A Colony of Intelligence

Ants' Growing Influence on Artificial Intelligence

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Table of Contents

Abstract

Research in artificial intelligence has begun to draw on sources other than ourselves for design ideas. Biology is a newly tapped well of creativity. When looking through these advances one sees that ants have had a large impact on AI design. This is based on similar ant behavior. The most important foundation of this ant behavior is their usage of pheromones while traveling and interacting with each other. Despite being a novel ideas these biological processes yield simple and straight forward artificial intelligence algorithms. It is important to note that the intelligence being modeled is not based on the individual ant mind but how ants and hive minded organisms interact with their environment as a colony. These advances have affected many different fields. One hope of this review is to draw attention to these new advances in order to inspire more artificial research that has its roots in time tested biological phenomena.

Introduction

Humans can do remarkable things. We can walk, we can fly, and we can build logic and intelligence using little bits and bytes. Artificial intelligence research has long been a burgeoning field in computer science and computer engineering. At this point in the artificial intelligence development we have yet to really create anything that is on its own intelligent, for lack of a better word. As we look for ways to stretch our fingers toward the goals of smarter artificial intelligence we draw on different sources for inspiration. One obvious source of inspiration would be ourselves - humans. However, recent conclusions by experts in the field leave us pondering the repercussions of modeling another super intelligent machine potential of sentience on our own intelligence. [1] Do we really want a new species of super humans? A spiteful, vengeful humanoid with intelligence humanity couldn't dream of attaining. We definitely don't want to create a new sentience that is as violent and unpredictable as ourselves. So who if not ourselves do we try to mimic in our artificial intelligence creation plan? One solution would be mimicking the behavior of other organisms, as opposed to mimicking the actual sentience. We're a long ways away from creating something sentient but we already have new ideas for future artificial intelligence developments. Close your eyes, and imagine what's in this box. What creature has inspired some of the greatest leaps in artificial intelligence in the last ten years? Is it a chimpanzee? A dolphin? Nope, the box is filled with ants. An entire colony of ants.

This literature review hopes to draw attention to the rising influence of ants and their impact on the artificial intelligence field. As more research is conducted it becomes clear that although drawing on similar concepts the applications for this research are beyond counting. Ants are almost the furthest from sentience we can imagine, so how can an ant do something like that? The answer is individual ants can't do that. However, as a swarm they can work together to efficiently solve different variations of problems using similar biological principles. The algorithms that are yielded in this research stand up very well to other approaches to solving the same problems which help support the idea that this new shift in AI research could have further untapped resources. [2]

Inspired by Biology

There are three different ant behaviors that are mimicked in developments that help build artificial intelligence algorithms. The first way is how colonies of ants travel. Ants travel by smelling the pheromones of other ants that have just passed by. Ants want to stay with the group so they go to where they smell the most pheromones left over on the ground – which would imply that area had the most ants pass over it. If you start a colony of ants at the beginning of a maze the ants will wander and explore aimlessly in all directions. However, the nice thing about aimlessly wandering is you will discover the exit of the maze eventually. When those first ants do find the exit they leave and the ants behind them follow their pheromones on out of the maze. Now of course, there are ants dropping pheromones on the ground as they find themselves approaching a dead end. But when that ant stops moving the ant behind it has to stop moving, too. Thus that trail of pheromones is staying stagnant in strength while the pheromone trails of the ants exiting the maze out of sheer luck get stronger and stronger. So, as time goes on, ants no longer need to randomly spread out through the maze to find the exit, because they have a really stinky trail of ants to follow already. This is a remarkably simple and amazing way of navigating through a maze, or through the wild. Scientists have mimicked this behavior in small robots. But when they work in a team they do the exact same thing ants do. Scientists built them to follow light trails instead of pheromone trails. As the robots move through a maze, a laser stationed overhead marks the path. These robots see the brighter areas and adjust their courses to be in the brighter paths of the maze which will lead to the exit just like it did with the ants. [3][4]

The first principle deals with ants traveling through an environment in a quick and efficient manner. The second behavioral phenomenon being modeled is actually just a slight variation to the first principle discussed. It concerns how ants travel independently to collect food as a colony. Keeping in mind the two biological rules discussed before: Ants travel along the pheromone trails of preceding ants, and ants will prefer to travel on paths where more ants have traveled before them. In this application the ants travel towards food sources dropping their pheromones and when other ants in the search for food decide where to begin their search they will prefer to search in the direction other ants have searched for food. Ants that find food return along the same path leaving twice the amount of pheromones. This introduces the unique concept of a 'safe' path and 'unsafe' path. Perhaps an equal amount of food lies in two separate locations. At first it is likely that ants are drawn equally to each source of food bringing more ants with them. However if one food source is an ant trap which traps and kills the ants that find it they will not return along the paths they came. This does not add a second layer of pheromones that strengthens the scent. Seeing that trend and keeping in mind the two rules from before ants will not only follow ants to more food they're going to prefer paths that have seen successful return trips before. [5][6][7]

The final behavior being modeled in the development of these artificial intelligence algorithms is how ants identify intruders. Ants identify intruders with a voting system of sorts. Ants will mark a potential intruder that meets a certain set of criteria. Stimuli that don't follow the orders of a leader, such as a queen ant, will cause other ants to mark it. Different types of stimuli will stimulate different types of votes. A rival colony's army ant will cause a different response than say a rival colony's abandoned queen which could make a valuable source of food or a 'safety' in case the original queen dies suddenly. [8][9][10]

Applications and Intentions

Although drawing on a small range of biological behavior these research articles help solve problems in a variety of different fields. There are several instances of trying to create solutions to NP complete problems. Furthermore, there are articles that look to make real world processes more efficient. These problems would generally be considered to be NP complete but due to its applications in the real world optimization can be achieved since the algorithms don't need to account for an input as large as infinity. There are other applications that are based in network security.

One algorithm based on the way ants find food tries to solve a NP complete problem referred to as The Vehicle Routing Problem, or TVRP. In this real world application of TVRP the aim was to find the most efficient path for multiple garbage trucks to collect rubbish in a neighborhood and return it to a recycling center when their loads were full. [7] Some researchers more recently have expanded upon these methods to include what is referred to as 'dead ants.' As discussed before ants prioritize safe routes over unsafe routes to find food. In most applications of algorithms derived from this, ants that try unsafe paths die are deleted from memory and are not kept track of for remainder of the algorithm's life span. However, in real world instances of TVRP such as waste disposal, garbage trucks do not die if they pick a bad route. A bad route may be indicative of traffic or weather conditions. Instead of deleting the 'ant' that gets caught up in these situations the algorithm keeps it in memory and adjusts the path of the garbage truck/ant. These trucks would learn new ways of navigating through issues that could prevent future unsafe paths of return. [6]

Another article addresses the vehicle routing problem but with a different real world application of sending and receiving data through a mobile network. This algorithm is developed to navigate through web traffic in order to find its destination quicker and more efficiently. Swarm intelligence algorithms were compared to artificial immune system algorithms and both did very well at delivering their data. However, it is clear that the algorithm based on swarm intelligence worked more consistently and more efficiently. [5] Although working with the same essence of problems. One research group did not use a real life example of graph traversal. They did develop algorithms though for the general purpose in hopes of working towards a solution for NP complete problem sets. It is acknowledged that there are applications in internet network traversal as well as a general path finding algorithm. [3]

The work of Garnier, Simon, Maud Combe, Christian Jost, and Guy Theraulaz started off as a biological experiment. Although this experiment will greatly benefit artificial intelligence, its purpose was to verify current theories on ant colony movement were feasible. The article talks about three leading theories in how ants roam their environment - one being the pheromone trail prioritization while traveling. The scientists tested for this specific theory because it is the most widely accepted theory by biologists. Although their intent was to help solidify the ideas of how we think ants travel, the result they have is an efficient algorithm for finding paths through mazes. [4]

Much of the research inspired by the way ants detect intruders has helped create security measures that would find attacks on mobile networks. The specific instance of detection would prevent so called sinkhole attacks on networks. A sinkhole attack is an attack that maliciously reroutes data in a network to cause congestion or data corruption. Interestingly enough this algorithm can be paired with the network routing algorithms discussed before. When data does not respond routing commands it will get marked by the algorithm. There is a threshold that must be reached before a network can be determined to be under attack. There are many reasons why data may not immediately respond to a command to reroute just like there are reasonable things that could prevent an ant from following its ant brothers. [9] A conference proceeding from 2011 theorized this could be done. With very limited implementations to do a proof of concept researches theorized that ant behavior could greatly influence our counter cyber-attack technology. [10]

So far all of the research discussed has influenced a large variety of topics. To demonstrate the far reaching effects of swarm intelligence one group's work should be considered. There is a computer algorithm called KANTS that takes in data in the form of pictures and then the algorithm derives new colors and pictures that are representative of different things depending on the experimenter's wishes. The biology this algorithm draws on for inspiration would be the way ants identify intruders. Rating and marking different points in the data depending on criteria set up by the experimenter. One long term goal of the algorithm would be to take a data in the form of a cat scan and weigh and measure the data in a way that it would derive the image being imagined in the patient's brain. Currently KANTS would be unable to do that due to our limited knowledge of the brain. A more modern day application would be to design certain image filters that act much like a low pass or high pass filter. However in this instance, KANTS was used to create new abstract art after receiving artistic paintings as a form of color input. The algorithm analyzing each point on the graph and creates a weighted color to assign to the corresponding spot of the output. The result is referred to as Swarm Art and yields interesting and abstract art which has already received praise from the sciences and arts alike. [8]

Conclusion

One interesting thread that you can find in all of these research papers is how simple yet novel the ideas are. The hardest part of this research is just finding the correct well of creativity – our ant friends. Children learn in seventh grade that termites and ants follow each other using pheromones and anyone can turn on animal planet and listen about ants being really good at getting from point A to point B. We've known all of these things. We just applied it to a new problem and it works phenomenally. This is a similarity in all of these developments. These great leaps in research are being inspired by ideas that are only unique to the field of Artificial Intelligence. How many times have computer scientists and biologists sat next to each other and not even realize how much they could be benefiting from a conversation about ants?

Humans haven't created anything that could be called truly intelligent however we are drawing on exciting, new ideas. Ants are the common theme in emerging articles. These advances in AI research apply to biology, solving NP complete problems, and network security. Thanks to these advanes we can let algorithms worry about minor details. Which house do I visit first? How do I get over there quickly? If ants seemingly answer these questions with ease what other life forms have something they can bring to the table? Perhaps ants even have untapped potential in the forms of biological behavior we just don't understand currently. As humans attempt to add intelligence to software it seems that progress is going to move one (surprisingly efficient) ant step at a time.

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