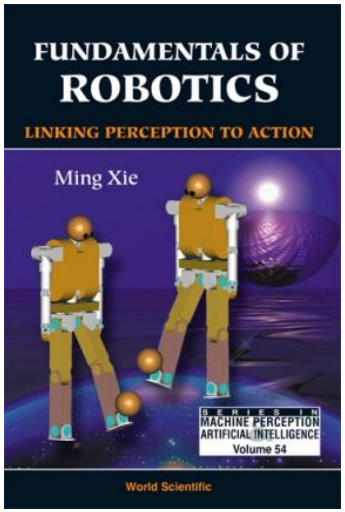
Outline of Today's Talk

- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

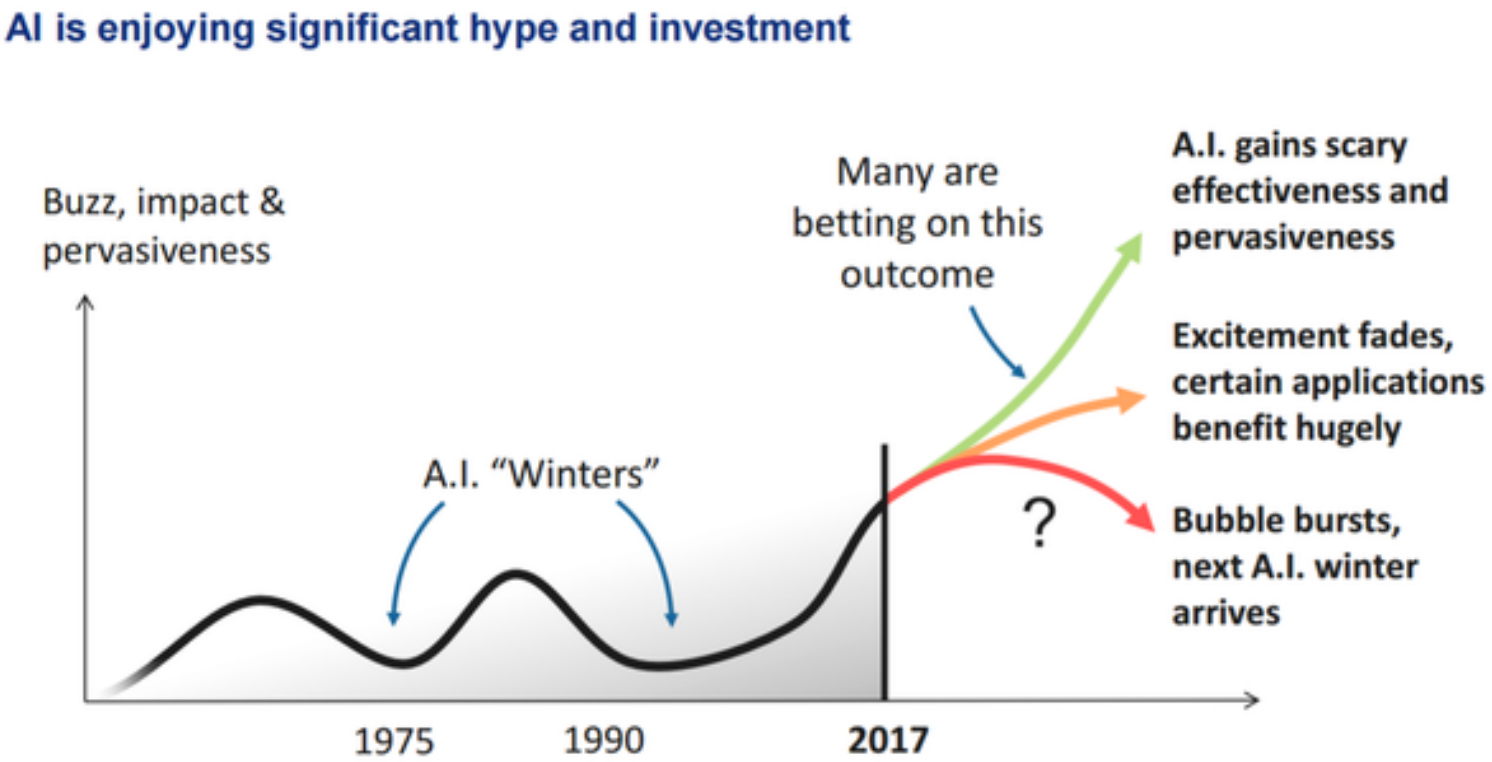
AI is making slow progresses in the past …

2003

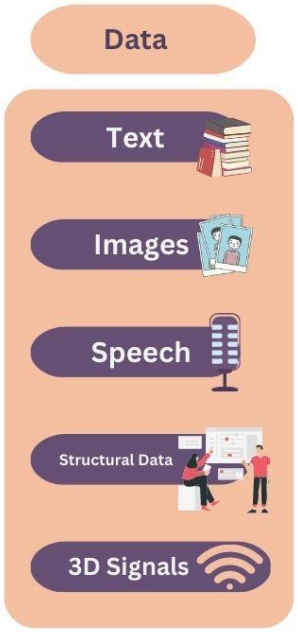


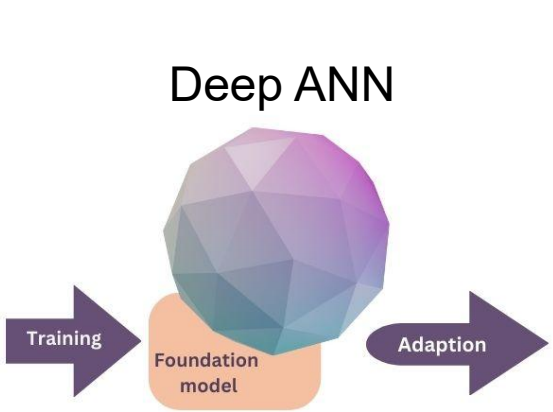


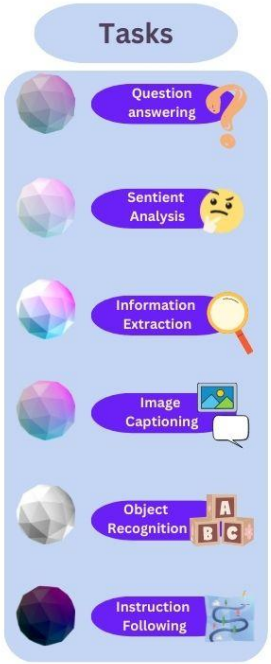
2003

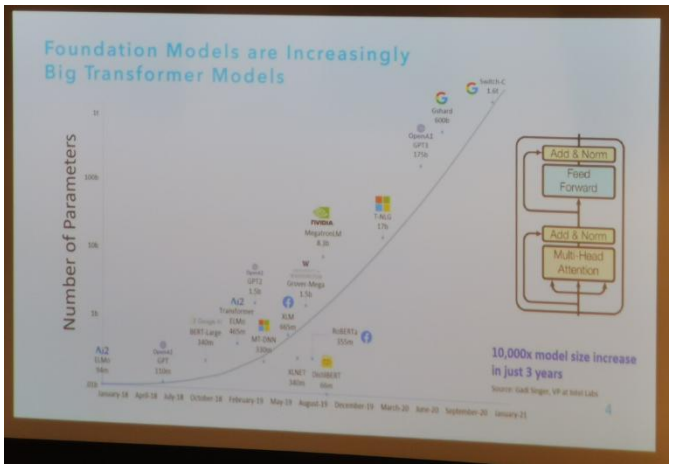


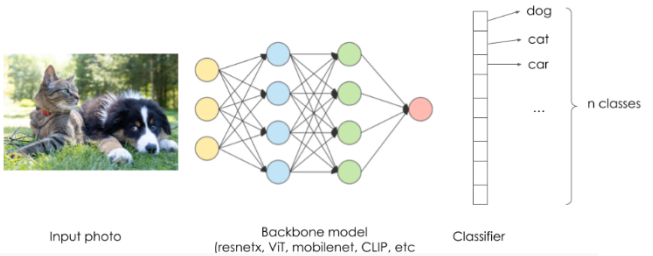
Huge Investment Wasted to FMs …

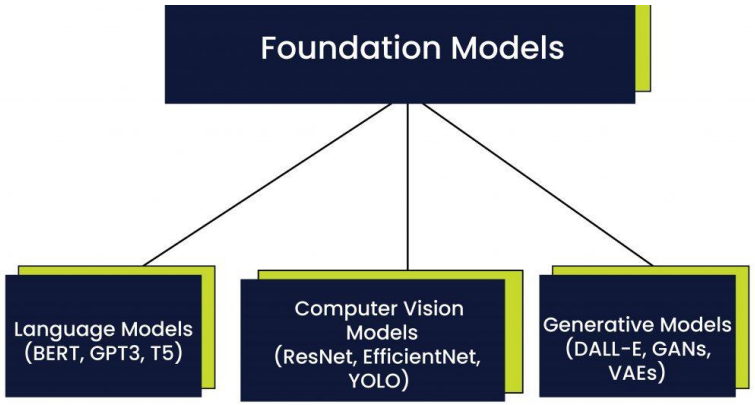


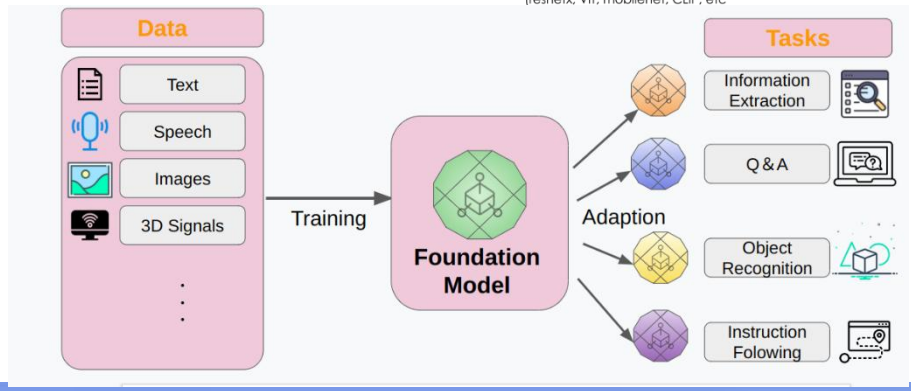




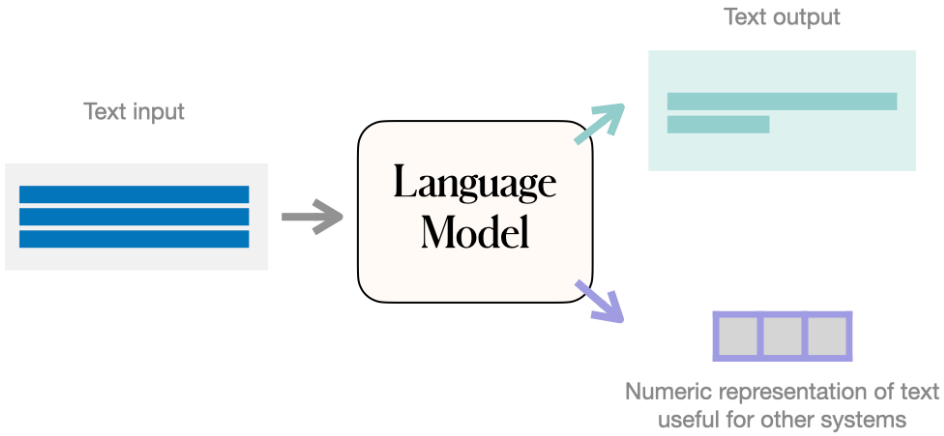


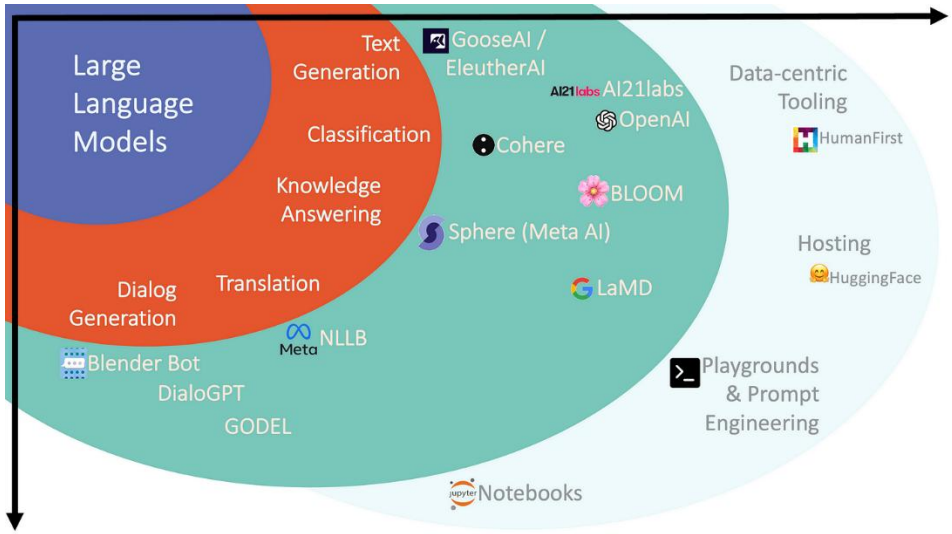


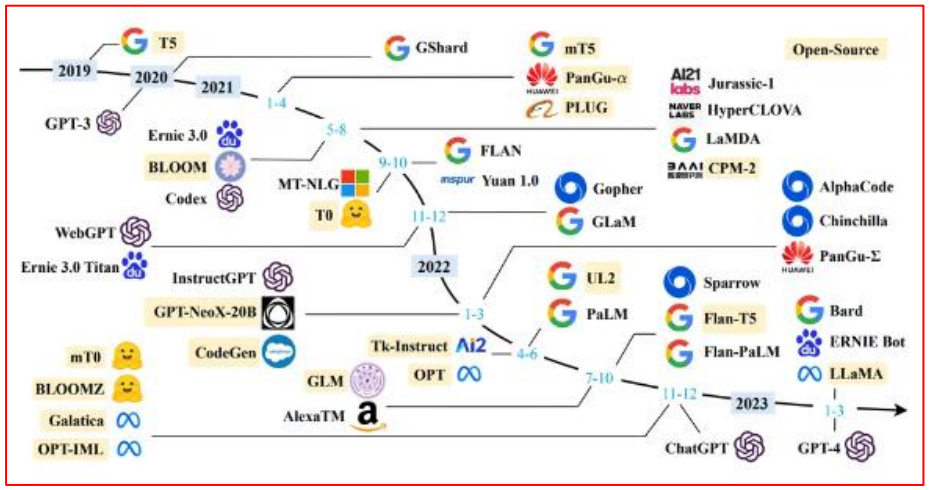


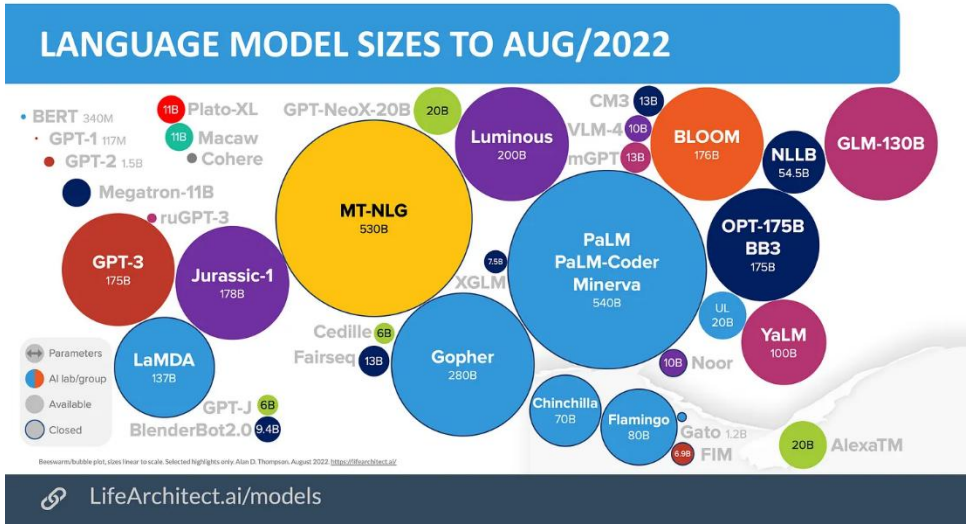


Huge Investment Wasted to LLMs …

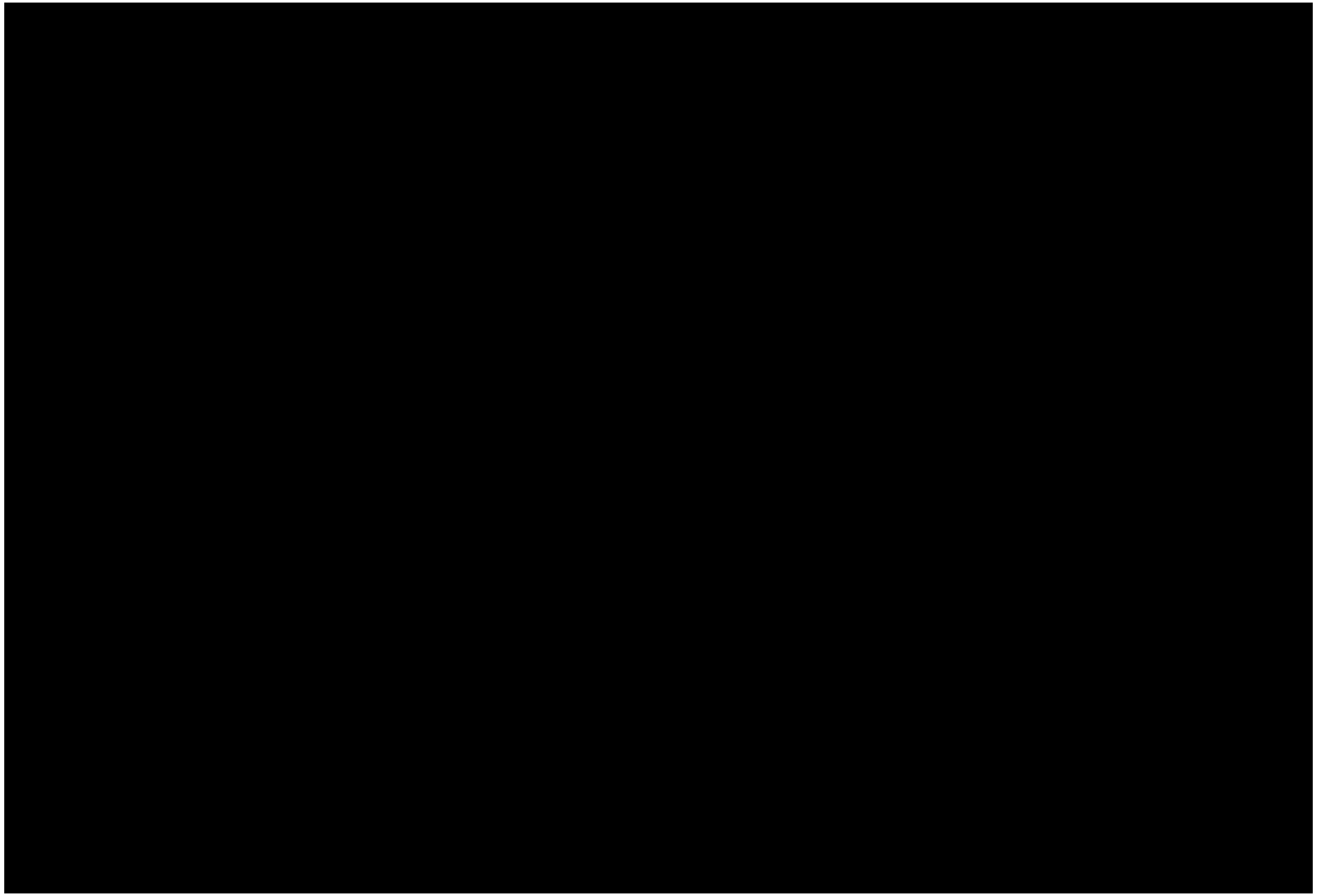




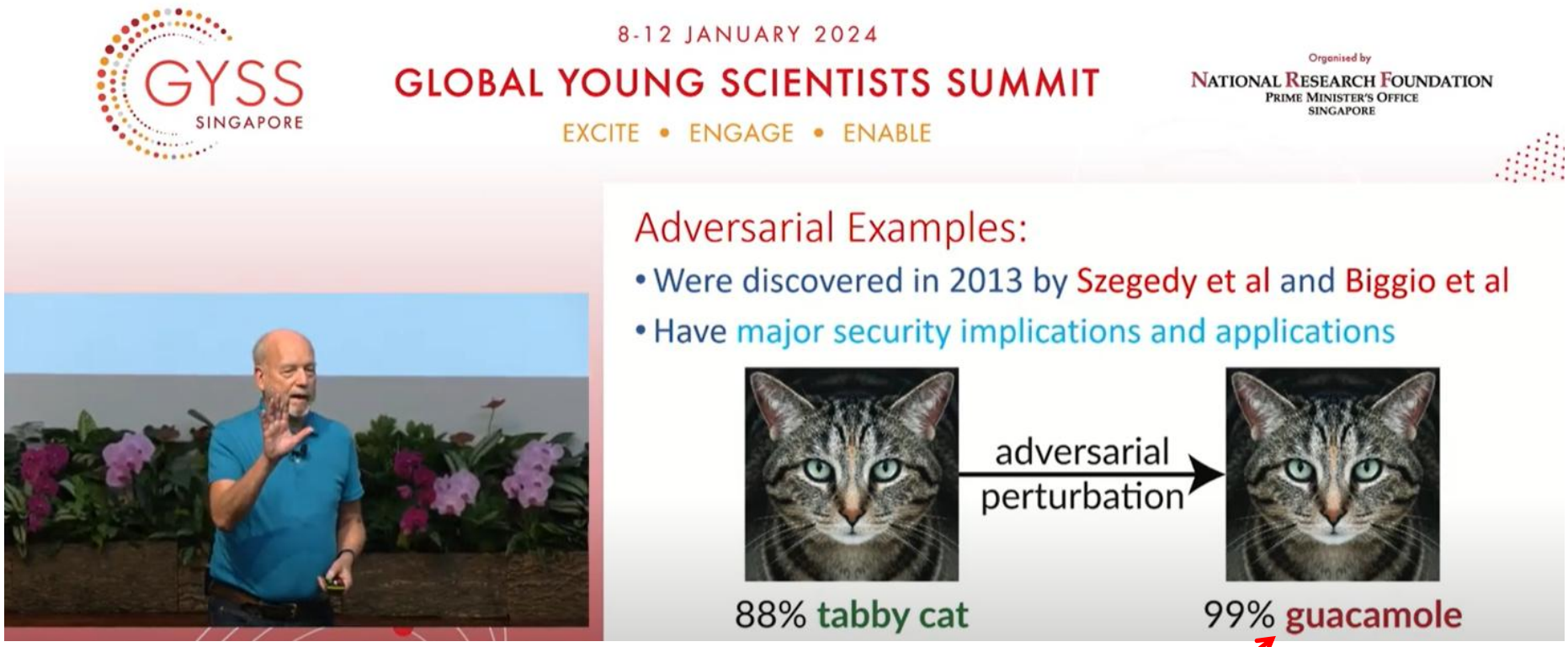




Fake AI: Is Deep Machine Tuning equal to Deep Machine Learning? (from MIT)



Example of Machine's Fake Learning



Salad made of avocado

Another Example of Machine's Fake Learning

GYSS SINGAPORE

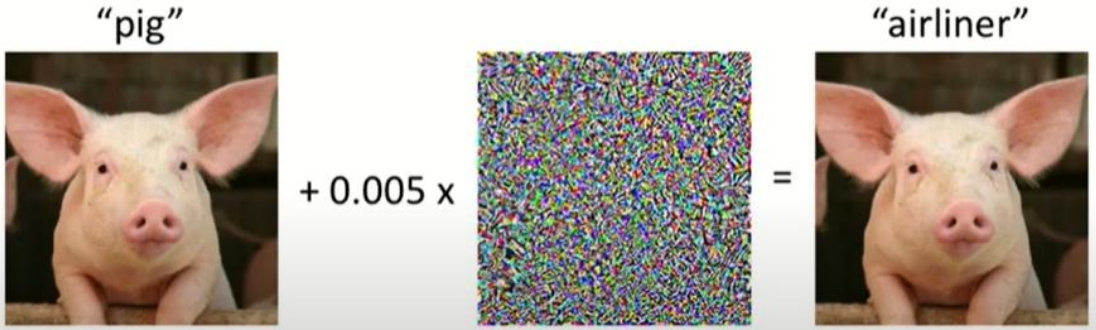
8-12 JANUARY 2024

GLOBAL YOUNG SCIENTISTS SUMMIT

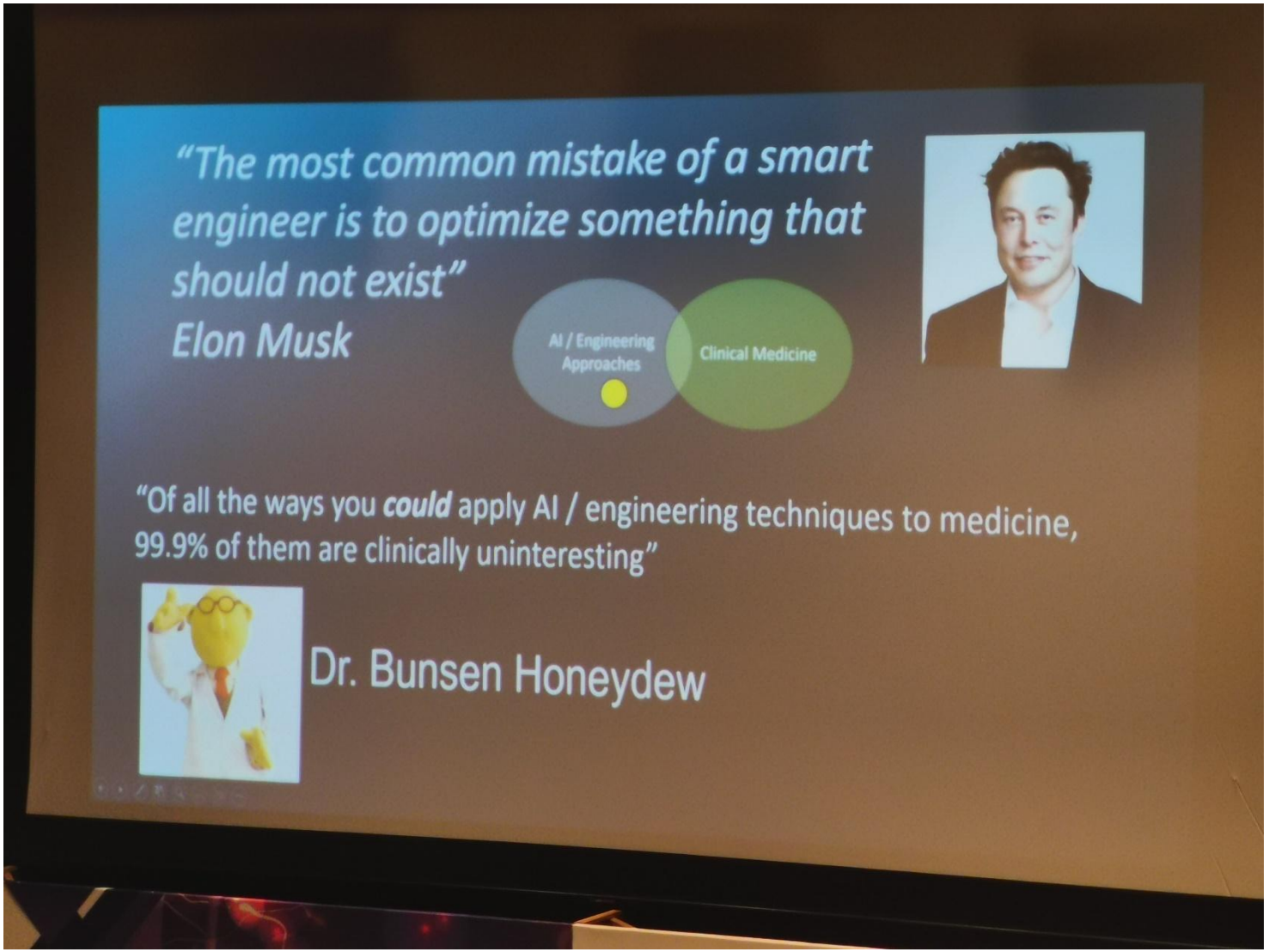
EXCITE • ENGAGE • ENABLE

Organised by
NATIONAL RESEARCH FOUNDATION
PRIME MINISTER'S OFFICE
SINGAPORE

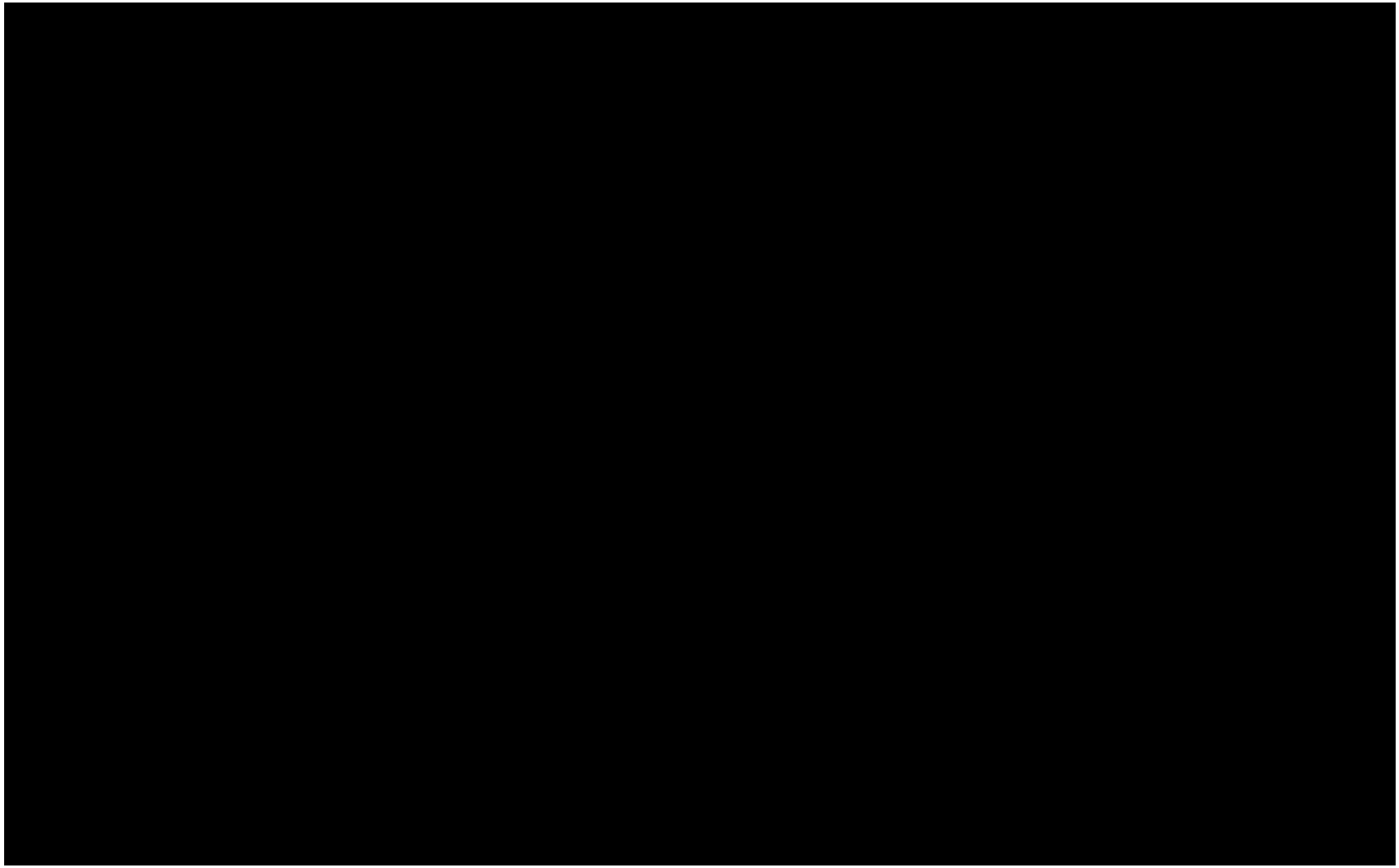
Pigs can fly:



Fake AI: (from a talk by NUS)



Speech on 18 October 2023

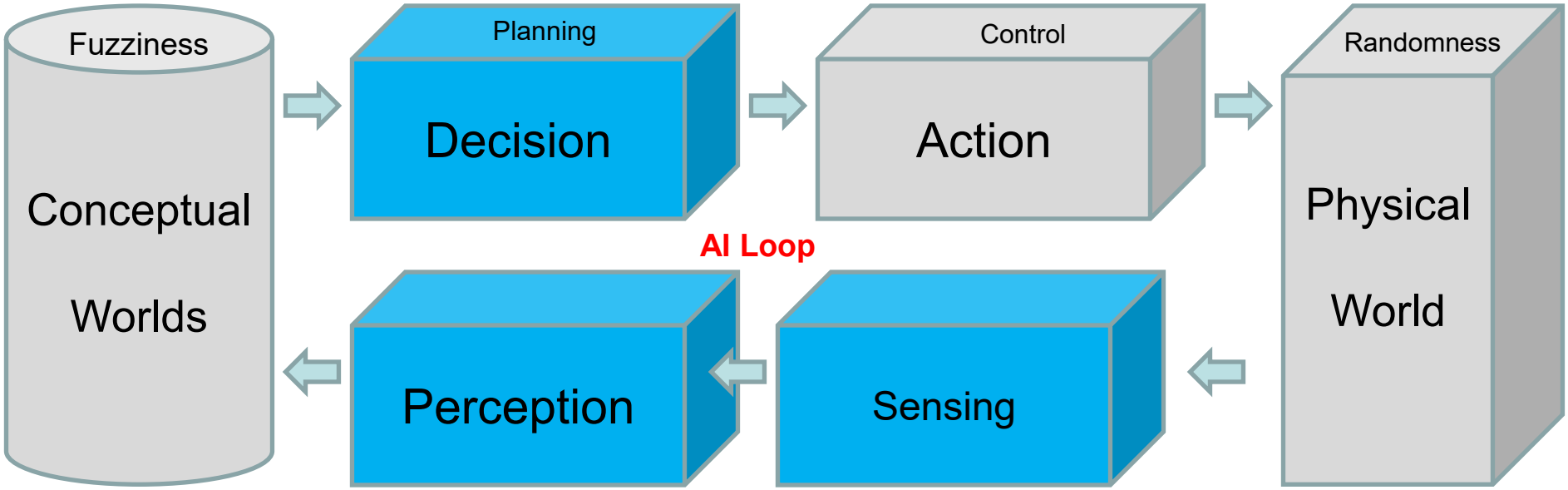


Singapore's AI Strategy 2.0

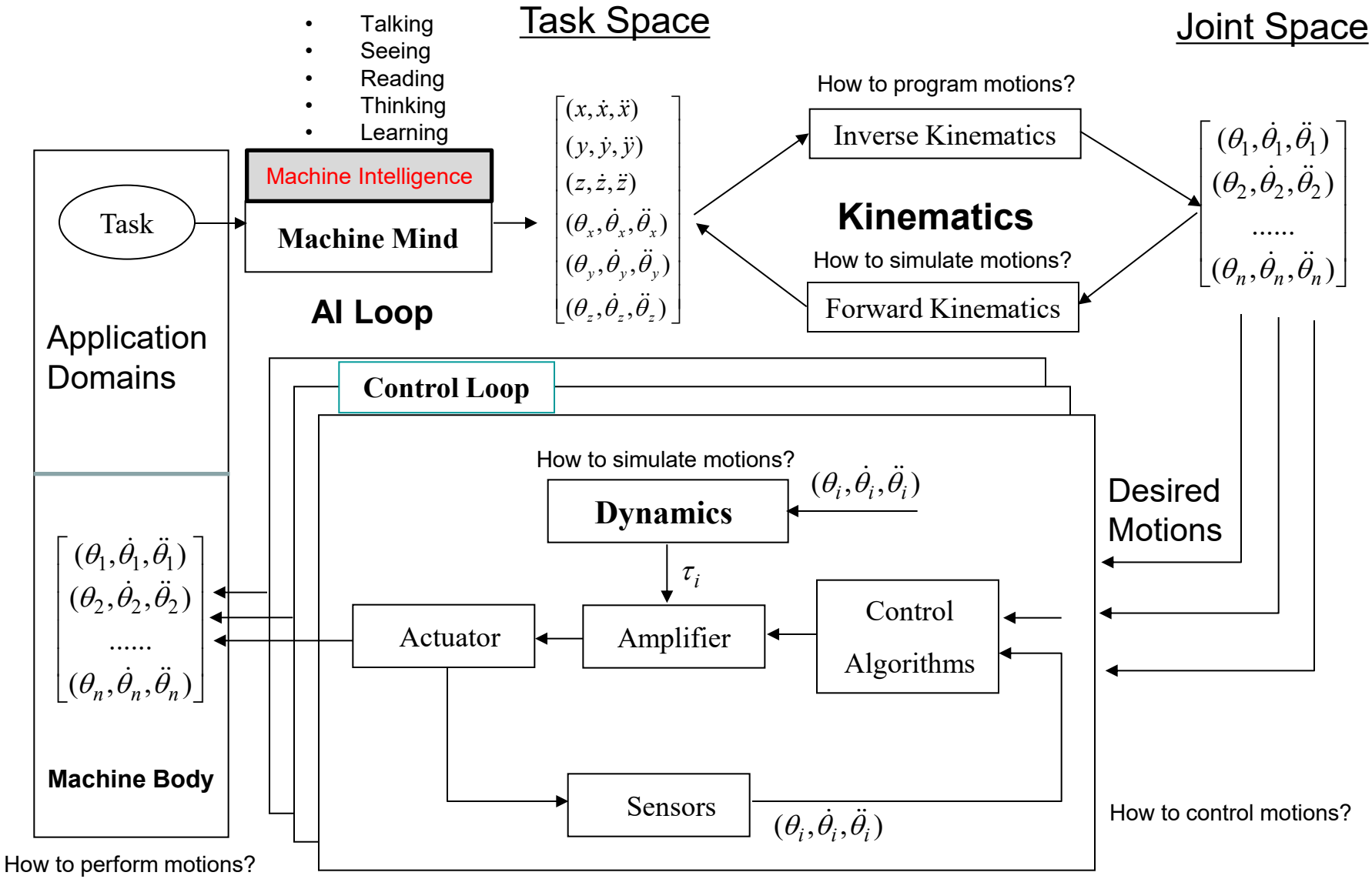
Outline of Today's Talk

- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

AI should be the mental capability of a system which consists of …



AI loops depend on control loop …



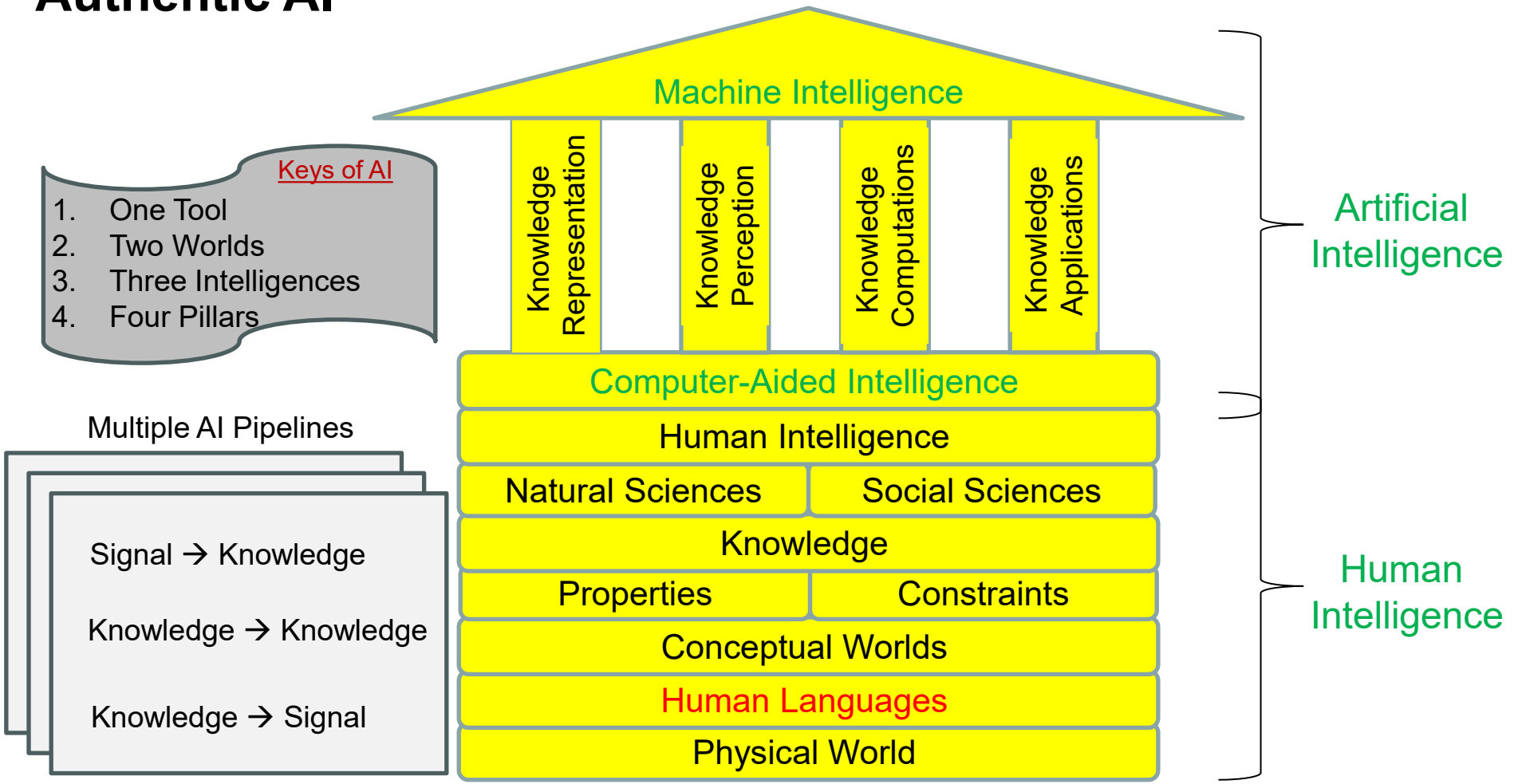
Example of AI-Driven Robot …

More Example of AI-Driven Robot …

The blueprint of AI 3.0 is …

Authentic AI

"We are living inside an ocean of signals"



AI is now on right track with an upside-down history …

- AI 1.0: Machine Thinking
- AI 2.0: Machine Learning
- AI 3.0: Machine's Self-Intelligence

1943-1956 **AI 1.0**
John McCarthy
Marvin Minsky
Nathaniel Rochester
Claude Shannon
1956 Dartmouth Workshop

推导与演绎
Inference and Reasoning

1992-2000 **AI 2.0**
John Weng
James McCelland
Alex Pentland
2000 MSU Workshop

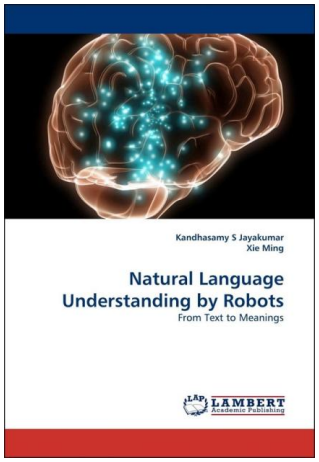
发育与学习
Development and Learning

AI 3.0

2003-2009
Ming Xie et al.
2009 IJHR Paper

语言与认知
Language and Cognition

2010



First Generation of Artificial Intelligence

Second Generation of Artificial Intelligence

Third Generation of Artificial Intelligence

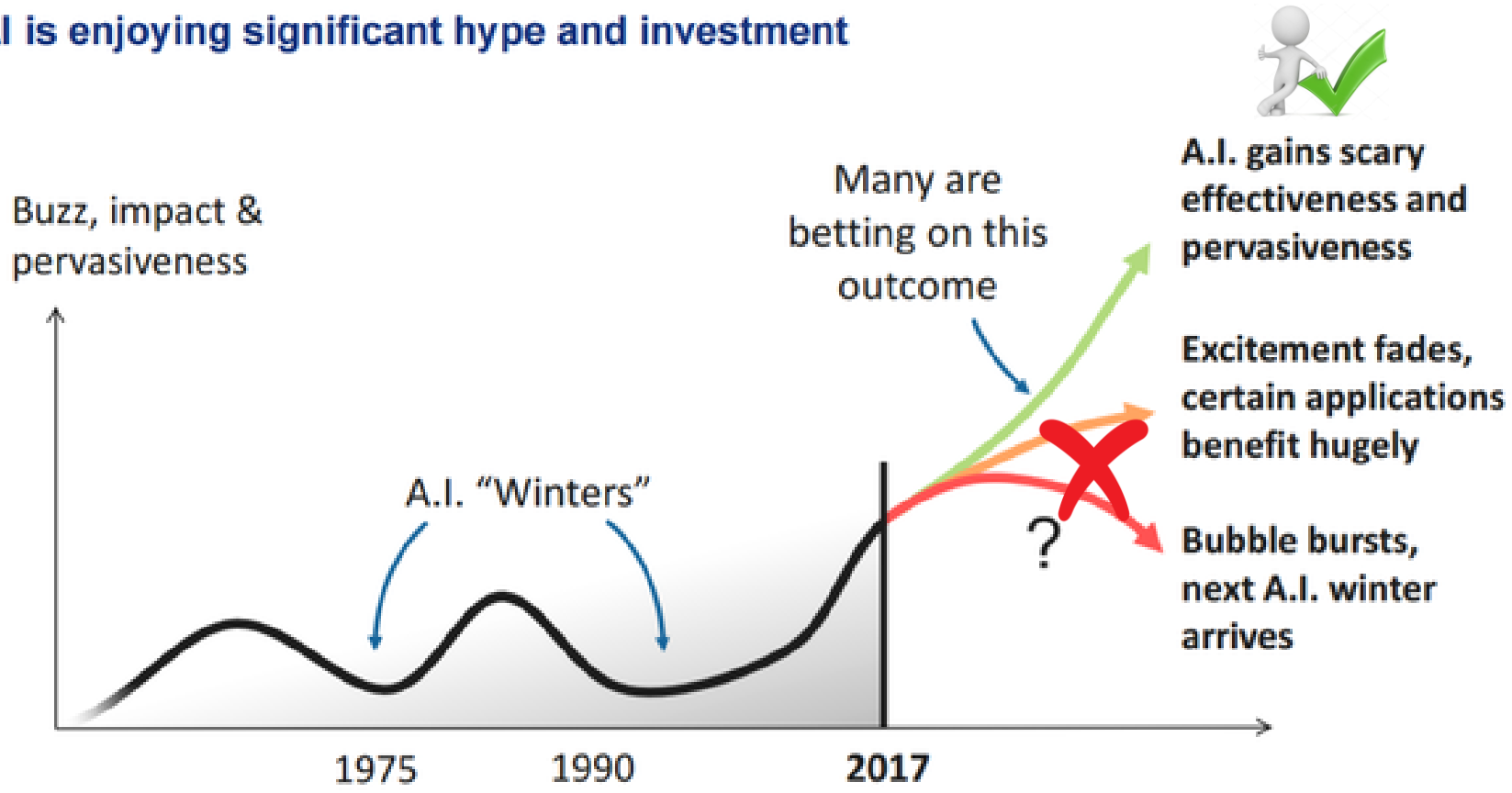
AI's Foundation

Finding the Root of AI

寻根问源

AI will undergo steadily growth …

AI is enjoying significant hype and investment



2009	AI 3.0 (Machine's Self-Intelligence) (机器内智) (自具之智，人赋)
2000	AI 2.0 (Machine Learning) (机器学习)
1956	AI 1.0 (Machine Thinking) (机器思考)

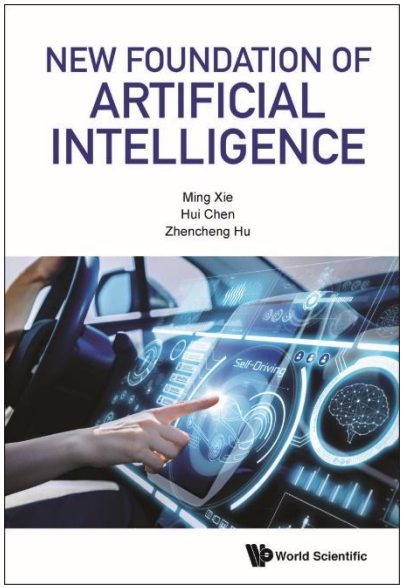
Outline of Today's Talk

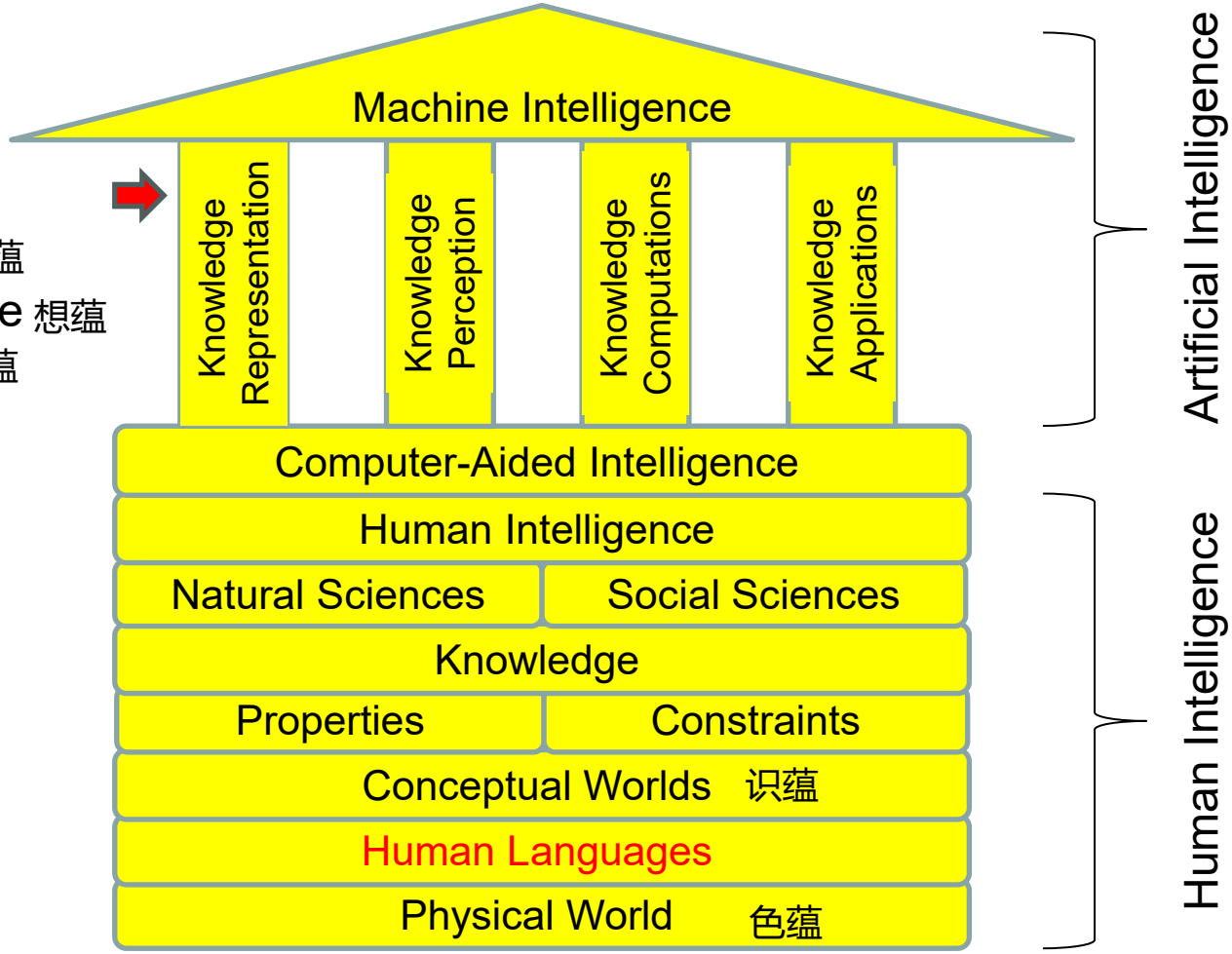
- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

It is the Pillar No. 1 of AI 3.0 …

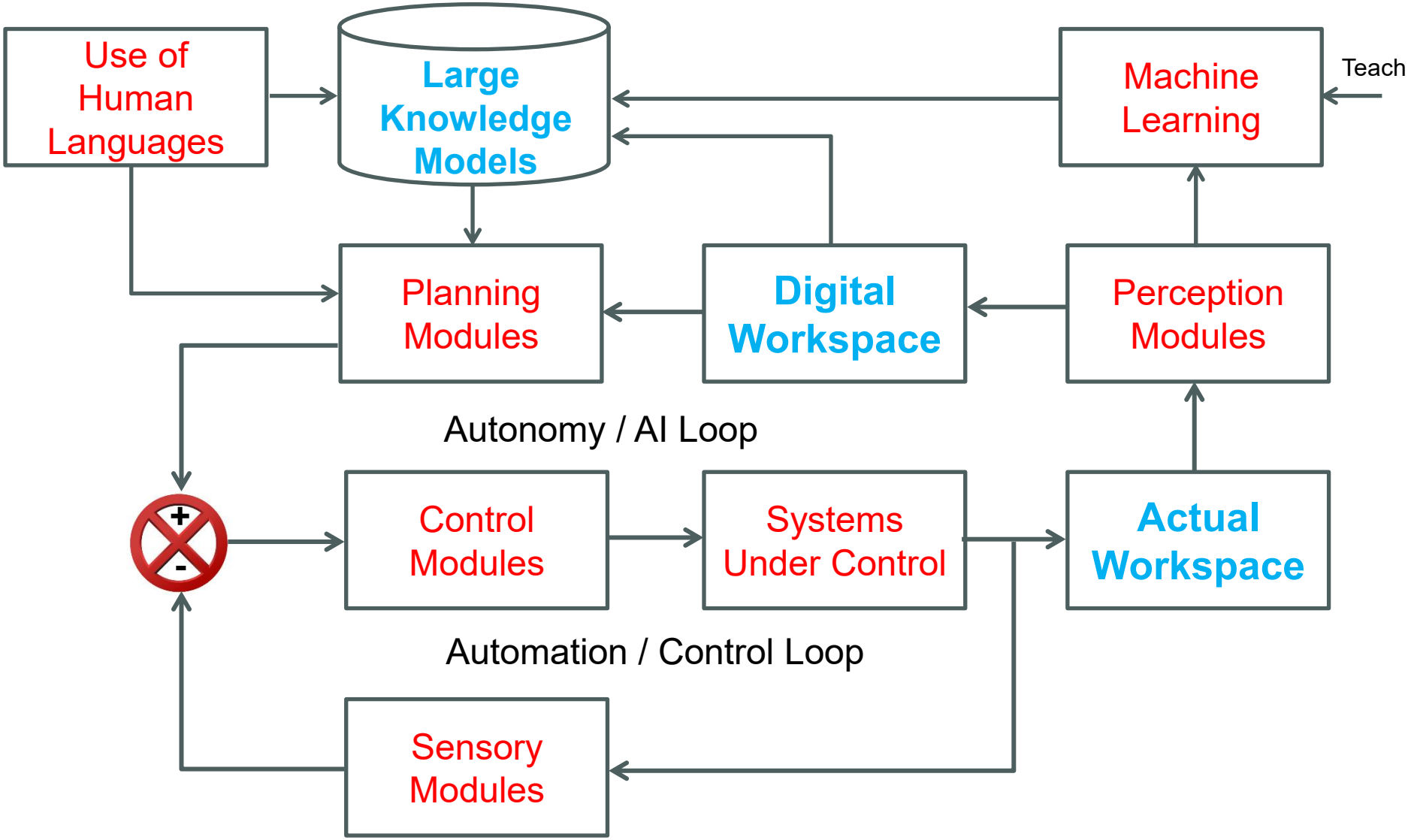
- One Tool
- Two Worlds
- Three Intelligences
- Four Pillars

- Signal to Knowledge 受蕴
- Knowledge to Knowledge 想蕴
- Knowledge to Signal 行蕴

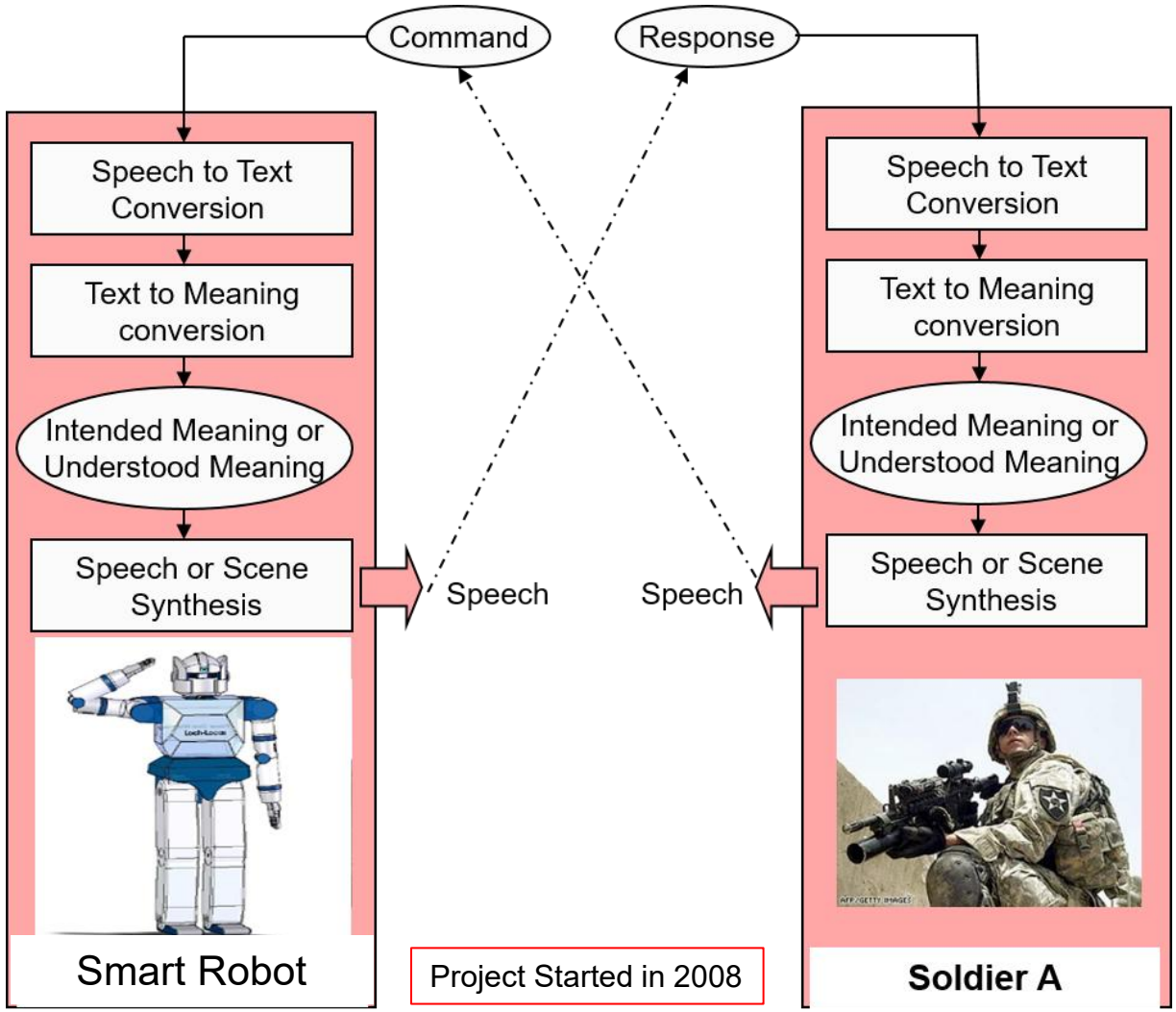




It is the foundation of Autonomous Machines ...



Without Large Knowledge Models, Human-Robot Interaction at Cognitive Level is not Possible …



Example of Human-Robot Interaction at Cognitive Level …

Before 2010

Example of Human-Robot Interaction at Cognitive Level …

After 2010

Outline of Today's Talk

- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

Definition of Large Knowledge Model …

- The integrated representation of knowledge in both physical world and conceptual world is called a Large Knowledge Model.

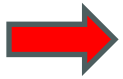
- *A large knowledge model includes the representation of texts.*

- *A large knowledge model includes the representation of physical meanings.*

- *A large knowledge model includes the representation of both entities and relationships.*

What is the Definition of Knowledge?

- Knowledge refers to:
  - Properties
  - Constraints
  - Behaviors



What is the best way to represent knowledge?

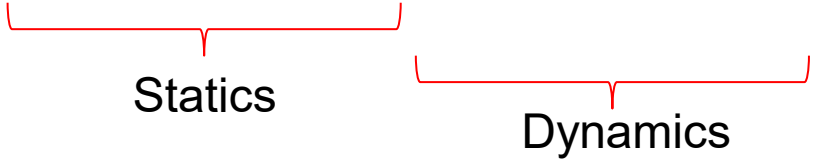
Answer:

The use of human languages which include:
1. Natural Languages
2. Technical Languages
3. Programming Languages

- of any entity or system in the universe.

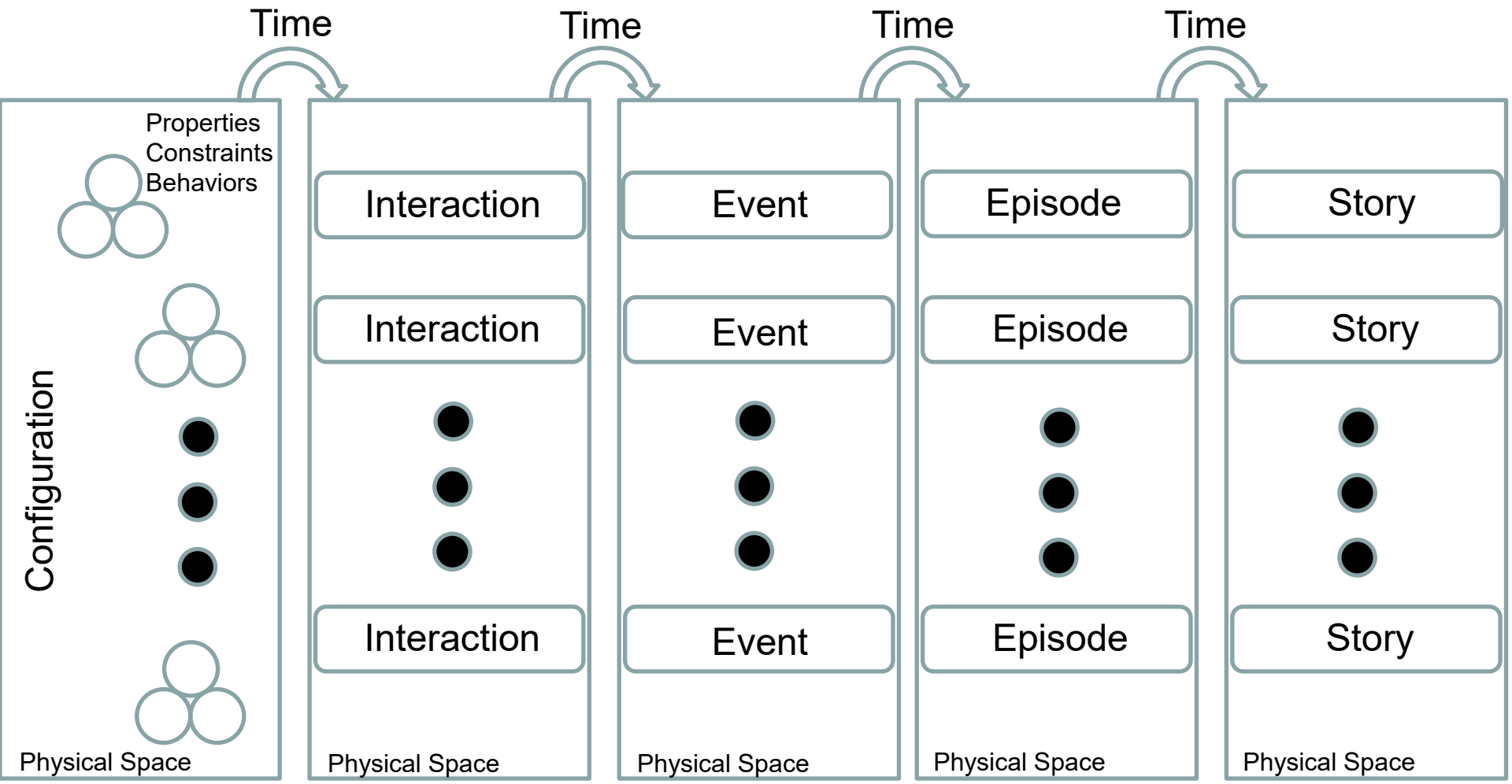
What is the Scope of Knowledge?

- Knowledge = properties + constraints + behaviors



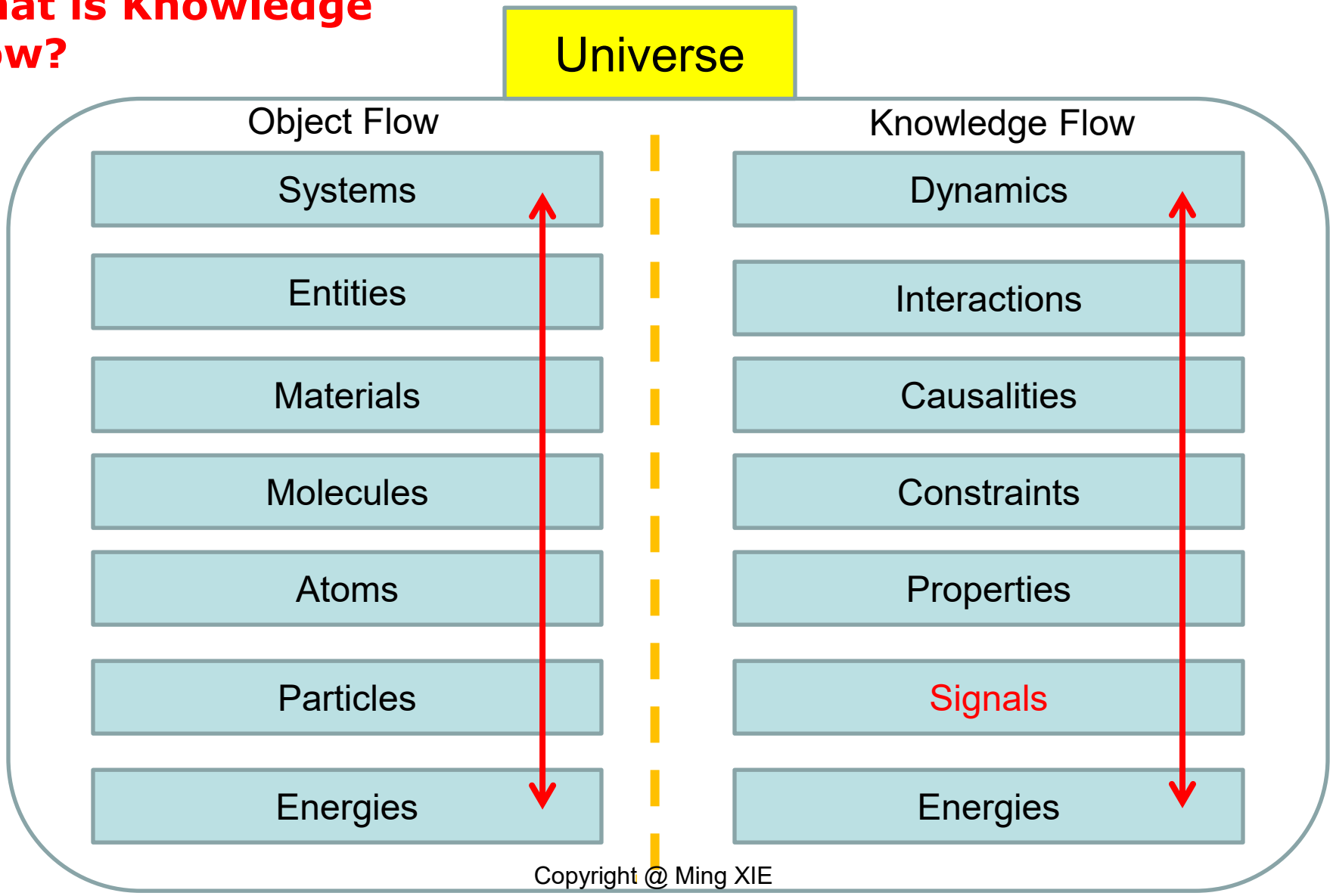
- Knowledge includes:
  - Knowledge about Individual Entities and Words
  - Knowledge about Interactions
  - Knowledge about Events
  - Knowledge about Episodes
  - Knowledge about Stories
  - Knowledge about Histories

What is the Hierarchy of Knowledge?

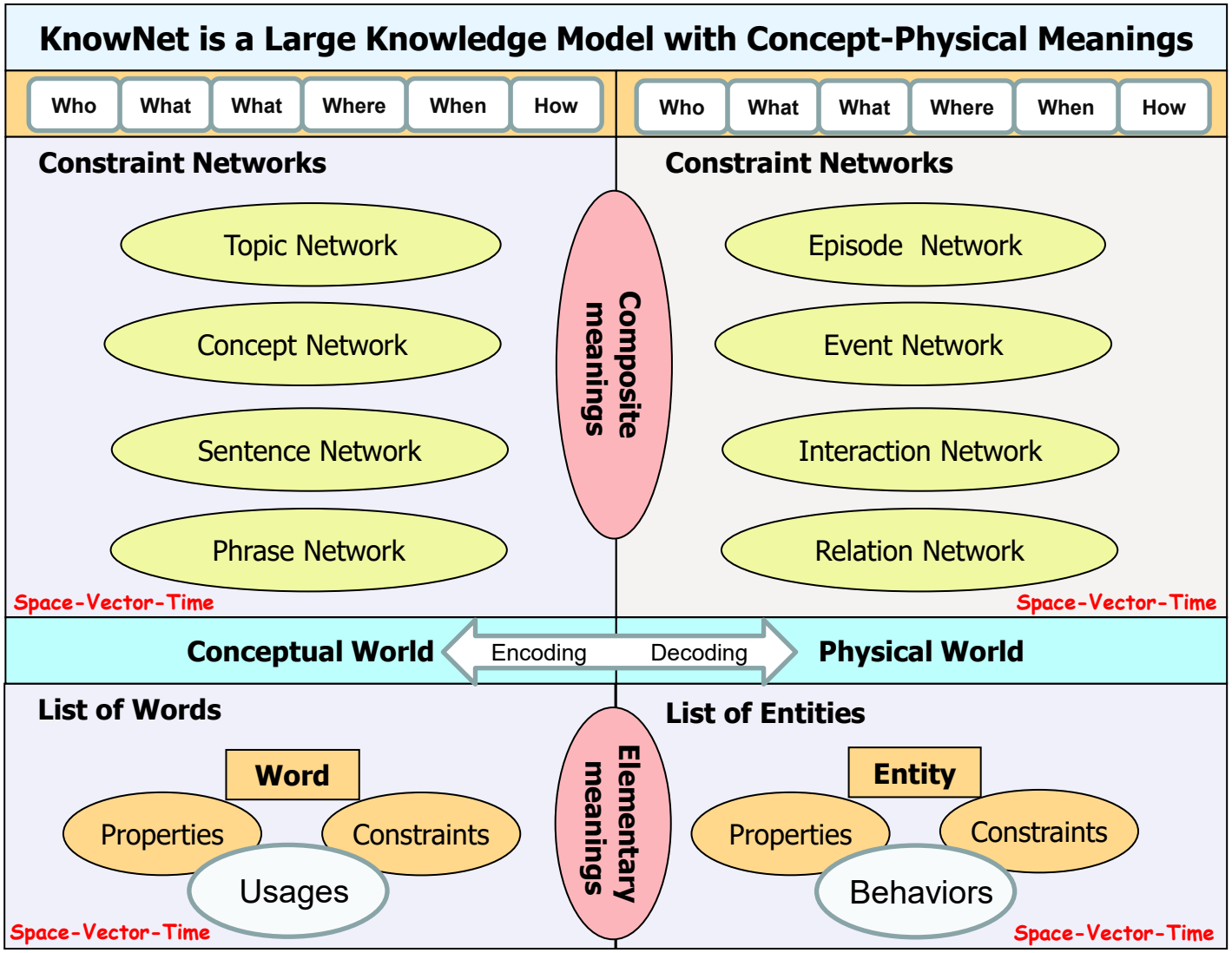


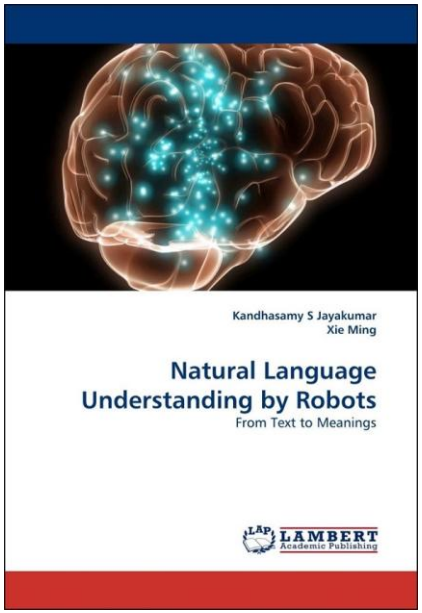
What is history? It is equal to a set of {stories}

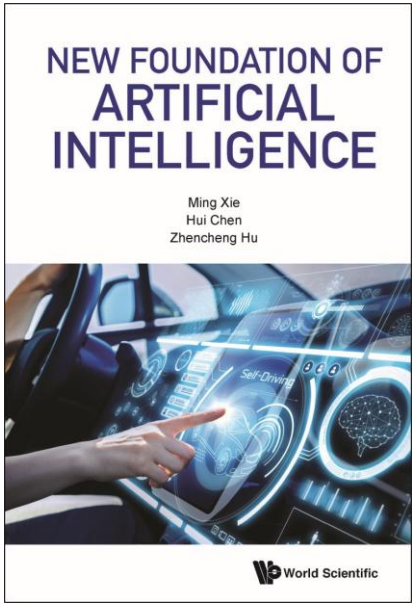
What is Knowledge Flow?



How does a Large Knowledge Model look like?

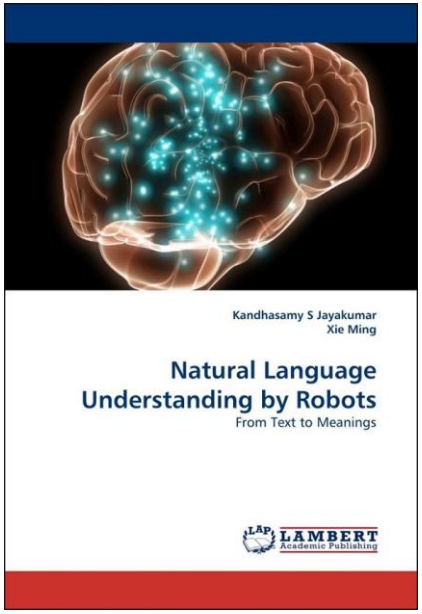


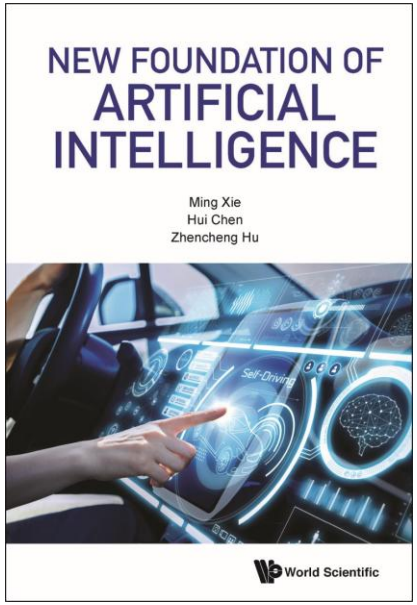




Granted Patent …

- **Xie M.**, (2014), 基于自然语言的人机对话系统 Human-Machine Dialogue Systems Based on Understanding of Texts in Natural Languages, ZL2009 1 0040170.1, 授权日期: 2014.02.12, Granted on 12 February 2014, Filed on 2009.6.11

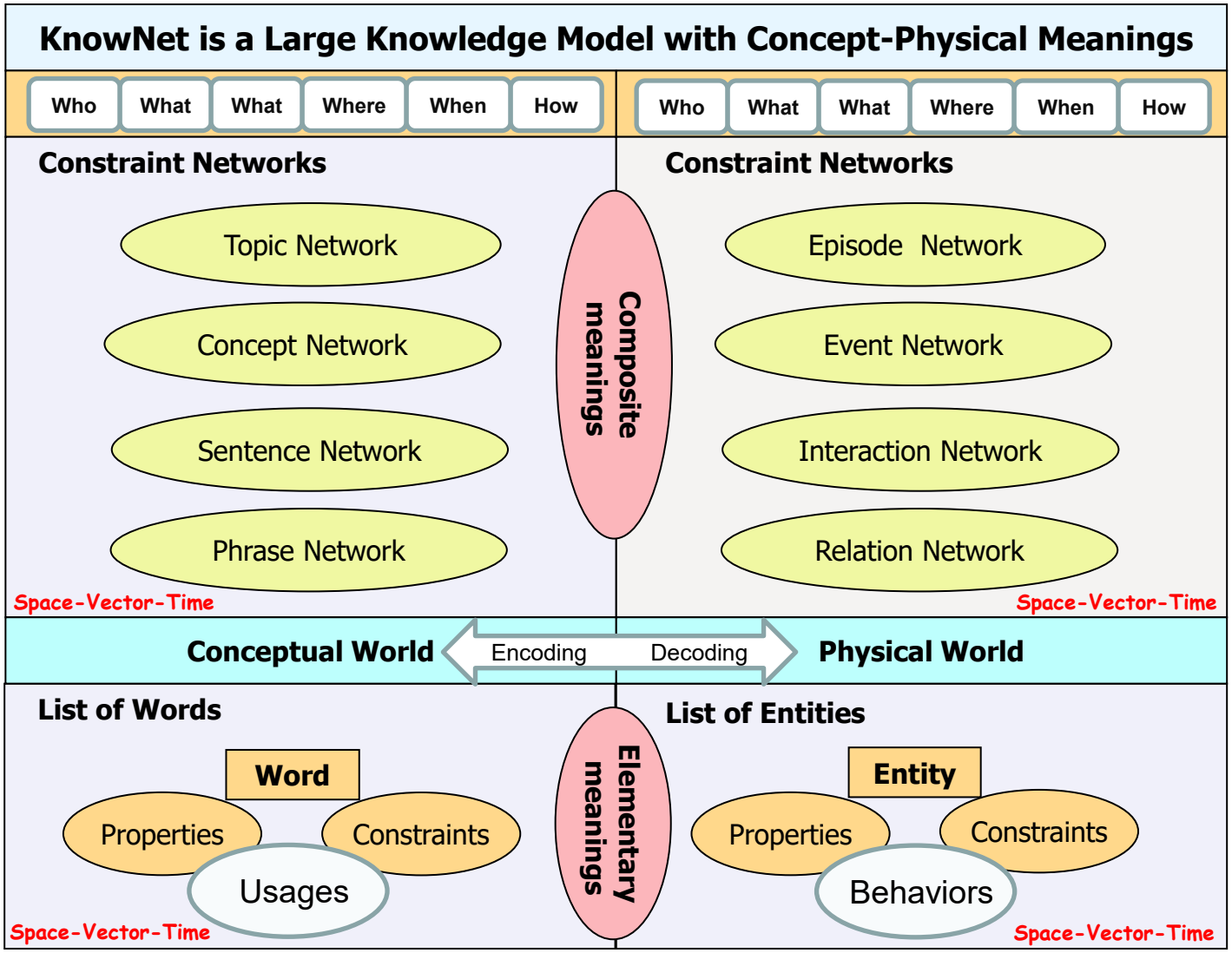


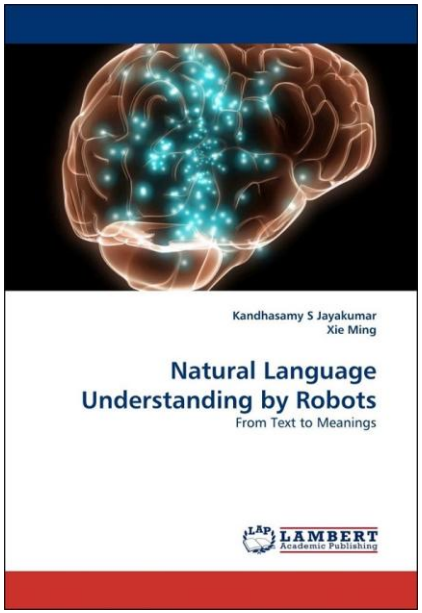


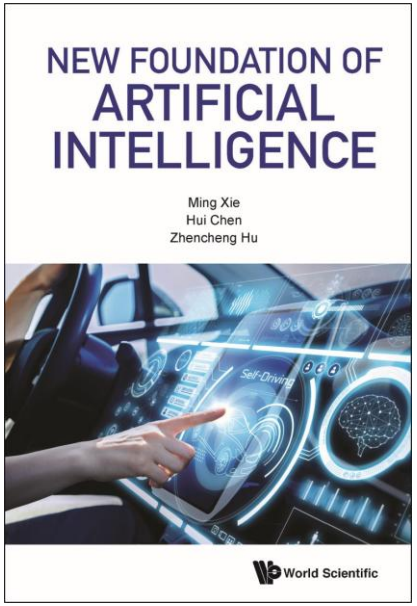
Outline of Today's Talk

- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why A Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

How to implement a KnowNet?



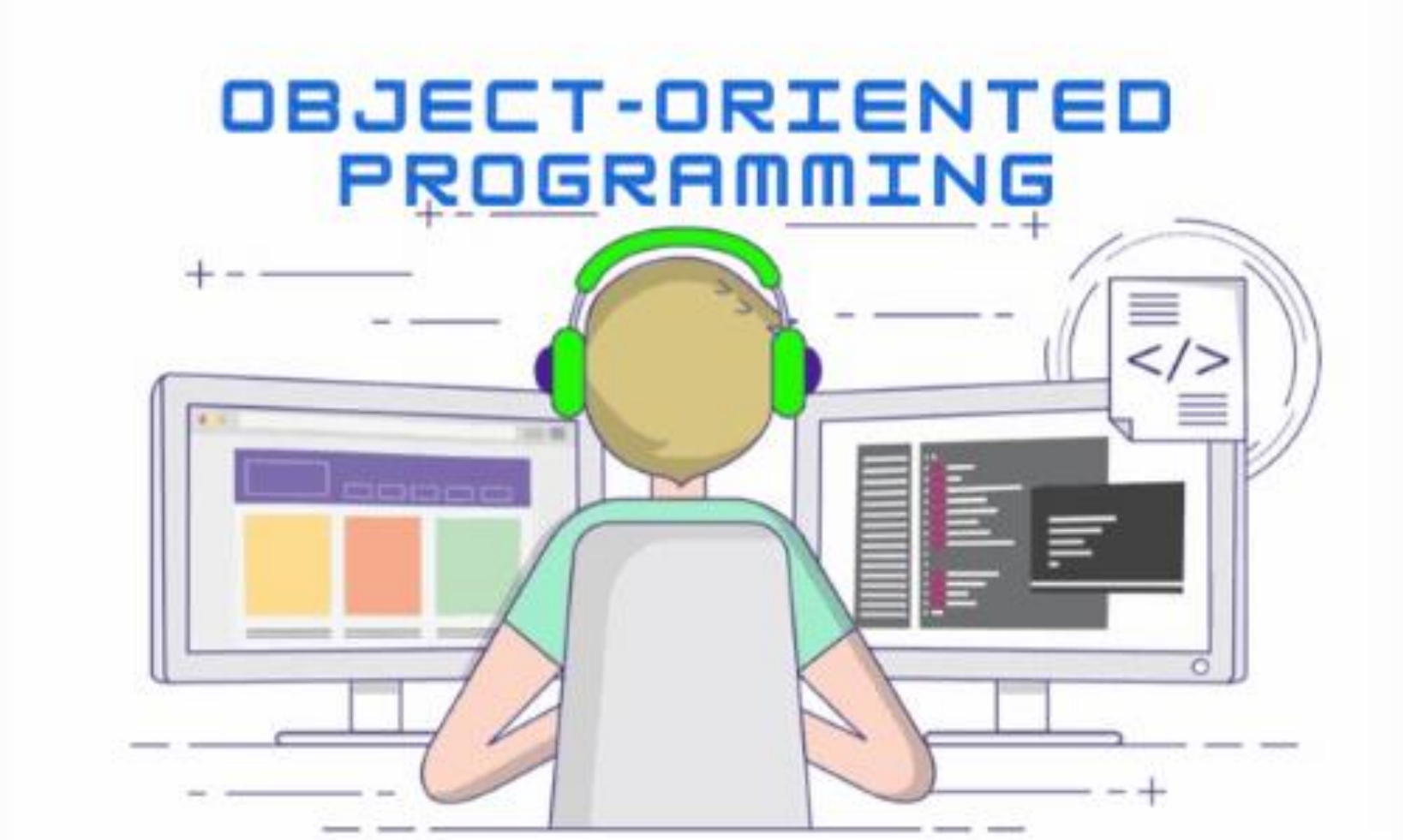




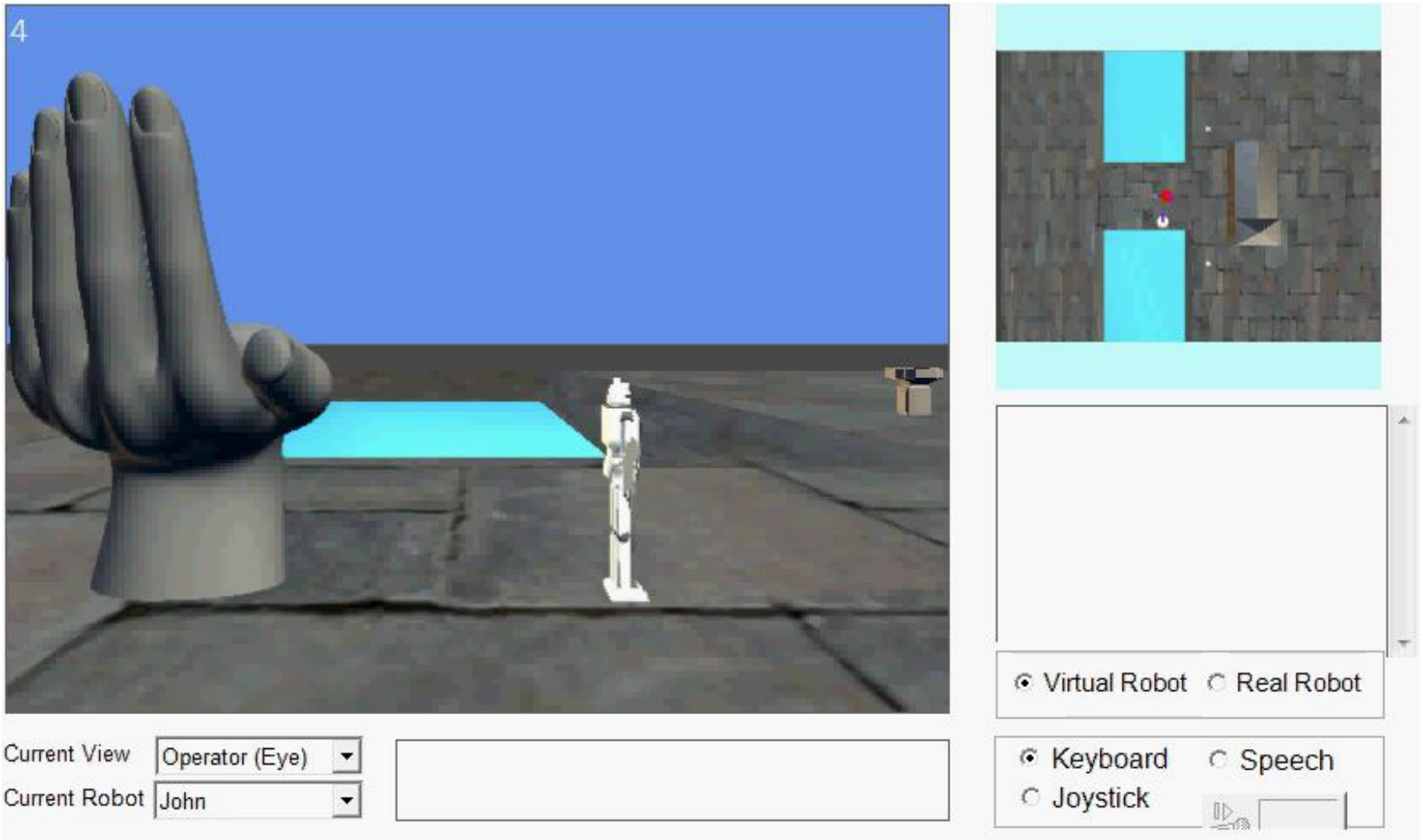
What is the best tool to use for representing knowledge?

- Answer:
  - The use of human languages which include:
    1. Natural Languages
    2. Technical Languages
    3. Programming Languages

Which programming language to use for representing knowledge?



Preliminary Results (2008-2012) …

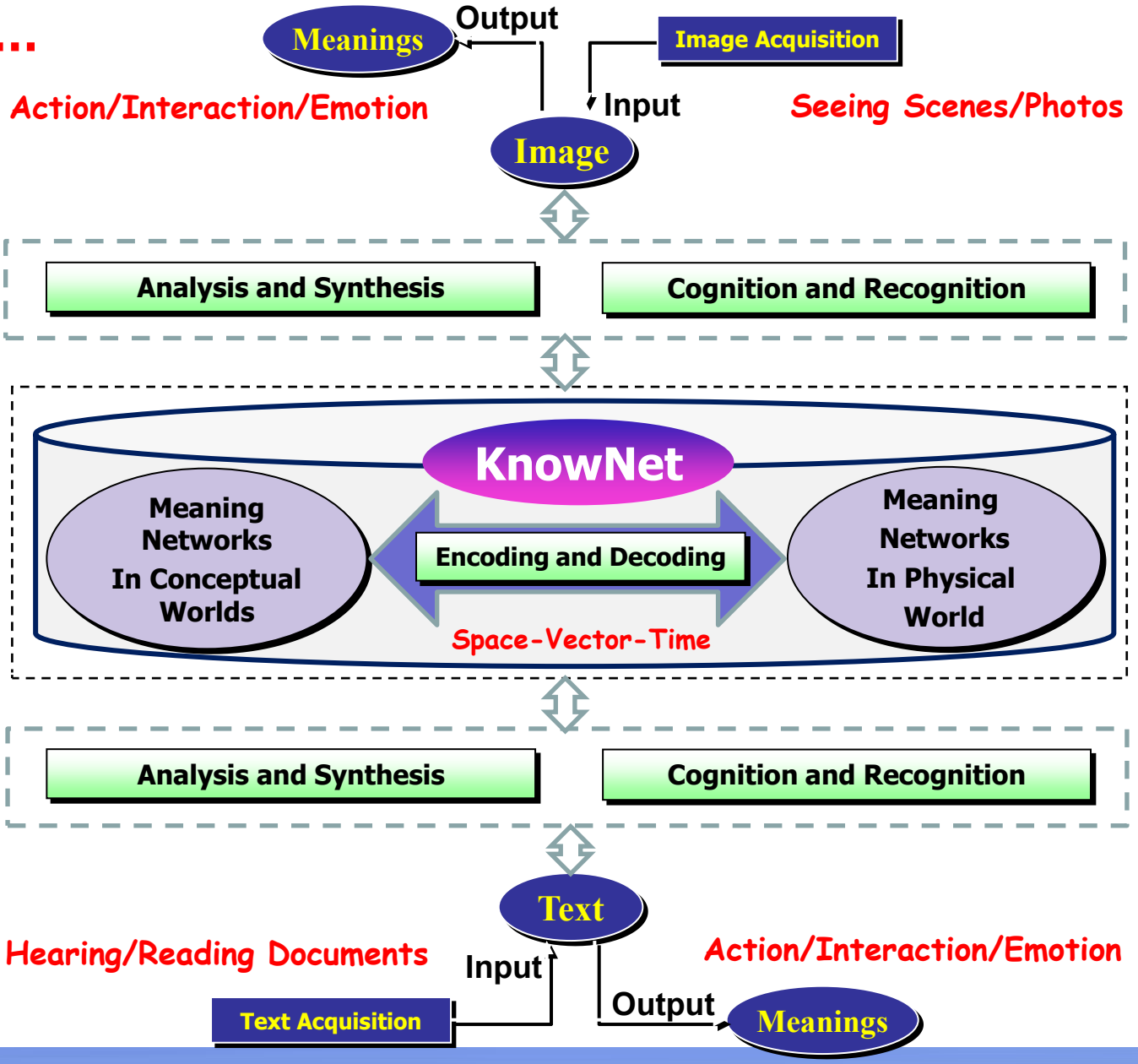


Preliminary Results (2008-2012) …

On-Going Works ...

- **Three Mental Dualities:**
  - Cognition and Recognition
  - Encoding and Decoding
  - Analysis and Synthesis

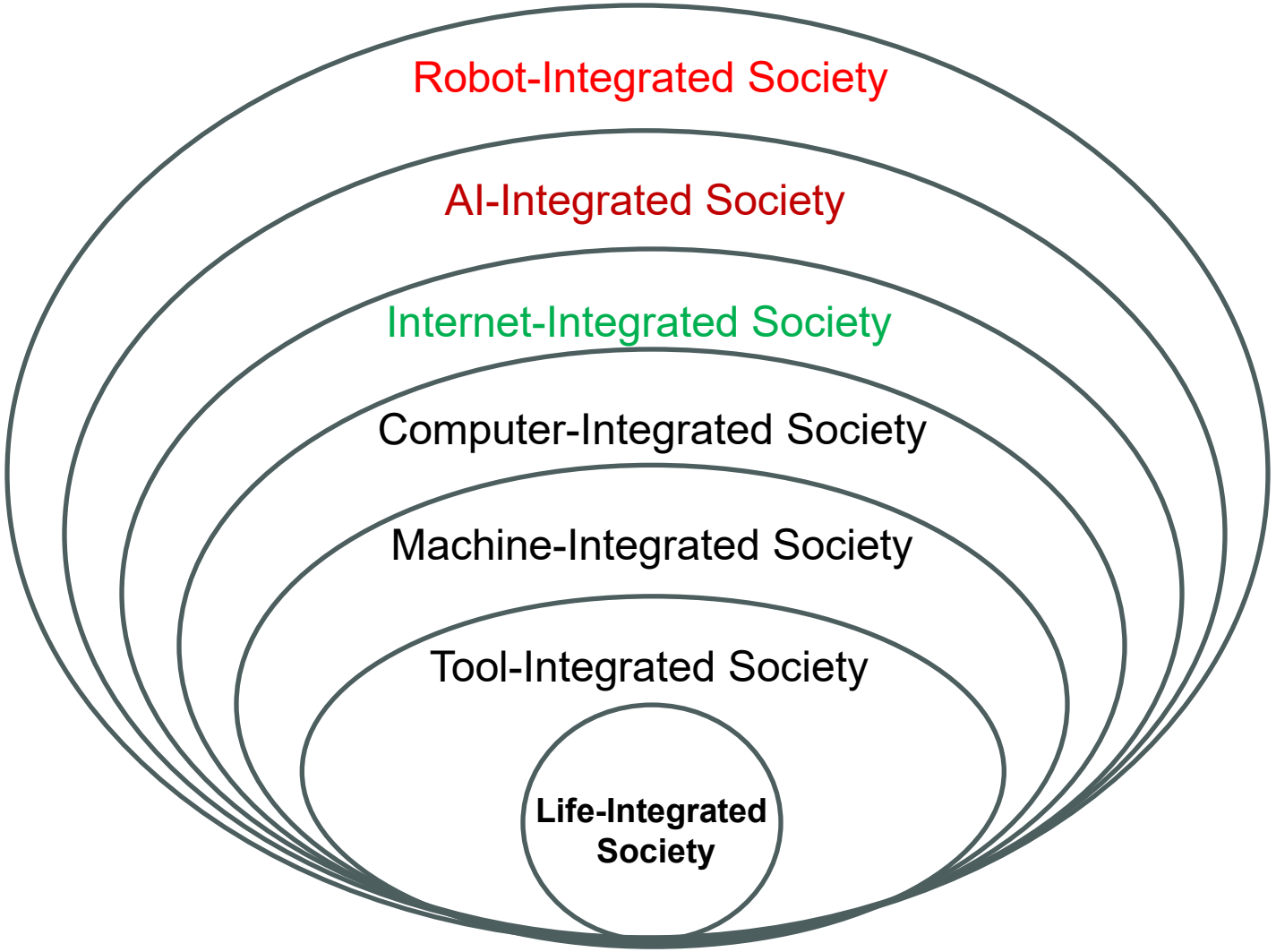
- **Full Scope of AI Pipeline:**
  - Signal → Knowledge
  - Knowledge → Knowledge
  - Knowledge → Signal



Outline of Today's Talk

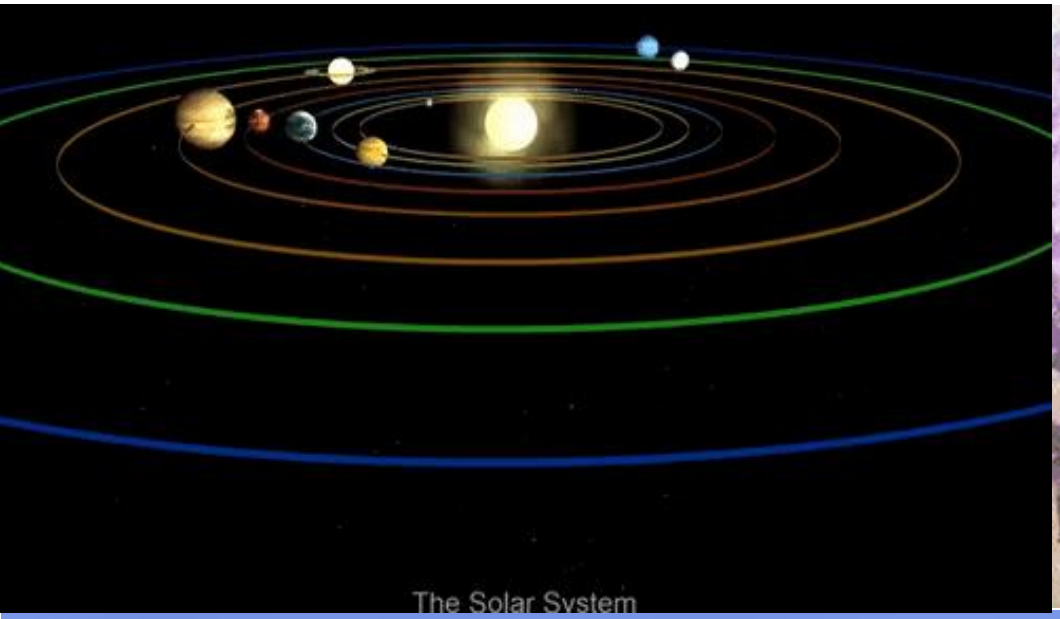
- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

Future Trend of Human History



What are the driving forces?

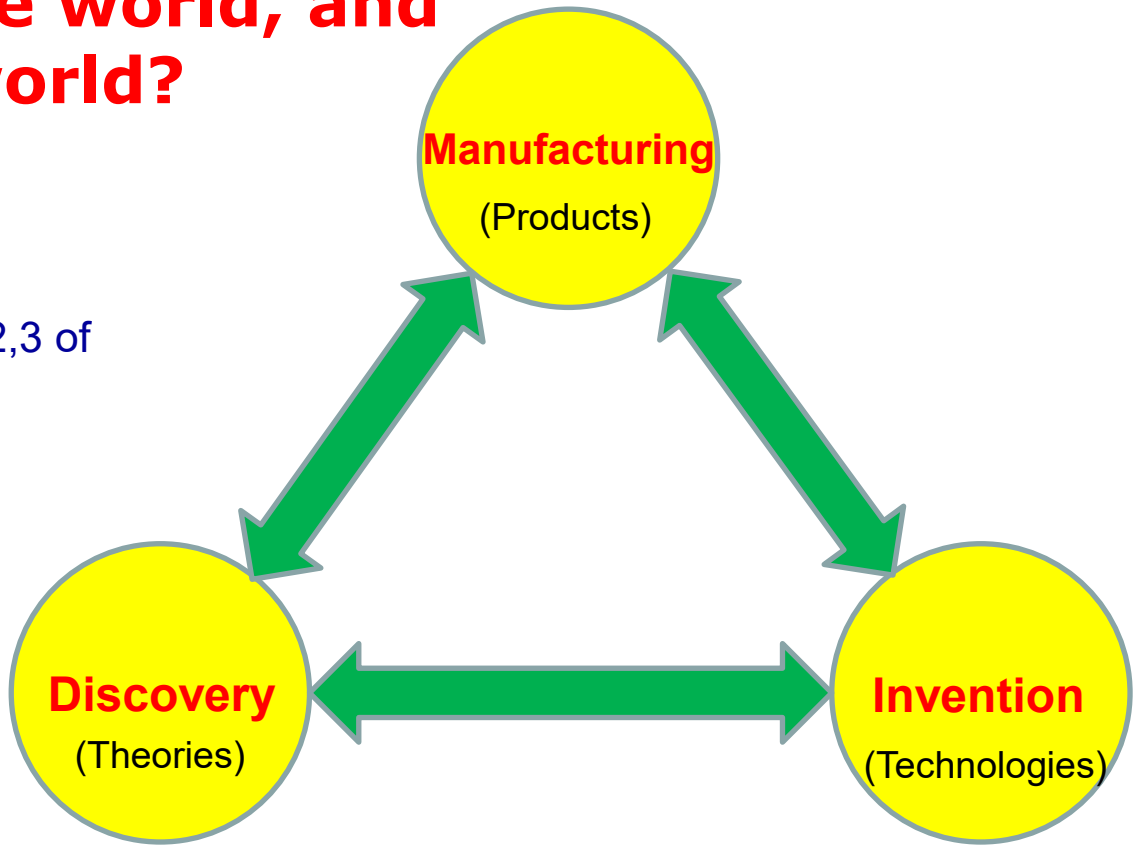
- (1) to understand the world, and
- (2) to improve the world?



How to fulfill our missions on Earth, which include:
(1) to understand the world, and
(2) to improve the world?

Research comes first:

- What is research? What are the 1,2,3 of research?



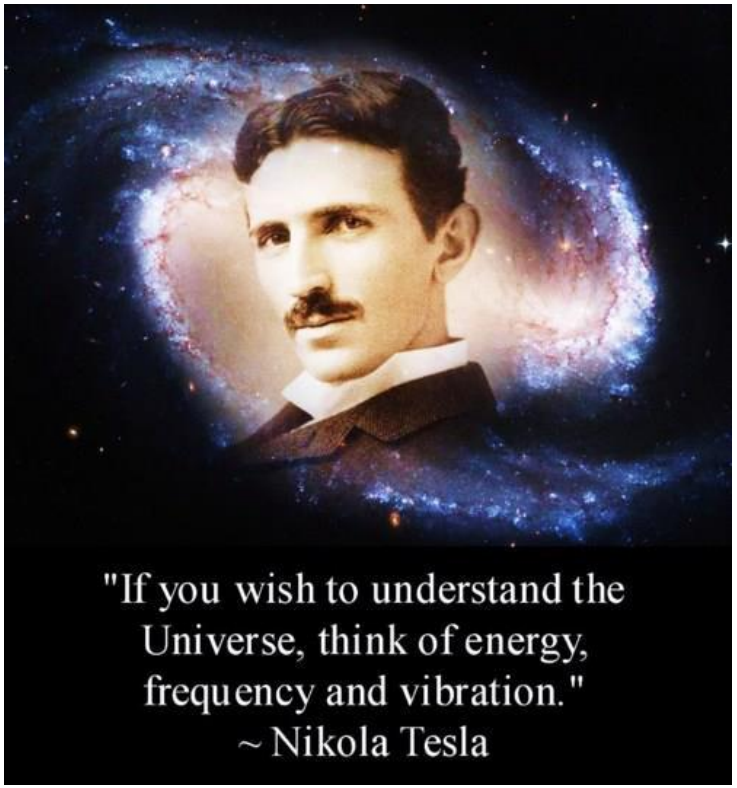
One Objective:
1. Research has one objective which is to create values by finding better ways of solving problems.

Two Driving Forces of Research
1. Scientific Problems
2. Social Needs

Three Outcomes:
1. Creation of Better Theories
2. Creation of Better Technologies
3. Creation of Better Products

How to understand the universe?

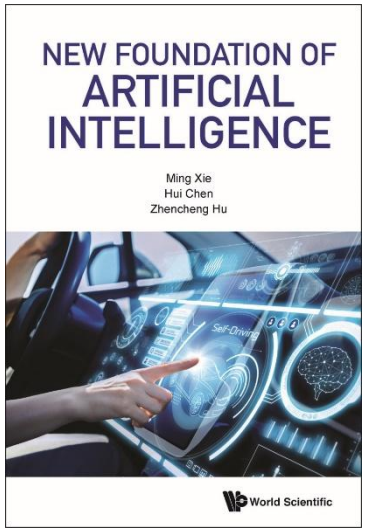
- If you wish to understand the secrets of the universe, think in terms of energy, frequency and vibration. – Nikola Tesla



How to understand the world?

- If you wish to understand the organizations of the world, think in terms of systems, devices and materials – Ming XIE

- If you wish to understand the meanings of the world, think in terms of space (空), vector (色) and time (无常)? - Ming XIE



How to improve the world?

- To invent smarter products,
- To invent smarter systems, and
- To invent smarter machines.

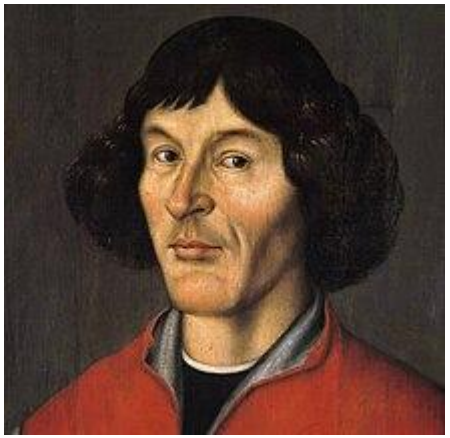
Dilemma before 15th Century

In the study of astronomy, one of the biggest dilemma was about the center of the solar system:

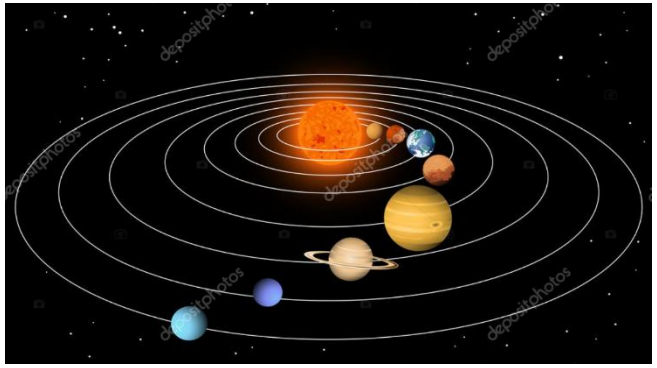
- Hypothesis 1 (Geo-Centrism): Earth is the center of the solar system.

  (e.g., What is 昆仑? Point of Sunrise? Point of Sunset?)

- Hypothesis 2 (Helio-Centrism): Sun is the center of the solar system.



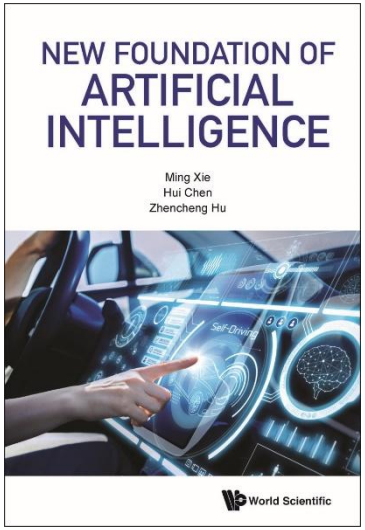
Nicolaus Copernicus
(1473 - 1543)



Dilemma before 21st Century

In the study of artificial intelligence, one of the biggest dilemma was about the origin of intelligence:

- Hypothesis 1 (Brain-Centrism): Brain is generator of intelligence.
- Hypothesis 2 (Mind-Centrism): Mind is generator of intelligence.



2021

An Interesting Parallel in Human History …

Earth-Sun Relationship

- Nicolaus Copernicus was an astronomer who proposed a heliocentric system, that the planets orbit around the Sun; that Earth is a planet which, besides orbiting the Sun annually, also self-rotates once daily on its own axis. Sun is at the center of the universe, but not Earth which orbits the Sun.

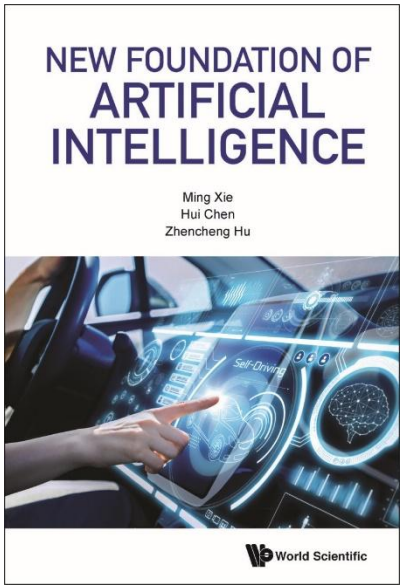
Brain-Mind Relationship

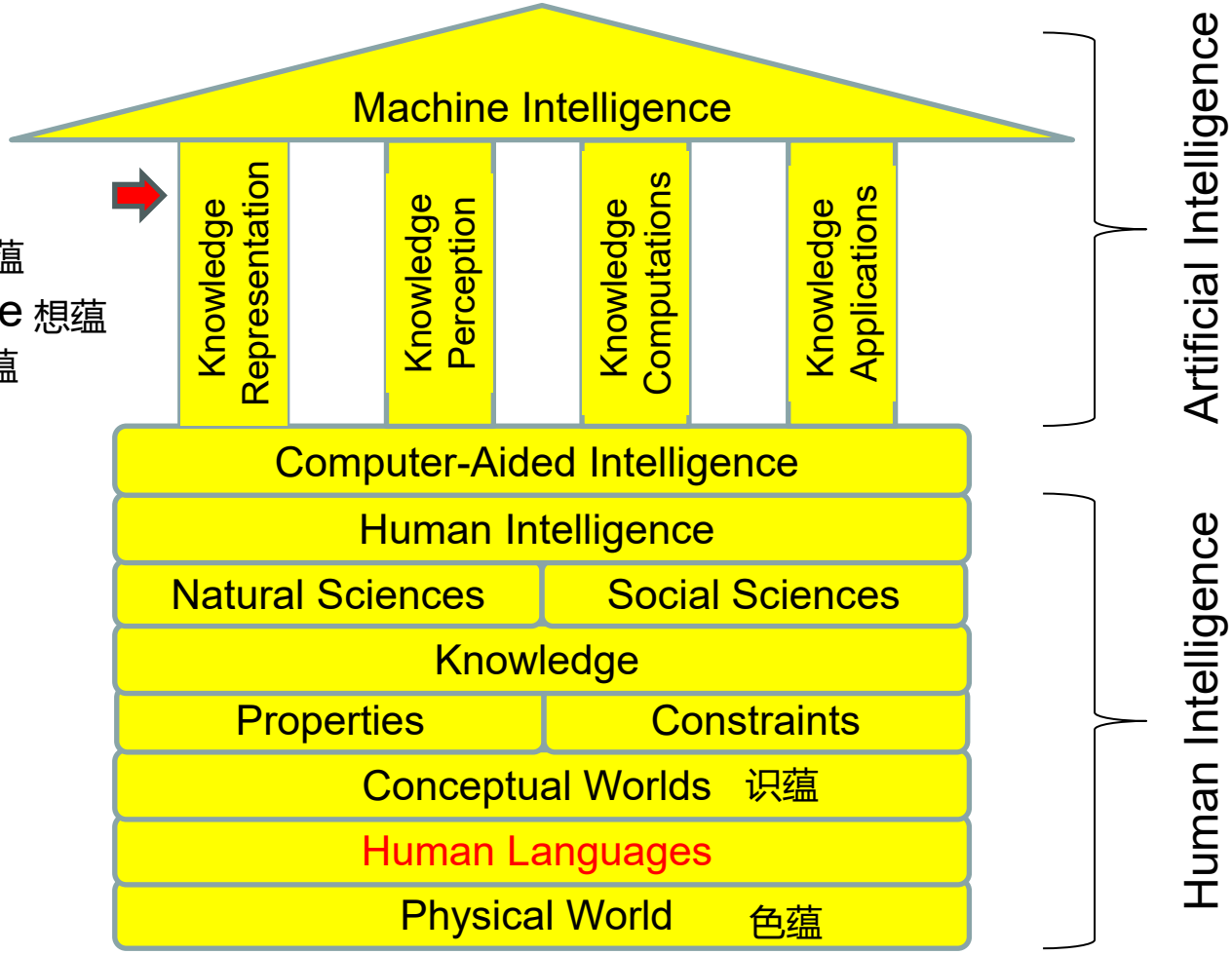
- Brain provides hardware support to the functionalities of Mind. Brain's primary functions are computation and memorization (or storage), while Mind's primary functions are cognition and recognition. Mind is at the root of natural or artificial intelligence. Intelligence arises from Mind directly, but not Brain which supports Mind.

Key Takeaway No.1 …

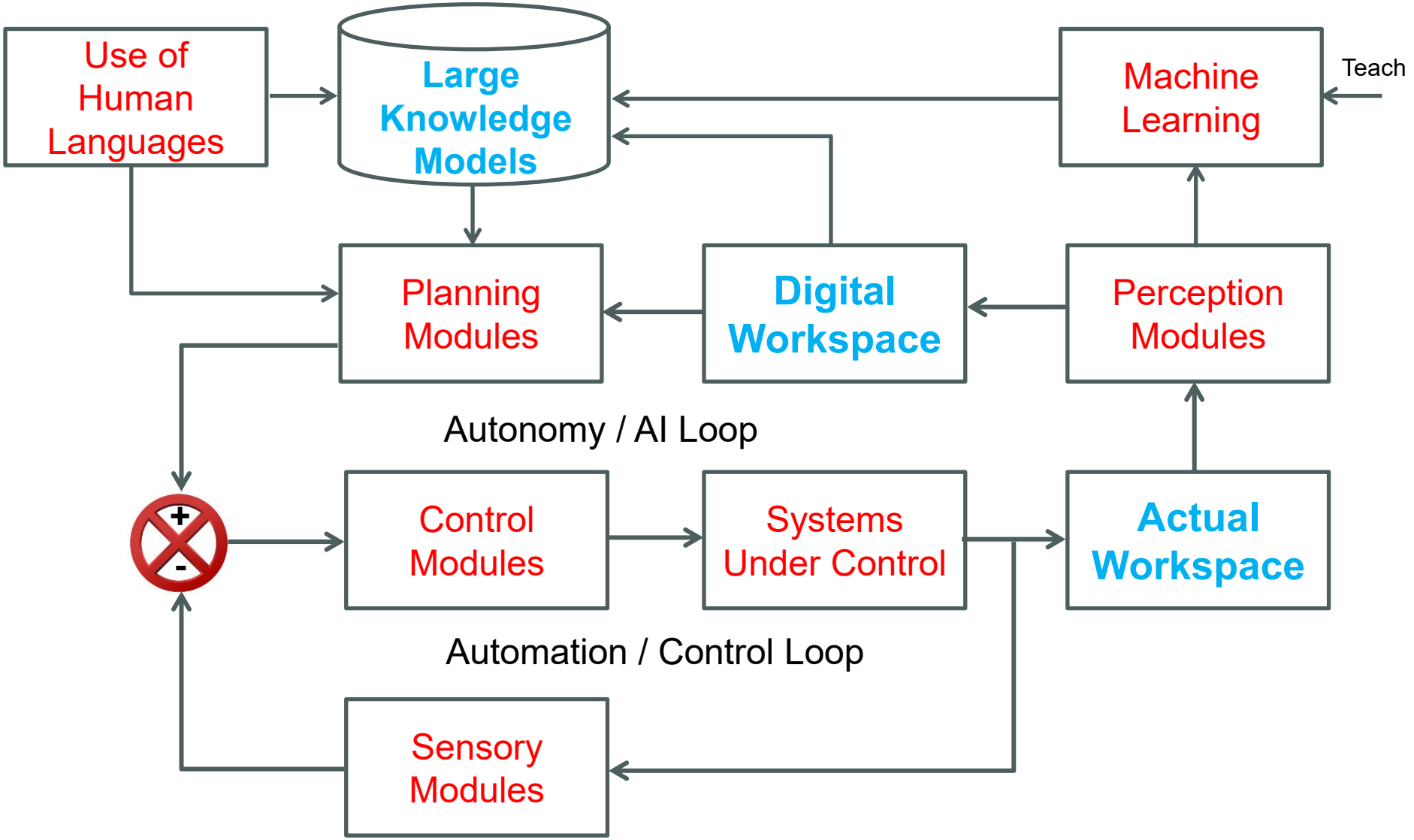
- One Tool
- Two Worlds
- Three Intelligences
- Four Pillars

- Signal to Knowledge 受蕴
- Knowledge to Knowledge 想蕴
- Knowledge to Signal 行蕴

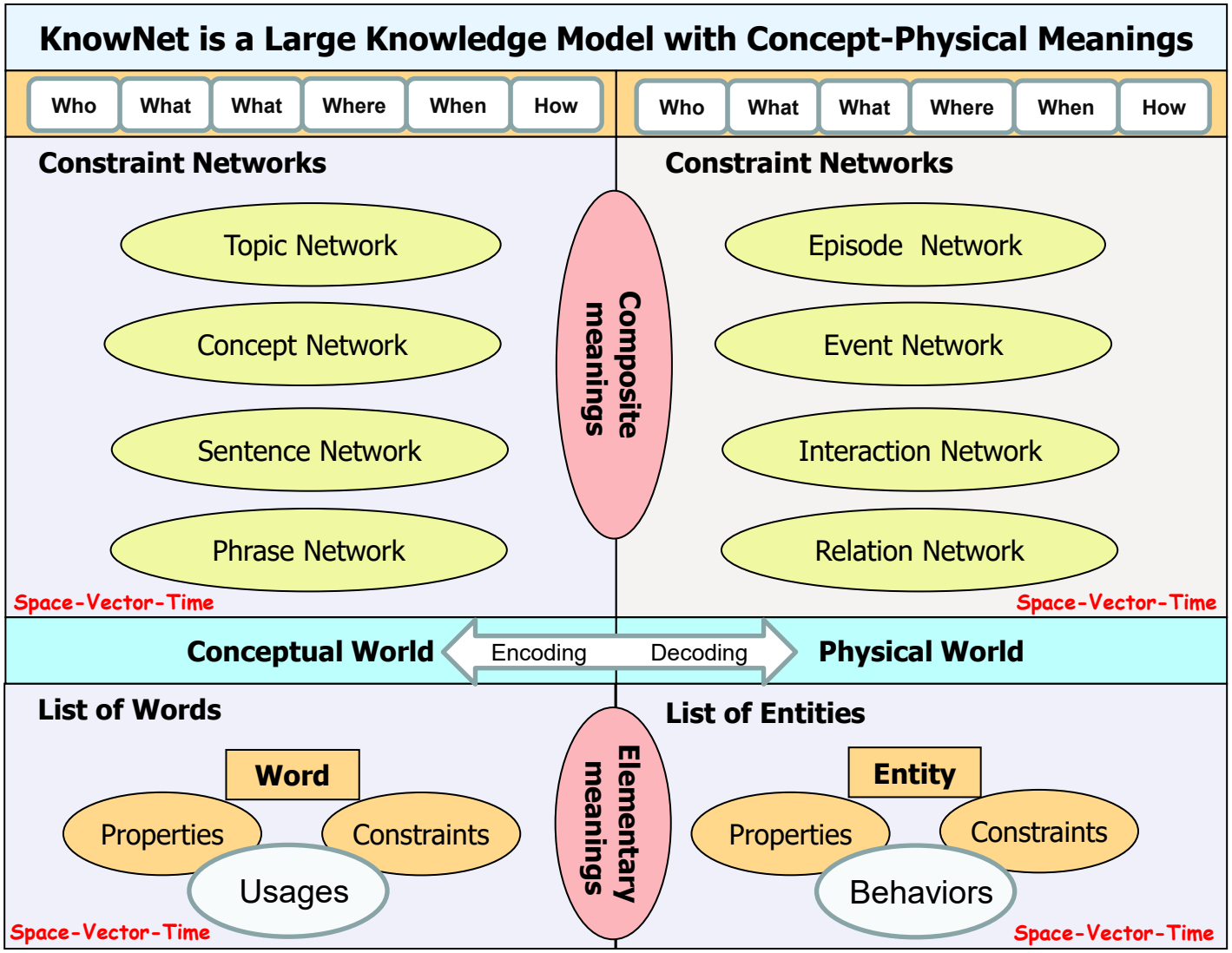


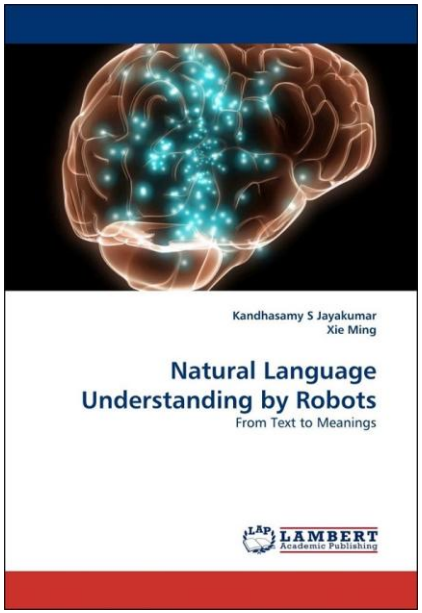


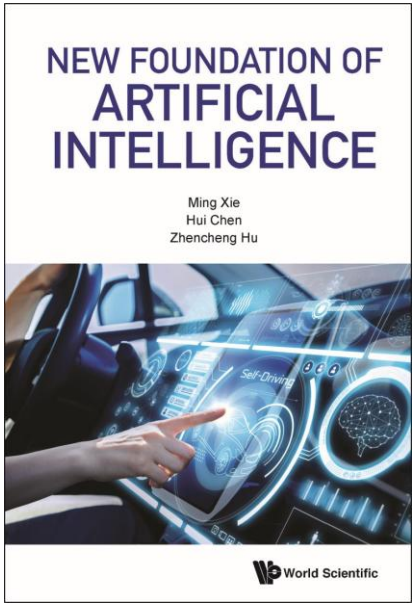
Key Takeaway No.2 ...



Key Takeaway No.3 …







Summary of Today's Talk

- What are Existing Limitations of Old AI?
- What is True Foundation of New AI?
- Why a Large Knowledge Model Matters?
- What is a Large Knowledge Model?
- How to Implement KnowNet?
- Concluding Remarks

"Ask not what your country can do for you – ask what you can do for your country," - John F. Kennedy

"Do not think that you are needy – think that you are needed in the world", - Manis Friedman

"Study will make you knowledgeable, resourceful, and hence more needed", - Xie Ming

Thank You for Listening!