Tecnológico de Monterrey

Evidence II

Modeling of Multi-Agent Systems with Computer Graphics

(Gpo 301)

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Challenge: Catch the Robber

The inefficacy of the current tracking system in the materials bank presents a substantial risk to the company's financial health. Unregistered truck movements result in the unaccounted loss of materials, directly impacting cost management and profitability. The inability to effectively monitor these movements leads to a significant breach in supply chain integrity, potentially resulting in considerable financial losses.

The project's objective is to develop a robust, real-time monitoring system that ensures every truck entering and exiting the premises is accurately logged and accounted for. To achieve this, the project will employ intelligent agents capable of sophisticated communication and interaction, leveraging the latest advancements in computer graphics to create a dynamic simulation environment within the Unreal Engine platform.

To mitigate these risks, a technology-driven solution is proposed. Using Unreal Engine for real-time simulation, this solution aims to overhaul the existing security infrastructure. At the heart of the solution is the integration of Unreal Engine with real-world terrain mapping, where trucks are simulated using 3D models moving along predetermined splines. Key to this plan is to place trucks within the simulation following predetermined splines that mimic their real-world routes across the terrain. These splines are strategically positioned to optimize the simulation process and enhance the accuracy of the security monitoring system.This setup allows for a realistic representation of the trucks' movements across the site. Mounted cameras, both streaming and recording, will be strategically positioned to monitor these movements. These cameras, fixed on 3D modeled poles, will feed live data into the system.

As trucks traverse these splines, the camera system, empowered with AI algorithms, scrutinizes both incoming and outgoing vehicles. The AI model, trained with extensive truck imagery, distinguishes between loaded and unloaded trucks, effectively identifying potential material theft incidents.

The intelligent agents, governed by a well-defined Agent Communication Language (ACL) based on FIPA standards, will facilitate seamless interactions and information exchange. These agents will analyze the video feeds, using advanced AI algorithms to differentiate between loaded and unloaded trucks, effectively identifying potential security breaches. This agent-based system will not only bolster site security but also provide valuable data insights for operational optimization.

The implementation of this AI-enhanced monitoring system is not merely a security upgrade; it is a strategic investment. By ensuring accurate tracking of all trucks, the system directly contributes to preventing material theft and loss. This enhanced oversight leads to better inventory management, reduces unnecessary expenditures, and optimizes the supply chain. Moreover, the data collected and analyzed by this system can offer valuable insights into logistical patterns, aiding in further refining operational strategies. Over time, this not only safeguards the company's assets but also fosters an environment of efficiency and accountability, which is crucial in maintaining a competitive edge.

Architecture

The BDI Model Architecture:

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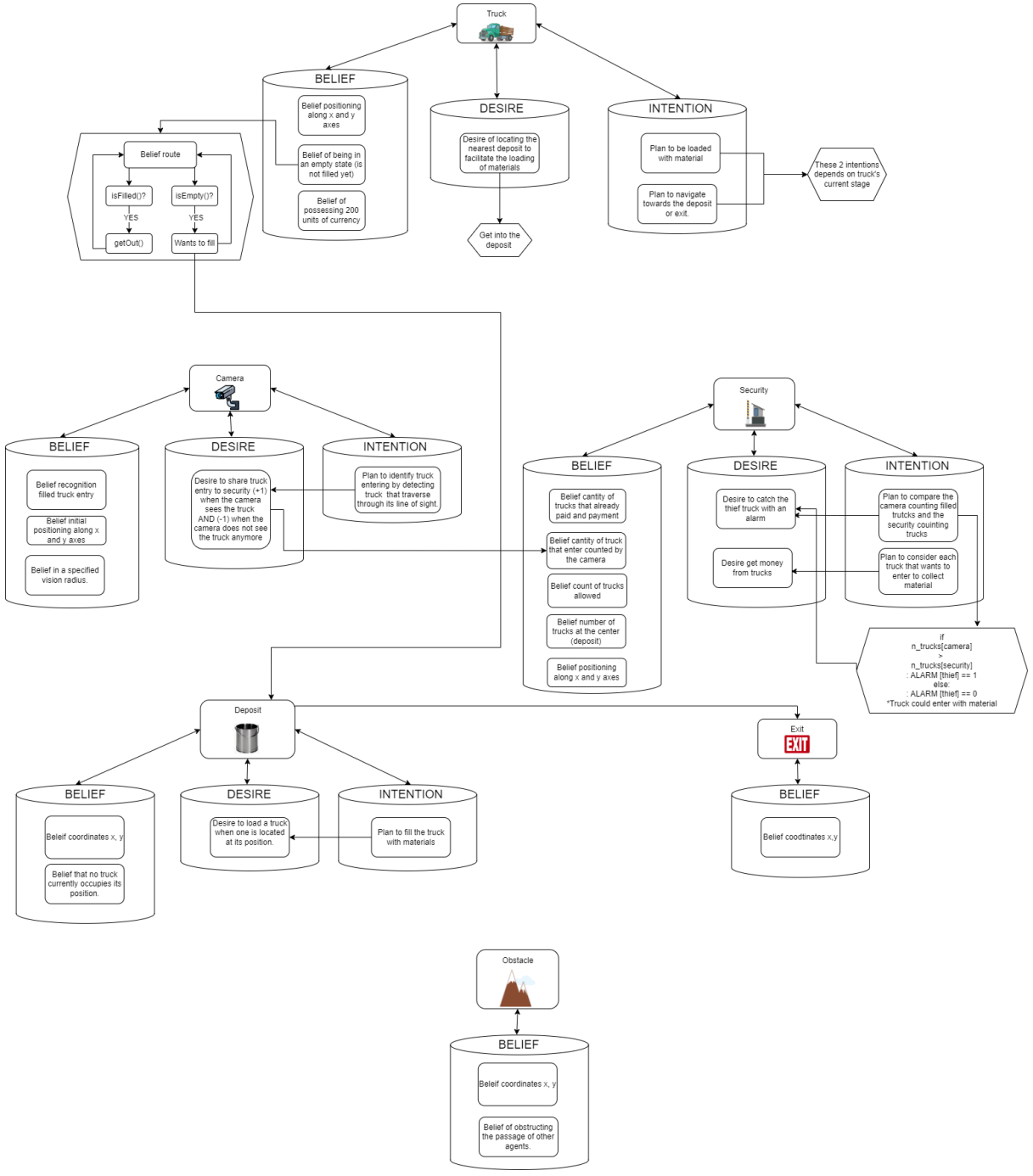
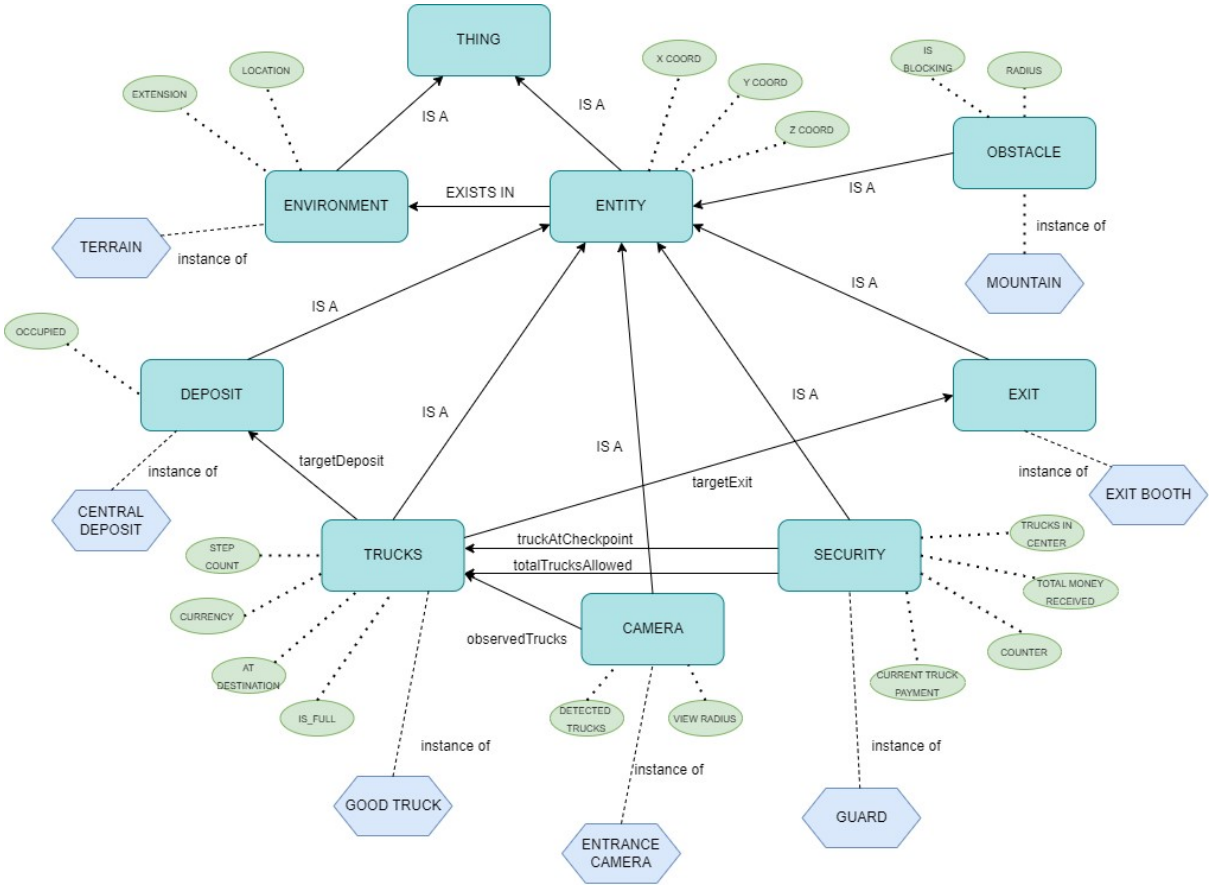


In the previous sections, the logistics and BDI architecture were defined. With these references the ontology was designed:



Agent Communication

Our model language is based on the Knowledge Query and Manipulation Language (KQML). KQML is designed for programs to communicate attitudes about information, covering a range of actions such as querying, stating, believing, requiring, achieving, subscribing, and offering. This language facilitates effective communication between intelligent agents by expressing various knowledge-related tasks.

The meaning of a KQML message is defined in terms of constraints on the message sender rather than the message receiver. This allows the message receiver to choose a course of action that is compatible with other aspects of its function.

We started creating a constructor to build a new message, considering the following parameters (msg, performative, content, sender, query and is_reply):

- msg: The entire message.
- performative: The type of action, such as "request" or "inform."
- content: The information or data being communicated.
- sender: The identifier of the message sender.
- query: Identifier for tracking queries or replies.
- is_reply: A flag indicating whether the message is a reply.

The semantic language includes key parameters essential for understanding the message:
content*: The actual information being conveyed.*
sender*: Identifies the agent sending the message.*
reply-with or in-reply-to*: Facilitates tracking of messages and responses.*

Our system incorporates two primary performatives: "request" and "inform."

Request*: Used when an agent seeks information or an action from another agent.*
Inform*: Employed when an agent communicates information to another.*

These performatives provide a concise and expressive way for agents to convey their intentions and expectations.

The messaging system facilitates effective communication between the intelligent agents, allowing them to exchange information seamlessly within the multi-agent framework. Each agent utilizes the custom Message class to create and interpret messages.

Agents Interaction

The model has three main interactions between agents:

1. **Interaction between trucks and deposits:** When the truck is located at the same coordinates as one deposit, the truck agent changes its status from empty to filled.In this case, the deposit agent broadcasts its location, allowing the truck to change its property. In addition, the truck that is being filled has a delay to represent said process. The deposit agent broadcasts a signal to all the other trucks to let them know about this delay. Consequently the other trucks stop for a determined amount of time to avoid collisions between each other.

2. I**nteraction between cameras and trucks**: if a truck enters the vision range of a camera, the camera will detect the agent and run a function to add a new value to the counter (one of the cameras properties).

3. **Interaction between cameras and security**: each step, the cameras and the security compare their results to see if there is a discrepancy between the data. If the cameras detected more trucks than the ones expected, an alert was raised. Here we use the communication system.

All the agents of the model work as a team to achieve a functional system. The interactions do not use a bidding system, as the agents only broadcast their task (task sharing). This can affect the later behavior of other agents, but because of the nature of the code, ***there is no actual bidding that determines which instance of an agent should perform a task***.

The previous interactions are from the AgentPy model. The Unreal model has fewer interactions which are simpler, as there is no multi-agent logic inside that simulation.

Business proposal

After creating both simulations, we planned a solution proposal plan, where the cost of implementation is considered. The following products and services were selected due to their characteristics and price:

Product	***Description***	***Unitary Price***	***Total Price***
Camera	Hikvision Cámara IP Bullet IR Outside IDS-TCM403-BI, Wired	$1124.45	$2,248.90 (2)
Post	Specialized 6m pole for CCTV installation, XGAPOLE-6M	$363.49	$726.98 (2)
Maintenance	Between 8 and 12% of the total project cost.		$297.58
		Total	$3,273.46

For the real life implementation, that considers 2 cameras with their infrastructure and maintenance the price would start at $3,273.46. It is important to mention that the previous table considers a maintenance period of 4-6 months. These prices may vary depending on the specific necessities of the client.

For further information the links to all the products can be found at the references section of this document.

Results

Truck recognition: For the demo of the camera recognition, once each truck has been trained to be recognized, we implemented the following structure: the camera has 2 predefined spaces that simulate the delineation of the area, allowing trucks to be recognized and captured only within that previously established range. The goal is to determine when a truck enters and exits the camera. Therefore, if a truck enters and exits, the counter in both spaces will be one, if another truck enters and exits, the counter will be two, and so on.

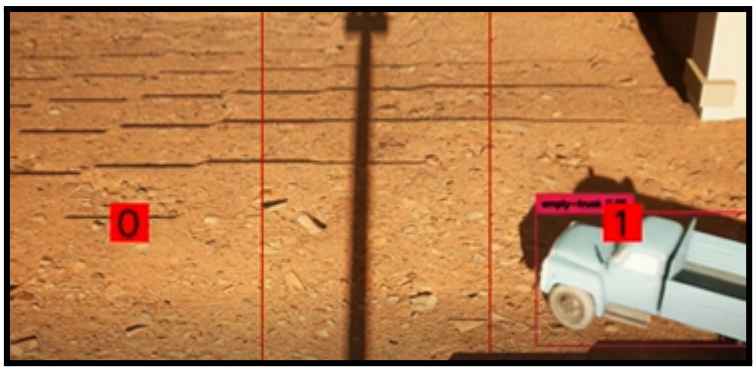


Image 1. Truck recognition by camera (entry and exit)

Filled truck recognition: For this AI model validation we have to only consider trucks that were filled of material, because we'll not care if a truck is empty (can not be a robber if it doesn't have material on it), we trained each truck with Python and roboflow to consider if a truck is fill or empty as we can see on the following image 2

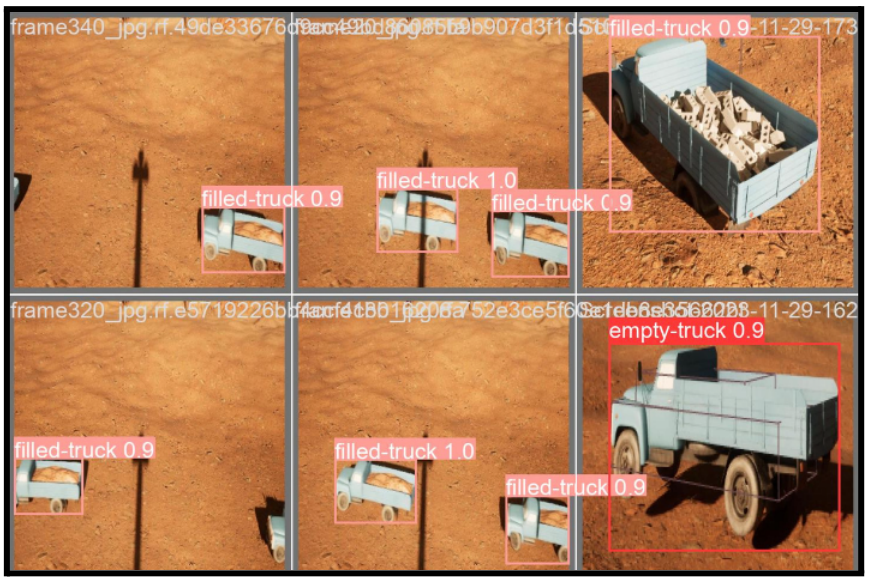


Image 2. Filled and empty truck detected

For the filled truck recognition we have the following model validation:

- The empty trucks: 0.860 → 86%
- The filled trucks: 0.934 → 93.4%
- All classes: 0.897 → 89.7%

These validations refer to the error with the bounding boxes and to the mean average precision to detect classes

Effectiveness: For our simulation, we considered 10 empty trucks entering and for exit 7 full trucks and 3 empty trucks. Using our version 12 → 7 full trucks and 1 empty goal

AgentPy model:

For this simulation we consider the following agents:

Truck = 0, Deposit = 1, Camera = 2, Obstacle = 3, Security = 4, Exit = 5

Our simplified simulation on Python for agents interaction and communication

For these 3 following steps the camera does not detect any truck yet (due the range detection of the camera)

```
============ Step   1 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 0

============ Step   2 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 0

============ Step   3 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 0
```

Now for the following steps the camera has detected trucks with available funds on each truck's driver: 200$ each truck available funds → total for 3 = 600$ and total trucks = 3

```
============ Step   4 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security agent >> Detected truck at checkpoint with available funds. Collecting payment...
<< Security agent >> Total funds: 200
<< Security Agent >> Total trucks registered at checkpoint: 1

============ Step   5 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 1

============ Step   6 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security agent >> Detected truck at checkpoint with available funds. Collecting payment...
<< Security agent >> Total funds: 400
<< Security Agent >> Total trucks registered at checkpoint: 2

============ Step   7 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 2

============ Step   8 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security agent >> Detected truck at checkpoint with available funds. Collecting payment...
<< Security agent >> Total funds: 600
<< Security Agent >> Total trucks registered at checkpoint: 3

============ Step   9 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security Agent >> Total trucks registered at checkpoint: 3
```

The fourth truck has not enough money, BUT the security guard let the truck go in

```
============ Step  10 ============
<< Camera Agent >> Full trucks currently in view :  0
<< Camera Agent >> Total full trucks observed :  0
<< Security agent >> Truck doesn't have enough money... Eh, I'll let them through...
<< Security Agent >> Total trucks registered at checkpoint: 3
```

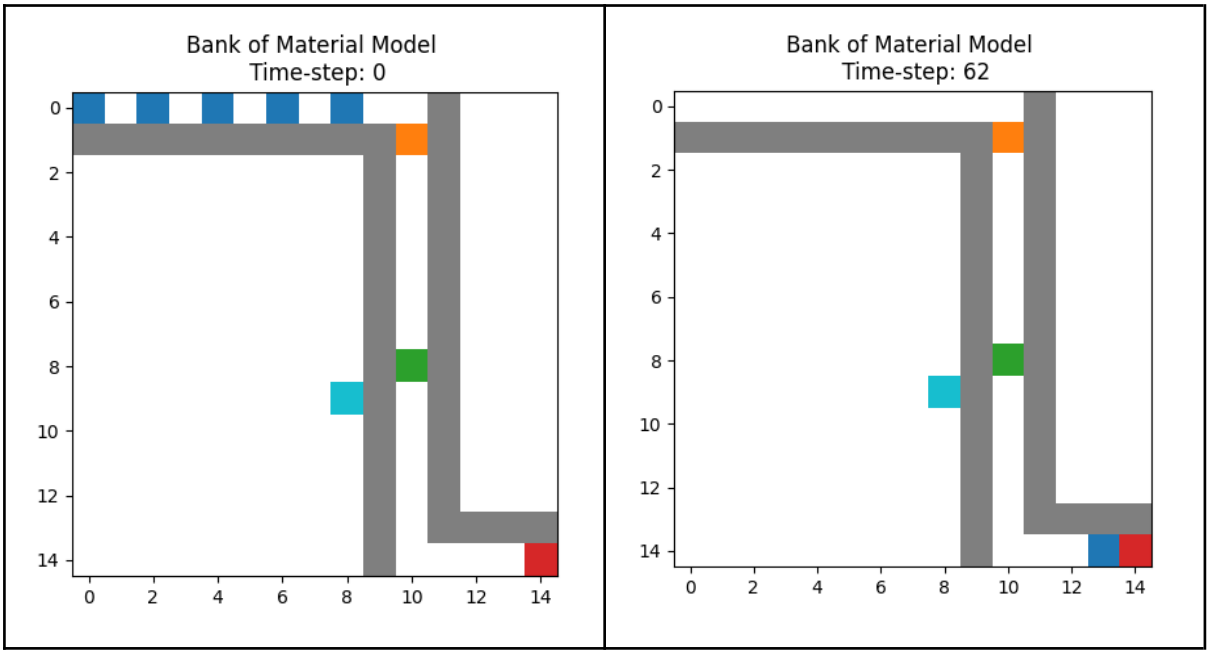
Now the total fund are 600$ but with the entrance of another truck the updated founds are 800$ because it should be ONLY 4 trucks now (not counting the truck that didn't pay)

```
============ Step  19 ============
<< Camera Agent >> Full trucks currently in view :  1
<< Camera Agent >> Total full trucks observed :  1
<< Security agent >> Detected truck at checkpoint with available funds. Collecting payment...
<< Security agent >> Total funds: 800
<< Security Agent >> Total trucks registered at checkpoint: 4
```

But now that there are 5 trucks on the terrain detector by the camera and there is a discrepancy between money and # of trucks → ALARM (Should be 1000$ for 5 trucks instead of 800$) because there are 4 trucks for the security and 5 for the camera

```
============ Step  53 ============
<< Deposit Agent>> Currently loading truck61
<< Camera Agent >> Full trucks currently in view :  2
<< Camera Agent >> Total full trucks observed :  5
%%%% Alarm! Truck count discrepancy detected! Security Guard compromised! %%%%
<< Security Agent >> Total trucks registered at checkpoint: 4
```

Plotted simulation: The orange square represents the entry, the green the deposit, the read the exit, the light blue the camera and the dark blue the 5 trucks



Conclusions

The designed infrastructure not only presents the capability to scale up or adapt to address future security challenges and operational expansions but is also strategically positioned to align with the evolving needs of industrial security. The selection of the Knowledge Query and Manipulation Language (KQML) as the agent communication language is a key for effective communication among intelligent agents, offering not just a current solution but also adaptability to future requirements. KQML language's expressiveness, compatibility with knowledge centric tasks, and alignment with the project's objectives contribute significantly to the system's agility.

Furthermore, the flexibility of the Unreal Engine and Python framework enhances the adaptability of the system to dynamic changes. As the security landscape evolves or new

functionalities become imperative, the infrastructure can incorporate modifications. The fusion of Unreal Engine's real-time simulation capabilities and the versatility of Python ensures that the system stays at the forefront of industrial security technology. Crucially, our proposal holds paramount importance for any enterprise, as having a system capable of detecting internal theft by trucks is critical for financial integrity and security. This approach not only safeguards against economic losses but also establishes a strong security framework, positioning the project for sustained success by offering scalability, adaptability, and heightened resilience against potential threats.

External Resources

GitHub Link: https://github.com/DelRosal/MultiAgents

Environment Video: Link

Simulation Video: Link

References

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