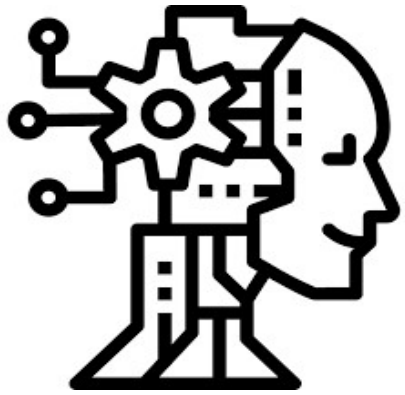
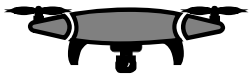
Institute for Flight Systems
Applied Artificial Intelligence for Dynamic Systems





Emergency in the Air: AI as a companion?

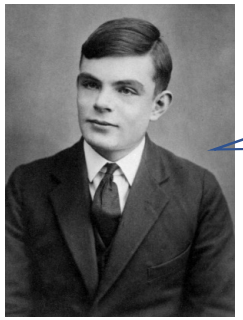
Jun.-Prof. Dr.-Ing. Jane Jean Kiam
jane.kiam@unibw.de
M.Sc. Prakash Jamakatel
Univ.-Prof. Dr.-Ing. Axel Schulte

Forschungsgruppe: Angewandte KI für dynamische Systeme

der Bundeswehr Universität München

What is AI?

© wikipedia



Alan Turing (23.06.1912-07.06.1954)
– father of computer science

I propose to consider the question, "Can machines think?"

Alan Turing (1950)
=> AI is a system that thinks like humans.

It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

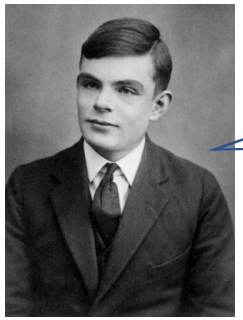
© wikipedia

John McCarthy (94.09.1927-24.10.2011)
– father of artificial intelligence

John McCarthy (2007)
=> but AI does not have to confine itself to methods that are biologically observable

What is AI?

© wikipedia



I propose to consider the question, "Can machines think?"

Alan Turing (1950)
=> AI is a system that thinks like humans.

Alan Turing (23.06.1912-07.06.1954)
– father of computer science

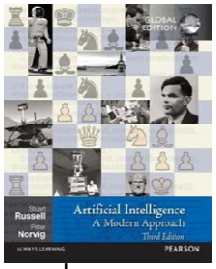
It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.

© wikipedia

John McCarthy (2007)
=> but AI does not have to confine itself to methods that are biologically observable

John McCarthy (94.09.1927-24.10.2011)
– father of artificial intelligence

From the textbook by Stuart Russell und Peter Norvig:



Thinking Humanly:
- "The exciting new effort to make computers think . . . machines with minds, in the full and literal sense." (Haugeland, 1985)
- "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)

Thinking Rationally:
- "The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)
- "The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)

Acting Humanly:
- "The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)
- "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)

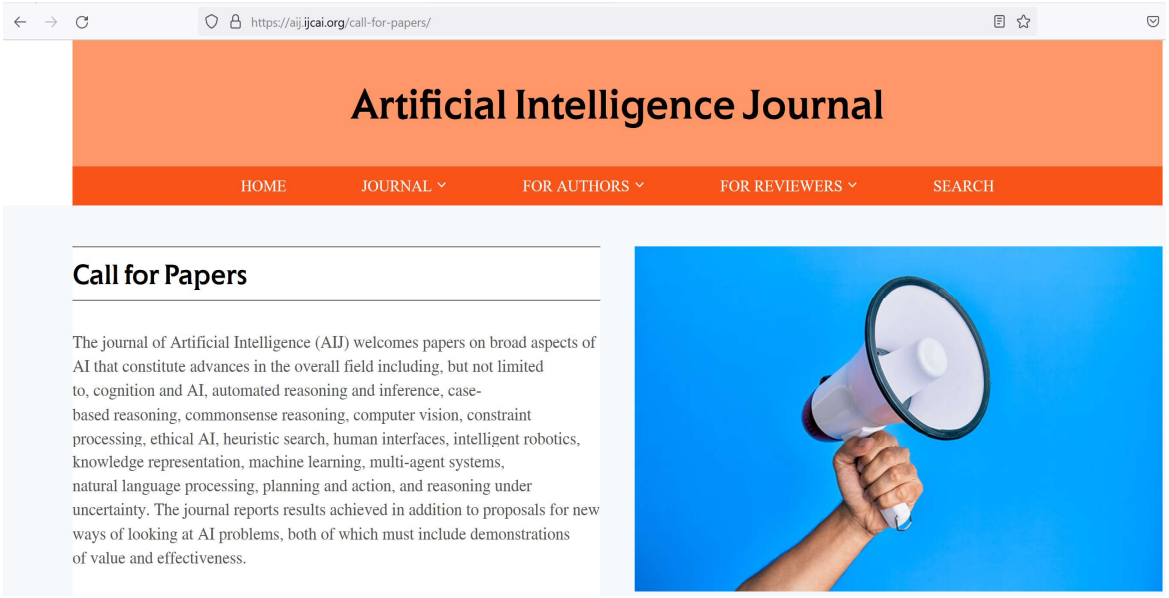
Acting Rationally:
- "Computational Intelligence is the study of the design of intelligent agents." (Poole et al., 1998)
- "AI . . . is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

What is AI?

- AI evolves, with hardware availability, with algorithmic capability, and with its own achievements.
- AI is multifaceted, it is inclusive, rather than exclusive.

IJCAI – International Joint Conference in Artificial Intelligence
(Sessions in 2022):

- Agent-based and multi-agent systems
- Computer vision
- Machine learning
- AI ethics, trust and fairness
- Data mining
- Knowledge representation and reasoning
- Constraint satisfaction and optimization
- Search
- Planning and scheduling
- Natural language processing



Given a planning problem: $P = < D, s_0, G >$, what is the plan (sequence of actions) to achieve the set of goals G ?

In AI-planning, P can be of any domain => The solver is hence the *domain-independent planner.*

Univ

International Conference on Automated Planning and Scheduling (ICAPS)

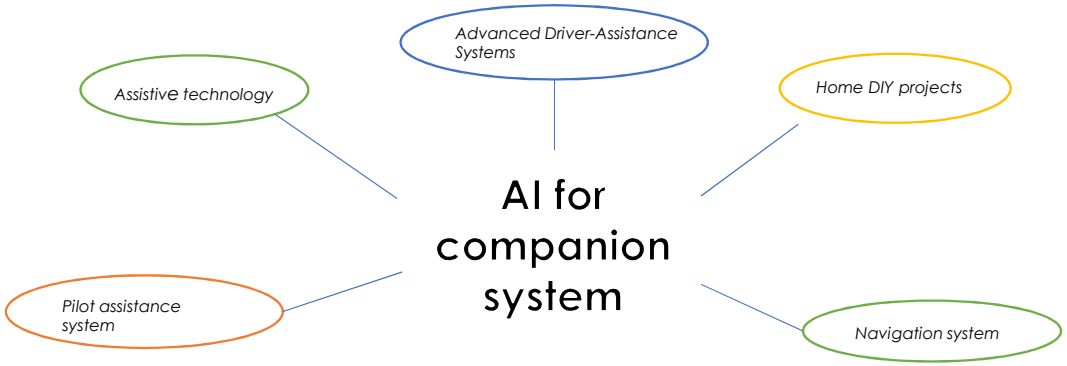
LRT

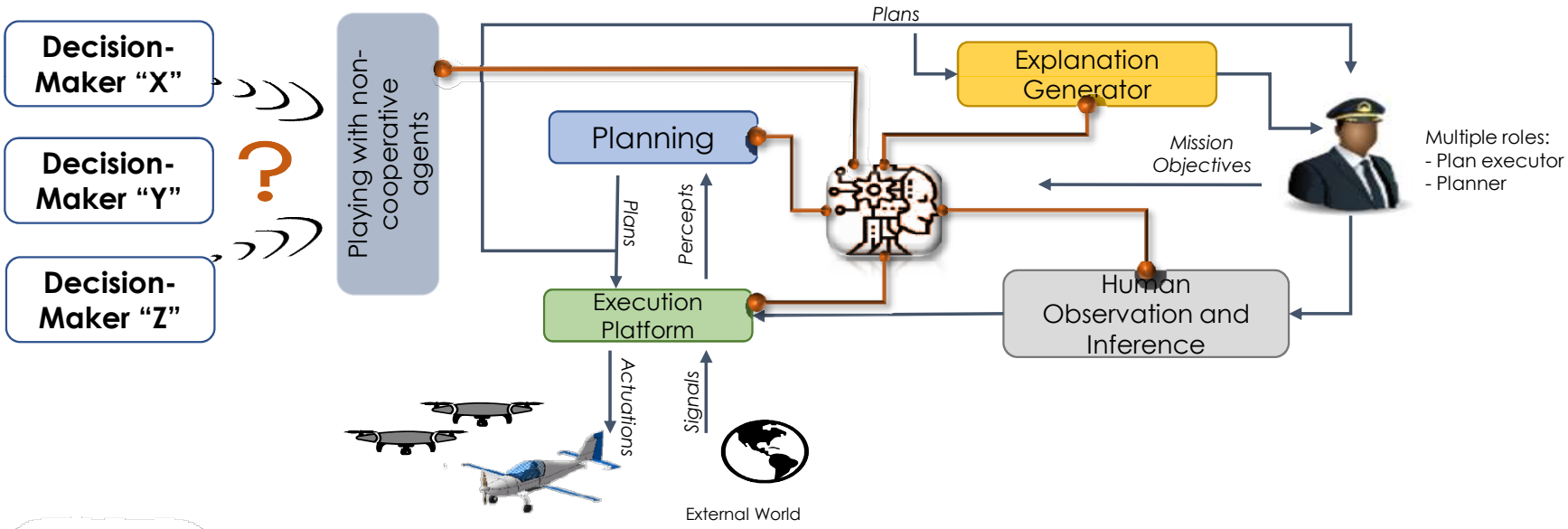
AI as a companion system

What is a companion system?

*A cognitive technical system that has the following characteristics**

- *Competence*
- *Individuality*
- *Adaptability*
- *Availability*
- *Cooperativeness and trustworthiness*





AI as a companion system in aviation

*Susanne Biundo, Andreas Wendemut; "Companion-Technology for Cognitive Technical Sytems", Künstliche Intelligenz, 30:71-75, 2016.

der Bundeswehr Universität München

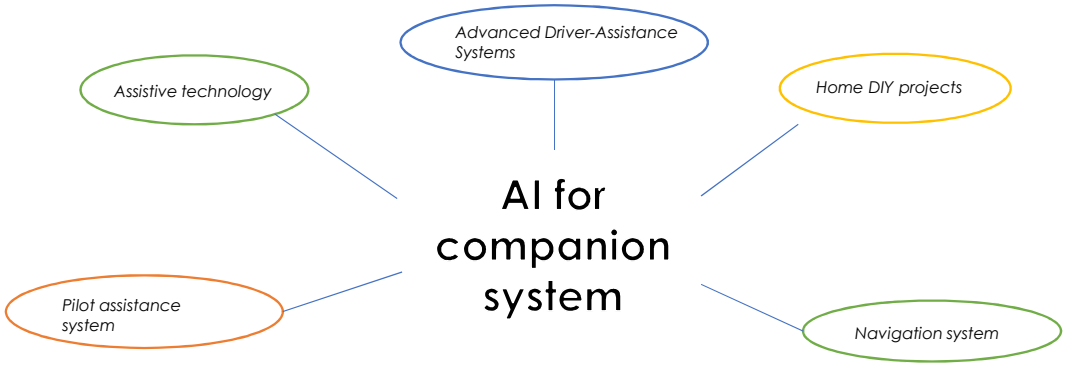
IFS LRT

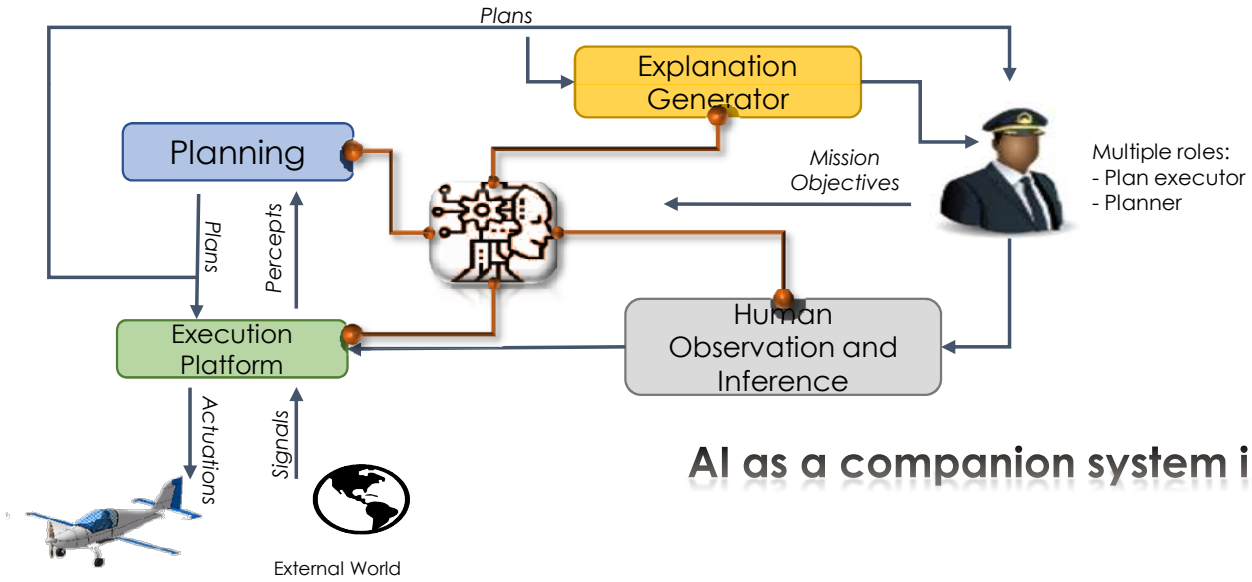
AI as a companion system

What is a companion system?

*A cognitive technical system that has the following characteristics**

- *Competence*
- *Individuality*
- *Adaptability*
- *Availability*
- *Cooperativeness and trustworthiness*



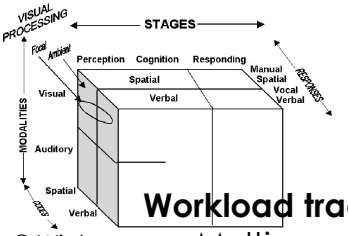


AI as a companion system in aviation

der Bundeswehr Universität München

IFS LRT

Pilot assistance system for Single Pilot Operations: FRICO



© Wickens

Workload tracking
- Multi-resource mental workload
- Context-rich workload assessment

Intention tracking
- Plan recognition
- Goal recognition

Activity tracking
- Gaze tracker
- Interaction tracking
- Speech recognition

[redacted]

FRICO
your FRIendly CO-pilot

Personalising pilot's preferences
- Learning of human model (knowledge, computational capacity, preferences)

Flight guidance
- Optimal flight path planning
- Assistance in emergency situations (low-fuel, defect, incapacitation)

Cockpit dialog
- Transparency and interpretability/explicability
- Mixed-initiative decision-making

der Bundeswehr Universität München

IFS LRT

FRICO's Framework

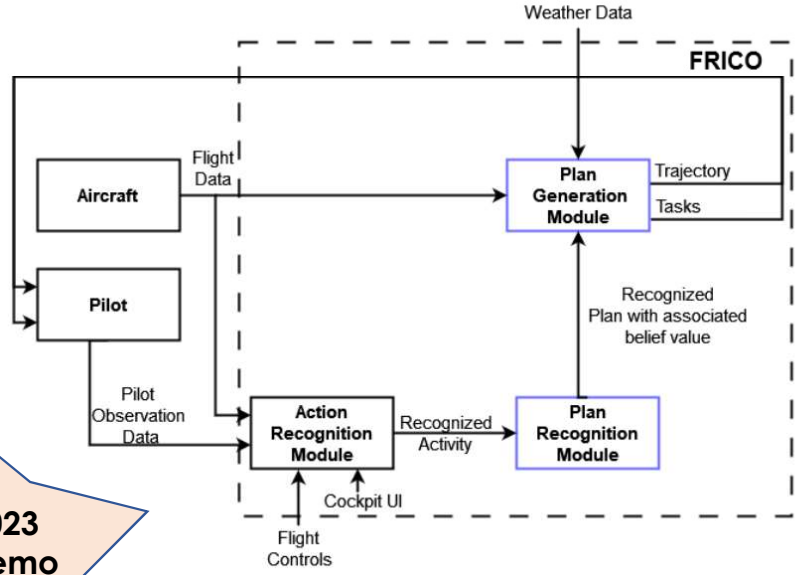
FRICO
your FRIendly CO-pilot

- Pilot assistance system based on *domain-independent planning and scheduling methods* =>*for more* (re-)usability
- Open source, open architecture => for more transparency

Automated planning
- Given the start state, what sequence of decisions will achieve our goal
- *Planning consists of synthesizing an organized set of actions to achieve some purpose ["Automated Planning: Theory and Practive", Malik Ghallab, Dana Nau and Paolo Traverso, 2004]*

Planning and acting
- Planning by considering the deliberative acting of an agent *["Automated Planning and Acting", Malik Ghallab, Dana Nau and Paolo Traverso, 2016]*
- Acting is how to perform chosen actions (≠Execution) by adapting actions and reacting to current context

FRICO: General architecture

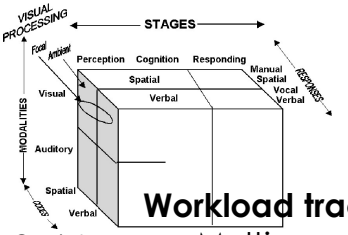


ICAPS 2023 System Demo Track

der Bundeswehr Universität München

IFS LRT

AI-Planning in FRICO



© Wickens

Workload tracking
- Multi-resource mental workload
- Context-rich workload assessment

Flight guidance
- Optimal flight path planning
- Assistance in emergency situations (low-fuel, defect, incapacitation)

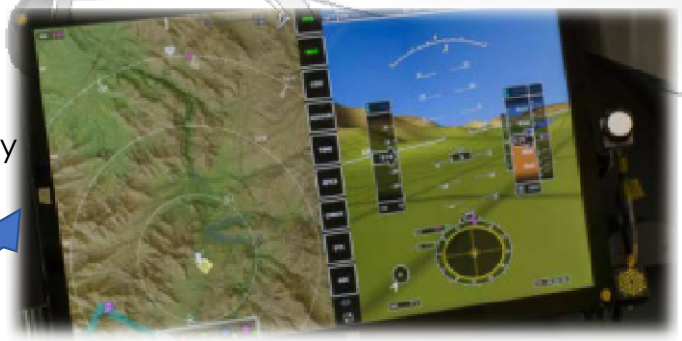
Intention tracking
- Plan recognition
- Goal recognition

Activity tracking
- Gaze tracker
- Interaction tracking
- Speech recognition

FRICO
your FRIendly CO-pilot

Personalising pilot's preferences
- Learning of human model (knowledge, computational capacity, preferences)

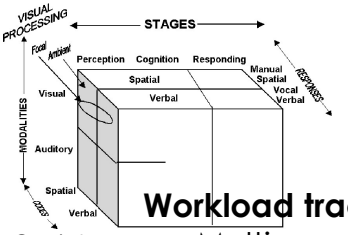
Cockpit dialog
- Transparency and interpretability/explicability
- Mixed-initiative decision-making



der Bundeswehr Universität München

IFS LRT

AI-Planning in FRICO: Current development



© Wickens

Workload tracking
- Multi-resource mental workload
- Context-rich workload assessment

Intention tracking
- Plan recognition
- Goal recognition

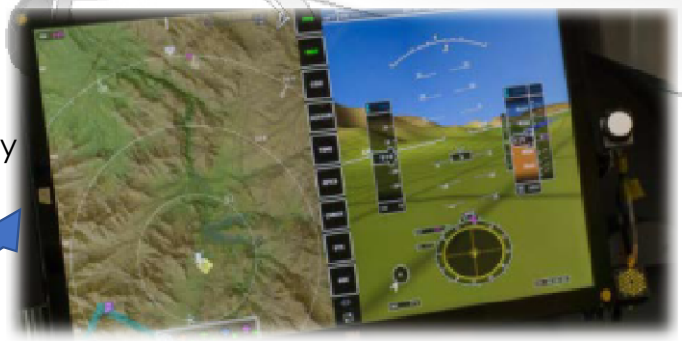
Activity tracking
- Gaze tracker
- Interaction tracking
- Speech recognition

FRICO
your FRIendly CO-pilot

Personalising pilot's preferences
- Learning of human model (knowledge, computational capacity, preferences)

Flight guidance
- Optimal flight path planning
- Assistance in emergency situations (low-fuel, defect, incapacitation)

Cockpit dialog
- Transparency and interpretability/explicability
- Mixed-initiative decision-making

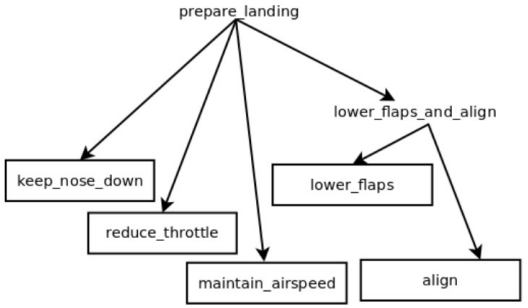


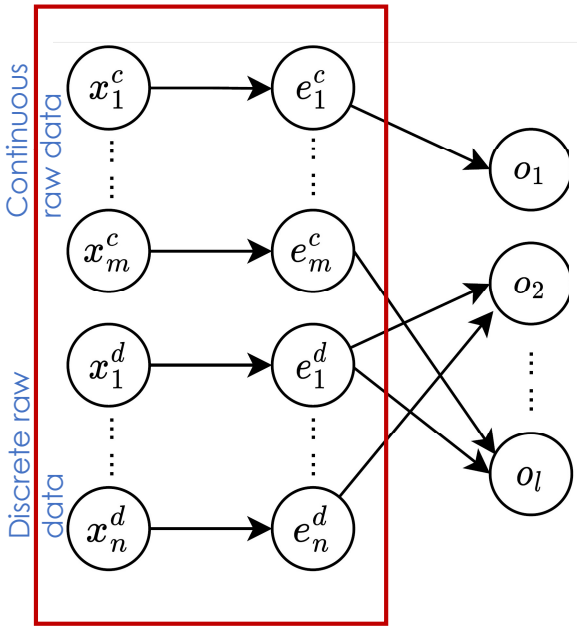
der Bundeswehr Universität München

IFS LRT

FRICO's Activity and intention tracking

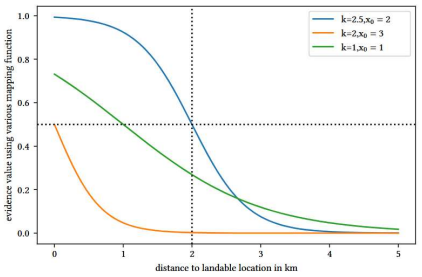
We use hierarchical task network (HTN) planning
- Convenient for using domain expert knowledge in planning
- Example planners: PANDA, FAPE, LiloTane, SIADEX
- Example applications: CHAP-E by NASA (pilot execution system for pilots), UPOM-RAE by University of Maryland, LAAS-CNRS and FBK (SAR-mission with unmanned vehicles)

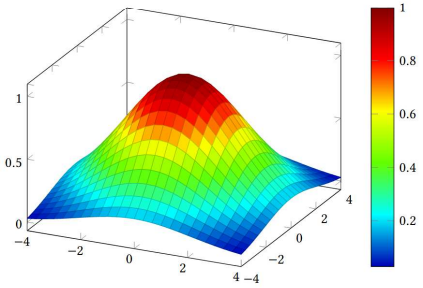




Mapping raw observation data into evidences

$$f_t(x) = \frac{1}{1 + e^{-k(x - x_0)}}$$





Pilot's intention: prepare landing

If we know the (prefix of) actions performed, we know the pilot's intention.

But the pilot's actions are only partially observable…

x^c = Flight position → reduced distance to landing site → get_near_to_landing_site

x_1^c = Gaze point → Checking airspeed

x_2^c = Airspeed → Stable airspeed

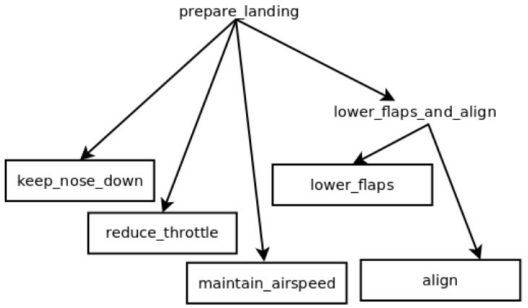
$$bel_t(P_1) = bel_t(a_1) \oplus bel_t(a_1) \oplus \ldots \oplus bel_t(a_n)$$

maintain_airspeed

F. Honecker, A. Schulte; "Automated Online Determination of Pilot Activity Under Uncertainty by Using Evidential Reasoning", Engineering Psychology and Cognitive Ergonomics: Cognition and Design, 2017.

FRICO's Activity and intention tracking

We use hierarchical task network (HTN) planning
- Convenient for using domain expert knowledge in planning
- Example planners: PANDA, FAPE, LiloTane, SIADEX
- Example applications: CHAP-E by NASA (pilot execution system for pilots), UPOM-RAE by University of Maryland, LAAS-CNRS and FBK (SAR-mission with unmanned vehicles)



x^c = Flight position → reduced distance to langing site → get_near_to_landing_site

x_1^c = Gaze point → Checking airspeed

x_2^c = Airspeed → Stable airspeed

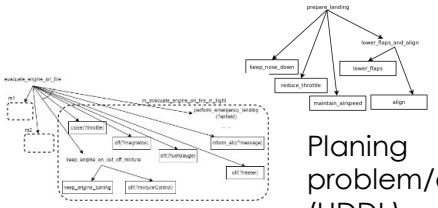
$bel_t(P_1) = bel_t(a_1) \oplus bel_t(a_1) \oplus \ldots \oplus bel_t(a_n)$

maintain_airspeed

Pilot's intention: prepare landing

If we know the (prefix of) actions performed, we know the pilot's intention.

But the pilot's actions are only partially observable…

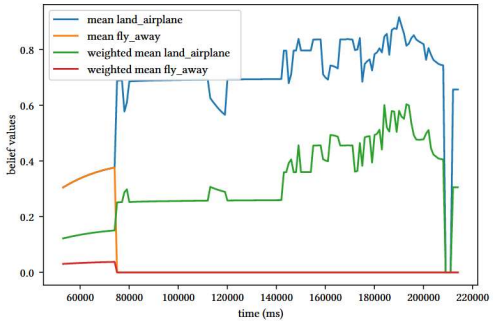


Planing problem/domain (HDDL)

Expressed as prefix of actions

PANDA PGR

Plan

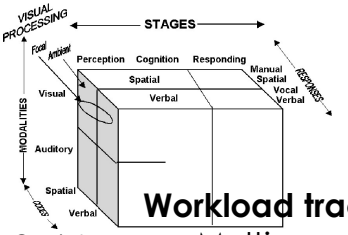


der Bundeswehr Universität München

D. Höller, G. Behnke, P. Bercher and S. Biundo, "Plan and Goal Recognition as HTN Planning *2018 IEEE 30th International Conference on Tools with Artificial Intelligence (ICTAI)*.

LRT

AI-Planning in FRICO: Next step



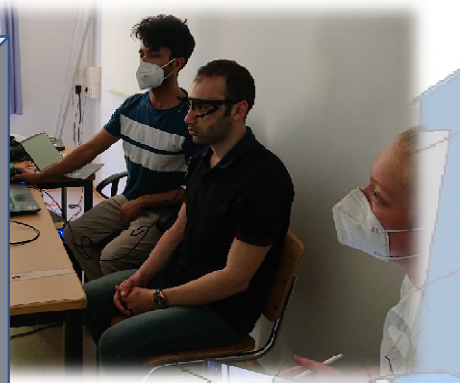
© Wickens

Workload tracking

- Multi-resource mental workl
- Context-rich workload asses

Flight Guidance and Adaptibility to Pilot's Preferences

- Top-k planning
- Planning and action with operational model



FRICO

your FRIendly CO-pilot

Personalising pilot's preferences

- Learning of human model (knowledge, computational capacity, preferences)

Flight guidance

- Optimal flight path planning
- Assistance in emergency situations (low-fuel, defect, incapacitation)

Cockpit dialog

- Transparency and interpretability/explicability
- Mixed-initiative decision-making

der Bundeswehr Universität München

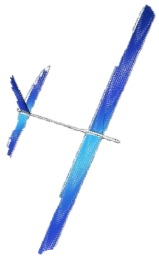
IFS LRT

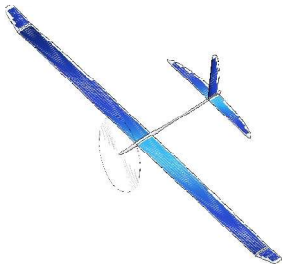
Why domain-independent AI-planning?

1 Applicable to different application domains

2 Transparency and interpretability / explicability

6 HAPS missions





2 UAM – Air taxi

1 General aviation

4 Rescue helicopter

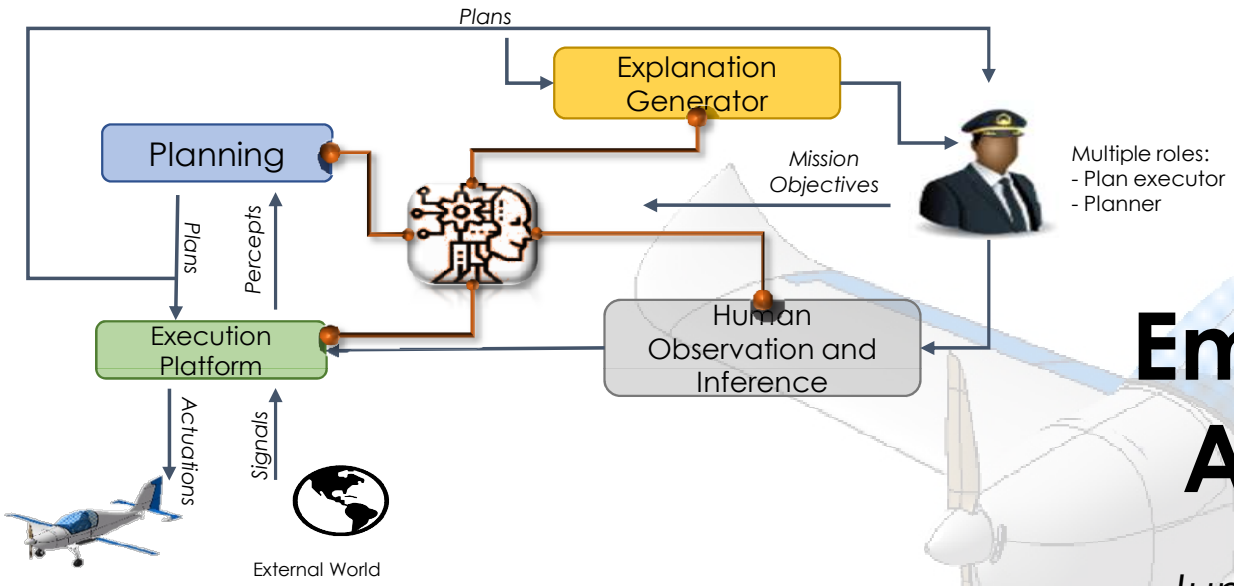
3 UAM - Drone

5 Rescue drone(s)

der Bundeswehr Universität München

IFS LRT

Institute for Flight Systems
Applied Artificial Intelligence for Dynamic Systems



Emergency in the Air: AI as a companion?

Jun.-Prof. Dr.-Ing. Jane Jean Kiam
jane.kiam@unibw.de
M.Sc. Prakash Jamakatel
Univ.-Prof. Dr.-Ing. Axel Schulte

Forschungsgruppe: Angewandte KI für dynamische Systeme

der Bundeswehr Universität München