HEER

NATURAL LANGUAGE AI FOR MILITARY DECISION SUPPORT AND SWARM CONTROL FOR AUTONOMOUS UAS TRAINED IN A COMBAT SIMULATION

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20.10.2023, NATO MSG Symposium MSG-207 in Monterey, USA

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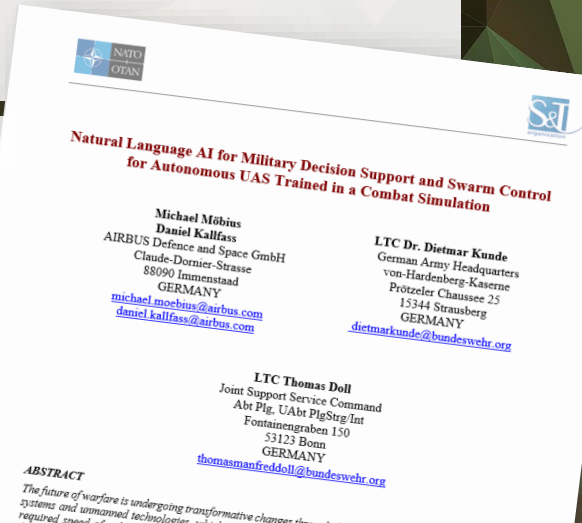

Natural Language AI for Military Decision Support and Swarm Control for Autonomous UAS Trained in a Combat Simulation

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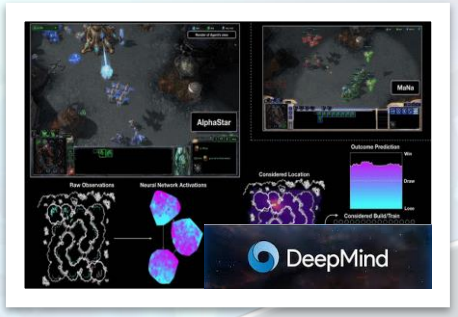
ABSTRACT

GROUNDBREAKING DEEP REINFORCEMENT LEARNING HISTORY



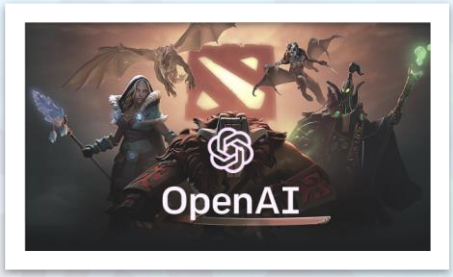
2020
AlphaDogfight (DARPA)

2019
AlphaStar
(DeepMind)

2018 Dota 2
(OpenAI)

2016
AlphaGo Zero

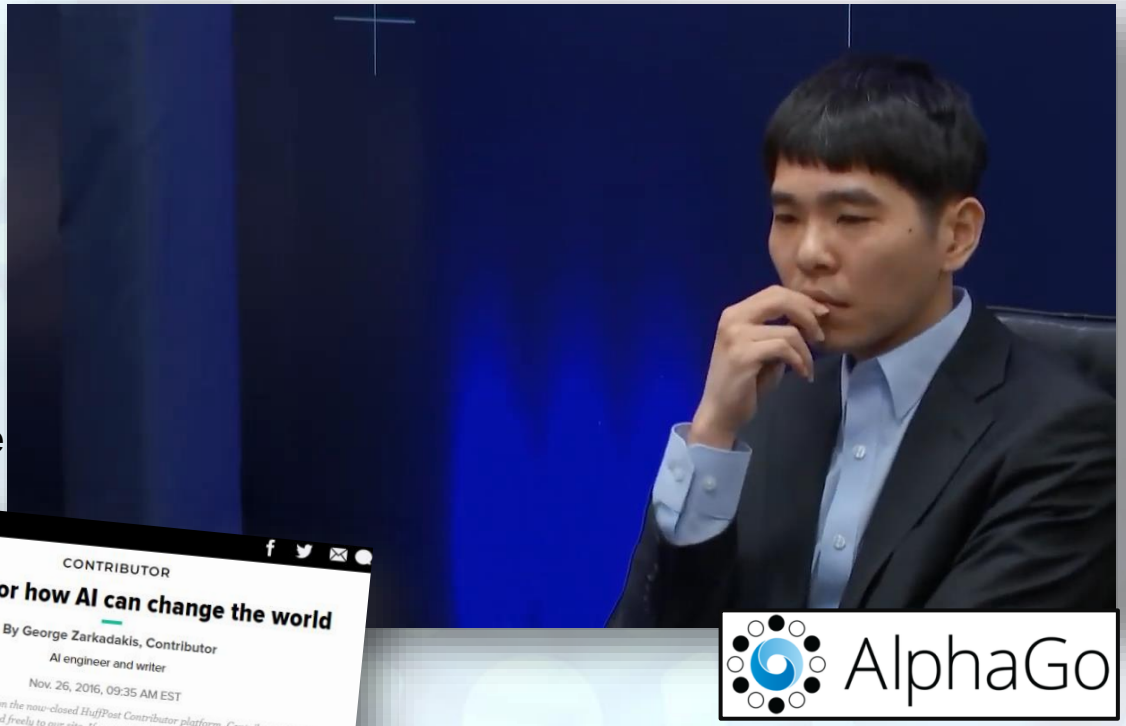
2013
Atari
Games



"SUPER HUMAN STRATEGY" THROUGH DEEP REINFORCEMENT LEARNING

AlphaGo surprise in 2016

- "**Move 37** in game 2 were **so surprising** that they upended hundreds of years of wisdom.
- Players of all levels have extensively examined these moves ever since." https://deepmind.com/research/case-studies/alphago-the-story-so-far
- "...caused Lee Sedol to **step away from the board for a full 15 minutes** just because of the peculiarity of the move and **resulted in his loss**." (Holcomb et al. 2018)



CONTRIBUTOR

Move 37, or how AI can change the world

By George Zarkadakis, Contributor

AI engineer and writer

Nov. 26, 2016, 09:35 AM EST

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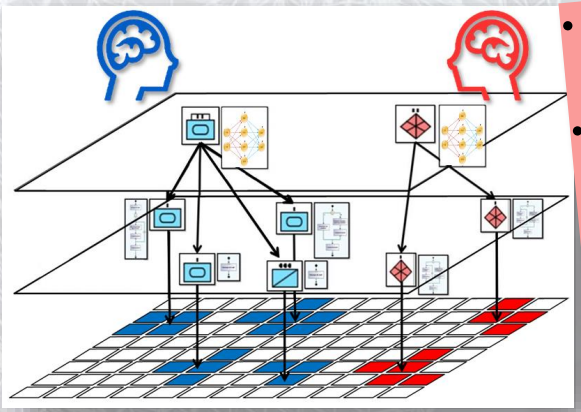
LEVELS OF AUTOMATION / USE - CASES

1. Decision Support Use-Case

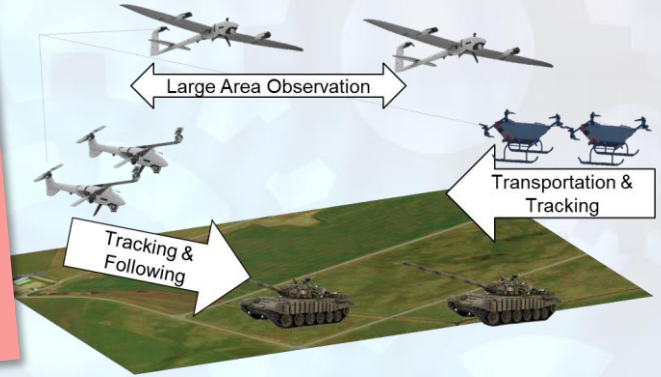
- **AI agent** at the battle group level
- The AI agent **leads the companies & units**
- platforms are **controlled algorithmically**
- The AI agent has a mission: **attack or defend**



- Complex & only partially observable environment („**fog of war**“)
- **Effect of actions** can be far in the **future** (e.g. Artillery effects)
- Many unpredictable **random effects** (e.g. kill probabilities)
- **No real data**
- limited **computation power**

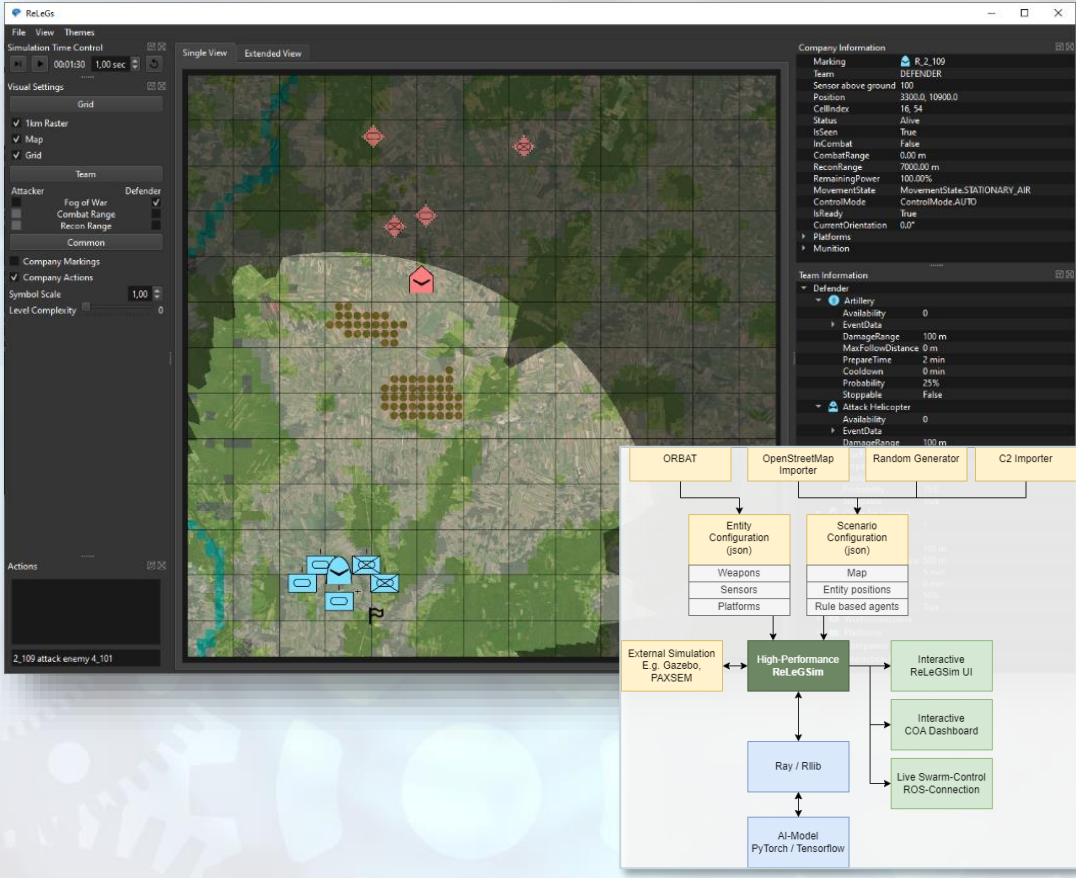
2. UAV-Swarm Autonomy Use-Case

- **AI agent** to control a **Swarm of UAS** in real-time
- The AI agent has the mission to maintain the **reconnaissance** with **limited resources**
- Use in simulation trained AI with a **real UAS-Swarm**

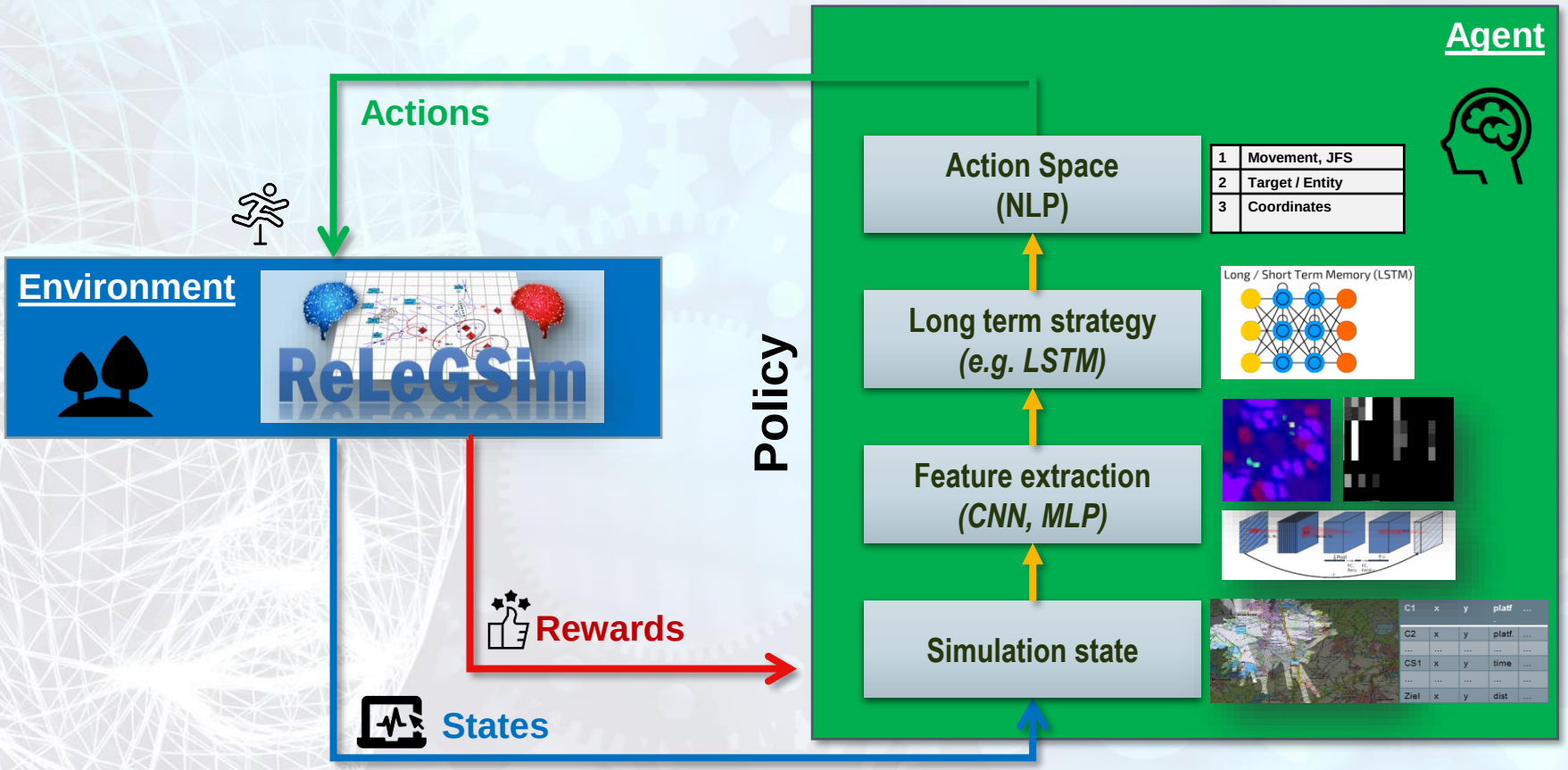


SIMULATION RELEGSIM AS A TRAINING ENVIRONMENT

- ReLeGSim developed as a **dedicated high-performance** training environment (python based discrete event simulation)
- **"as simple as possible, as complex as necessary"**
- **Modelling optimized** for reinforcement learning
- **GUI optimized** for humans
- **Game modes:** computer-computer, human-human, human-computer
- **Randomized** training scenarios
- **Level / League System** for Training (RL)



DEEP REINFORCEMENT LEARNING – OVERVIEW & ARCHITECTURE



DEEP REINFORCEMENT LEARNING – NETWORK ARCHITECTURE

Action Space

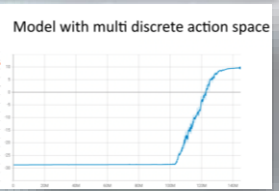
Replacing the common task encoding MLP with a natural language interface

- Improve the **flexibility** of the action space
- outputs different kind of sentences / tasks
- Make the action space **human understandable**
- Sentence can **describe a task in detail to avoid micro management**
- Human operator can override tasks given by the AI **(human on the loop)**

→ The NL-Interface improves the flexibility and understandability of the given actions

- **Simple LSTM** Based NLP Network
- 100 different words (vocabulary)
- Max 8 word long sentences
- **Half training time** need compared to multi discrete action space

Task examples
FixedWing1 observe x:10 y:30 range 500m
UAS1 identify Unkonwn1
UAS2 hide x:20 y:3
UAS3 follow hidden attacker4



DEEP REINFORCEMENT LEARNING – REWARD DESIGN

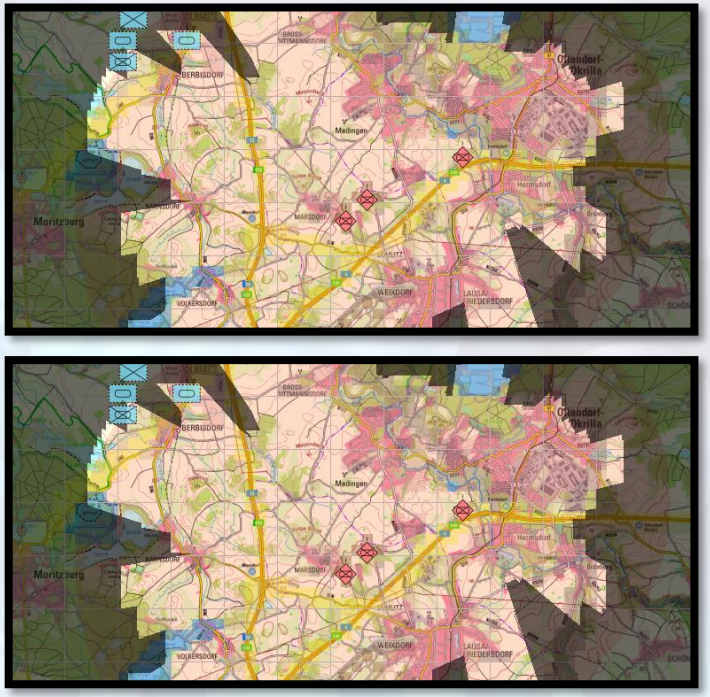
Reward

The performance of the model and the goodness of the reward function are closely related

- Add a reward for giving good/poor sentences to make sure the AI forms the sentences correctly

→ generic behavior can be achieved by designing the reward as abstract as possible

→ **the best reward during the study consisted of a combination of rewards:**
sentence reward, reaching the objective, successful engagement / task fulfillment and win/loss of episode



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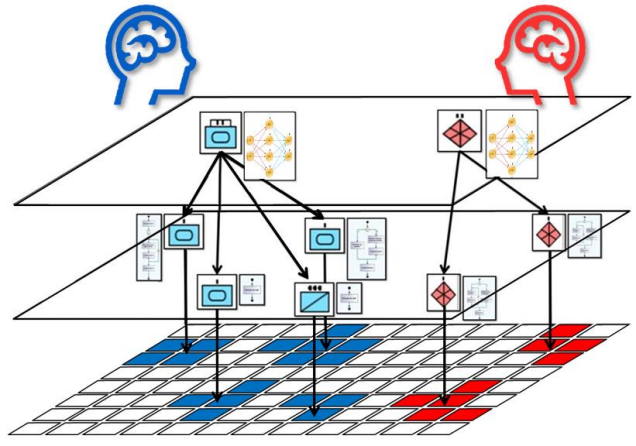

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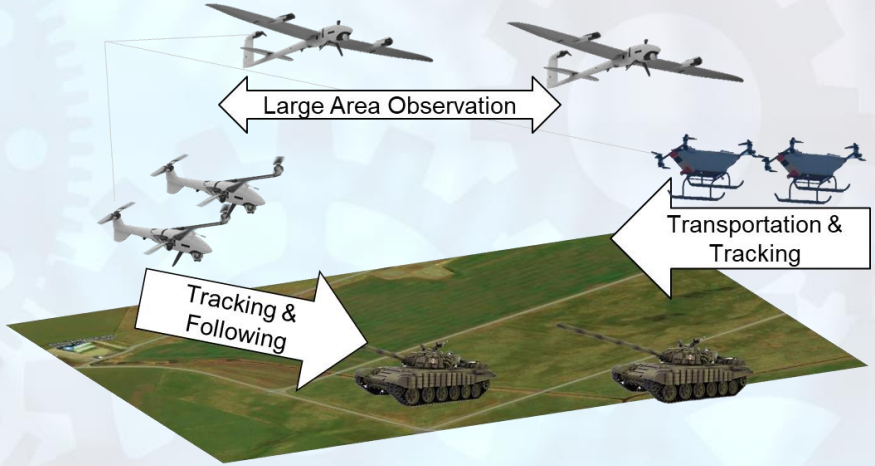
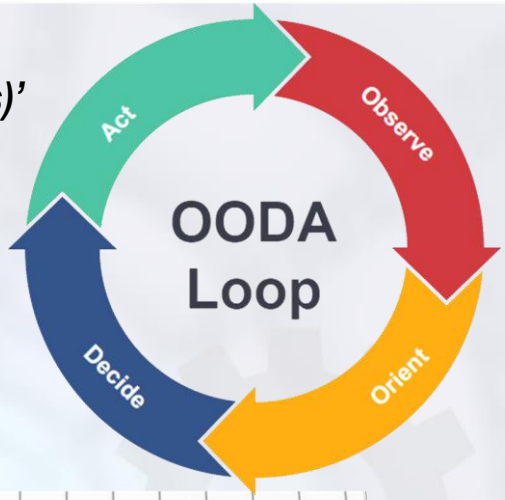


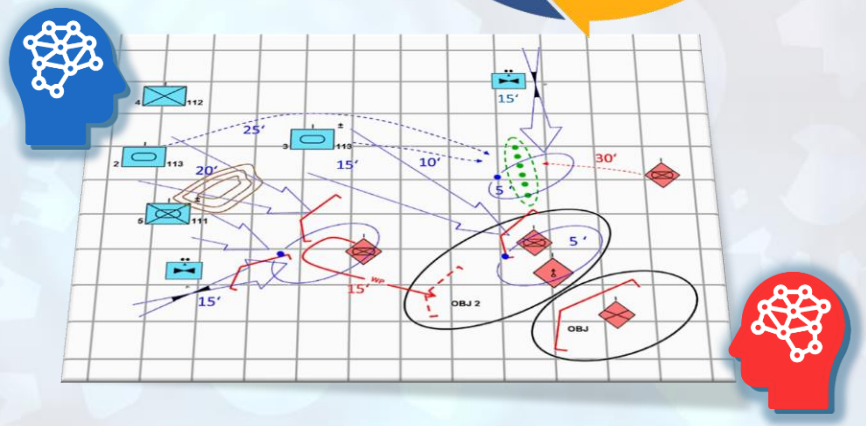
AI FOR DECISION SUPPORT & AUTONOMY

GER Study '*Reinforcement learning for complex battlefield situations (ReLeGs)*'

- **Context:** Speed-up the military decision cycle (OODA)
- **Goal:** Develop efficient tactics to be used for Decision Support
- **Train** a deep neural network capable to:
  - Effectively command & control available subordinated elements
  - Fulfil a military task
  - Cope with uncertainties ('fog of war')
  - Adapt to the given terrain
  - Cope with given constraints (range, amunition..)

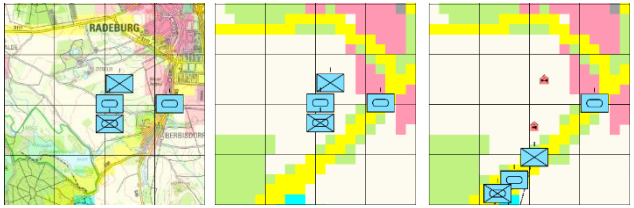
→ **Vision: "Super-human strategies"**





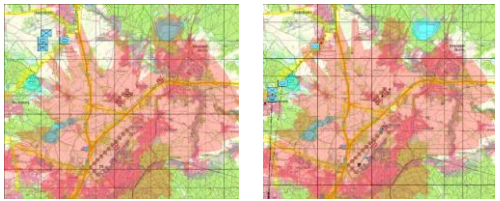
EXAMPLES FOR OBSERVED BEHAVIOR

1.



Early usage of the scout unit to observe and identify hostile units

2.



Take firing distances of hostile troops into account when moving own forces

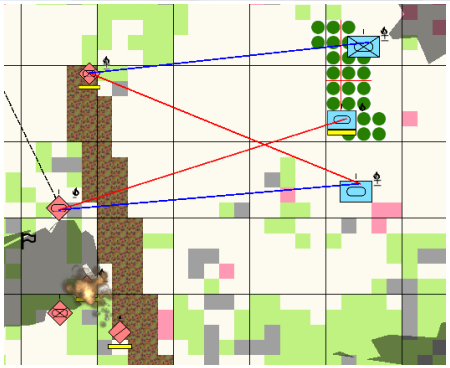
3.

Early request for fire support (before the attack)

4.

Synchronized attack of ground forces (incl. pincer attack)

5.



Utilization of mines to stop attacker

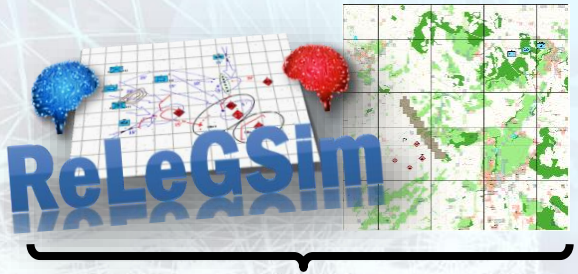
1. DECISION SUPPORT USE-CASE IN COMPLEX COMBAT SITUATIONS

REINFORCEMENT LEARNING FOR COMPLEX COMBAT SITUATIONS

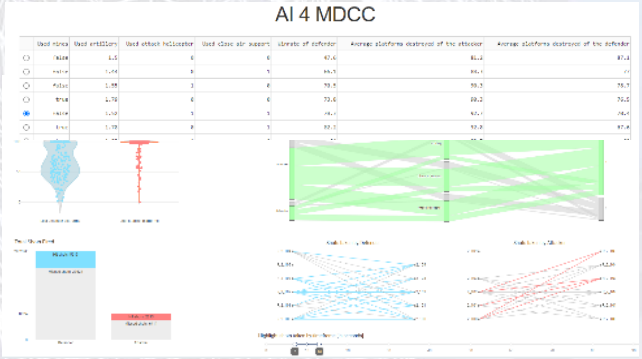
RL Agent capabilities

ANALYSIS DASHBOARDS TO VISUALIZE THE AGENT‘S BEHAVIOR

Analysis Process example

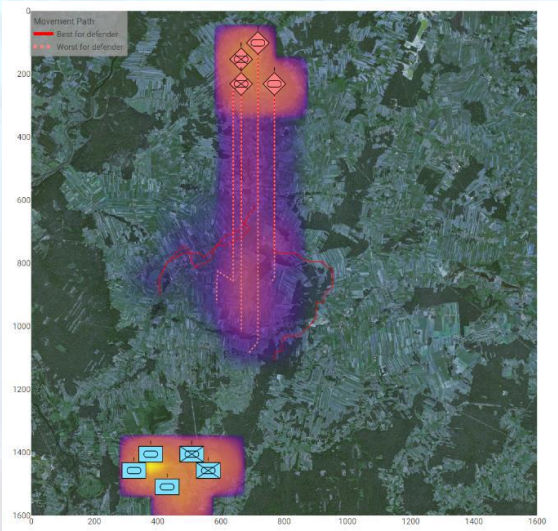


Process current situation multiple times with different options



Dashboard example

Attack as quick as possible



Attack minimizing own losses

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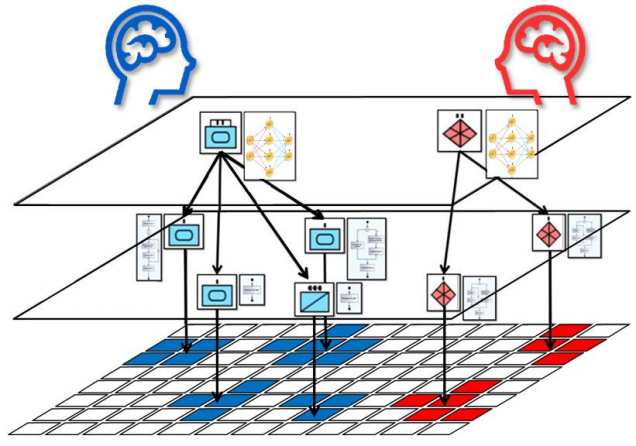

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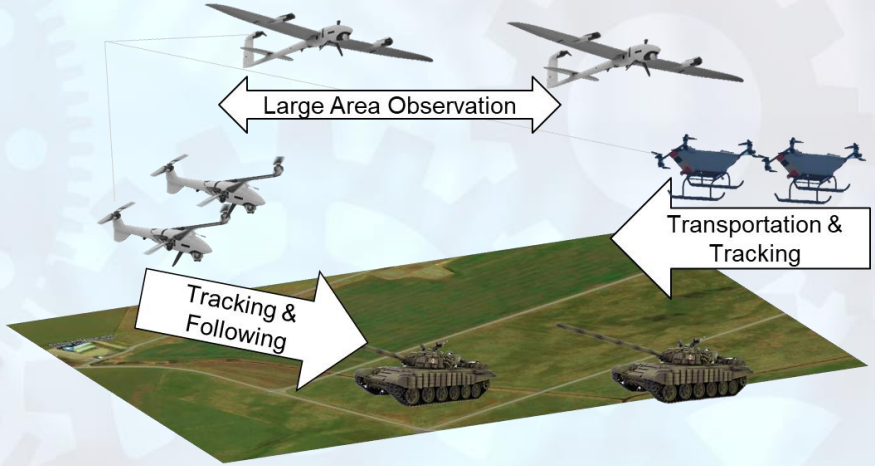
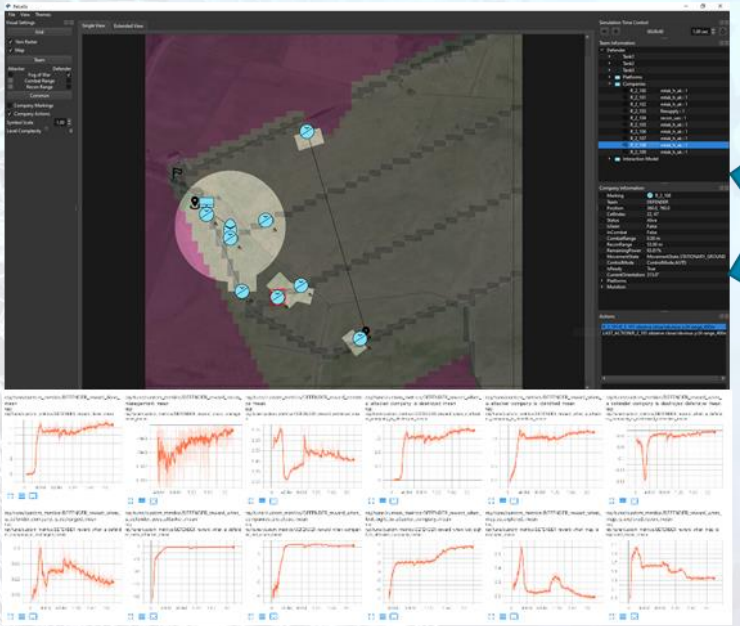
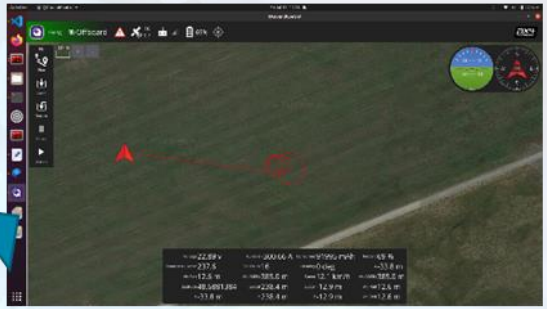


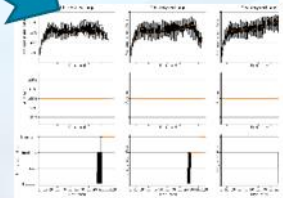
FROM RL-TRAINING → VERIFICATION → REAL FLIGHT

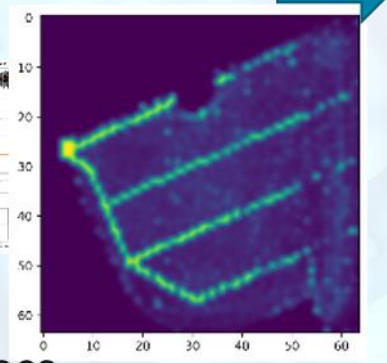
AI-Training in ReLeGSim



Verification in jMAVSim







V&V analyses

Real Flight

KITU DEMO VIDEO

CONCLUSION

- **Deep reinforcement learning with military simulations** is a breakthrough technology with great potential for automated learning of reasonable tactical behavior
- It can be adapted to **various military applications** such as
  - Decision Support
    e.g. for Combat / Planning / Logistics
  - Autonomous Systems
    e.g. autonomous swarms
  - Development of new (superhuman) tactics
    e.g. new TTPs for future systems
  - Computer Generated Forces
    e.g. for Training
  - Synthetic Data Generation for AI training
    e.g. creating synthetic behaviors for AI trainings e.g. Activity Based Intelligence
- **ReLeGSim** can be used as powerful training environment **in multiple domains**
- **Natural language** can be combinded with **reinforcement learning** and used as a **human-on-the-loop** interface

WAY AHEAD

Ongoing activities and challenges to be solved:

- Continued **Training, Evaluation & Improvement**
  - *How to speed up the training (e.g. Supervised Learning pre-training*
  - *How to embed additional constraints (e.g. rules of engagements)*
- **Explainable AI (XAI), Robustness & Trustworthiness**
  - *New technologies and processes to test and assess the AI agent*
- **Scalability** and **Real-World Testing**
  - Increase Technology Readiness Level (TRL) and tackle “simulation-to-reality gap”
  - Human-in-the-Loop Integration
- Adaptation to **Evolving Technologies** (e.g. LLM)
  - *Can LLMs be used for complex planning?*

THANK YOU!
ANY QUESTIONS?

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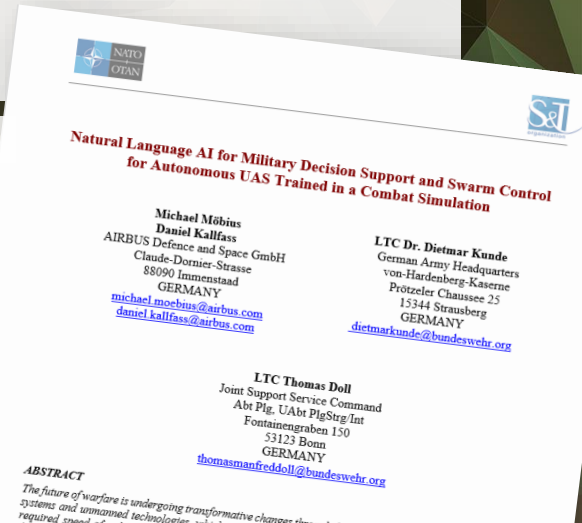

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