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Combat Efficiency and Effectiveness of AI-driven Multisensory Search-and-Destroy Agent

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Conflicts of Interest
There are no conflicts to declare.

ABSTRACT

Artificial Intelligence-powered smart systems have started to outperform their human counterparts in many ways. However, their efficiency, effectiveness, and performance depend heavily on the data being received by the machine. As a result, a lack of sufficient data can cause an AI to make the wrong decision. While in most cases this sort of malfunction is not capable of inflicting irreversible damage, in some particular cases it can be life-threatening. AI agents tasked with human interaction such as smart devices capable of mechanical movement and physical manipulation relies on complicated sensor systems for that data to be collected, and lack of proper sensors means lack of sufficient data to make an effective decision. This paper conducts a study on a behavior tree-driven agent equipped with multiple sensor systems capable of utilizing a coordinated dataset and even compensate the loss of a primary sensor system with auxiliary sensors to carry on its mission. The goal here is not to see what the agent does, but to observe how it manages to do so while being faced with technical difficulties like sensor malfunction and whether the executed task is within the mission parameters or not.

Keywords: ARTIFICIAL GENERAL INTELLIGENCE, BEHAVIOR TREE EXPERT SYSTEM, SENSOR ARRAY, VIRTUAL ENVIRONMENT

Introduction

Data-driven expert systems and artificial general intelligence as a whole have grown exponentially in recent years to the point where it is effective enough to replace a fully functional human being. While Artificial Intelligence has seen rapid development in the past decade, an AI-driven agent is only as good as the data that drives its decision-making capabilities. Nowadays Amazon's Alexa is a very popular choice because of its ease of use and superior command execution capabilities as a human interaction device. Despite being augmented with all the state-of-the-art technology, it's often known to malfunction. While Oliver Haberstroh, a resident of Hamburg, Germany, wasn't home one night, his Alexa unit randomly started playing loud music at midnight (Amazon Alexa Partied A Little Too Hard, 2021). Law enforcement agency had to break into his sixth-floor apartment in order to investigate the disturbance, which was reported to them by Mr.Haberstroh's neighbors.

According to Amazon's claim, Alexa received the command to play the music remotely but it simply lacked the functionality to detect that there is none around to issue the command. There have been other instances where news broadcasts triggered several Amazon Alexa devices to purchase dollhouses when Alexa failed to detect that the voice command wasn't issued by her owners (Amazon's Alexa started ordering people dollhouses after hearing its name on TV, 2021). Although no major harm was done, it just shows how severe the situation can be when AI systems are heavily reliant on limited sources of data to execute tasks. A drone can easily crash into a transparent glass window if it only relies on the camera to maintain flight path instead of using an ultrasonic sensor as well as the camera to detect obstacles.

The purpose of this paper is to conduct a study of a strictly programmed behavior tree-based artificial general intelligence-driven agent which takes advantage of multiple different sensor systems in conjunction to execute certain tasks in a virtual environment. The study also includes unique scenarios where certain sensor systems simply fail to deliver any data or deliver contradicting data due to simulated environmental manipulation and how the agent overcomes this issue by utilizing other available sensor systems to compensate for the sensor systems that have failed. Knowledge gained through this study could be very helpful in the development of expert systems and other fields such as robotics to create bipedal or quadrupedal robots or even autonomous vehicles.

Review of related literature

In February 2020 researchers from OpenAI and Google Brain published a paper named "Emergent Tool Use From Multi-Agent Autocurricula" which was a combined effort of Bowen Baker, Ingmar Kanitscheider, Todor Markov, Yi Wu, Glenn Powell, Bob McGrew from OpenAI, and Igor Mordatch from Google Brain which discussed agents discovering progressively more complex tool use while playing a simple game of hide-and-seek in a virtual environment (Baker et al., 2020),(Strickland, 2019). Blue Team members (Hiders) are tasked with avoiding line-of-sight from the Red Team members (seekers), and Red Team members are tasked with keeping the vision of the hiders.

There are objects scattered throughout the environment that Blue Team members and Red Team members can grab and lock in place, as well as randomly generated immovable rooms and walls that agents must learn to navigate. Before the game begins, Blue Team members are given a preparation phase where Red Team members are immobilized to give Blue Team members a chance to run away or change their environment. This was an amazing attempt at discovering some emergent behaviors from the agent and the results were beyond everyone's expectation(Baker et al., 2020).

The agent turned out to be so smart and efficient that it found multiple glitches in the virtual environment and manipulated them to its advantage, essentially "breaking" the game (Strickland, 2019) and leaving everyone speechless.

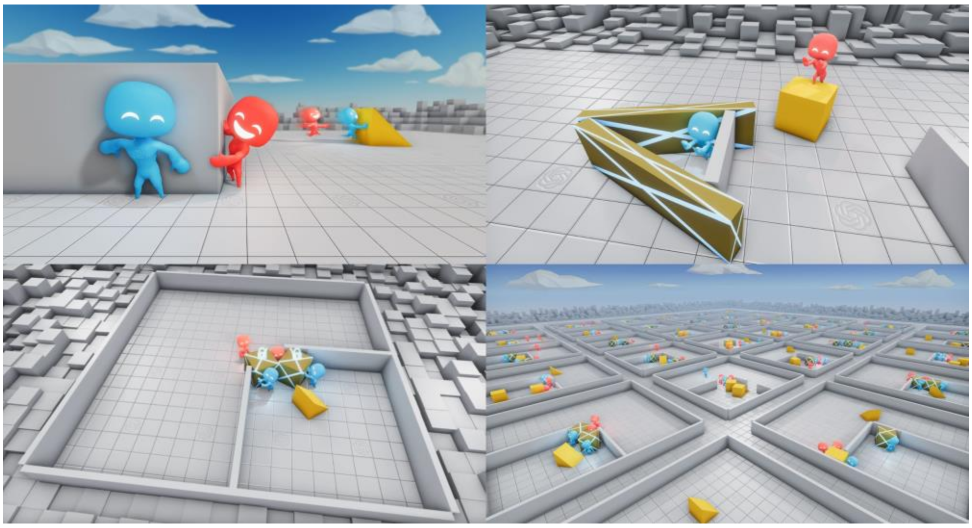

Fig. 1. Simulated multi agent environment used by OpenAI

Another research paper named "Learning Quadrupedal Locomotion over Challenging Terrain" published in Oct 2020 by Joonho Lee, Jemin Hwangbo, Lorenz Wellhausen, Vladlen Koltun, and Marco Hutter discussed the development and training of a "blind" quadrupedal robot trained in a virtual environment and later deployed in real life to study if robust locomotion over challenging terrain in natural environments can be achieved by training in a virtual domain instead of real life.

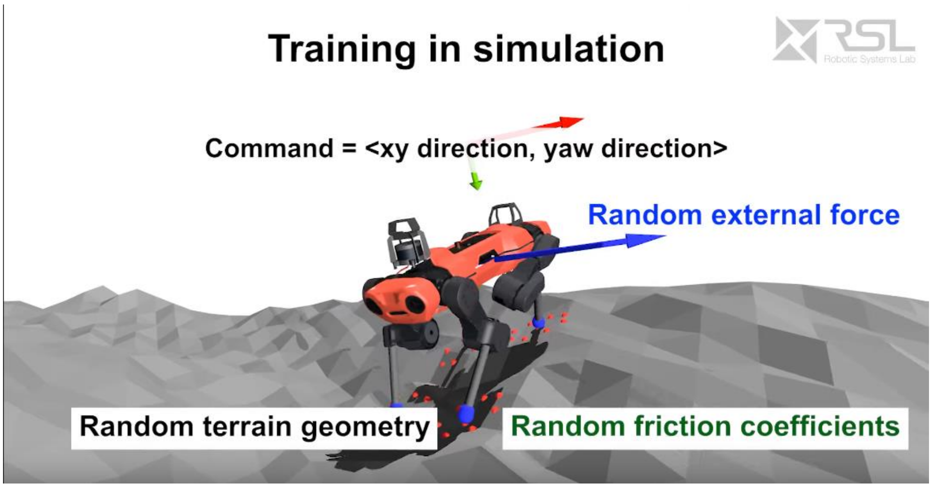

Fig. 2. Virtual training environment for quadrupedal locomotion

Their project was funded in collaboration by the Intel Network on Intelligent Systems, the Swiss National Science Foundation (SNF) through the National Centre of Competence in Research Robotics, the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program grant agreement no 852044 and no 780883. The research was conducted as part of ANYmal Research, a community to advance legged robotics.

Fig. 3. Deployment of the test cases

This paper took a huge inspiration and knowledge base from the works mentioned above. While The previous research focused on multi-agent operations and quadrupedal locomotion, this study focuses explicitly on human interaction and the effects of multi-sensory abilities of a behavior tree-driven bipedal agent within a virtual environment. Thanks to the outstanding research done by pioneers in the industry, there is no need to reinvent the wheel and all the efforts can be directed toward sensory manipulation and observation instead.

It should also be mentioned that this study wouldn't be possible without OpenCAGE (Filer, 2020), a brilliant open-source software developed by Matt Filer, and exceptionally remarkable AI documentaries (Thompson, 2016), (Thompson, 2020) of Dr.Tommy Thompson.

Research methodology

Conducting such experiments in a controlled environment can be rather expensive, not to mention life-threatening in the unlikely case some error occurs. The most cost and time-efficient way to study it would be a virtual environment that can be easily manipulated and where it would be safe to interact with the agent through digital means. And nothing beats a game engine when it comes to a very similar representation of real-life confined within a very detailed map that serves as the environment to conduct the study safely.

Cathode (Stachowiak and Bonet, 2014) is an engine built by the Creative Assembly in partnership with AMD for the 2014 computer game Alien: Isolation which serves as the virtual environment for this study. It is a highly modified version of the engine created for an earlier title, Viking: Battle for Asgard. The Cathode engine was named after its bespoke node-based scripting functionality which allowed for live edit flowgraphs to control game logic. This system ran inside of a toolkit created for Cathode named the Creative Assembly Game Editor (CAGE) in a ‘’what-you-see-is-what-you-get’’ (WYSIWYG) style. It allowed for the use of prefabs to quickly build upon existing scripts. The Cathode scripting system covered: particles, lighting, props, AI scripts, audio, zoning, and character setup.

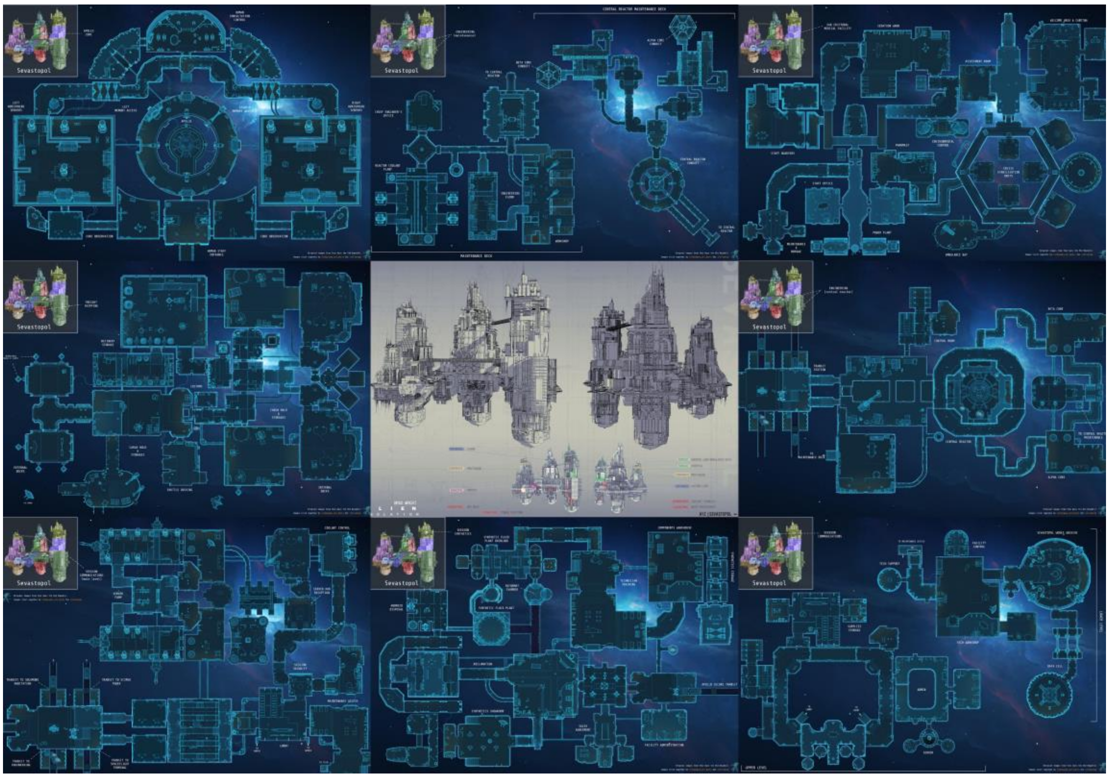

Fig. 4. Sevastopol Space Station Virtual Rendering

The environment in which the interaction between the agent and the target occurs is essentially a virtual map of a space station named Sevastopol running within CAGE. This serves as an ideal virtual environment since the only thing outside the environment is the endless void of outer space. Needless to say, that is the perfect barrier to keep test subjects within boundaries. It's also quite convenient to manipulate through OpenCAGE as mentioned previously.

Fig. 5. A matured xenomorph specimen

The agent manifests itself into the environment as a Xenomorph (Xenomorph, 2017), a very well-known entity from Ridley Scott's classic movie franchise. The agent is bipedal in appearance with a segmented, blade-tipped tail but will either adopt a more hunched stance or remain quadrupedal when walking or sprinting (Alien (creature in Alien franchise) - Wikipedia, 2021). It goes without saying this is the perfect creature to simulate and conduct tests on if the objective is to study search and destroy (Xenomorph, 2017). Although some different manner of interaction could be staged with a cute and lovable character similar to the other researches conducted in this field, this study went with this particular design of agent to better understand and observe the effectiveness of the agent while it interacts with the target.

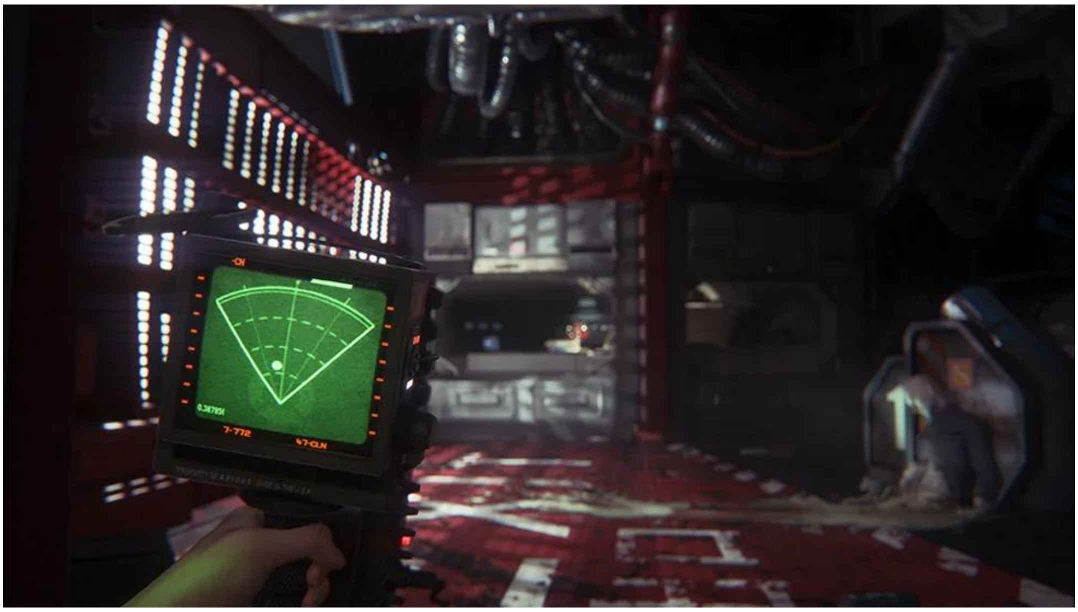

Fig. 6. Usage of Tools in the virtual environment

The target is a digital representation of an average person. To make it fair the target has the capability to utilize tools and equipment found within the environment. The target is strictly human-controlled since it would be quite difficult to observe the effects of the sensor systems of the agent if both the agent and the target is AI operated due to the fact that the target will start taking advantage of the unique scenarios where the sensor systems of the agent will be manipulated to force the agent to utilize other means of sensing the target. So in order to attain the best experience possible, the controls of the target are kept manual.

To conduct the study it's vital to know about the working principles of the AI and its sensory abilities which are going to be discussed in section 4 and section 5 of this paper. The first simulation is a rather standard one with the full potential of the agent unleashed and unchecked while the later simulations consist of unique scenarios where specific sensor systems of the agent are disabled on purpose so that the agent has no other option to use auxiliary or secondary sensor systems to carry out its mission.

Dual tier system

It's very essential to note that there are effectively two systems that control the agent. The agent itself is driven by what's known as a behavior tree. The agent's behavior tree has a variety of behaviors for searching the corridors of the environment, investigating foreign noises, or checking out areas that the agent is interested in. Specific behaviors such as searching lockers and crawling into smaller vents only activated after the target has repeatedly managed to evade the agent using these methods several times, which creates the illusion that the agent is self-aware and is learning. The behavior tree is ultimately responsible for making sure that the agent hunts down and terminates the target. But the agent must do it on its own accord and rely on what it detects within the environment from its own audio and visual sensors.

However, this can lead to a deadlock where the agent traps the target in a corner of the environment with no escape routes or completely loses the target as the target runs for his life. Both of these situations complicate the test environment and requires a restart, which is pretty much time-consuming. And that's where the second AI system comes to the rescue. The second system is an AI director which is designed to manage the agent. The director's job is to instruct the agent to head towards the target throughout a given level. It never reveals the actual location of the target but shares the general vicinity of the target to the agent and the agent's behavior tree does the rest. What that means is while the director shares the same prime directive as the agent which is to search and destroy, the agent still has to seek out and terminate the target on its own merit. This ensures that the agent serves its purpose while also making sure that it acts according to expectations.

Dual Tier Expert System	*Macro AI* Director	A scenario manager that monitors and manipulates the environment, the agent, and even the target if necessary.
	Micro AI Agent	A reactive, sensor-driven system that reacts both to target and the instruction from the Director

Fig. 7. Dual Tier Expert System

When the agent is wandering throughout the environment looking for the target, that's something called frontstage. The agent is searching the environment either because of the directive from the director or it detected something that caught its attention. Once the agent is in the proximity of the target, the director maintains something called a menace gauge which is designed to record the intensity of the agent's presence. The menace gauge increases at different rates depending on whether the agent is nearby and whether the target can hear it moving or actually see it in front of them. Once it reaches a threshold, the agent will go into the vents for a time which is known as a backstage mode. During the backstage mode, the agent will take a stationary position and try to ambush the target by predicting where the target could go next.

Job System	• What to execute • Where to execute • When to execute	*Active* Front Stage	Conduct Search and Destroy
		Passive Back Stage	Fall back and orchestrate an Ambush

Fig. 8. AI Job system

Sensor Systems

As mentioned previously the agent must search and destroy the target by itself. While the director always knows the exact location of all anomalies the agent must be able to find the target on its own. To make that happen the agent is equipped with multiple sensor systems. It utilizes several types of vision, capable of detecting noise within proximity, and registers the target through touch sensors when the target makes contact in extremely close proximity or registers damage received from the environment.

In theory, the agent needs all three sensors to detect and engage the target. There are three ways to make sure that the agent will sense and go after the target. Either the visual or touch sensors confirm with confidence that the target has been spotted or several sensors activate when the target is hiding.

Vision

Vision is the easiest way for the agent to register anomalies as targets. For the vision, the agent makes use of a vision cone or view cone where it can essentially "see" within a certain proximity, practically in the shape of a cone, and registers when objects have been in the cone for a period of time. View cones are a widely utilized technique for visualizing how an AI can "see" something in the environment, given they're easy to visualize and debug.

The vision sensors have four different view cones. The normal cone for seeing directly in front, which can see pretty far ahead, a tighter view cone known as focused, which is used when the agent is looking at specific objects or locations but within a shorter range, the peripheral cone that is shorter in length but much wider and lastly a cone called close that is very short but very broad and is designed to register anything right next to it. It means the target can't go crawling around sitting mere inches away dodging all of its other visual sensors.

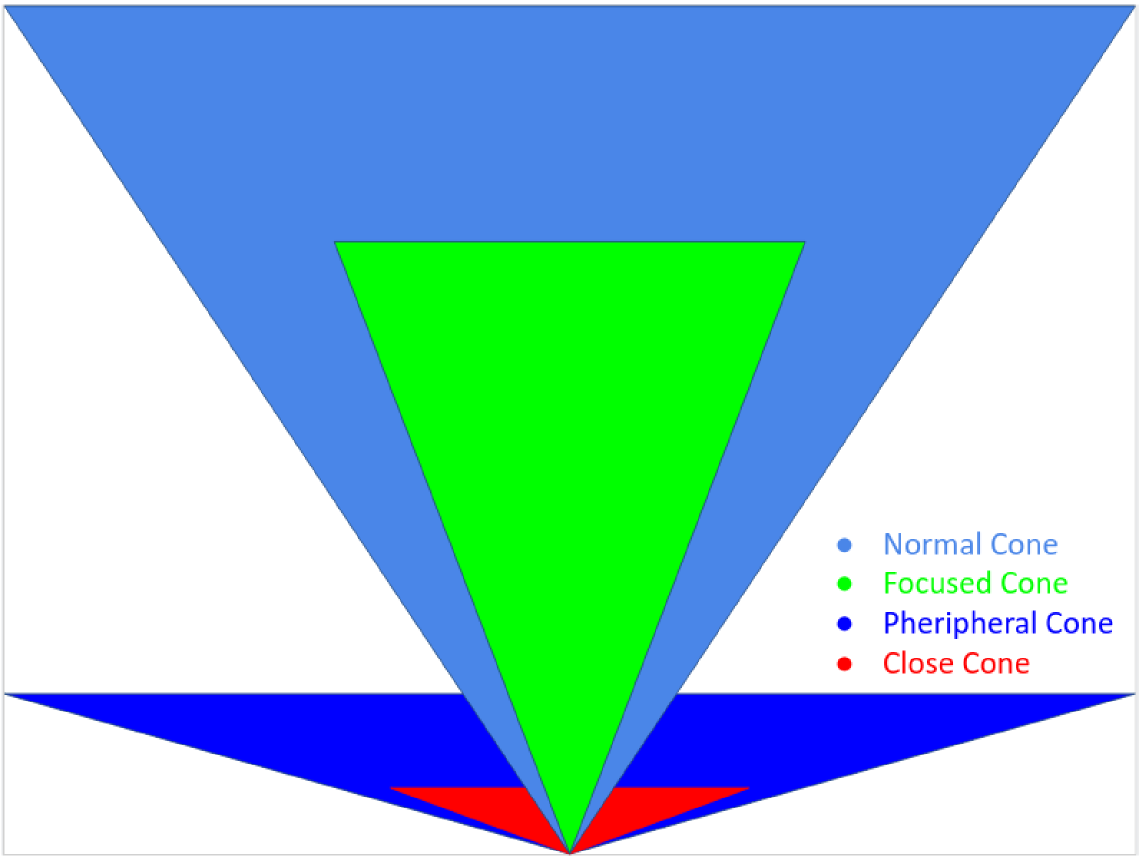

Fig. 9. Agent Vision Cone

Here, the principle idea is that should the target intersect the view cone and there is nothing that would block the line of sight from the agent to the target, then in practice, the agent has "seen" the target, but the sensor doesn't register the target as spotted immediately. The longer the target stays in the view cone, the signal from the sensor becomes stronger. Once that sensor reaches a certain value it enables certain paths within the behavior tree to become available to the agent, because it can most definitely "see" the target now. The value of the reading from each of the view cones varies and will increase at different rates depending on which of the view cones the target is situated.

However, it's worth noting that the vision of the target can be obscured based on the variables in the environment such as light level, fog, smoke, etc. In fact, each view cone has modifiers that dictate how well the agent can see the target in different conditions. Hence the environment the agent is operating in has a huge impact on how well it can see since it can obscure the agent's view.

Sound

The agent's next best sense is sound, where it can hear a variety of different noises at different strengths. Each sound the target makes has a variety of strength levels. In a manner similar to vision, a sound registered by the agent is driven by activation thresholds, with weapon discharge in particular scaled to trigger sensor activation way faster than any other sounds. These sounds pinpoint the agent to a location to investigate.

The movement has three stages of noise, crouched, walking, and running, and the noise generated and sound radius is quite different for each. Meanwhile, usage of equipment, including even hitting a surface with a tool will trigger the agent's interest and have a much faster rate of activation.

Touch

Although it's possible to have all the surfaces of the agent covered with cameras it's not a very effective solution to respond to external stimuli. Sometimes it's better to feel rather than see. This is why the agent utilized multiple touch sensors to detect environmental changes such as heat and even register the target in the event it gets close to the agent or sneaks up behind the agent.

Results

Usually, behavior tree based agents are rather predictable due to the fact that it only acts according to a limited number of the hardcoded event-driven tasks. But due to the dual tier system, the agent was able to overcome this obstacle and, even going as far as outsmarting the human target a number of times.

Normal Scenario: All sensor systems fully operational

Case 1 : The target was attempting to open a door. The agent was patrolling the area after being instructed by the director. The agent made successful visual contact with the target due to the lack of cover in that particular room and carried out termination immediately.

Case 2 : The target utilized the motion tracker to determine the proximity of the agent and attempted to hide in a utility closet. But the agent registered the noise made while opening and closing the locker door. As a result, the agent started searching all the closets in the room and eventually found the target.

Case 3 : The target decided to avoid a room that was being searched by the agent and went through the utility shaft instead. The agent noticed movement in the shaft and then discovered that the hatch was left open. It immediately went in and found the target at the opposite end of the shaft.

Case 4 : The target managed to assemble a makeshift flamethrower by repurposing some repair tools and engaged the agent while it was attempting to attack the target. The agent registered some damage and went to backstage mode. Later the agent ambushed the target from an overhead ventilation shaft and succeeded.

Case 5 : The target was spotted by the agent in an intersection and the target tried to utilize the flamethrower again. However, the agent remembered the effects of the flamethrower from their last interaction. So it evaded the line of fire by climbing the walls and quickly closed the distance between them to get the target within attack range.

Case 6 : The target compromised the air purity controls and caused the moisture level in the air to increase rapidly. This resulted in the visual range of the agent being reduced significantly. However, it still spotted the footsteps of the target, rushed in, and acquired the target within the visual range.

Case 7 : The target ignited some ordnance in the fire which resulted in a massive explosion and produced a lot of noise. The agent rushed toward the explosion like a bullet while the target tried to make use of it as a diversion to escape. This worked in some cases but it failed in this particular one because the target could not anticipate the route the agent took this time around and essentially ran into it.

Unique Scenario: Sensor systems handicapped

Vision Sensors Disabled

Case 1 : The target was attempting to escape however the agent heard the footsteps, came rushing toward the noise it registered, and bumped into the target from the back. From the touch, it immediately determined the presence of the target and carried out the execution.

Case 2 : The target hid underneath a table to avoid being sensed by the agent who was patrolling the surrounding area. The agent failed to find the target and went into the backstage mode. The target took this opportunity and escaped by the room only to be ambushed by the agent in the next room.

Sound sensors disabled

Case 1 : The target made a lot of noises while going through the environment but the agent could not detect them. However, it still managed to score the kill when visual contact was established during a patrol.

Case 2 : The target decided to attack the agent from the back hoping that it won't be able to detect the origin of the attack now that it's deaf. But the agent turned immediately upon damaging received and engaged the target.

Touch sensors disabled

Case 1 : The target was able to inflict some damage by using a projectile weapon. Although the agent could not determine the nature of the damage being taken, it registered the noise of the projectile discharge, visually confirmed the target and engaged immediately before any more damage could be inflicted.

Case 2 : The target hid in a utility shaft while the agent was approaching the area. Although the target was not detected by the agent, Hatch couldn't be closed since the agent will definitely hear it and rush toward the noise to investigate. So the target left the hatch open, took cover behind some equipment, and decided to wait for the agent to leave since that particular hatch is too small for the agent to get to the other side. Unfortunately for the target, the agent discovered the open hatch, understood the fact that the target went through the hatch to the utility shaft, and immediately ran toward a ventilation shaft that was connected to the utility shaft. Before the target could realize what just happened, the agent entered the utility shaft, recognized the target within seconds, and carried out the execution.

Discussion

As seen on the test results, the agent can make highly accurate tactical decisions thanks to the coordinated data it receives from the sensor systems and capable of compensating for lack of data from the primary sensors with the secondary or auxiliary ones. The agent even managed to turn the table on the target despite the fact that the target had more situational awareness in particular cases and carried out the mission by outsmarting the person it was interacting with.

Although the results are impressive, it's not recommended to interface this specific agent with any sort of mechanical assembly capable of locomotion in real life. The goal here was to observe the process, not to implement the consequences. The knowledge obtained here can be very useful in a number of fields such as robotics, unmanned aerial vehicles, and even self-driving cars. For instance, an automated vacuum cleaner started "eating" cat food and turned the pet into its biggest rival in the household. While it had no intention to rob the poor cat's food, it could not distinguish between dirt and food that was on a cat feeder since these kinds of robots are instructed to clean anything and everything on the floor that resembles debris. The robot could easily carry out the task without making an enemy out of the cat if it had a camera to see exactly what is being vacuumed.

Another robot, this time a smart lawnmower, drove itself into a campfire while mowing the lawn. It had sensors to detect obstacles, but no thermal sensors to detect the abnormal heat sources on its path. The unfortunate owner of the mower even posted it on social media.

Conclusion

By implementing multisensory agents unpredictable incidents can be reduced significantly. Coordinated data from multiple sensor systems not only ensure a higher chance of success but also provides a failsafe system at the same time. The possibilities are endless and the only limitations are imagination and research funds. The current state of the industry is already advanced enough to integrate existing technology in conjunction with current models of robots and smart devices. The only new element that needs to be introduced is a safe practice of allowing the agent the ability to receive and process relevant data on a wider scale.

While the study conducted on the virtual environment turned out to be a success and confirmed the hypothesis, much more conclusive data needs to be collected for further study in order to find any unforeseen difficulties or limitations of such agents. The future direction for this study would be to develop a multisensory mechanical entity in real life and allow the agent to interface with it to have an even better observation of its capabilities.

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