Ecological Automation:
making the invisible visible

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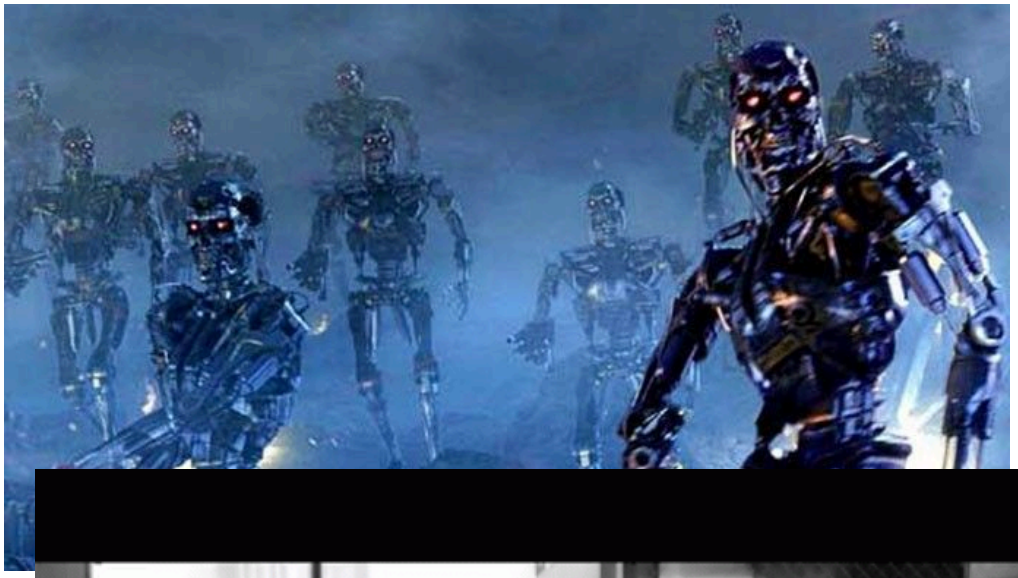
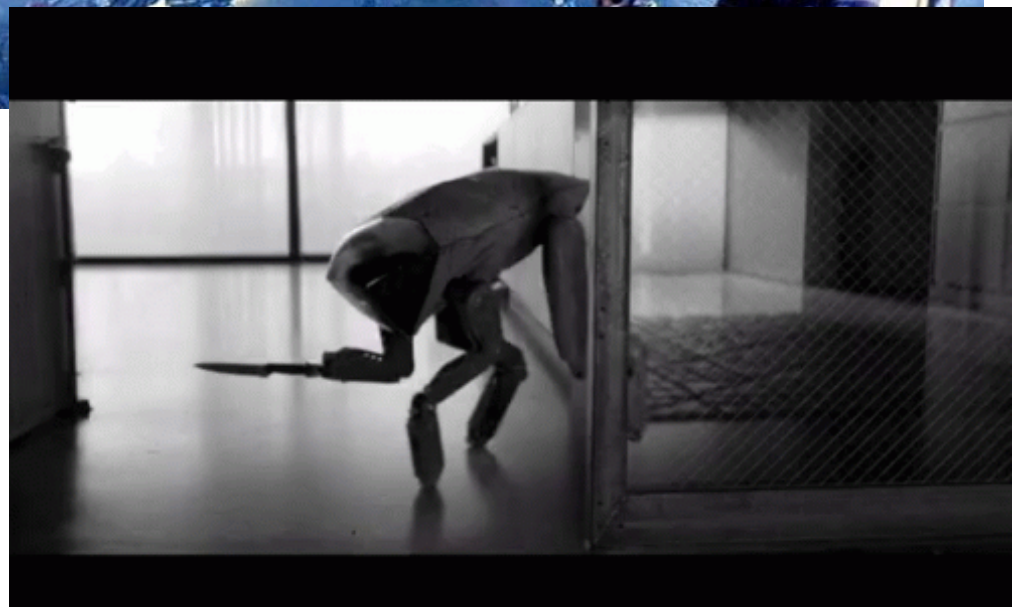
Overview

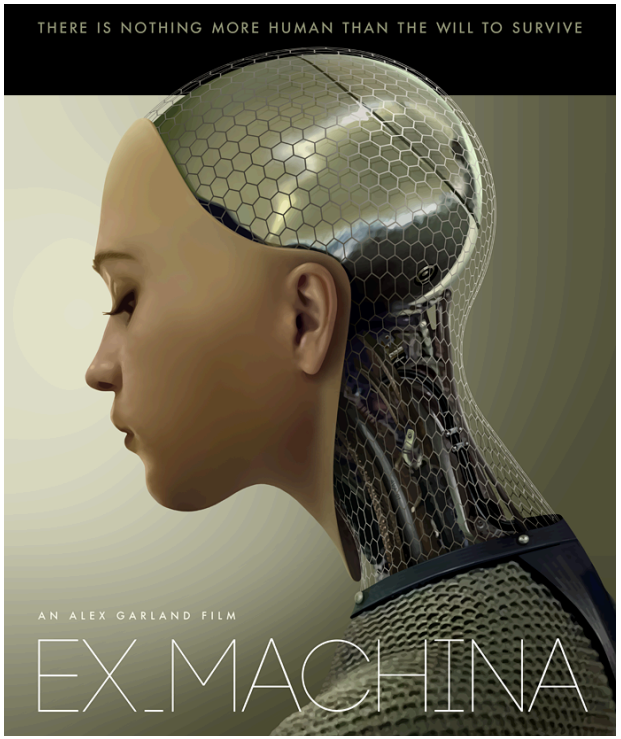
- Context and problem
- My approach
- Example
- Outlook & concluding remarks

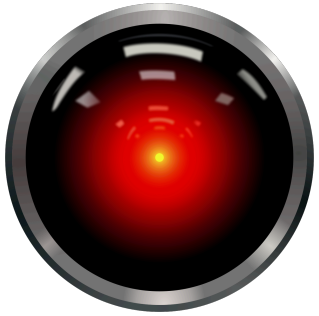
CONTEXT AND PROBLEM

People's view on Artificial Intelligence



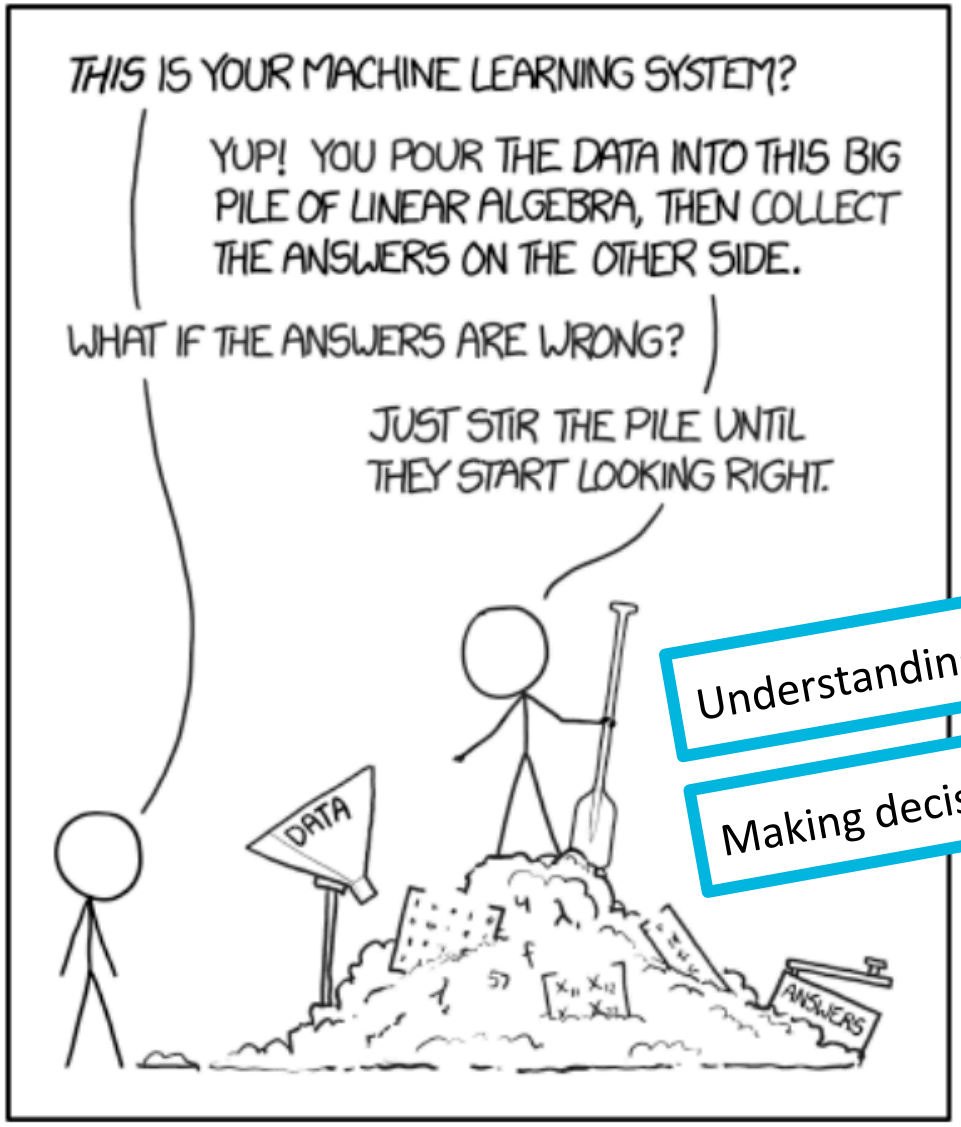






Why are we so afraid of it?

What actually is AI and machine learning?



https://xkcd.com/1838/

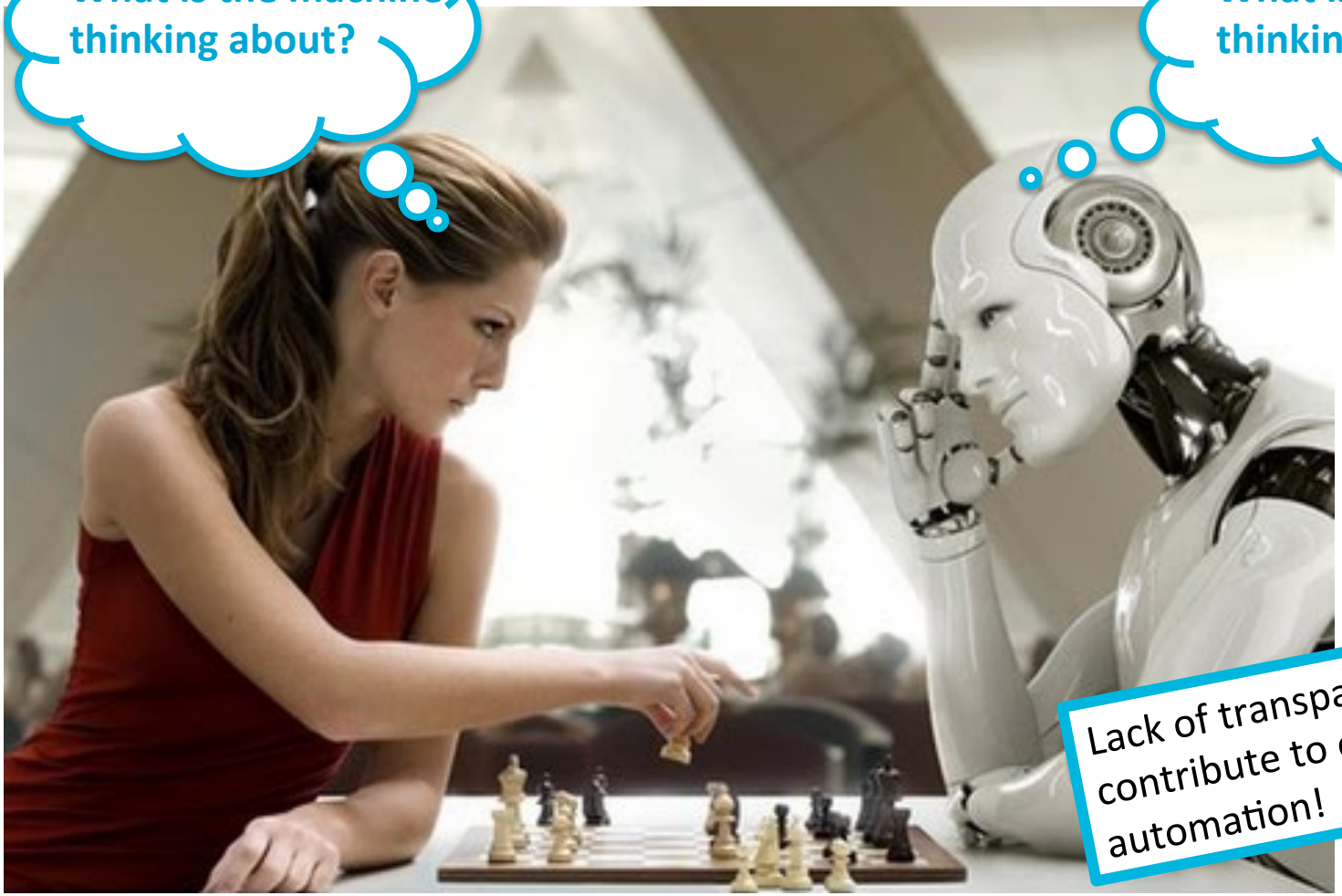
Understanding (pattern recognition)

Making decisions + taking action

Don’t panic: AI (and automation in general) is not expected to fully replace humans just yet

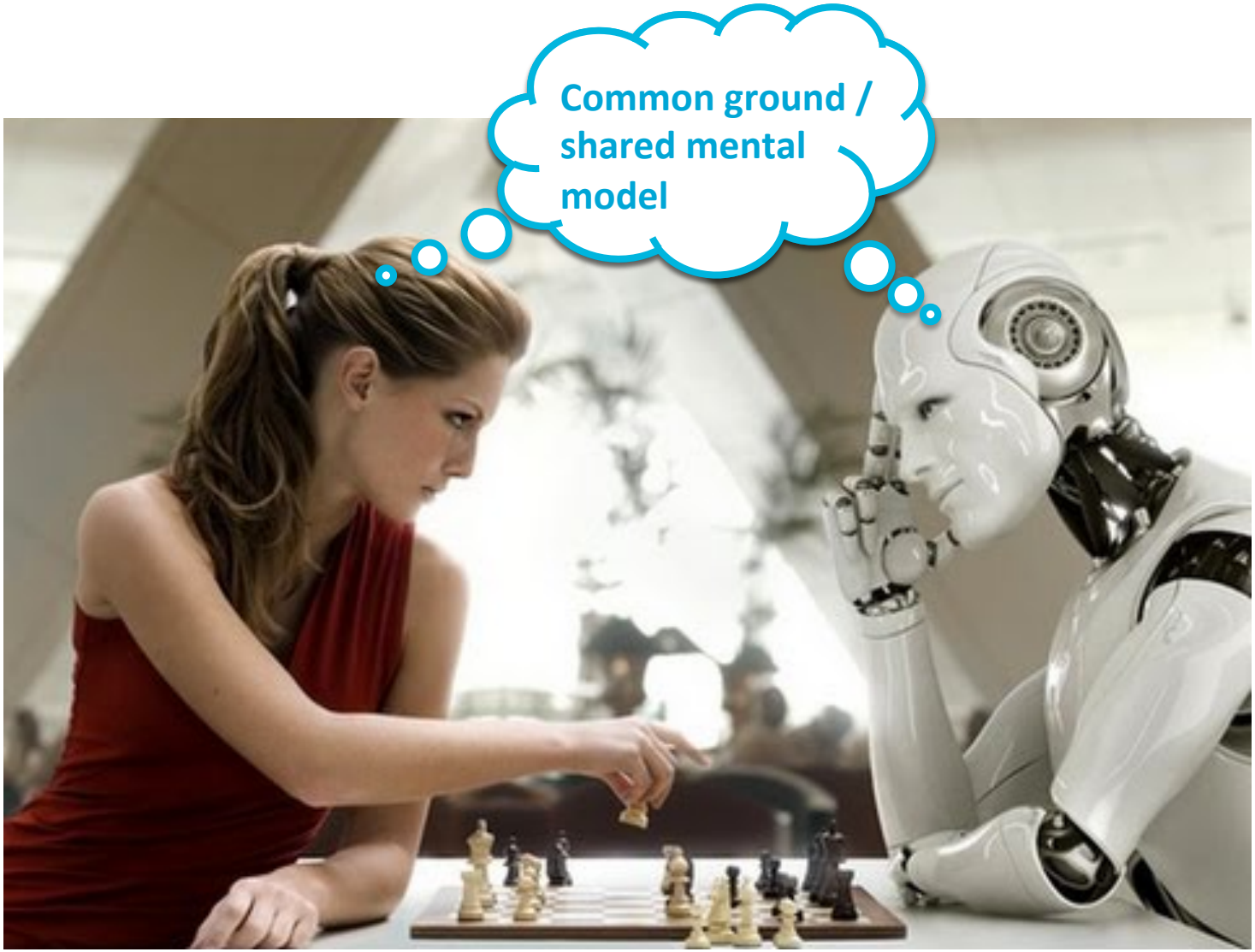
Despite the advances in AI and modeling techniques, we cannot yet guarantee **100% safe** and **reliable** autonomous operations under all possible situations without any human intervention. In the coming decades, the task left for humans is **supervising (highly) automated processes**.

Supervision requires transparency

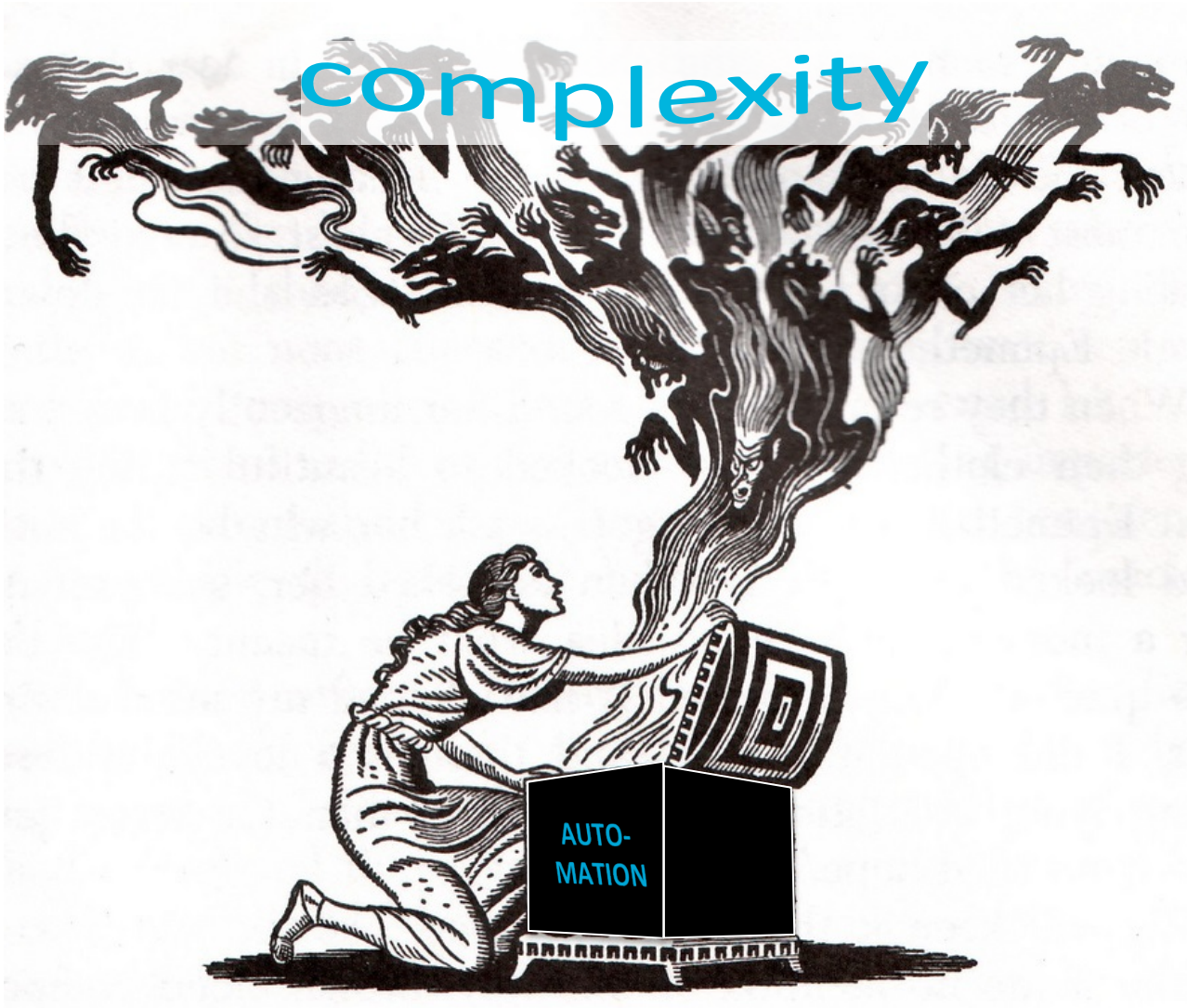


Lack of transparency can contribute to our fear of automation!

One possible solution: establish a common ground



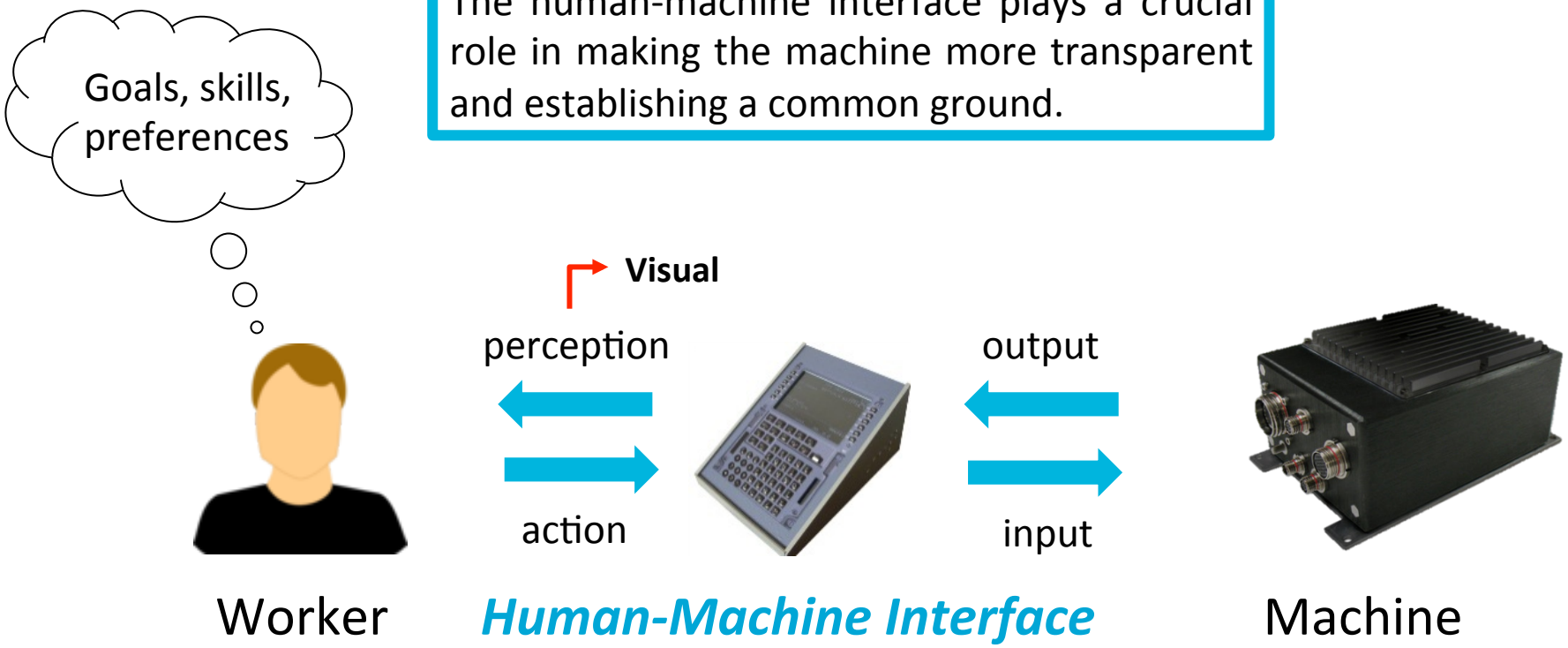
Challenge: how to manage complexity?



THE “ECOLOGICAL” APPROACH

My research: transparent automation through visual representations (on a human-machine interface)

The human-machine interface plays a crucial role in making the machine more transparent and establishing a common ground.



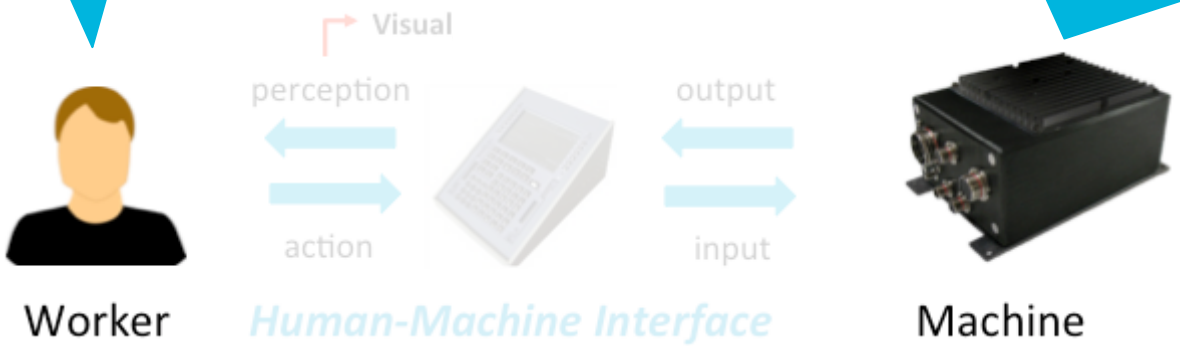
Common approaches to interface design

User-Centered Design

People have limited abilities and information processing capacities to solve problems.

Technology-centered design

Machines are superior in multitasking and accurately and quickly performing repetitive and routine tasks.



The approach determines what will be shown

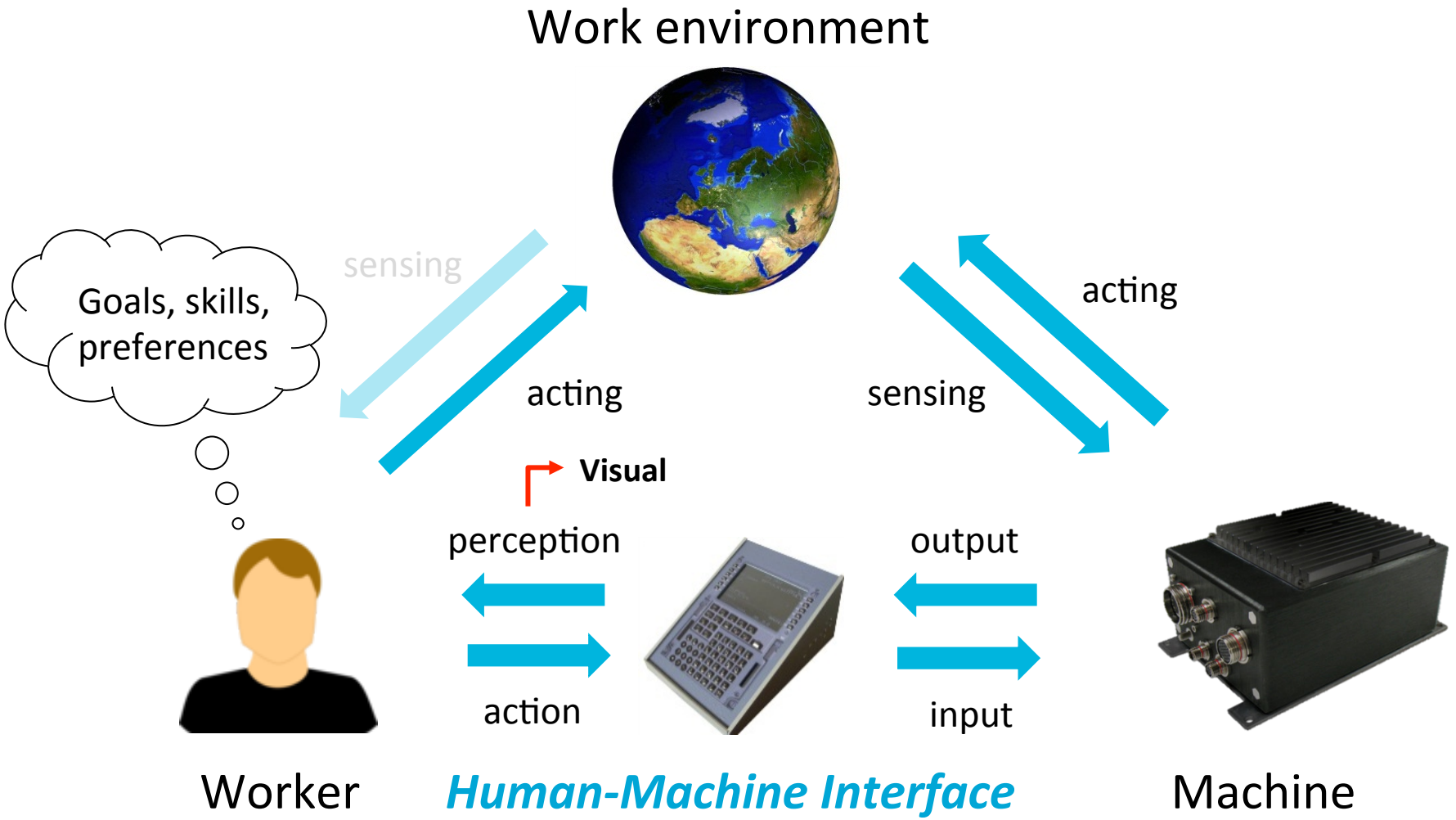
Tailor the interface to the user's needs.
Show information people want and can handle.

People have limited abilities and information processing capacities to solve problems.

Automate the user out of the control loop.
Show nothing or elementary status information.

Machines are superior in multitasking and accurately and quickly performing repetitive and routine tasks.

Ecology-centered design: broader perspective



The work domain (ecology) provides behaviour-shaping constraints

Put the emphasis first on understanding the world!

Rules

Principles

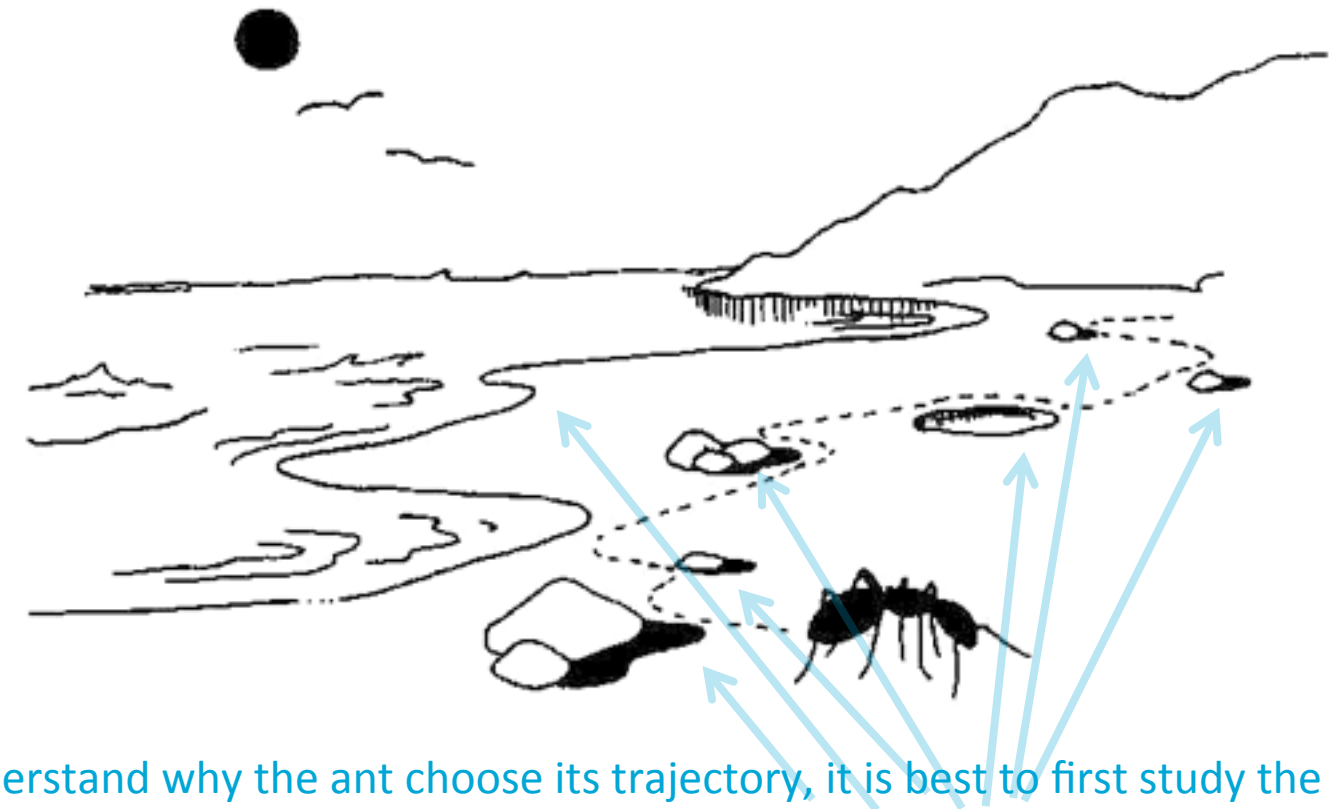
Laws of physics

Irrespective of human and/or automated agents, we all need to obey the laws of physics of the work domain!

Thus, this approach goes beyond the use of colors, fonts and lines, and also specific technical capabilities, by focusing first and foremost on the laws and principles governing work.

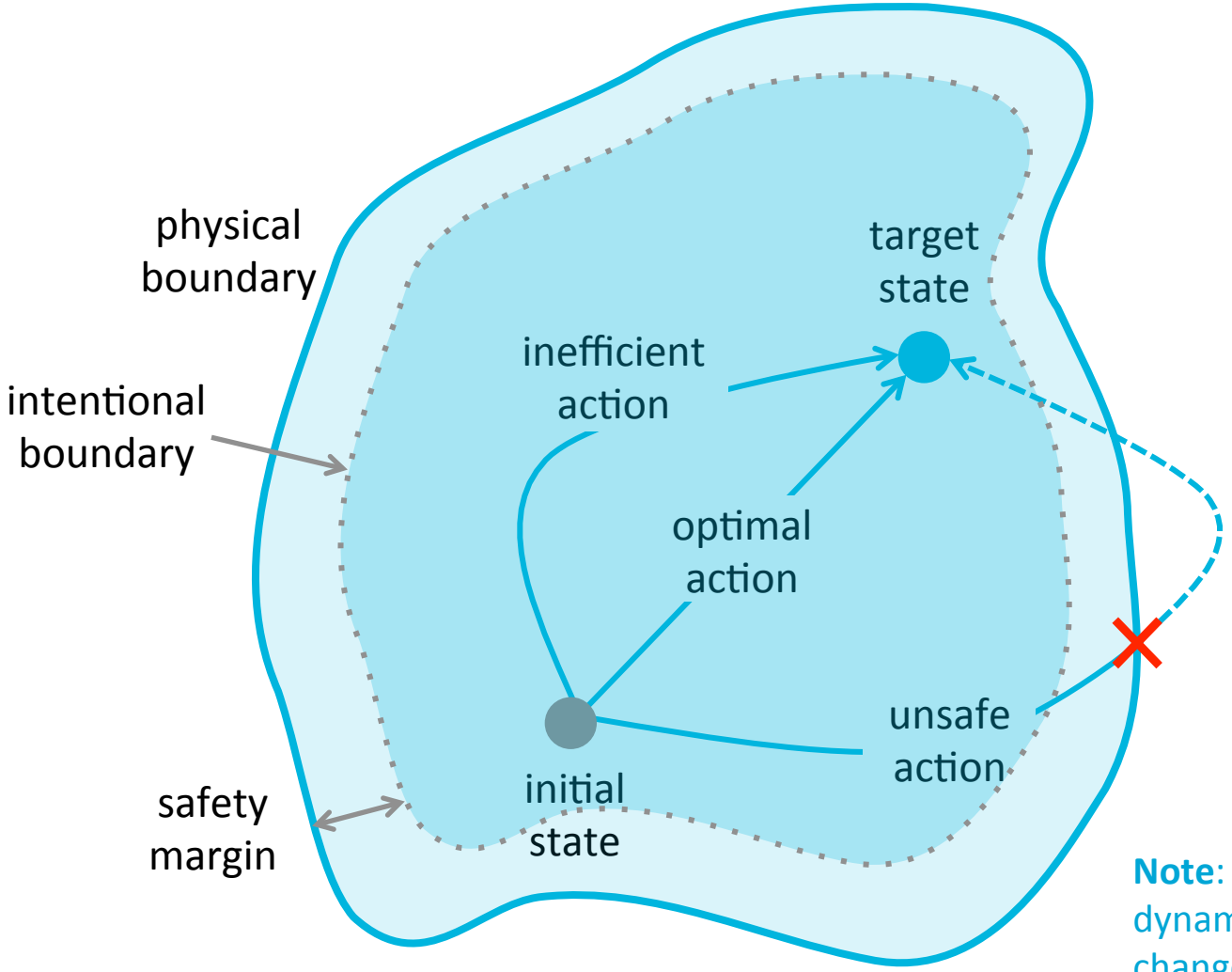
Herbert Simon's "Ant-on-the-Beach" parable

"The Sciences of the Artificial" (1969)



To understand why the ant choose its trajectory, it is best to first study the beach instead of the ant's mind, because the beach provides **behaviour-shaping constraints**.

Ecological Interface Design (Vicente & Rasmussen, 1992)



Note: boundaries are dynamic in nature and can change over time.

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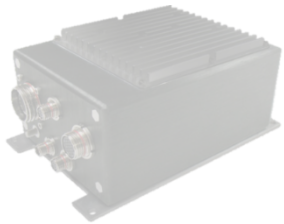


Involve the user and facilitate adaptivity and creativity.
Show (physical) boundaries and constraints on actions.

People are creative problem solvers who can adapt to novel work domain states or situations.

So what is the ecological approach?

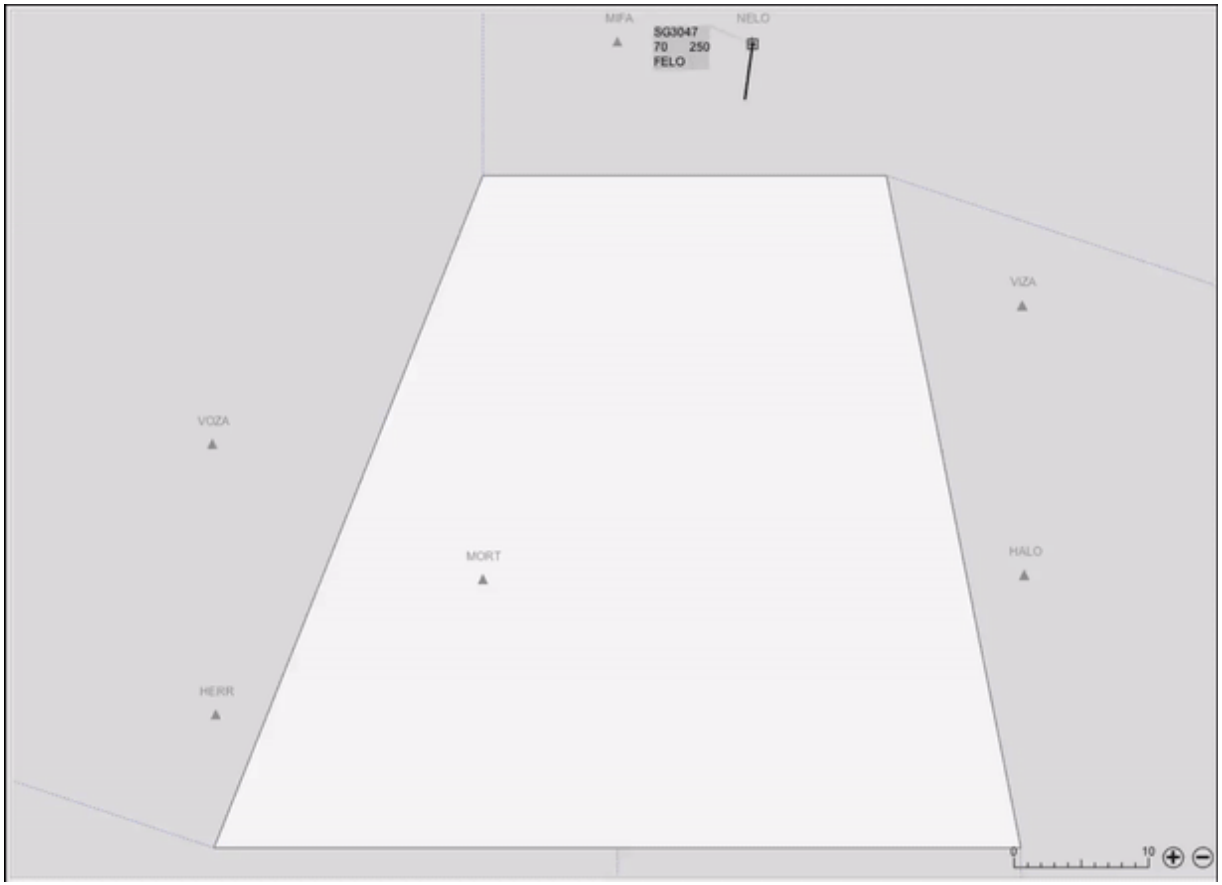
My definition:

Ecological Interface Design is a **design framework** that encourages a **constraint-based approach** with the goal to visualize the **space of possibilities*** in a way that supports people's **skill-, rule- and knowledge-based behavior**.

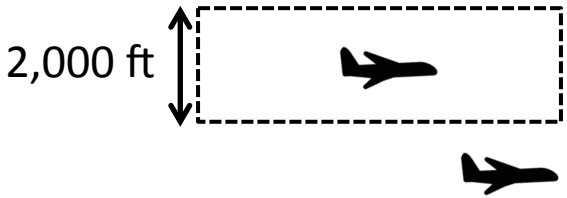
* **space of possibilities**: opportunities for action governed by laws (of physics), principles and rules of the work environment.

EXAMPLE IN AIR TRAFFIC CONTROL

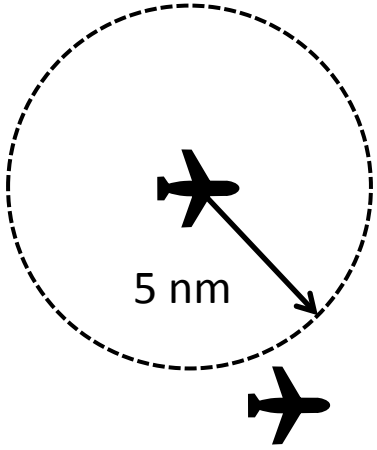
ATC: Keep the moving blips safely separated



Vertical separation

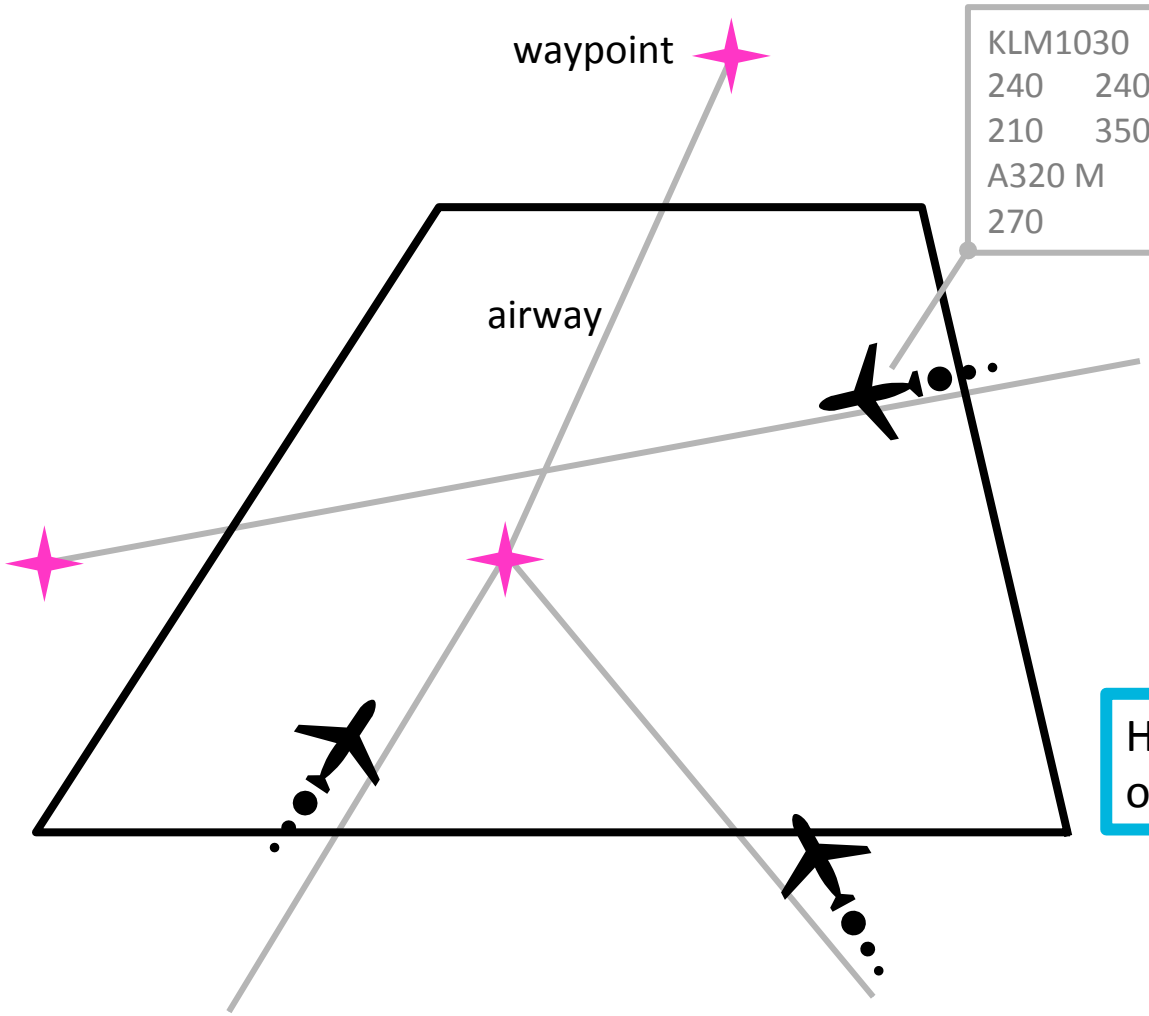


Horizontal separation



Current means to control traffic

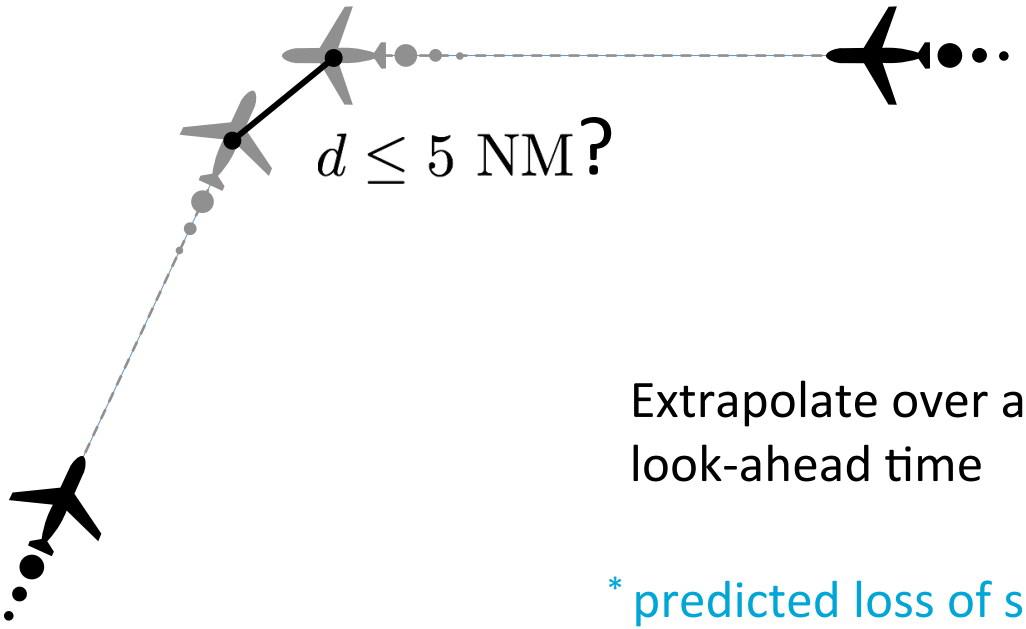
Electronic radar screen: Plan View Display



Humans base their decisions on this information!

Crash course in conflict detection & resolution

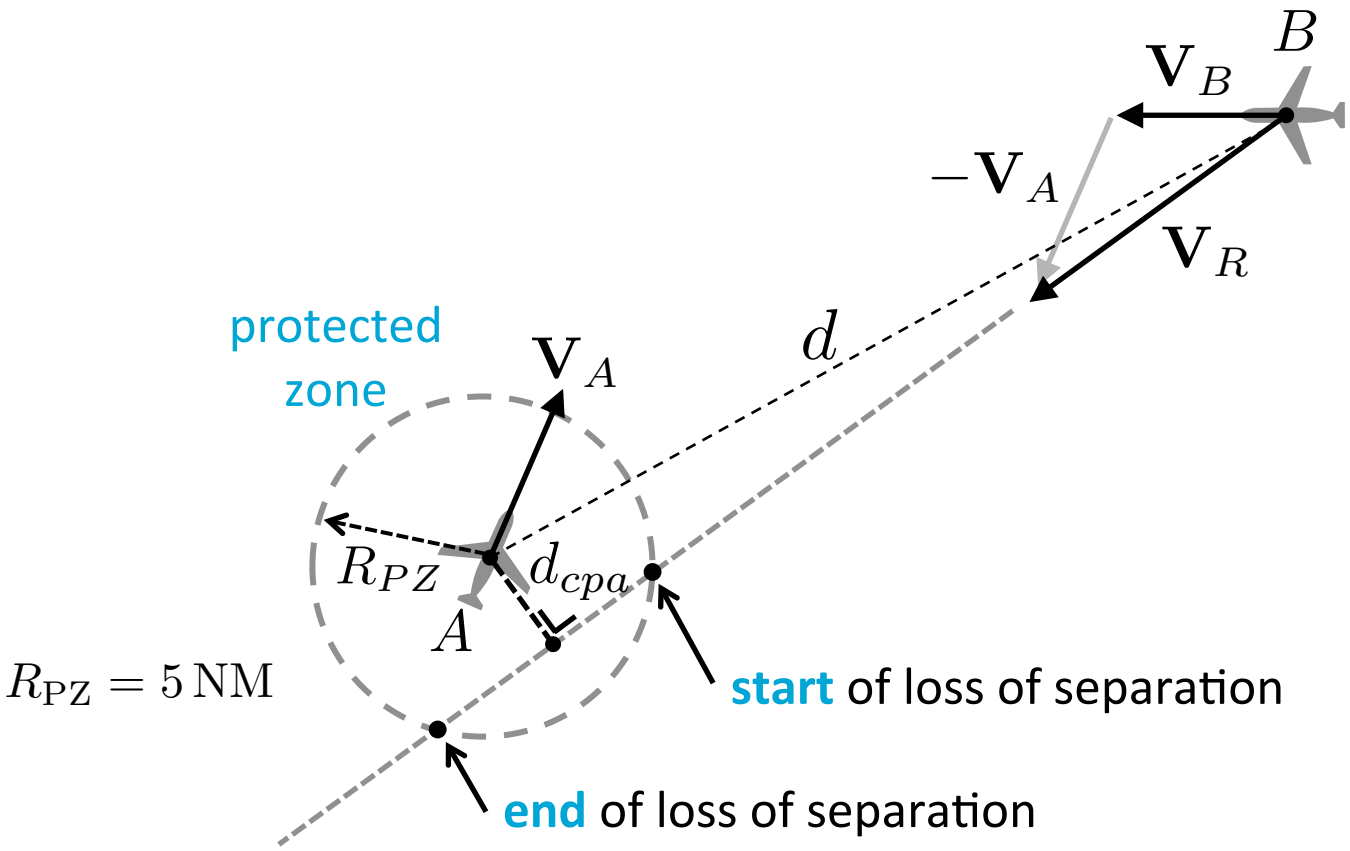
Are these two aircraft in a conflict*?



Extrapolate over a certain look-ahead time

* predicted loss of separation

Deeper structure of the control problem



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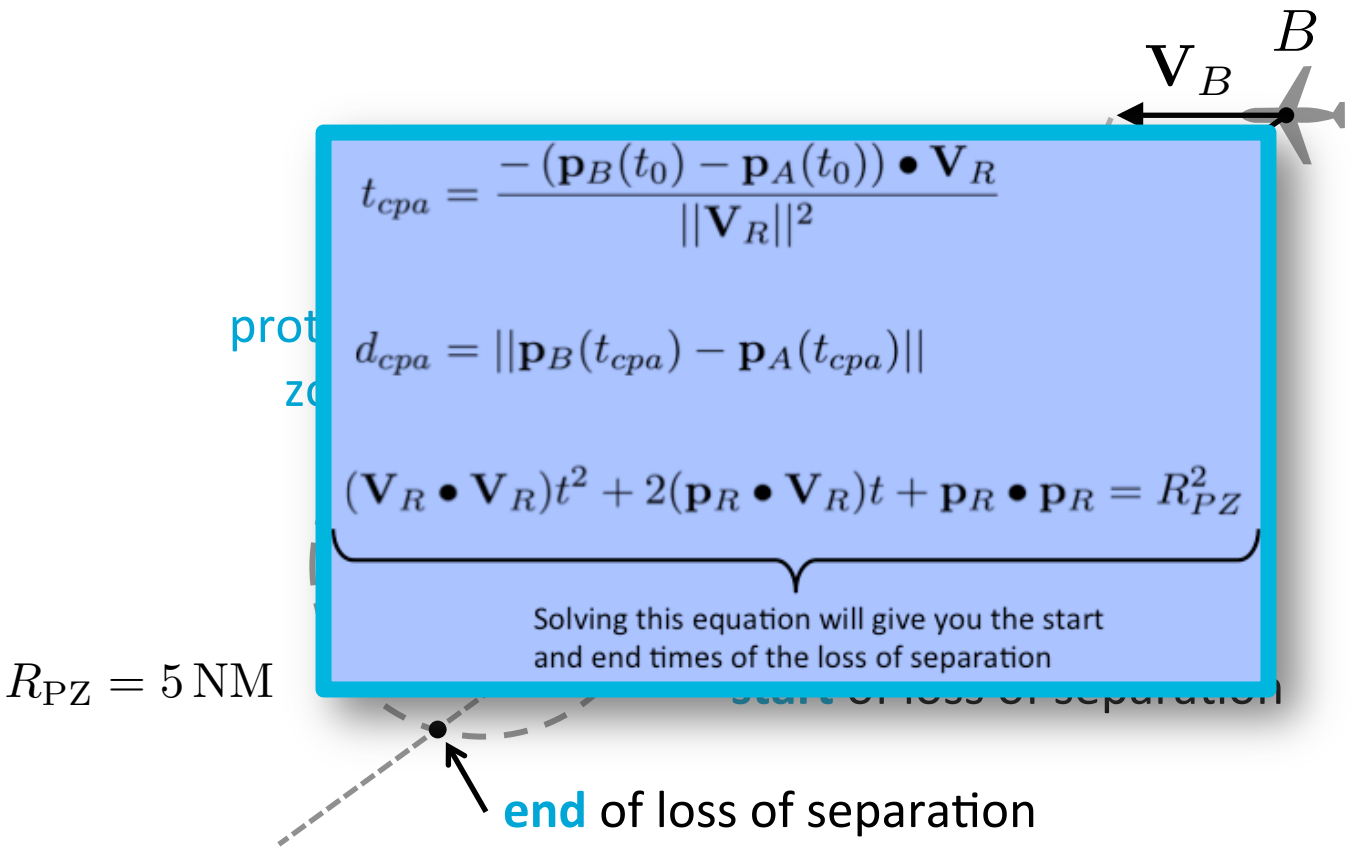
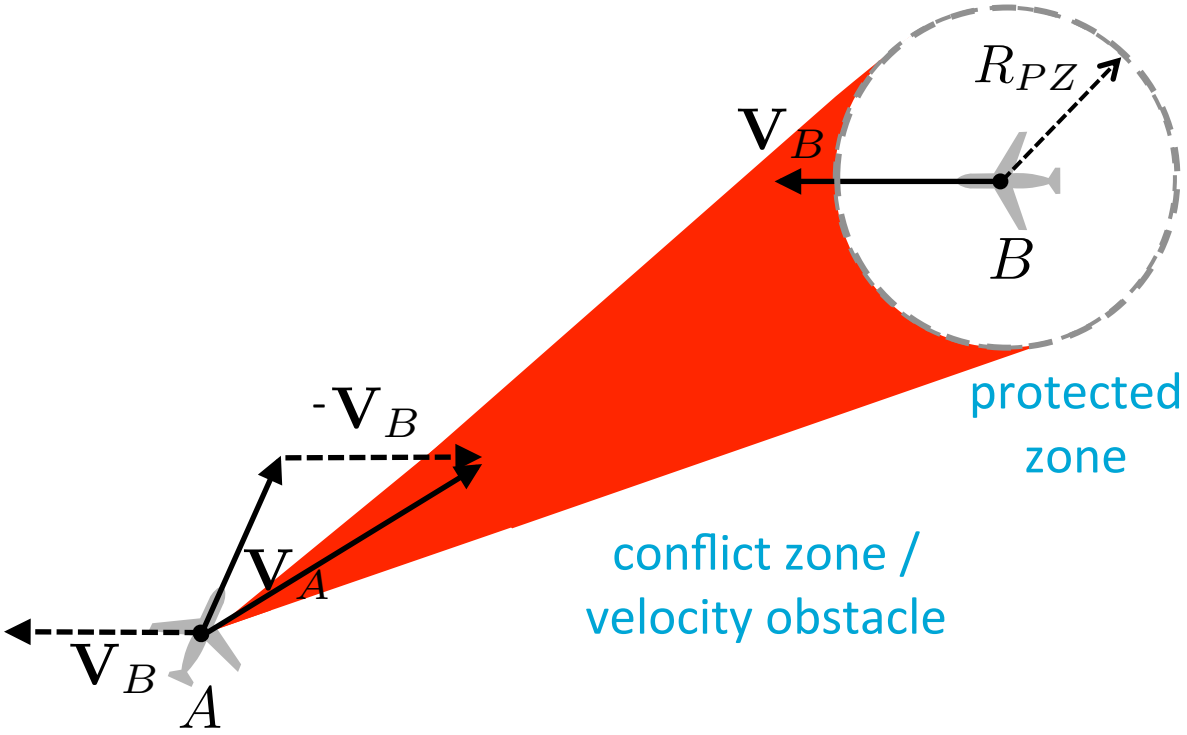


How to share this model with humans?

EID: find an alternative representation for conflict detection & resolution that can be visualized.



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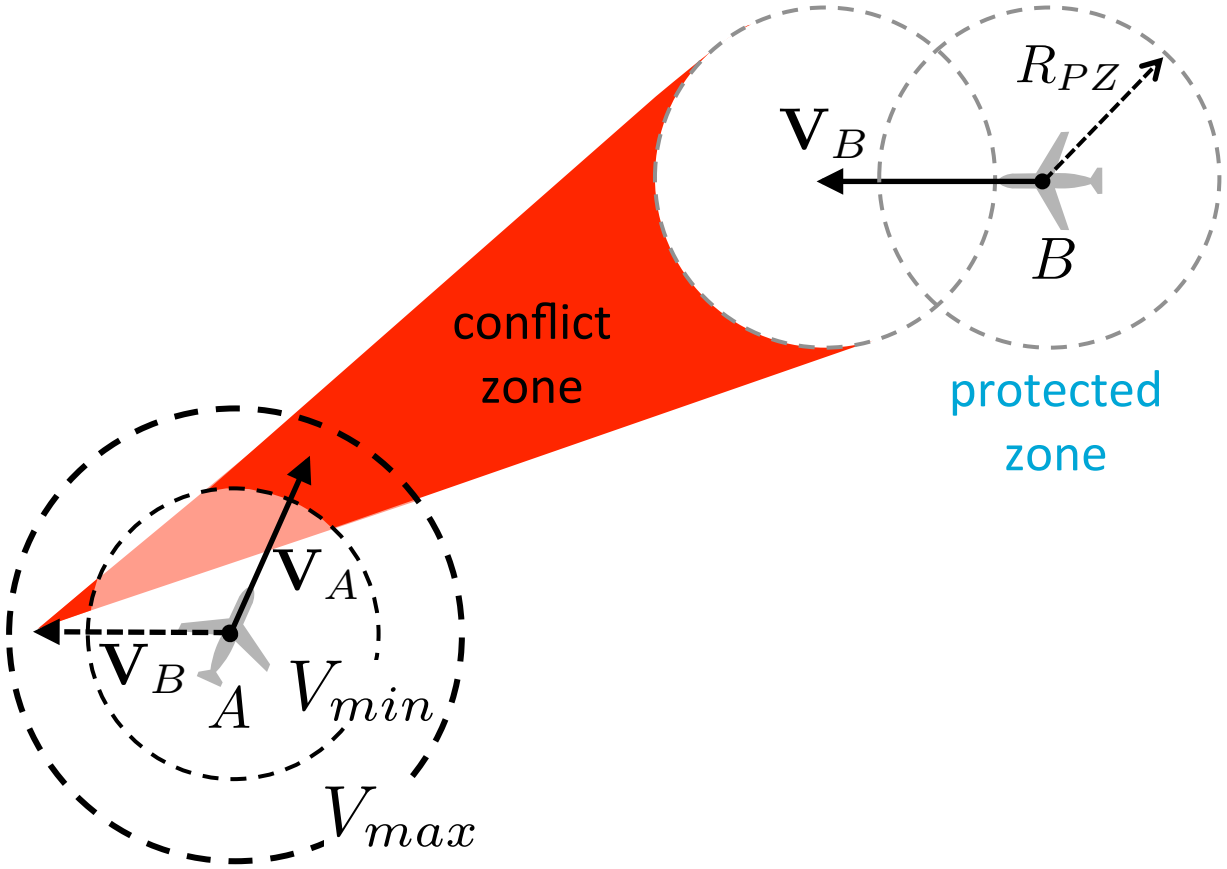

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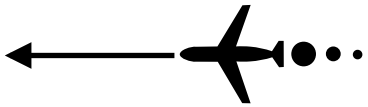

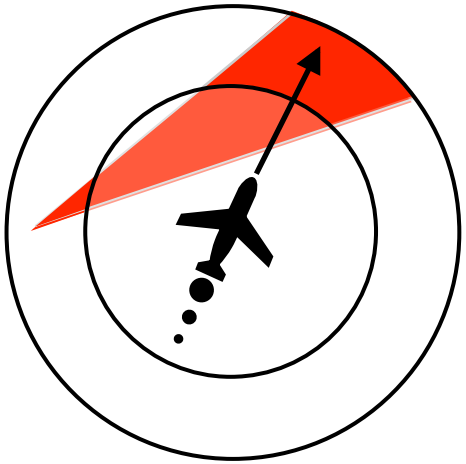

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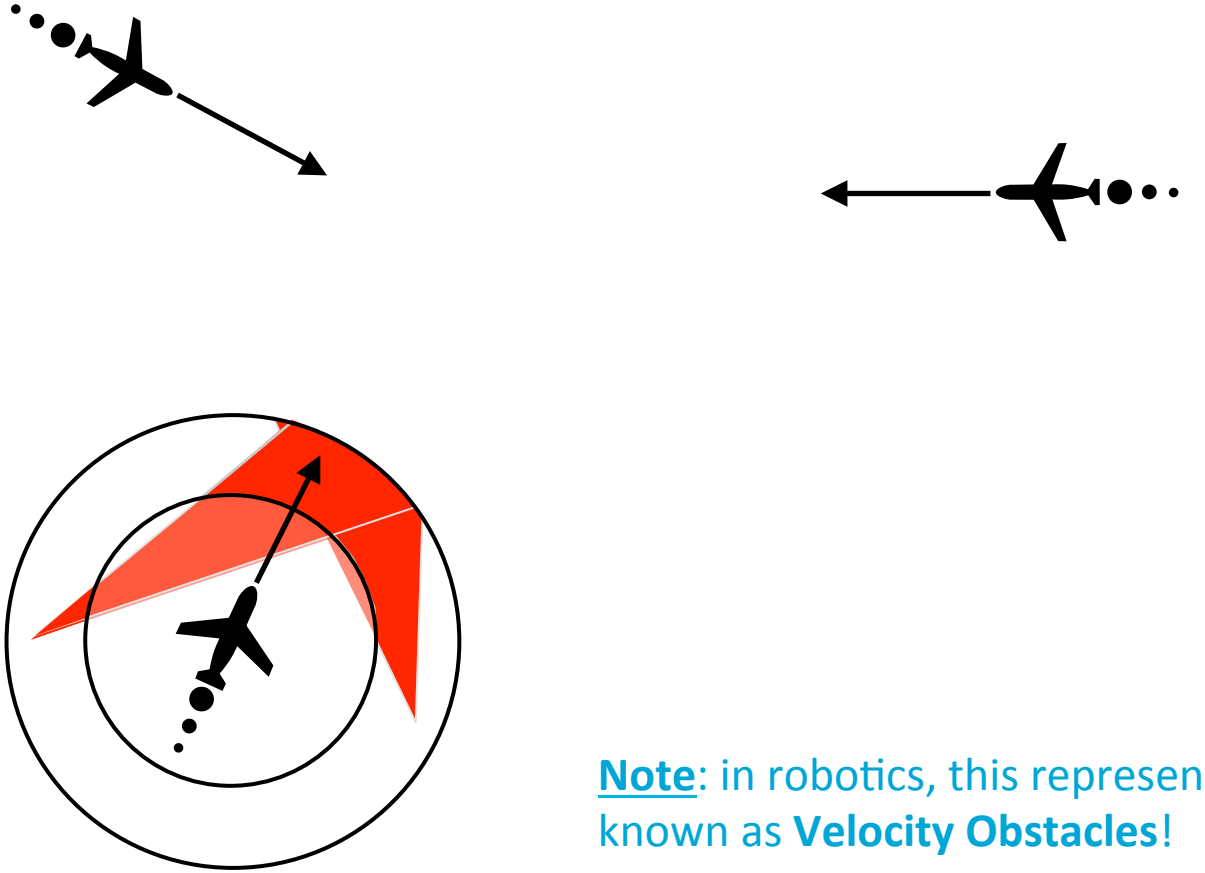
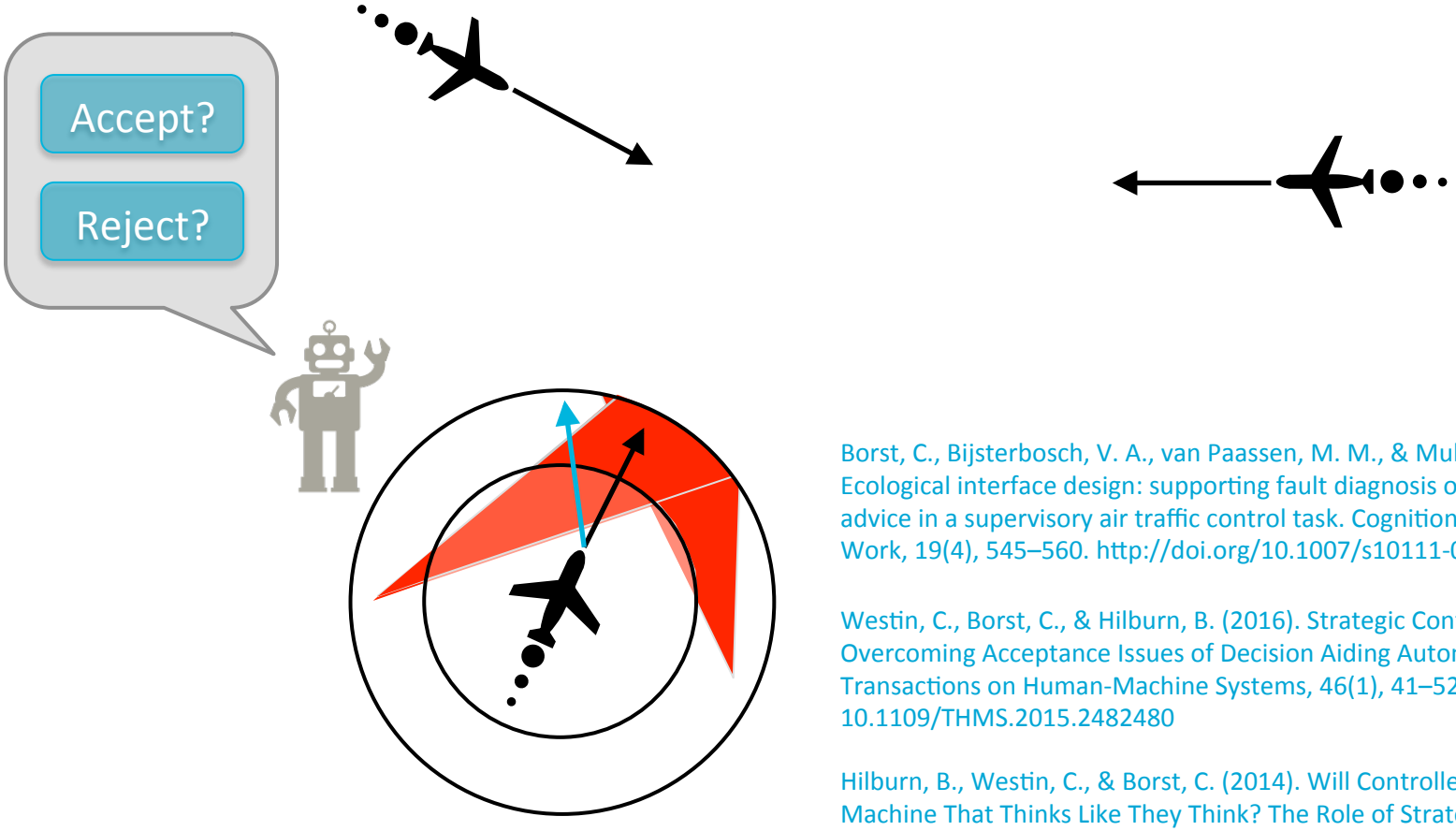


Note: in robotics, this representation is known as **Velocity Obstacles**!

Facilitate human-automation collaboration?

EID: find an alternative representation for conflict detection & resolution that can be visualized.



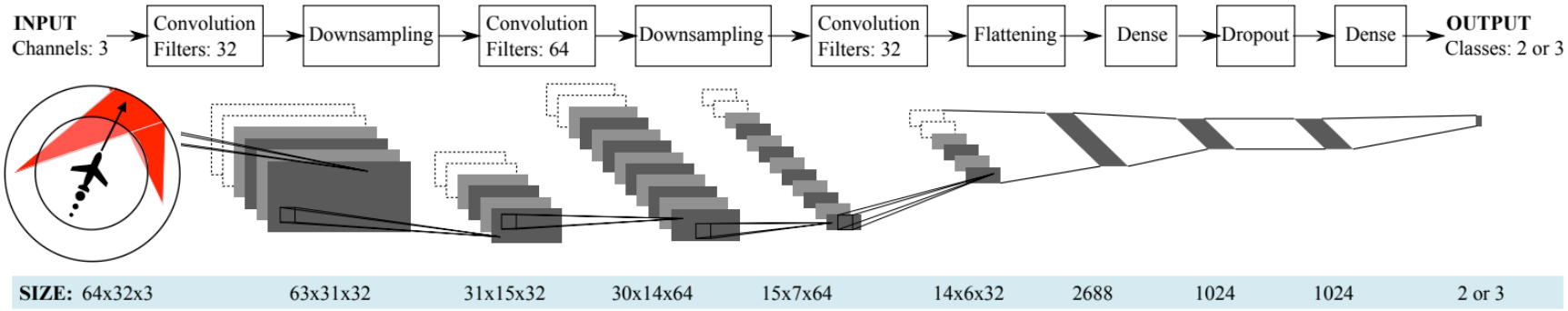
Borst, C., Bijsterbosch, V. A., van Paassen, M. M., & Mulder, M. (2017). Ecological interface design: supporting fault diagnosis of automated advice in a supervisory air traffic control task. Cognition, Technology & Work, 19(4), 545–560. http://doi.org/10.1007/s10111-017-0438-y

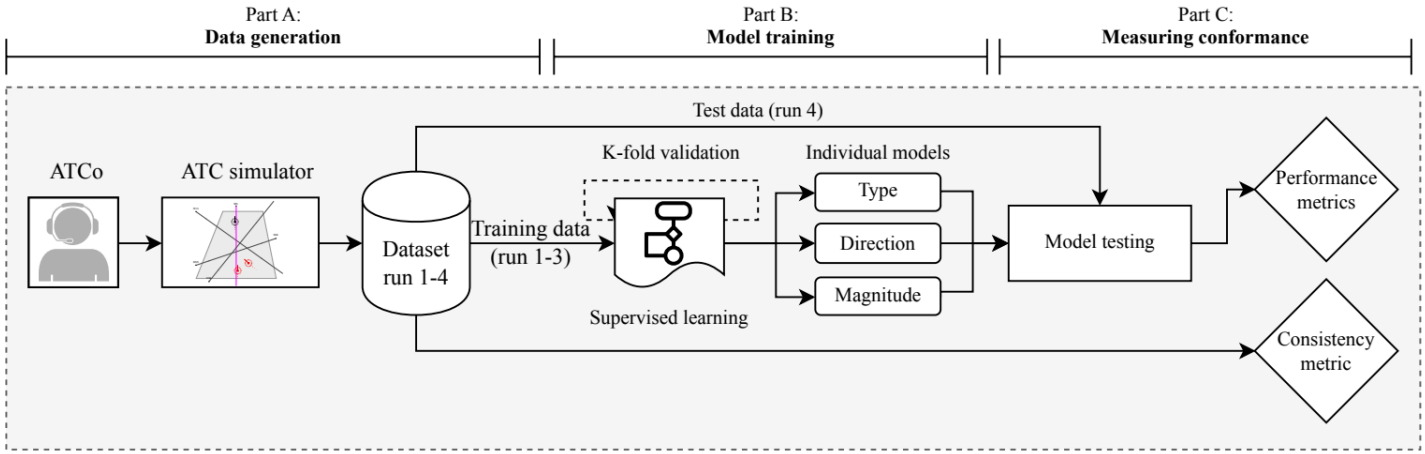
Westin, C., Borst, C., & Hilburn, B. (2016). Strategic Conformance: Overcoming Acceptance Issues of Decision Aiding Automation? IEEE Transactions on Human-Machine Systems, 46(1), 41–52. http://doi.org/10.1109/THMS.2015.2482480

Hilburn, B., Westin, C., & Borst, C. (2014). Will Controllers Accept a Machine That Thinks Like They Think? The Role of Strategic Conformance in Decision Aiding Automation. Air Traffic Control Quarterly, 22(2), 115–136.

How to share this visual model with a computer?

Convolutional Neural Networks – good for processing image data



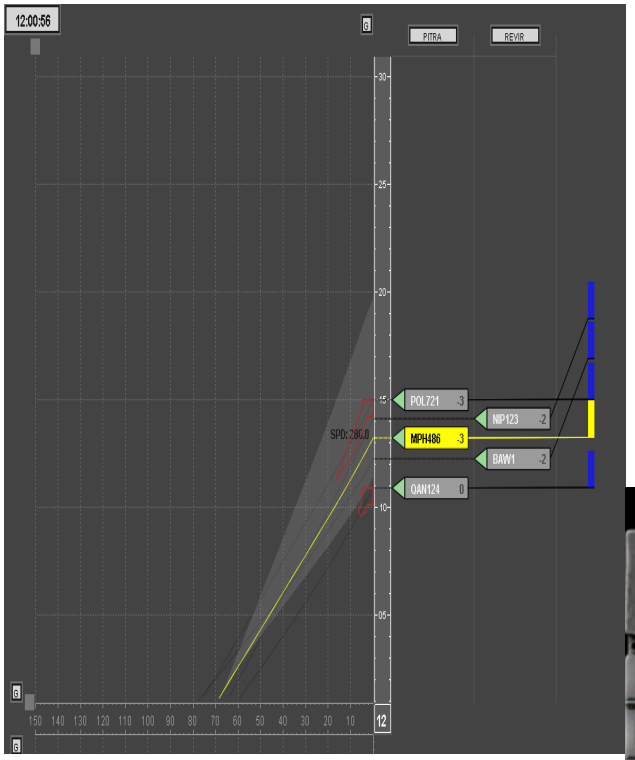


Rooijen, S. J. Van, Ellerbroek, J., Borst, C., & Kampen, E.-J. Van. (2019). Conformal Automation for Air Traffic Control using Convolutional Neural Networks. In Thirteenth USA/Europe Air Traffic Management Research and Development Seminar (pp. 1–10). Vienna.

OUTLOOK

Using all our other ecological displays as a basis for machine learning

Aircraft energy management



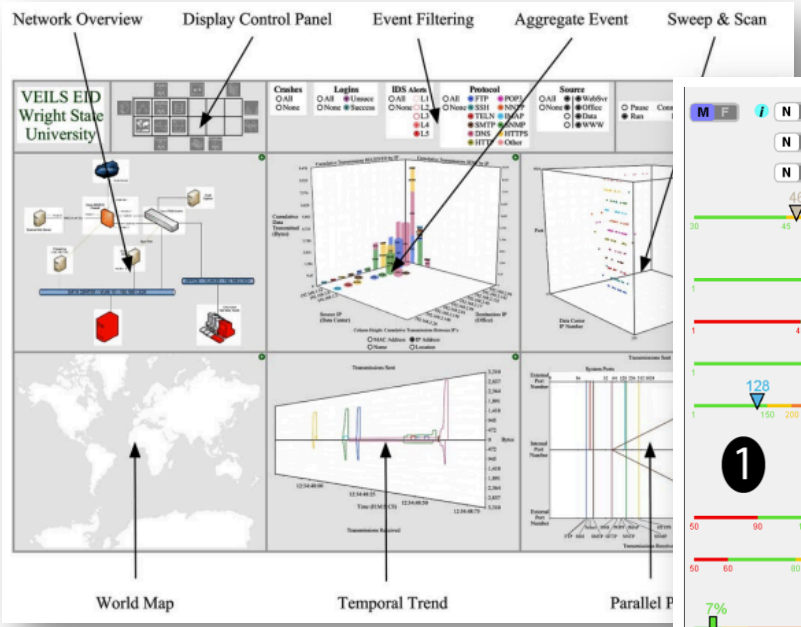
Aircraft terrain avoidance

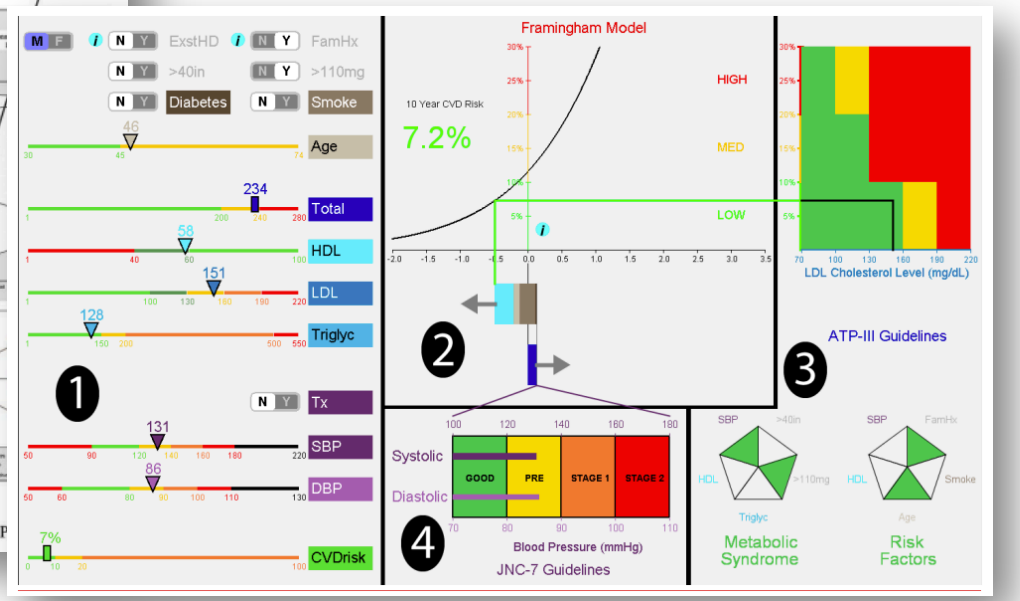
Aircraft arrival management (planning & sequencing task)

and many more…

Ecological displays exist in other fields as well

Cyber security: computer network defense





Medical: assessing risks of cardiac disease

…and process control, power plants, automotive domain, etc.

Concluding remarks

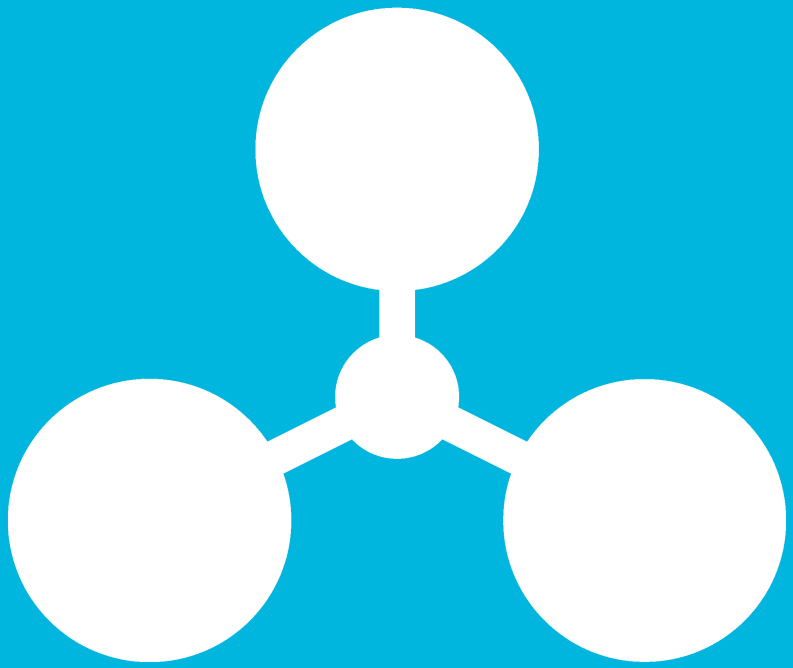
- Ecological interfaces should not be interpreted as “natural” and “intuitive” displays!
- Designing ecological displays requires a deep understanding of the control problem to be solved!
- A remaining challenge is how much domain complexity can be shared with humans!
- How “ecological” automation impacts human understanding, acceptance, trust, etc. is ongoing research!

Further reading:

Van Paassen, M. M., Borst, C., Ellerbroek., J., Mulder, M., & Flach, J. M. (2018). Ecological Interface Design for Vehicle Locomotion Control. IEEE Transactions on Human-Machine Systems, 48(5), 541–555. http://doi.org/10.1109/THMS.2018.2860601

Borst, C., Flach, J. M., & Ellerbroek, J. (2015). Beyond Ecological Interface Design: Lessons From Concerns and Misconceptions. IEEE Transactions on Human-Machine Systems, 45(2), 164–175. http://doi.org/10.1109/THMS.2014.2364984

TU Delft



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