Workshop on Human-Machine Teaming in Munich

Development of fundamental technologies for Human-Machine Co-Evolution future society

24th/June/2025

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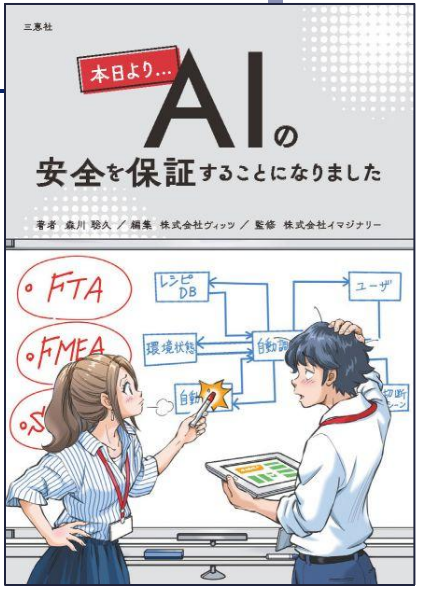
Human-Machine Co-Evolution Systems

We are software explorers

My self-introduction



Published: 2022/11/14
(from Amazon)

I specialize in developing highly safety and reliable embedded systems.

[Biography]

- Mainly experienced in new development of embedded software for information home appliances, in-vehicle software PF development, etc.
- Started functional safety development in 2006. Successful acquisition of **IEC 61508 process certification in 2010 for the first time in Japan.** Moreover **in 2012, ISO 26262 process certification is the first time in the world.**
- Leading business centered on functional safety / product safety / AI safety (supporting more than 100 companies in Japan)
- Organize methods for conforming to functional safety standards for AI and make international technical proposals (publish technical paper) https://arxiv.org/abs/2008.01263
- **Contributed to the formulation of the AI functional safety standard (ISO/IEC TR 5469) at ISO/IEC JTC1/SC42 WG3**
- November 2022: Publish a book that explains the points of safety assurance measures for AI systems in a story style

Published: 2022/7/1
(only PDF from JSA)

SEAMS Project https://www.seams-p.jp/

Ministry of Economy, Trade and Industry (METI) Support Project (**2017 to 2019**)

<Main R&D results>

1. Functional safety design/evaluation patterns for AI systems
   - "Safety design concepts for statistical machine learning components toward accordance with functional safety standards“
     - Akihisa Morikawa (Witz Corp.), Yutaka Matsubara (Nagoya Univ.), https://arxiv.org/abs/2008.01263
2. How to quantify uncertainty in AI systems
   - based on IEC/TS 62998-1
3. Building a reliable ML development process (procedures, templates and checklists)
   - based on 8.5 of UL 4600, Annex B of ISO/TR 4804, Automotive SPICE v4, ISO/PAS 8800, etc
4. Comprehensive verification method for complex conditions (using virtual simulation)
5. Safety design for a number of specific AI systems

Agenda

1.Technical issues for the future society we envision

2.Our R&D Project “HMCES Project”

3.[Theme 1] Human-Machine Co-Evolution System Guidebook （HMCES Guidebook）

4.[Theme 2] Verification platform for Co-Evolution System

5.[Theme 3] Evaluation using example applications

6.Future tasks

The future society we envision

Serious problems in Japan

・**Decrease in productivity** (aging society, shortened working hours, etc.)

・**Low sense of happiness** (51st in world happiness ranking)

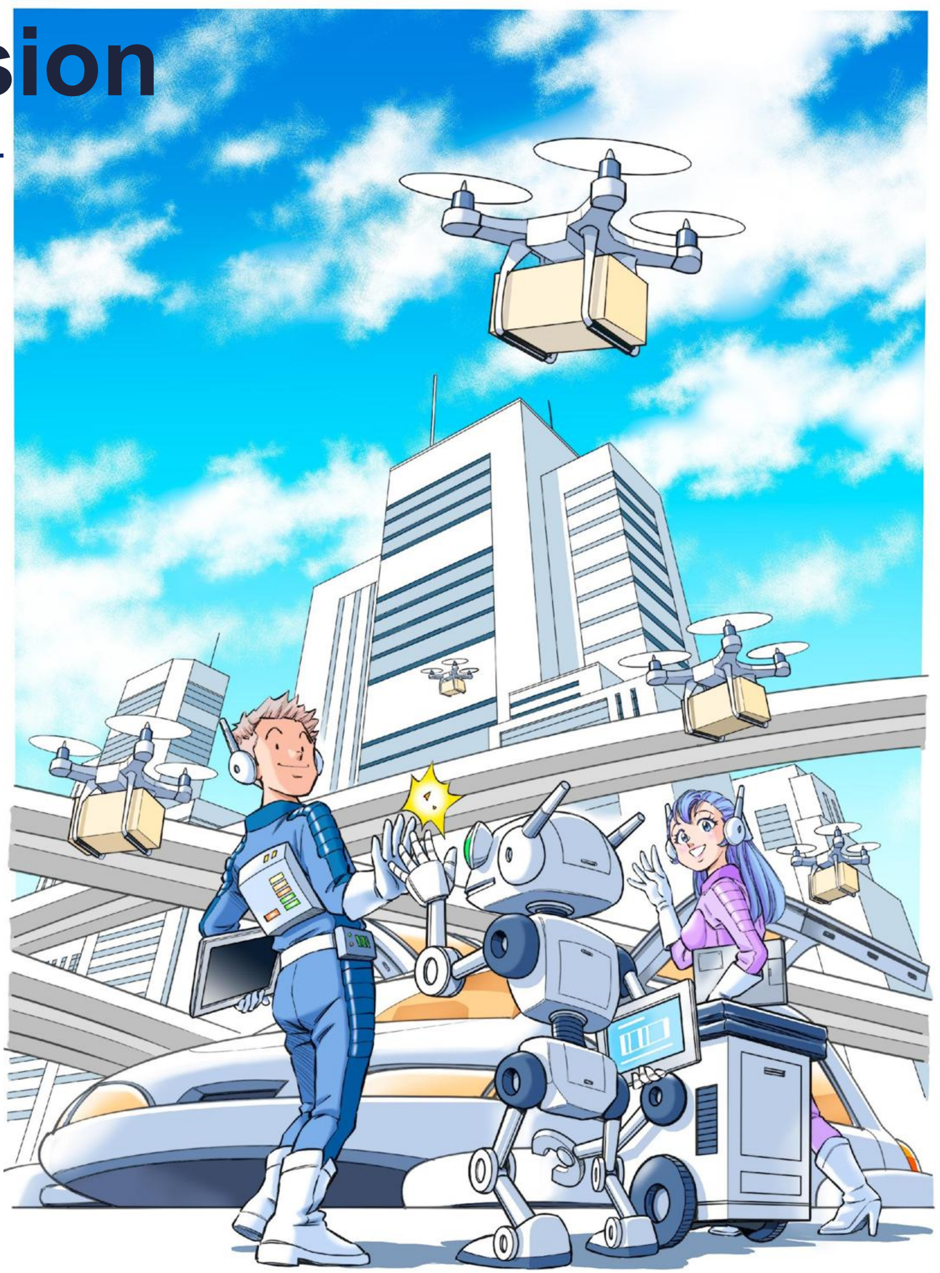
Improvement

Advanced symbiotic society of humans and machines (with AI)

- improves well-being by **optimizing for each individual**
- **continues to improve productivity, convenience, safety, and happiness**

"Co-Evolution" of humans, machines (AI), and society

1. Not only AI's improvement
2. Changes in human values and behavior
3. Changes in laws, infrastructure, lifestyles



Issues of continuous evolving social system

In future societies with fully co-evolution systems, conventional safety standards (**SOTIF, functional safety**) **might not be enough** to address below risks.

Technical Issues	Conventional systems	Co-evolution systems
(1) Verification timing for **continuous changing systems**	Conduct thorough verification before release.	Since the system is constantly changing, there is no timing for verification.
(2) Assurance methods for the quality and safety **of unknown systems**	Extract potential unknown risks from the assumed system (using guidewords) and implement risk mitigation measures (SOTIF).	It is possible to detect deviations (concept drift) from the assumed system and stop the system. However, this is inconvenient.
(3) In response to machine and environmental changes, **human need time to adapt**	Compliance with safety operation rules for the assumed system	Humans need enough flexibility to keep up with changes.

Organization of HMCES Project

[R&D Budget] → **[Management]**

Ministry of Economy, Trade and Industry (METI)

The Public Foundation of Chubu Science and Technology Center (CSTC)

[Advisors/Observers]

- Japanese members of ISO/IEC JTC1/SC42
- Big maker companies
  - Mitsubishi
  - Suzuki
  - Aisin
  - Kobelco
  - Meiden
  - Hitachi
- Japan Automobile Research Institute (JARI)
- Certification bodies
  - UL Japan
  - DNV

[R&D members]

- WITZ Group
  - Imaginary [Project Leader]
  - Witz
  - Atelier
- Nagoya University [Sub Leader]
- National Institute of Advanced Industrial Science and Technology （AIST）
- Gomes Company

[Theme-1] Arrangement of requirements to ensure the safety and security of human-machine cooperative systems

Human-Machine ™ Co-Evolution Systems GUIDEBOOK

Contribution →

Standardization activities (for AI system, Collaborative Safety, etc)

Guidelines / laws

Requirements for human-machine cooperative system development for safety

System operation requirements/social rule requirements for safety

Feedback

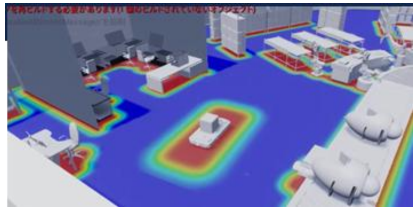
[Theme-3]

Advanced Pilot APPLICATION

Development of integrated control robot for hands, feet, eyes, ears, and mouth

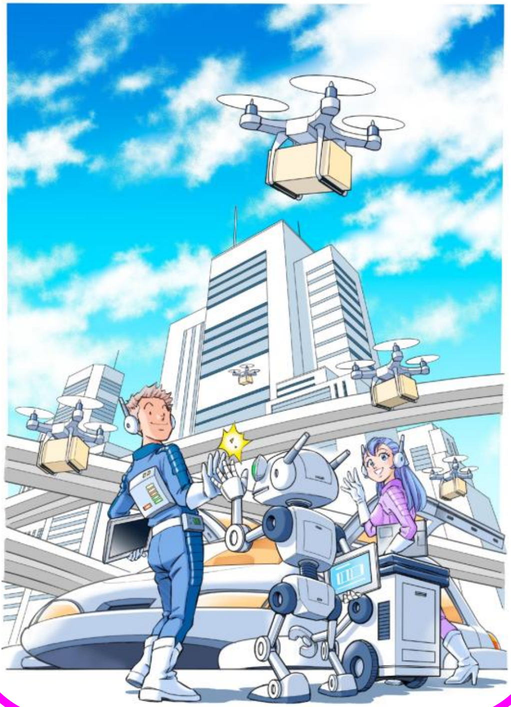
[Theme-2]

Human-Machine Co-Evolution Systems PLATFORM



social implementation

"Advanced symbiotic society" of humans and machines



＜Examples of application＞

- Intelligent collaborative robot （in factory）
- Housekeeper robot （in-house）
- Secretary robot （in the office）
- etc

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Guidebook against issues of continuous evolving social system

<Co-evolution Guidebook>

Supporting the Safety and Security of continuous evolving social system

✓Establish new design and verification methods

✓Guides to enable human flexibility and adaptability

Apply

<Key Existing Technologies>

- Human-Machine Teaming（HMT)
- Human behavior analysis
- Resilience Engineering (Safety II)
- Collaborative Safety
- Other several AI standards (by SC42)

Table of contents of HMCES Guidebook (1/3)

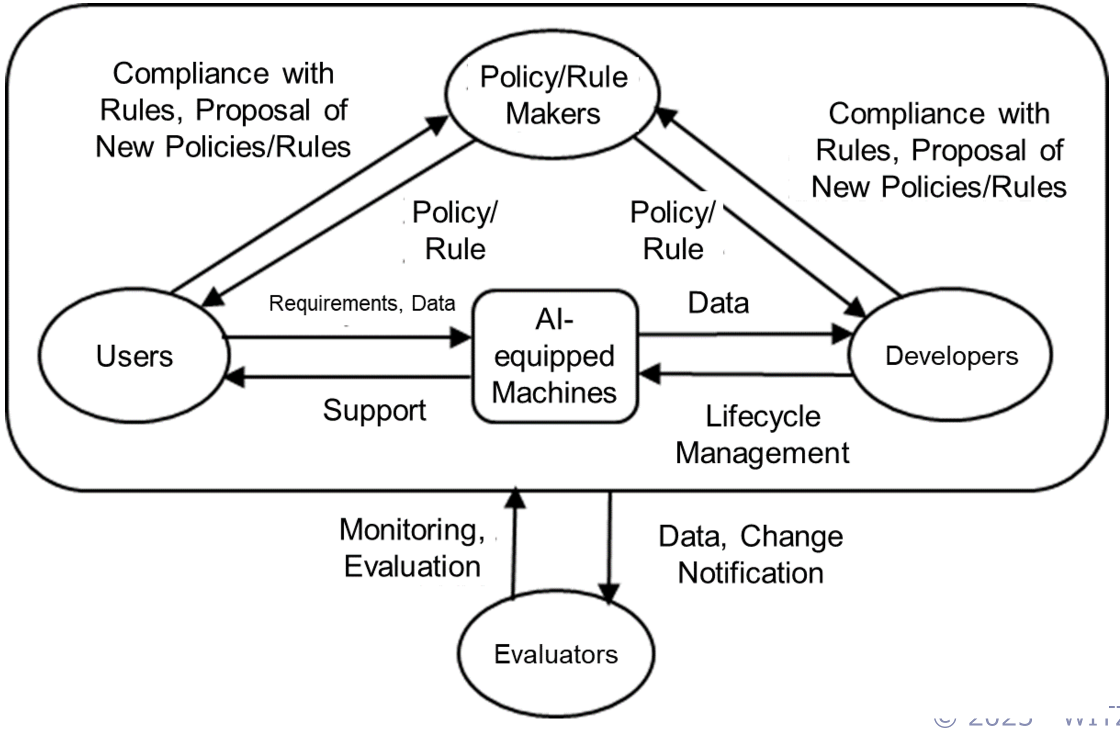
- **HMCES Guidebook Ver.1.0.0**
- **97 pages**
- **Public release in May 2025**

(EN) https://doi.org/10.18999/2012890
(JP) https://doi.org/10.18999/2012742

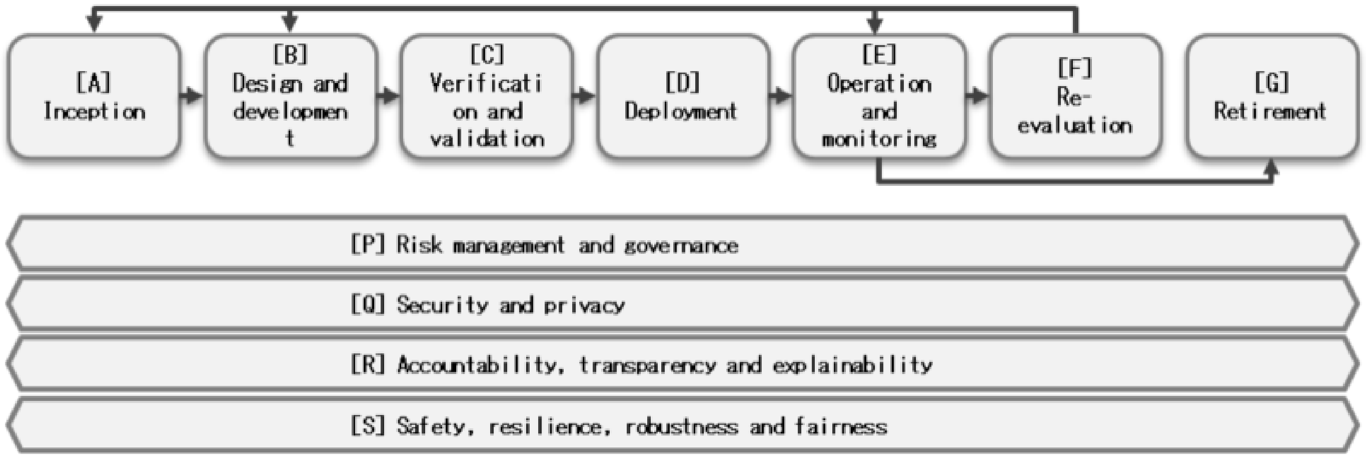
Definition of stakeholders and lifecycle

- Defining Co-evolution Systems and Stakeholders
- Definition of the co-evolution system lifecycle (based on Figure.3 of ISO/IEC 22989:2022)
- Organize the recommendations for human-machine co-evolution for each phase

<Concept of Co-evolution system>



<Co-evolution system lifecycle>



Relationships between phases and stakeholders

- Clarifying the roles of stakeholders in each phase

<Relevant Stakeholders for each phase>

Phase（System Development）	Stakeholders			
	Developers	Users	Rule Makers	Assessors
[A] Inception	✔ （Concept Design）	✔ （System Introduction Planning）	✔ （Basic Rule Formulation）	–
[B] Design and development	✔ （System Development）	–	✔ （Formulate detailed rules for phases [D] to [G], rule retirement）	✔ （Regulatory compliance evaluation of formulated rules）
[C] Verification and validation	✔ （System Verification）	–	–	–
[D] Deployment	✔ （System Provision）	✔ （System Deployment and Evaluation）	–	–
[E] Operation and monitoring	✔ （System Maintenance, Acquisition of Operational Data）	✔ （System Operation）	✔ （Monitoring Regulatory Revisions）	✔ （Data Collection on Activities and Changes）
[F] Re-evaluation	✔ （Analysis and Evaluation of Functions and Performance）	✔ （Operational Evaluation）	✔ （Rule Evaluation, Decision on Rule Revisions）	✔ （Evaluation of Rule Compliance in Operations, Multi-Perspective Assessment, Feedback to Stakeholders）
[G] Retirement	✔ （System Disposal）	✔ （System Disposal）	–	✔ （Verification of Compliance with Disposal Rules）

※Activities in parentheses are examples of main activities.

Table of contents of HMCES Guidebook (2/3)

Table of contents of HMCES Guidebook (3/3)

Metrics related to human-machine cooperation

- **Evaluation metrics are essential to promote, analyze, and improve the co-evolutionary system**

＜Base metrics＞

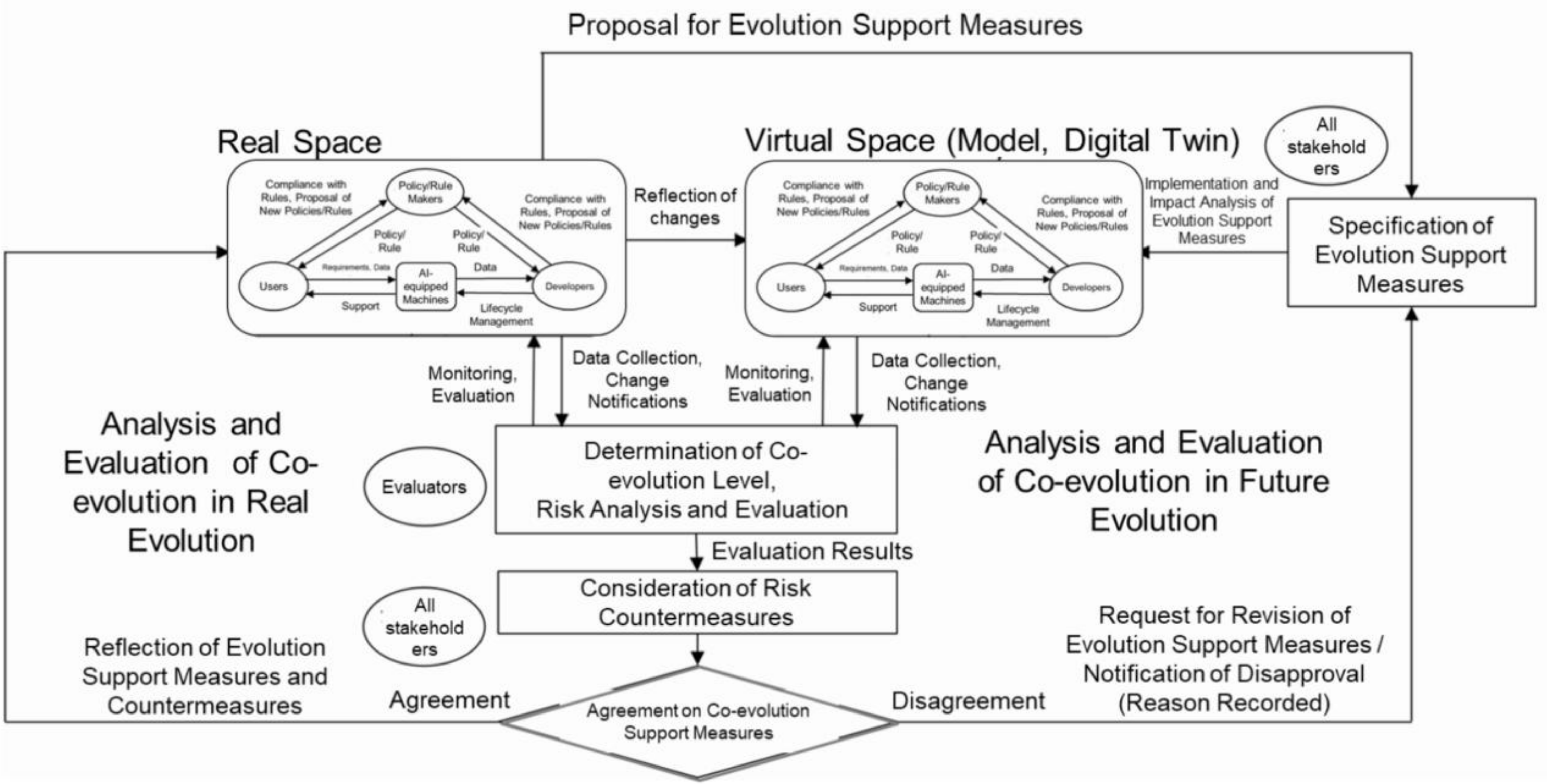
- ➢ HMT: Common Metrics to Benchmark Human-Machine Teams (HMT): A Review (https://ieeexplore.ieee.org/document/8404030)
- ➢ Resilience engineering: Resilience Engineering Indicators and Safety Management: A Systematic Review (https://www.sciencedirect.com/science/article/pii/S2093791120302663)

- **In addition, organize human-related metrics**
  - ➢ individual abilities and characteristics, team metrics, conditions that affect system collaboration

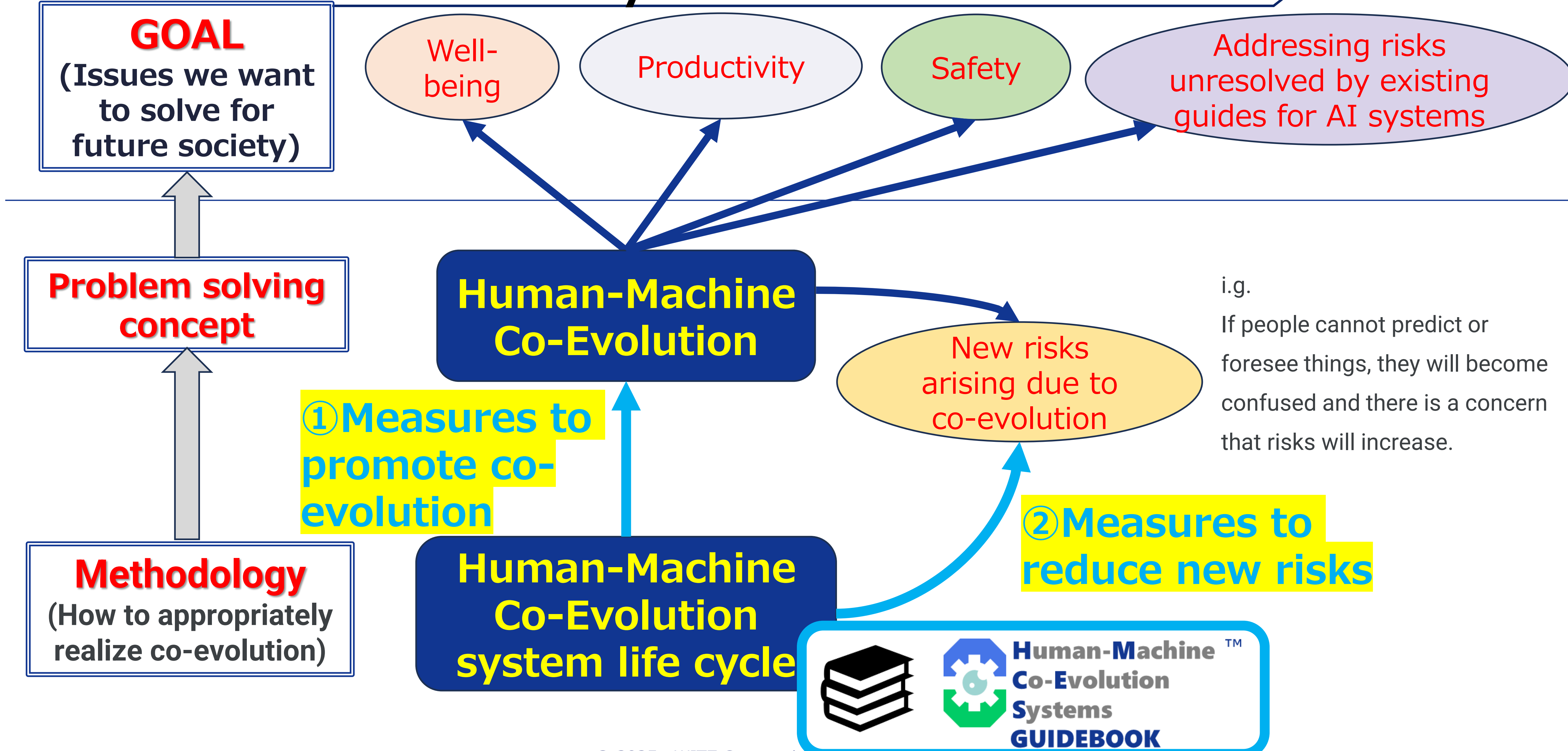
138 metrics | **Human/Machine measurement** | **Applicability**

							Stakeholders			
	Metrics/RE indicators	指標	指標詳細説明	計測可否			Users	Developers	Rule Makers	Assessors
				Users側にしかわからない指標	システム側にしかわからない指標	全体統合しないとわからない指標 （For 全体監視 あるいは ルール）	システム側に提示が望ましい	ユーザ側に提示が望ましい	インフラとして計測が望ましい	第３者による監視が望ましい
1	Adaptability	適応性	主観的指標(SM)は、人間の知覚に基づいて抽象的な品質を測定するために使用される。適応性は専門家による5段階の評価を用いて測定される。主観的な尺度と人間の属性または特性は、観察者の尺度に依存する。リアルタイムで測定するのは困難	ー ユーザ評価の尺度は主観となってしまうため計測はできないが、開発側にとっては重要な指標と思われる。	ー	◯ 専門家による5段階の評価を用いて測定可能。 "Personality, adaptability, and performance: Performance on well-defined problem solving tasks," [102]	◯ ユーザの使い勝手に大きな影響を与える指標と思われる。	ー	ー	◯ 客観的立場でユーザが容易に使用できる操作性などの監視は必要を思われる。
2	Assertiveness	自己主張（自信に満ちた態度）	主観的指標(SM)。Rathus の自己主張尺度[103]、[104]に基づいて測定される。観察者の尺度に依存するため、リアルタイムで測定するのは困難。	ー	ー	◯ Rathus の自己主張尺度[103]、[104]に基づいて測定可能。 "A 30-item schedule for assessing assertive behavior," [103] "The effects of crit ical team member assertiveness on team performance and satisfaction,' [104]	ー	ー	ー	ー
3	Composure	落ち着き（冷静さ）	人間のパフォーマンスの向上を通じてチームの結束を高めるための人間のパフォーマンス属性の一つ。19の異なる尺度を使用して測定される[105]、[106]。観察者の尺度に依	ー	ー	◯ 19の異なる尺度を使用して測定される[105]、[106]。 "Academic resilience and the four Cs: Confidence, control, composure, and commitment,"	◯ ユーザの冷静な使用を考慮するのであればシステム側への提示は望ましい。	ー	ー	◯ ユーザの使用に関して、客観的立場での監視は必要と思われる。

Co-evolution Framework



Positioning of co-evolution necessary for future society



Agenda

2 main roles of virtual space

- Monitoring the real space
  - events and changes that are actually occurring in the field
  - **Known-known** events: sufficiently predictable
  - **Known-unknown** events: not easy but are somewhat predictable
- Simulation for unknown conditions
  - providing an opportunity to take countermeasures in advance
  - **Unknown-known** events: not clearly known at this time but could occur in the future
  - **Unknown-unknown** events: not expected at all

Overview of our Verification Platform for Co-evolution System

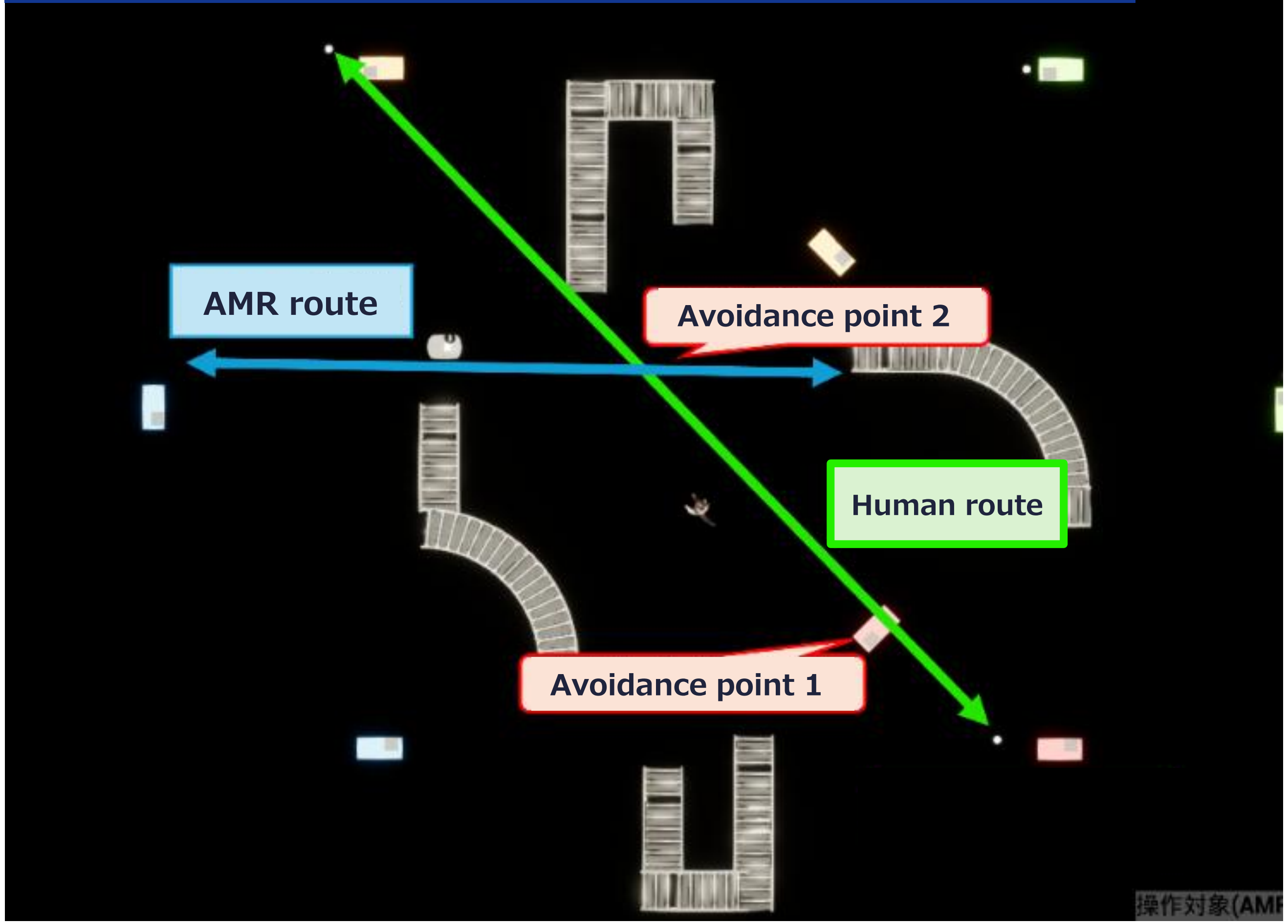
- Functionality extension for co-evolution system
  - **Future prediction verification** by comprehensive pattern execution
  - **Accelerated verification**

  - **Simulating human-machine interactions**
  - Individuality expression by incorporating a **human model**
    - e.g. capability, evolutionary model, physical condition, judgment preferences, etc.

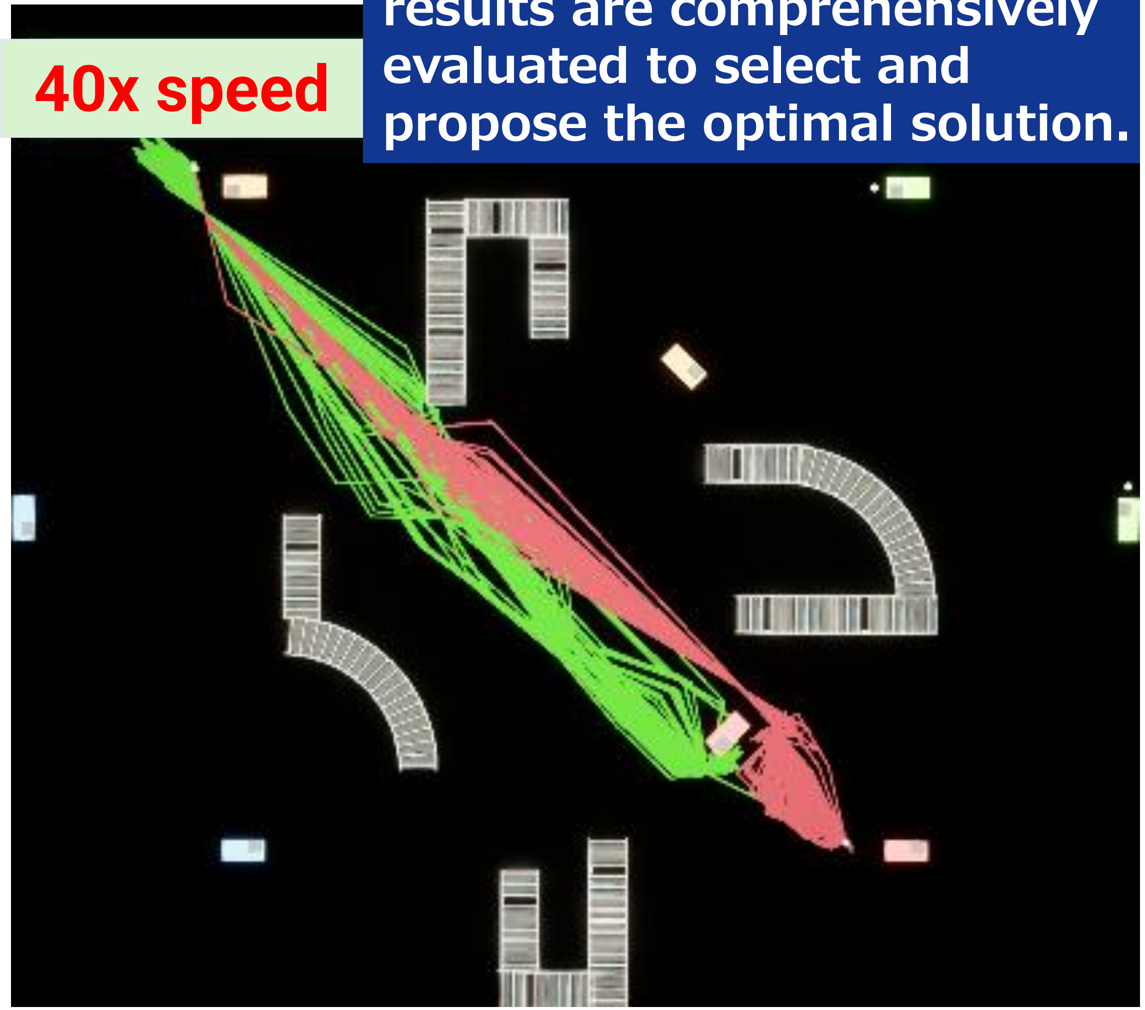
  - Integrated evaluation for safety and efficiency
  - Reinforcement learning using simulated execution and verification results

Comprehensive accelerated verification example

Simulation verification of the effectiveness of avoidance action control by predicting the possibility of collision between AMR and people and obstacles in the future



Accelerated verification is carried out by simulating all possible future patterns. The results are comprehensively evaluated to select and propose the optimal solution.



An example of human-machine co-evolution simulation

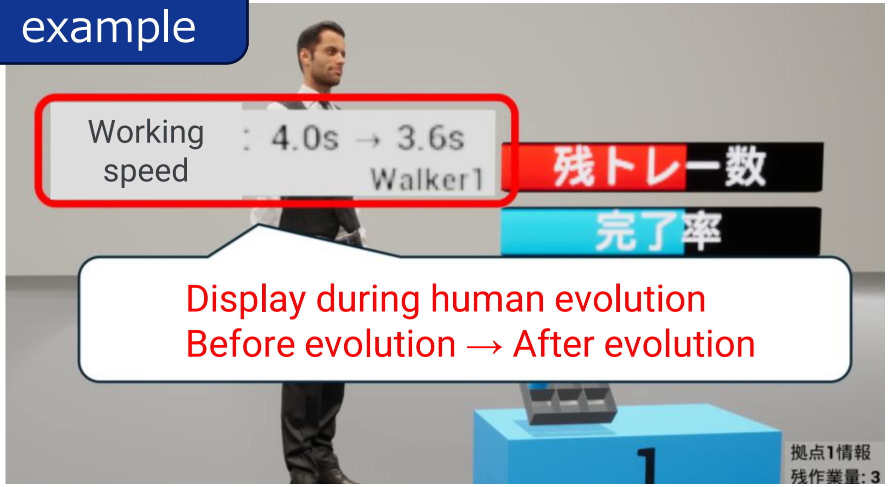
■ Evolution:

- The time required for human and machine work is reduced according to certain rules depending on the number of tasks.
- All of these evolution-related parameters and rules can be set arbitrarily (including ON/OFF).

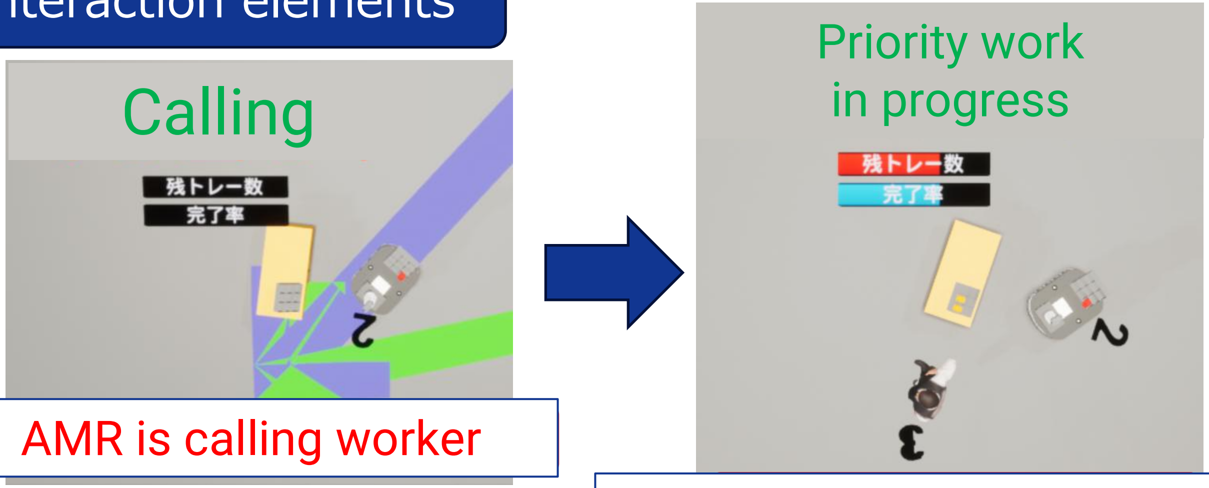
■ Machine-to-human interaction elements:

- The function that allows machines to call humans to the production site under certain conditions.
- This function can be set to ON/OFF arbitrarily.

Evolution example



Interaction elements



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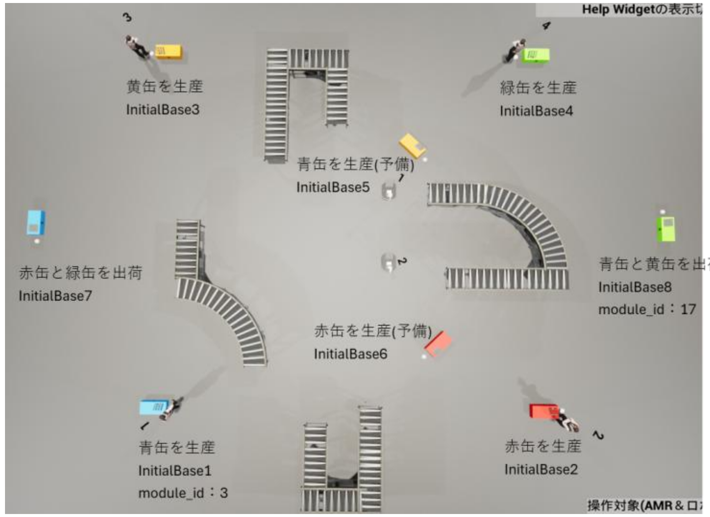
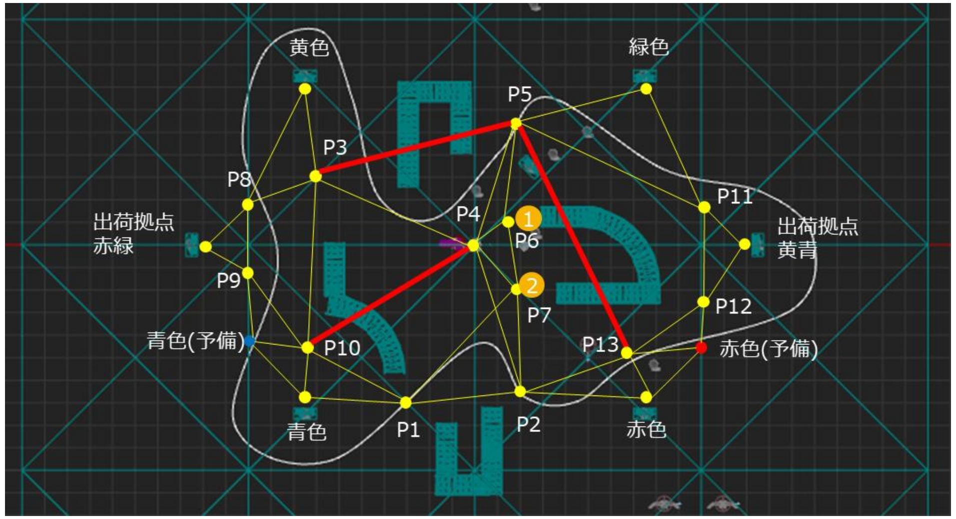
6.Future tasks

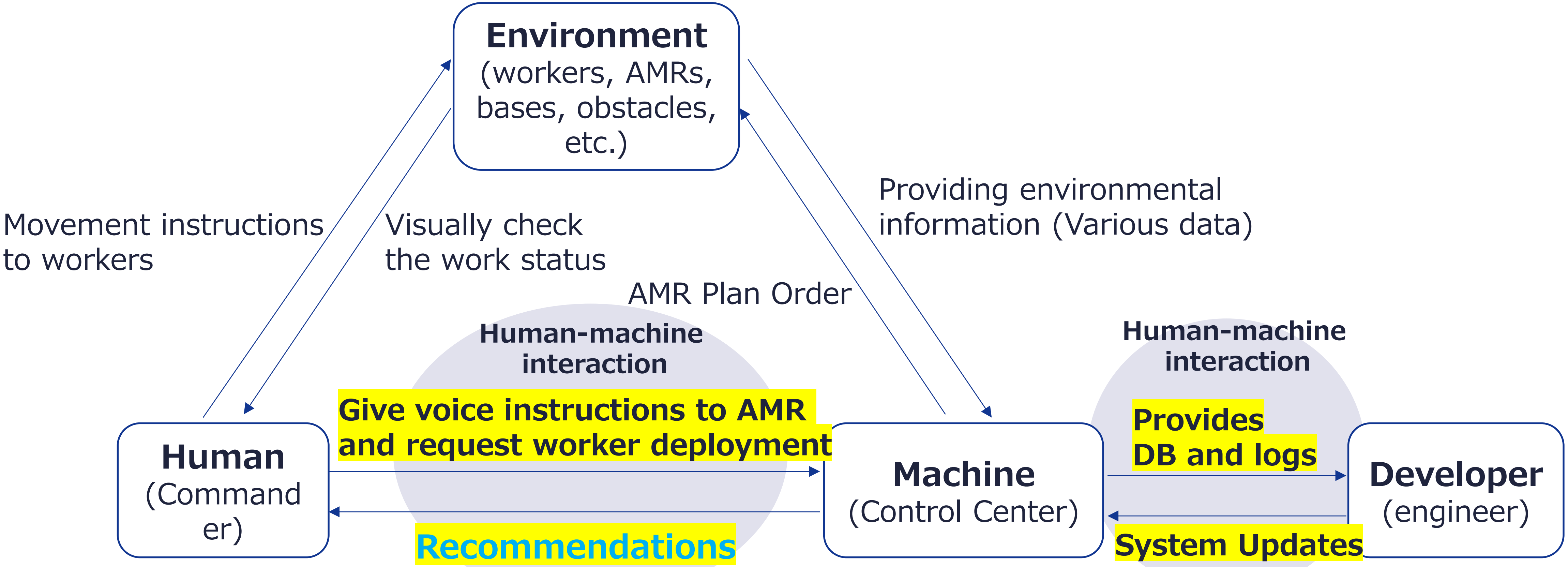
Scenario

- Workers produce parts at production sites.
- Workers ship parts at shipping sites.
- Workers can move to sites depending on the work situation.
- The production speed at a production site is determined by the skill of the worker assigned to the site.
- The AMR collects parts at the production site and transports them to the shipping site.
- The AMR follows a predetermined route (point ID).
- If an obstacle is found, the AMR will take evasive action to ensure that the route is taken.
- If the AMR takes evasive action N times on the same route, it will reoptimize the route so that it is not used.
- The commander (the human commander) monitors the work situation on a monitoring screen.
- If a change in plan occurs, the commander gives voice instructions to the AMR. The commander also decides on the placement of workers based on recommendations from the control center.





System Configuration



<Human evolution>
Gain insights from multiple recommendations and environmental conditions, and become able to make new decisions.
(Accumulation of experience, improvement of judgment ability)

<Machine evolution>
Developers will analyze environmental data and the commander's past choices, and use the data in future system updates.
(System updates)

Comparison of co-evolution and non-co-evolution

Non-co-evolution system

- Workers only perform assigned tasks

Co-evolution system

- Workers detect vacant locations and provide support
- AMR transportation plans are updated frequently
- Improved productivity across the entire system

Example: Recommendation function

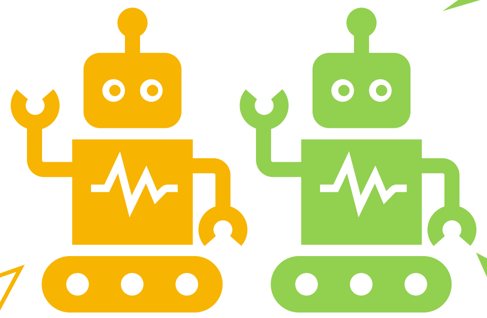
Machine makes recommendations regarding staffing.
This time, machine proposes a plan that specializes in specific parts and a balanced plan that strengthens production.

[REQUEST] I want to increase the production of part A.

[PLAN A] A plan focused on improving the production of specific parts

Move workers A, B, E, and F to the base X.

As a result,
the production rate of part A will decrease from 3 to 0 units per minute.
The production rate of part B will increase from 3 to 13 units per minute.
The production rate of part C will decrease from 3 to 0 units per minute.
The production rate of part D will decrease from 4 to 0 units per minute.



[PLAN B] A balanced plan with enhanced production

Move workers B, E, and F to base X, D to base Y, and C to base Z.

As a result,
the production rate of part A will decrease from 3 to 1 per minute.
The production rate of part B will increase from 3 to 9 per minute.
The production rate of part C will decrease from 3 to 2 per minute.
The production rate of part D will decrease from 4 to 1 per minute.

Findings gained from evaluating the behavior of co-evolution systems

- Proposals made by machines (AI) only satisfy the needs of humans. Therefore, it is difficult for a machine to make a proposal that takes into account all the disadvantages of changing the plan and all hidden prerequisites. → **Frame problem**
- **Human judgment is essential to make a comprehensive decision based on various hidden conditions.**
  →In this case, a recommendation was made to increase a certain production volume, but because the overall situation was not taken into consideration, the negative effect was that production at other production sites could not be carried out. →**The optimal solution is to make an optimal plan based on the recommendation.**

<Frame problem>
In the real world, it is extremely difficult to properly extract the conditions necessary to solve problems other than those that have been set. As a result, AI makes decisions without considering any phenomena other than those that have been set as a problem.

Future tasks

- Improvement of our guidebook
  - By clarifying the specific features of co-evolution system
  - By clarifying importance of the recommendations in the guidebook

- Improving the functionality of our verification platform
  - Actually using it and feed it back

- Safety assurance technology for co-evolution and teaming in an **avatar society**

Thank you

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