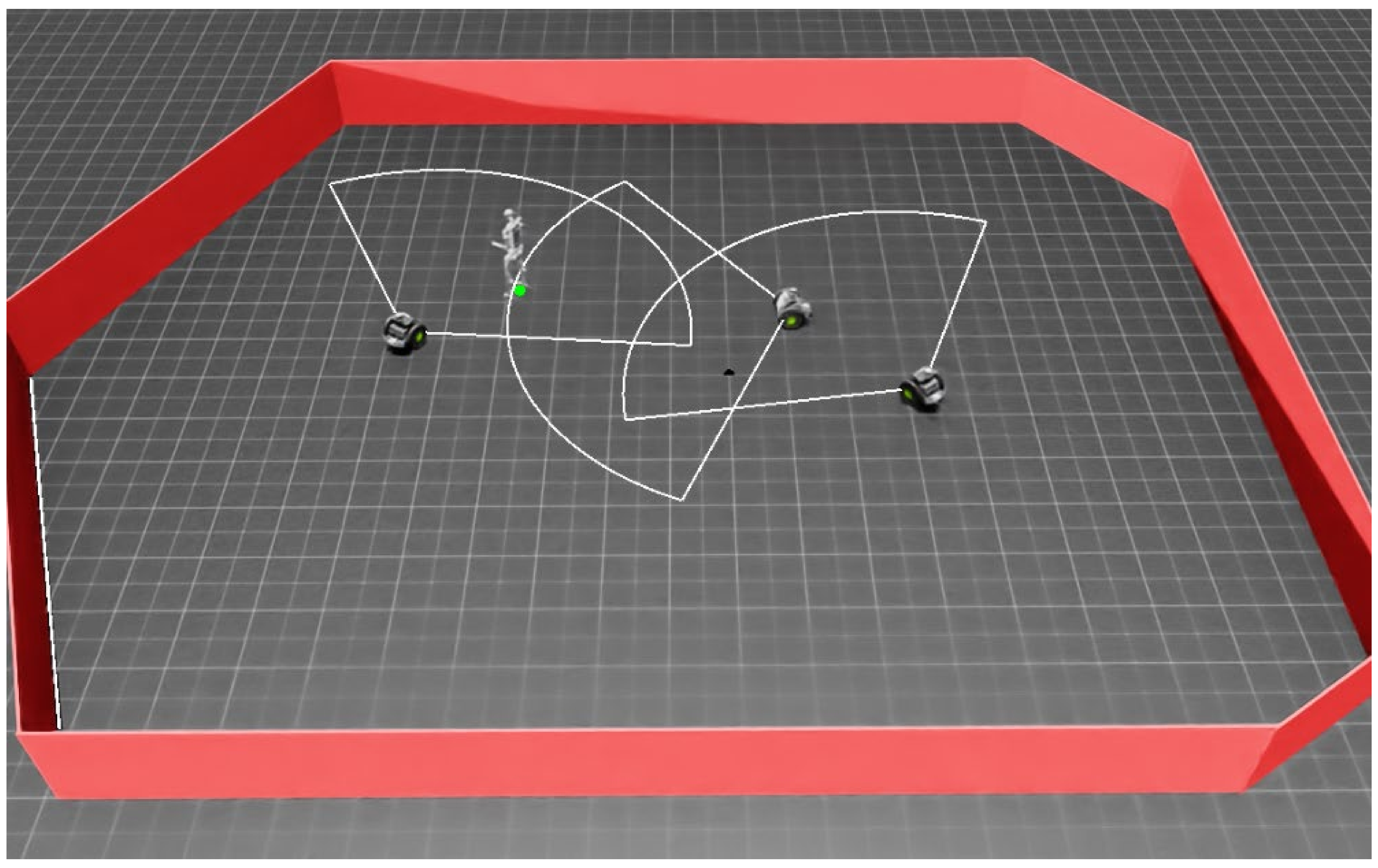
HSLU Hochschule Luzern

Technik & Architektur
Master of Science in Engineering
Mechatronics & Automation - Robotics

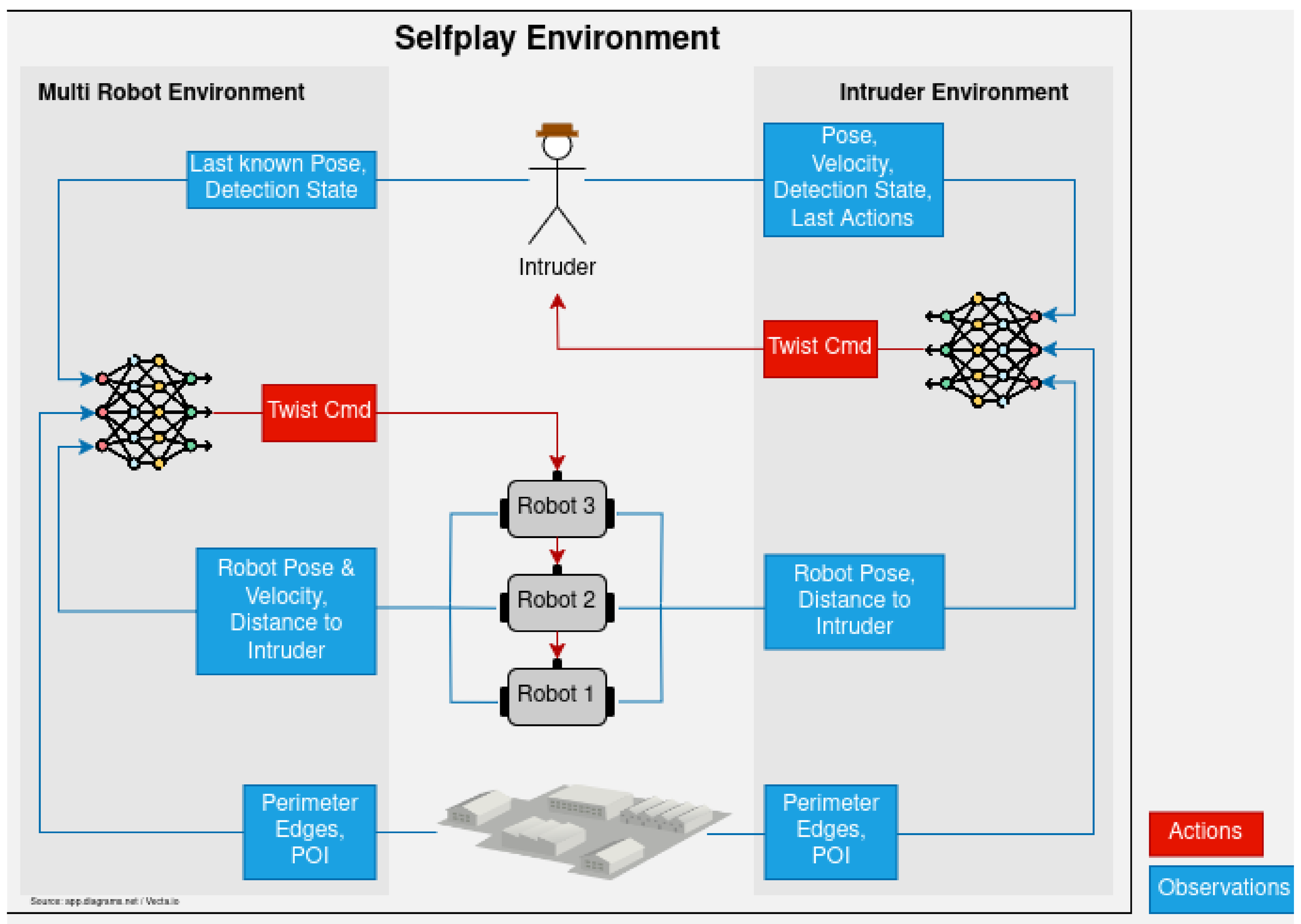
Master of Science in Engineering – Mechatronics & Automation

Site Surveillance with Robots

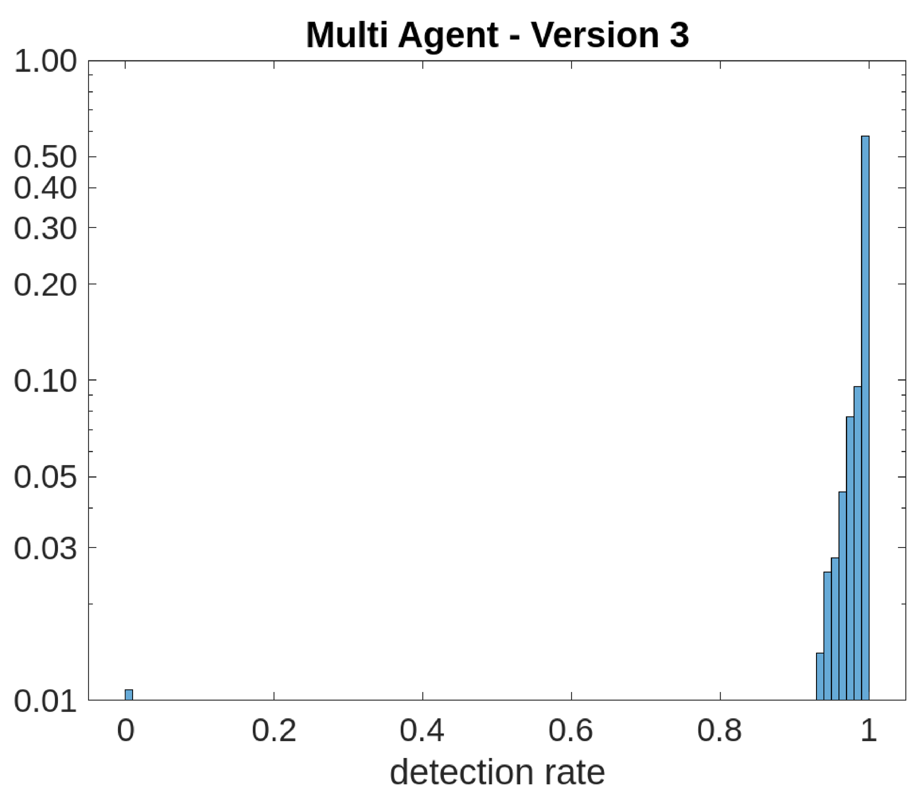
Digital Twin created in Isaac Sim with building data from Swisstopo



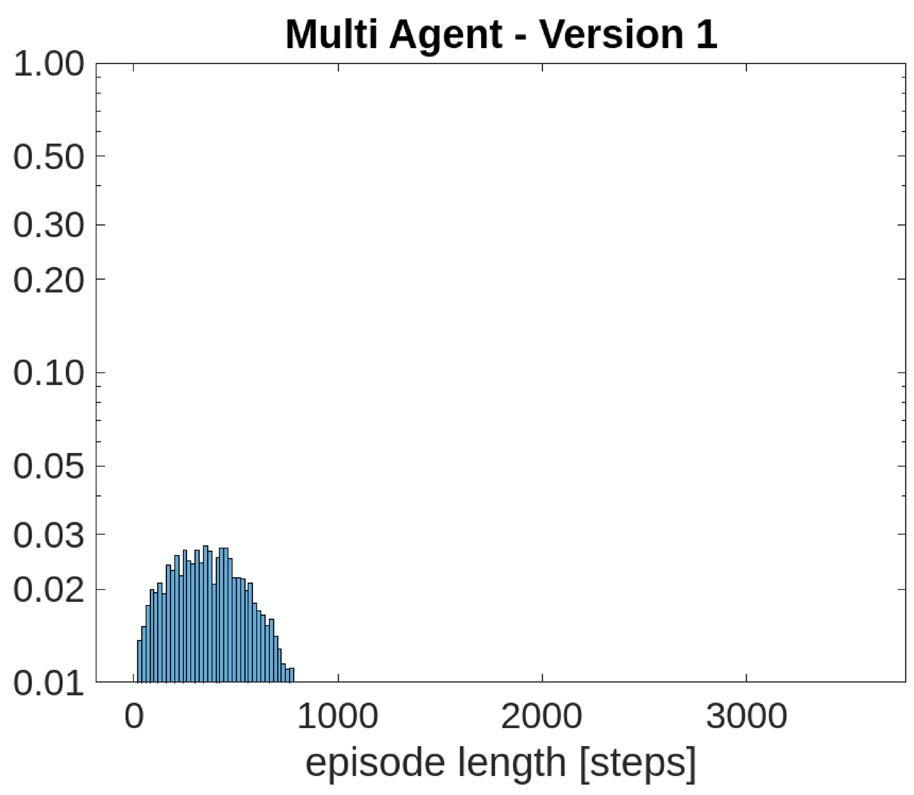
Three robots with constraint detection range are pursuing an intruder



Selfplay allow the robots and the intruder to adaptively evolve their strategies by competing against each other



Result of the tracking scenario: Three robots controlled by DRL are searching for and tracking an intruder.



Result of the patrol scenario: Time required until the intruder is detected by a DRL-controlled robot swarm

Problem Description

The integration of autonomous robots into surveillance systems has the potential to increase security while reducing operat-ional costs. However, current robotic surveillance systems typically rely on pre-programmed, fixed routes or basic reactive algorithms. This makes it difficult for them to adapt to dynamic events such as intrusions.

As the number of robots and the size of the monitored area increase, so does the complexity of the coordination problem. Analytical methods become inefficient and impractical due to the large number of possible permutations in robot constellations, environmental setups, and intrusion behaviours. To overcome these limitations, learning-based approaches such as Deep Reinforcement Learning (DRL) offer a promising alternative. DRL allows robots to develop autonomous strategies for intruder detection and response in real time by adapting behaviour to the current situation without the need for extensive pre-programming for different eventualities.

Concept

Multi-Agent Deep Reinforcement Learning (MADRL) is used to coordinate multiple robots in intrusion scenarios, including patrol, tracking, and building defense. A centralized training, centralized execution (CTCE) approach is used to train a DRL model in NVIDIA's Isaac Lab. The agents are ground-based robots with a constraint detection range.

Results

MADRL has demonstrated effective coordination in various intrusion scenarios such as intruder tracking and localization. The policy trained in the tracking scenario achieved an average detection rate of 94% against a random walking intruder, while the single-agent environment achieved only 71%. In the patrol scenario, the average detection rate was 92% with multiple robots and 51% with a single agent. Selfplay techniques were used to develop advanced strategies. The intruder learned the advantageous strategy of edge camping, which the robots learned to counter.

A detailed digital twin of the site was created using building data from Swisstopo and enriched with various assets from Isaac Sim to enhance realism. However, such environments are impractical for DRL training due to excessive memory demands.

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