Autonomous Swarms in Active Services

Abstract

Robotics has evolved across multiple industry segments, from manufacturing to advanced technology, surveillance, and disaster management. Typically, robotics-driven processes are characterized by a set of pre-defined requirements and operations, carried out by individual robots (bots), and performed at an accelerated pace. However, collective decision making by autonomous intelligent robots, leveraging the concepts of machine learning and artificial intelligence (AI), is becoming increasingly important for agile operations.

Technological advances have helped realize swarm operations, in which autonomous bots work in a coordinated manner to effectively execute tasks.

In this paper, we propose the approach, design, and implementation of a robot swarm ecosystem that enables:

- **Active servicing:** Collective decision making and execution to solve problems
- **Collaboration:** Automated swarm response to priority services, without external directives
- **Automaticity:** Leveraging blockchain for real-time processing of services being advertised as well as exchange of information

Autonomous Swarms: Current Trends and Challenges

The robotics landscape is rapidly evolving, with bots already being deployed for enterprise operations, commercial purposes, home automation and industrial applications. Robot swarms are being leveraged across segments including retail, travel, healthcare, manufacturing and semiconductors, for a variety of use cases. These swarms are being enabled with the autonomy to operate independently once a preset task or a passive service is assigned, leading to an evolved ecosystem of autonomous nodes or swarms.

However, autonomous nodes/swarms executing passive services have two specific failure points. One is central management and the other is a non-configurable preset task. De-centralized management is a viable option, but it only scales down the risk and does not eliminate the point of failure. Preset actions for autonomous bots require manual intervention, which defeats the purpose of automaticity.

Proposed Solution Approach

The efficiency of a swarm, or a group of bots, is quantified by its ability to detect its neighbors, or other robots, and communicate with them.

Existing approaches to collective task execution mainly depend on centralized management and passive services, such as pre-set operations executed as per already defined tasks. However, with the advent of digitization, proactive services that automatically update pre-defined actions in real-time, without any manual intervention or centralized directives, have become a real possibility.

We propose and demonstrate a viable approach that addresses the challenges faced by an autonomous swarm ecosystem. Salient features of this approach, which enables a truly autonomous swarm environment executing active services, include:

- **Auto-discovery:** Swarms are alerted when a bot is added or removed
- **Agile operations:** Collective tasks are proactively assigned
- **Response to active services:** Active reassigning of tasks to ensure order priority

The ecosystem broadly consists of blocks that leverage:

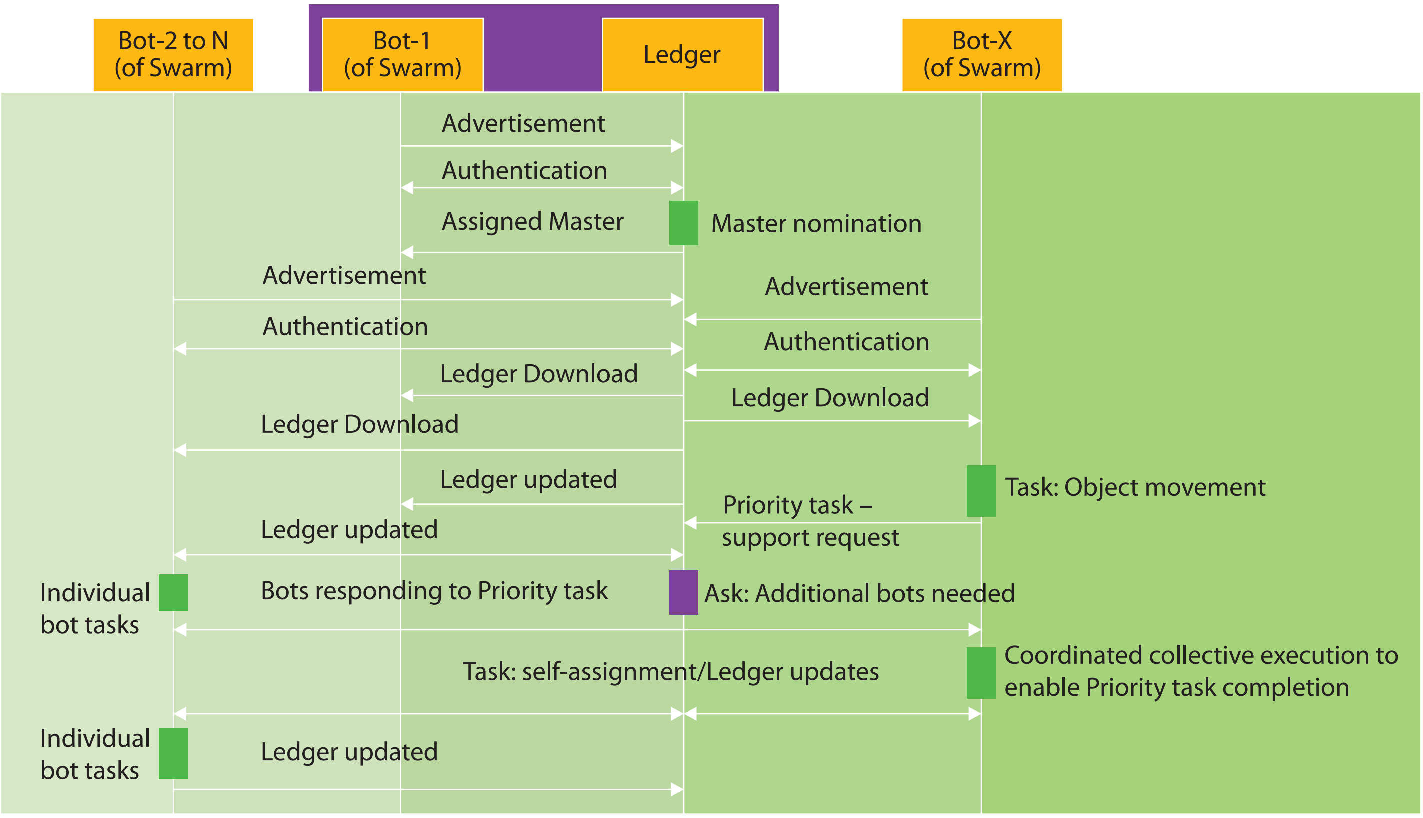
- ARGoS[1], a system designed to simulate a large-scale robot swarm
- MAVProxy[2], MAVLink protocol proxy suitable for embedding in small autonomous vehicles
- Multi chain, a blockchain platform

The approach ensures effective task assignment with decentralized management and fosters dynamic decision making, creating a simplified system for faster, reliable and secure resolution of business problems.

Let's consider a few use cases where such an autonomous ecosystem could be invaluable:

- **Search and rescue at accident sites:** Autonomous nodes comprising robot bots and unmanned aerial vehicles (UAVs), designated for the search operation, could step into the accident site and survey it. These bots and UAVs could then autonomously trigger swarms of rescue-bots provisioning facilities such as medicare supplies, emergency rations, wireless connectivity and battery packs.
- **Public safety:** Autonomous nodes deployed at public places can detect and process potential risks and trigger swarm bots to take appropriate safety actions.
- **Retail:** Groups of smart bots can enable customized shopping experiences
- **Travel/Entertainment:** Autonomous swarms can help execute complex operations such as event shows.

A broad level representation of the inter-communication between the solution components is as follows.



Cohesive Collaboration for Flawless Task Execution

Let's consider that a swarm of bots has been assigned the task of moving an 'Object'. The setup instantiates an ARGoS ecosystem that introduces an article (an Object with an unknown weight) and autonomous bots (Bot-1 and Bot-2). The system includes a multi-chain that interacts with ARGoS and uses MAVproxy as the intermediate gateway to enable the swarm to advertise and reciprocate for service requests.

Now let us assume the task is assigned to Bot-1 and that each bot has the ability to move only a certain amount of weight. Based on the assigned task, Bot-1 updates the ledger with the task assigned and executes the applicable robotics motor functions to move the Object. However, the service request cannot be completed by Bot-1 alone, as it does not have the ability to move the entire weight by itself. Existing approaches will likely flag this situation by sending an alert and await human instructions for the way forward.

However, with our proposed approach, Bot-1 will advertise for help within the swarm using the multi-chain ledger, asking for assistance from other bots to complete the task. This request, being a deviation to the passive service, will trigger the proposed approach for collective decision-making in-real time. The swarm will process the advertised request, which is an evolved task (active service), and will plan collaborative actions to solve the problem of moving the Object. This active service will be generated and processed in-real time with no external directives.

Continuing with this approach, the next idle swarm bot (Bot-2) that is listening to the advertised request will respond and acknowledge the request. Based on the acknowledgement, the task will get auto-assigned to Bot-2 in real time. Now Bot-2 joins Bot-1 in collaborating and moving the Object as per the original task assigned.

In this way, the approach provides a decentralized, autonomous ecosystem to execute active services, which would otherwise have required manual intervention.

Future Roadmap

While the approach demonstrates the use of an autonomous swarm ecosystem for active services, there is scope for additional enhancements as evidenced by the following:

- The swarm needs to be orchestrated perfectly to efficiently execute the active service in a collaborative manner.
- Bulk deployment of bots over time may expand the blockchain and lead to a situation where maintaining the ledger of transactions may result in risks of bloating.
- In case of a multi-device robot swarm, a voting process is recommended, to decide which bot would take up the next advertised or assigned task. This could be enabled by considering additional parameters, involving telemetry, statistics and prioritization of tasks.

With the advent of intelligence nodes, the qualification of a swarm extends beyond robotics to UAVs and IoT devices. Enabling active services leveraging the tenets of autonomous swarms be the trend going forward. The roadmap ahead could include:

- Collaboration of on-the-ground (robots, IoT devices) and in-air (UAVs) swarms. Possible use-cases could be fleet management, public safety and disaster management.

- Using AI to train swarm ecosystems, to bring in grater agility in executing active services
- Integrating multi-device type swarms with augmented reality (AR) or virtual reality (VR) to enable effective monitoring of the services being executed in the autonomous ecosystem

References

[1] ARGoS, accessed December 7, 2017, http://www.argos-sim.info/

[2] Python, MAVProxy 1.6.2, accessed December 7, 2017, https://pypi.python.org/pypi/MAVProxy

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