#18: Increasingly-Autonomous CPS: Taming Emergent Behaviors from an Architectural Perspective

Jérôme Hugues jjhugues@sei.cmu.edu

Daniela Cancila Daniela.CANCILA@cea.fr

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, PA 15213

This material is based upon work funded and supported by the Department of Defense under Contract No. FA8702-15-D-0002 with Carnegie Mellon University for the operation of the Software Engineering Institute, a federally funded research and development center.

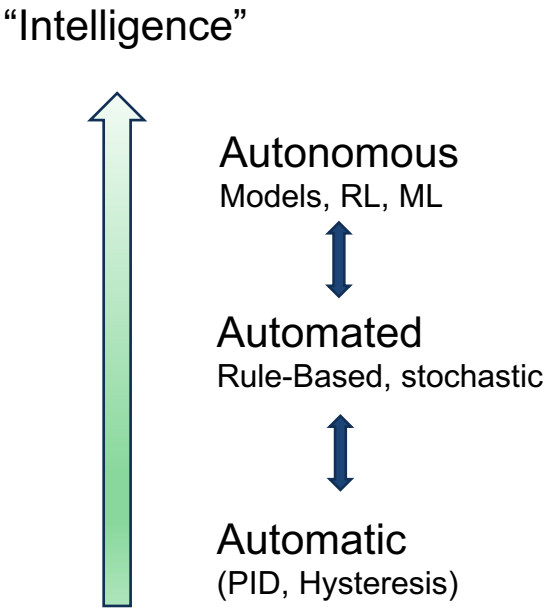
DM22-0628

The IA/AI fresh breeze …

General enthusiasm on Increasingly-Autonomous CPS [1] to

- Improve system efficiency (decrease # operators), system capability (automate high-level tasks), faster than human, ..

Increasingly-Autonomous Systems embeds advanced "intelligent" capabilities, from basic control to advanced AI



[1] E. E. Alves, B. Devesh, B. Hall, K. Driscoll, A. Murugesan, and J. Rushby. Considerations in Assuring Safety of Increasingly Autonomous Systems. Technical Report NASA/CR-2018-220080, NF1676L-30426, NASA AIR TRANSPORTATION AND SAFETY, 2018.

Notation Increasingly-Autonomous → IA [1] Artificial Intelligence → AI

Adapted from USD (R&E) Autonomy roadmap 2019 Webinar p2

The IA/AI fresh breeze .. coming from an iceberg ..

General enthusiasm on Increasingly-Autonomous CPS [1] to

- Improve system efficiency (decrease # operators), system capability (automate high-level tasks), faster than human, ..

Increasingly-Autonomous Systems embeds advanced "intelligent" capabilities, from basic control to advanced AI

But fast pace of actions, poorly-defined safety mechanisms makes it impossible for a human to mitigate issues

⇒ Distrust in system, longer V&V, or capability not deployed

⇒ May jeopardize capabilities of future projects

How to demonstrate that a system is safe?

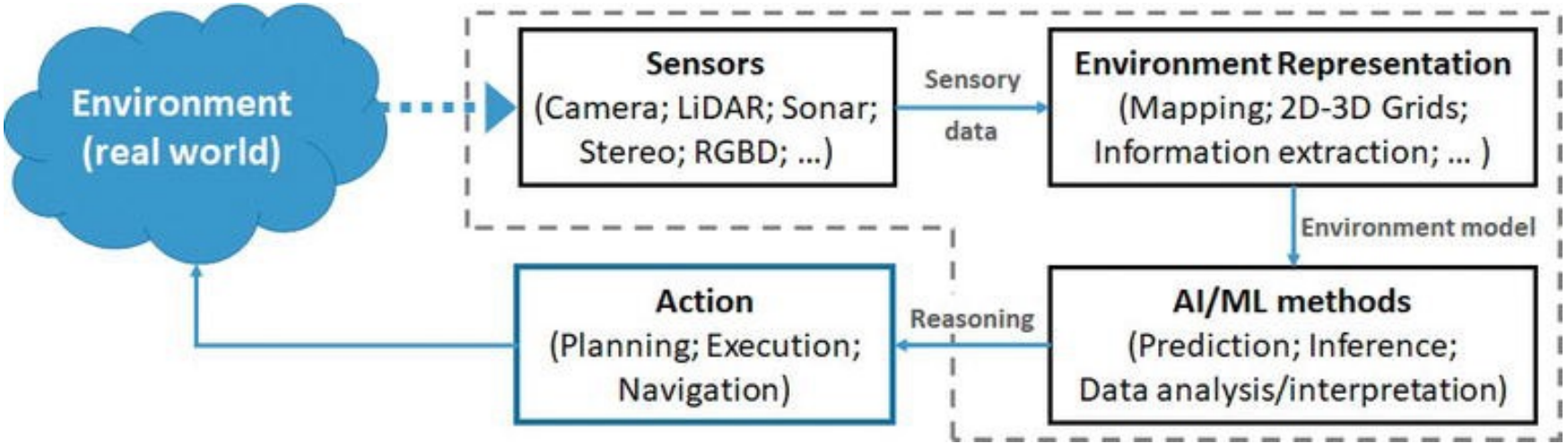
Image: CC BY-SA 3.0, Uwe Kils & Wiska Bodo, File:Iceberg.jpg - Wikimedia Commons, 2005.

[1] E. E. Alves, B. Devesh, B. Hall, K. Driscoll, A. Murugesan, and J. Rushby. Considerations in Assuring Safety of Increasingly Autonomous Systems. Technical Report NASA/CR-2018-220080, NF1676L-30426, NASA AIR TRANSPORTATION AND SAFETY, 2018.

Notation Increasingly-Autonomous → IA [1] Artificial Intelligence → AI

Architecture, Faults & IA-CPS

Notation
Increasingly-Autonomous → IA
Artificial Intelligence → AI

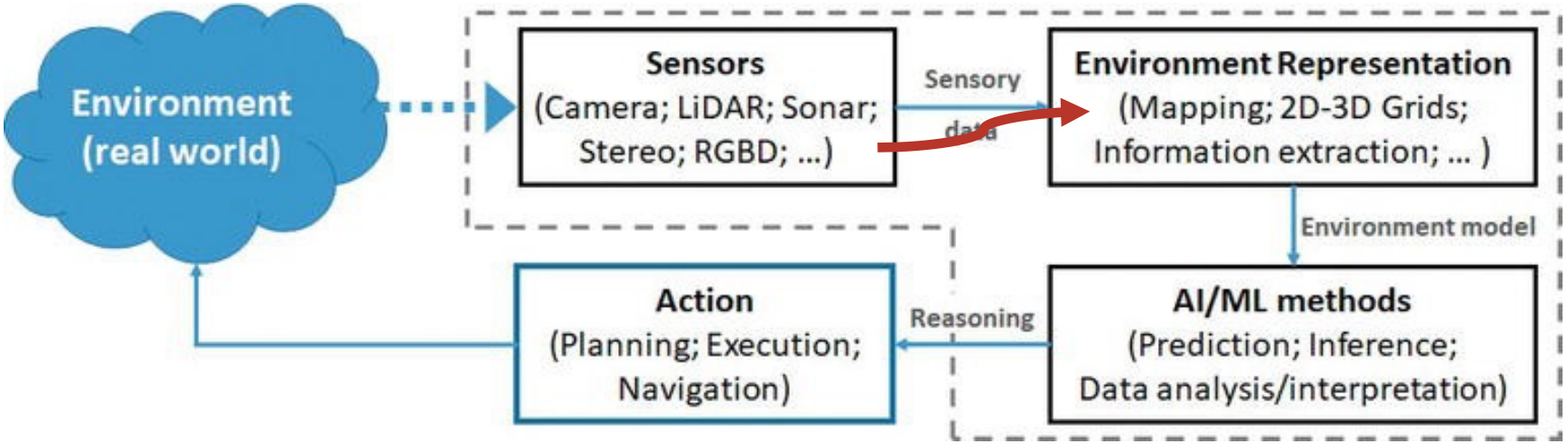


Adapted from DOI: 10.5772/intechopen.79742

Architecture, Faults & IA-CPS

Notation
Increasingly-Autonomous → IA
Artificial Intelligence → AI

Timing? Value?

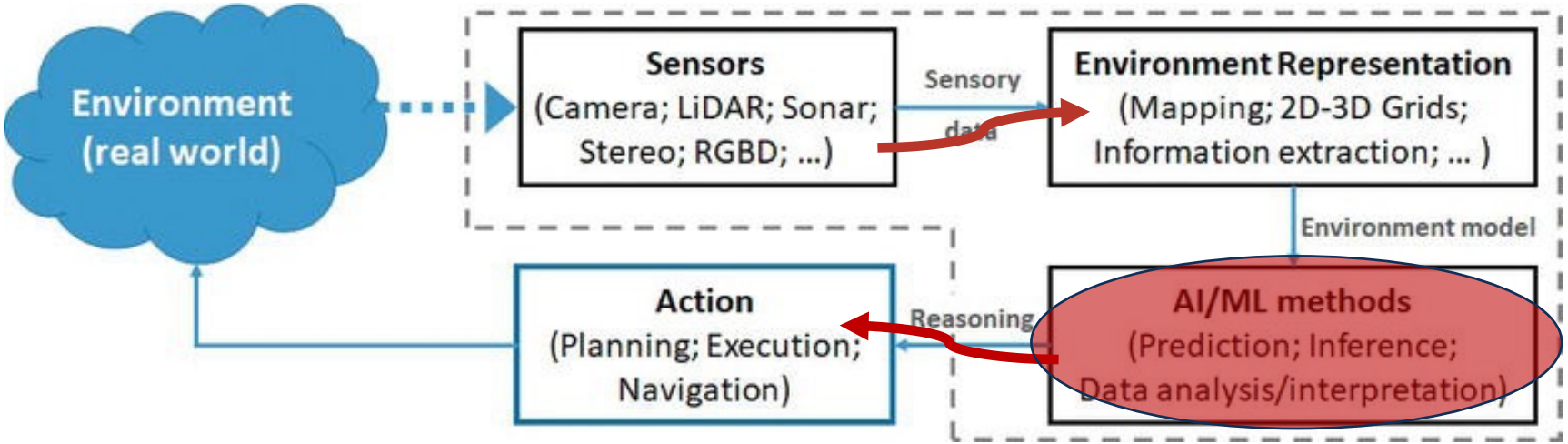


Adapted from DOI: 10.5772/intechopen.79742

Architecture, Faults & IA-CPS

Notation
Increasingly-Autonomous → IA
Artificial Intelligence → AI

Timing? Value?

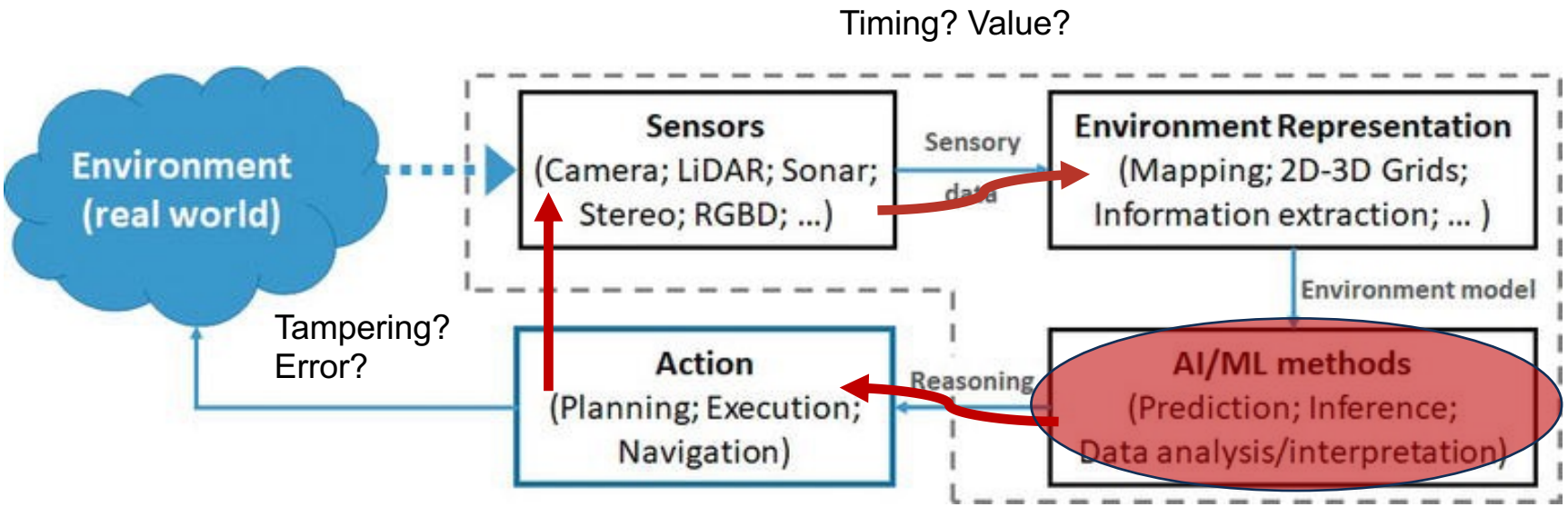


Accuracy/confidence?
WCET
Sensitivity to data

Adapted from DOI: 10.5772/intechopen.79742

Architecture, Faults & IA-CPS

Notation
Increasingly-Autonomous → IA
Artificial Intelligence → AI



Claim #1: the IA/CPS boundary gives rise to emergent behaviors

Accuracy/confidence?
WCET
Sensitivity to data

Adapted from DOI: 10.5772/intechopen.79742

Example of emergent behaviors and complexity

Notation
Increasingly-Autonomous → IA for short
Artificial Intelligence → AI

Emergent behavior characterized in CPS and AI,
- what about on Increasingly-Autonomous/CPS boundary?

Bad resource management: CPS -> AI
- Timing violations, jitter, non determinism may violate assumptions made by IA controllers
- Memory, bandwidth, battery scarcity may impede some functions

Bad resource management: AI -> CPS
- Conversely: variability in resource utilization by IA functions negatively impacts system

Cybersecurity and Cyber-Physical Security: AI <-> CPS
- RL-based systems can help detecting attacks or faults ; yet they introduce another layer of incidental complexity in system design

From Safety Assessment to Resilience Assurance

Notation
Increasingly-Autonomous → IA for short
Artificial Intelligence → AI

Previous examples illustrate the impossibility to perform a safety assessment

Difficulty to
- describe the requirements of AI-based functions
  - Except through examples …
- the worst-case budget used by the function
- test all conditions, etc.

Safety evaluation becomes impossible, we claim one must concentrate on defining resilient architecture and strategies to assure system resilience by leveraging

- Patterns for resilience systems, e.g. power plant
- Model-Based Architecture Description Languages + V&V capabilities
- System-theoretic approaches to elicit hazardous scenarios and their mitigation
- + built-in fail-safe strategies whenever possible