GO Ant Go

What can we learn from biological systems to solve the GO maze.

"Go to the ant, you sluggard! Consider her ways and be wise, which having no captain, overseer or ruler, provides her supplies in the summer, and gathers her food in the harvest. How long will you slumber, O sluggard!"

GO (aka Baduk, Weiqi) is a strategic and thinking game being the most ancient board game in the world. Its invention is dated back 2,500-4000 years in China. It has become the national game of Japan, Korea where it is called Baduk and The People's Republic of China.
Over 60 million fans play the game around the world.
Despite its simple rules the game reaches extremely high levels of sophistication. While chess is estimated to have 10^{64} possible games, GO has around 10^{172} possible game combinations, more than the number of atoms in the universe.
For many years a strong software is pursued. One, that could beat a professional GO player.
A prize of 1.6 million $ was offered and never claimed.
Other complex strategy games have been cracked and strong software exists today for Chess, Shogi, Backgammon etc.
Strong algorithms have been developed for these games, using sophisticated mathematic formulas and statistical tools.
The Shogi association has banned its members from competing against computer software.
There, just as in chess, the computer "machine" beat the Human. However, the computer power, cannot use brute force due the infinite number of possibilities and other techniques could not decipher GO. The models used to solve chess and bridge have been unsuccessful with GO.
Despite the advancement in computer power, calculation ability and speed, GO remains resistant.
Neural networks are applied in solving several games such as backgammon.
Other efforts in trying to solve GO are the Monte Carlo.
We choose a play we want to examine and try to play many random games.
If most of them lead to winning in the majority of games, than it is a good play

It is claimed that the solution to GO playing software may have many applications in other fields of Life Science research and cryptology. Similarly Google, Yahoo and other search engines may benefit from the proposed solution.
Therefore new ways must be explored. The pattern recognition has been incorporated into many such programs together with professional players game databases. The use of artificial intelligence has not been successful either. So this may be good time for some biological wisdom. The path of learning from biological systems should be explored.

We came across an interesting article discussing Argentinian ants, solving optimally the Tower of Hanoi.

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Ants have demonstrated an ability to find solutions to complex dynamic problems such as finding and bringing food to their nest. They do so by collaborating with each other.
Researchers try to decipher this mechanism, hoping it will enable them to improve computer algorithms.

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In the article referenced researchers translated the Towers of Hanoi problem into a physical maze representing ~33k options, and then placed 12 colonies of Argentinian ants in it. The ants were able to find their way to the food within an hour in the shortest way, thus providing a solution to the Towers of Hanoi. When the path was blocked ("someone moved their cheese"), they quickly identified the new source and got there in an optimal short way.
The way in which ants solve dynamic solutions can contribute to optimization algorithms, and from there to optimize human industries.

In the research the ants demonstrated the ability to solve 2 problems:

1. find food (the correct path) in time
2. Find the most efficient (shortest path in a maze).

The ants were able to respond to dynamic changes in the environment.
These abilities were used by the researchers to solve a seemingly unrelated problem.

The ants' behavior can be imitated by a computer algorithm, in order to solve a similar problem
There is a field in artificial intelligence by the name of "Agent Oriented Programming" which does just that – the program is composed of a multitude of agents(in our case – ants), and running it provides us the behavior of an entire colony.

The use of a biological system to solving GO seems fascinating.
The model used "the Towers of Hanoi" appears to be similar to Tsumego (Go riddles) - solving a specific problem.
When adding the dynamic nature of the ant biological systems, it may be extended to the whole game of GO.

We are offering a challenge to bridge the gap between the Towers of Hanoi and solving a Tsumego will be a landmark. The idea is as follows: translate a tsumego into a problem of finding the shortest path in a maze (In computer science it is referred to as a graph), and program an algorithm mimicking the ants behavior to find the solution.
The next phase will be to bridge to a whole game of GO/ Baduk/ Weiqi.

The challenge is to demonstrate good heuristics and how to use mazes / graphs to solve GO.
The heuristic solution may not bring at first the optimal/ ultimate solution but can lead to a concept / rule of thumb that can be further pursued in many GO problems. Such a solution, that will work in most problems will offer a technique that will eliminate the need to evaluate all options.

Extra readings: *J. theor. Biol.* (1999) 198, 575}592

So, GO do it and earn your PhD's investigating the ants way.

Gambatte ne

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RESEARCH ARTICLE

Optimisation in a natural system: Argentine ants solve the Towers of Hanoi

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SUMMARY

Natural systems are a source of inspiration for computer algorithms designed to solve optimisation problems. Yet most 'nature-inspired' algorithms take only superficial inspiration from biology, and little is known about how real biological systems solve difficult problems. Moreover, ant algorithms, neural networks and similar methods are usually applied to static problems, whereas most biological systems have evolved to perform under dynamically changing conditions. We used the Towers of Hanoi puzzle to test whether Argentine ants can solve a potentially difficult optimisation problem. We also tested whether the ants can adapt to dynamic changes in the problem. We mapped all possible solutions to the Towers of Hanoi on a single graph and converted this into a maze for the ants to solve. We show that the ants are capable of solving the Towers of Hanoi, and are able to adapt when sections of the maze are blocked off and new sections installed. The presence of exploration pheromone increased the efficiency of the resulting network and increased the ants' ability to adapt to changing conditions. Contrary to previous studies, our study shows that mass-recruiting ant species such as the Argentine ant can forage effectively in a dynamic environment. Our results also suggest that novel optimisation algorithms can benefit from stronger biological mimicry.

Key words: Argentine ants, *Linepithema humile*, optimisation problem, nature-inspired algorithms, trail pheromones.

INTRODUCTION

Routing telephone calls through busy networks while minimising connection time, constructing complex machinery while keeping costs and build-time low, and finding the most efficient set-down and pick-up routes for delivery vehicles are all examples of combinatorial optimisation problems (Gonzalez and Sahni, 1976; Alon and Srinivasan, 1997; Bell and McMullen, 2004). These problems become increasingly difficult to solve as the size of the problem increases. In many cases, the difficulty of the problem increases exponentially with the number of components in the system. In the worst case these problems are 'NP-hard' ('non-deterministic polynomial-time hard'), so that there is no known algorithm for solving general instances of the problem within a reasonable time frame. As a result, programmers must exploit 'heuristic' algorithms that find near-optimal solutions in a reasonable time.

Natural systems have proved to be a rich source of inspiration for computer scientists in designing optimisation algorithms (Bonabeau et al., 2000; Vassiliadis and Dounias, 2009). Many biological systems have been refined through millions of years of natural selection to efficiently exploit the ephemeral, often fiercely contested and spatially isolated resources of their environment. Such systems often hinge upon the construction of efficient transportation networks connecting the resources. Such networks have been studied at all levels of biological organisation: colonies of ants (Dussutour et al., 2004; Buhl et al., 2009) and termites (Perna et al., 2008), fungal mycelia (Bebber et al., 2007), acellular slime mould (Nakagaki et al., 2000; Nakagaki et al., 2001; Nakagaki et al., 2004; Latty and Beekman, 2009; Tero et al., 2010) and even the vasculature of plants and animals (Banavar et al., 1999; West et al., 1999). These complex systems are constructed in the absence of any central control by many individual autonomous components possessing only local information. It is this 'swarm intelligence' (Bonabeau et al., 1999) that has been widely used in a variety of computing techniques.

Probably the best-known nature-inspired algorithm used for NP-hard problems is Ant Colony Optimisation (ACO) (Dorigo and Stützle, 2004). ACO was inspired by the foraging behaviour of trail-laying ants (Dorigo et al., 1996). Many ant species construct foraging networks by laying pheromone trails towards food sources (Hölldobler and Wilson, 1990). Scouts deposit pheromones linking a newly discovered food source to the nest. The presence of the pheromone recruits nestmates to follow the trail, laying their own pheromone in turn and leading to a process of amplification. In addition, the trail pheromone is volatile and gradually evaporates, thus requiring constant reinforcement. As a result, longer trails are less competitive and eventually only shorter trails will be selected (Goss et al., 1989; Beckers et al., 1990). The ACO method for solving shortest path problems deploys virtual 'ants' to explore all possible routes, depositing pheromone on each edge they travel. The amount of pheromone is inversely proportional to the length of the tour, so that shorter tours receive the most pheromone. Evaporation of pheromone after each tour and many reiterations of the process means eventually only the shortest tour remains, or one close to it (Dorigo et al., 1996). The ant-based system has since been widely adopted for use in other combinatorial optimisation problems (Liang and Smith, 2004; Akay and Toksari, 2009; Zhang et al., 2009).

Although ACO and other nature-inspired algorithms often prove competitive in solving specific optimisation problems, apart from the original studies on binary choice shortest path problems there has been surprisingly little work on how real ants solve combinatorial

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חוקרים אוסטרלים מקווים שגילוי הדרך שבה נמלים פותרות בעיות יסייע לפתרון בעיות תוכנה ותקשורת

עבודת נמלים תשפר את מהירות הרשת

אסף שטול־טראורינג

לנמלים תכונה שמקסימה ומעסיקה חוקרים זה שנים: יכולתן לפתור בעיות שאמורות לדרוש זמן רב, כמו מציאת מזון והעברתו לקן בסביבה לא ידועה, בזמן קצר, תוך כדי שיתוף פעולה של פרטים פשוטים בנחיל עצום. יותר מ-100 מיליון שנים של התפתחות אבולוציונית הם לא עניין של מה בכך. גם מהנדסי מערכות ומתכנתים יודעים זאת, ובשנים האחרונות הם פונים אל הנמלים כדי לפתח בהשראתן אלגוריתמים למנועי חיפוש, מערכות טלקומוניקציה ורשתות ממוחשבות אחרות.

כאשר כריס רייד ועמיתיו מאוניברסיטת סידני באוסטרליה ראו שחלק מהאלגוריתמים המפותחים לאור נורות הפלורוסנטים אינם מגיבים היטב לתנאים משתנים, הם שבו ופנו לנמלים. במסגרת מחקרם, שביקש לדמות סביבה דינמית יחסית, הם יצרו מבוך שאליו הוכנסו 12 מושבות של נמלים ארגנטינאיות; ניתנה לנמלים שעה להגיע למזון שניצב בצדו השני של המבוך, כשיש להן בסך הכל 32,768 דרכים לעשות זאת.

התוצאות היו מרשימות: לאחר שתרו את המבוך והותירו את עקבות הפרומונים שלהם, הצליחו 83% ממושבות הנמלים להגיע למזון בדרך הקצרה ביותר בתוך שעה. כאשר שעה זו הגיעה לסופה, הדרך נחסמה, והנמלים נאלצו ליצור נתיב חדש למזון. בתוך שעה, כמעט 86% משאר המושבות בחרו בדרך השנייה הקצרה ביותר בכל המבוך.

הממצאים, שפורסמו בכתב העת Journal of Experimental Biology, מראים כי נמלים שנעו כשעה במבוך לפני שהונח בו מזון חצו אותו מאוחר יותר כשהן שוגות פחות. לדברי כריס רייד, "בניגוד לאמונות קודמות, קיומה של מערכת הפרומונים אינו מחייב שהנמלים ייתקעו במסלול ולא יסתגלו. כיוון שיש להן שני סוגים שונים של פרומונים יש להן גמישות רבה יותר שעוזרת להן להגיע לפתרונות טובים בסביבה משתנה. גילוי הדרך שבה נמלים פותרות בעיות דינמיות יכול לתרום באופן משמעותי לאלגוריתמים של אופטימיזציה, ואלו יכולים לתרום לפתרון בעיות תוכנה ולייעול תעשיות האדם".

פרופ' אלפרד ברוקשטיין מהטכניון, המפתח אלגוריתמים בהשראת נמלים, אומר כי "כבר שנים אנו שואבים השראה מהנמלים. כל סוכן בנחיל פשוט, כל שהוא יודע לעשות זה להסתובב בשטח כשהוא מחפש אוכל ולהשאיר סימנים עם פרומונים, אבל הנחיל כולו יודע למצוא את הקו הישר אל המזון. חוקרים רואים את האופטימיזציה הזו ושואלים – למה שלא נלמד מזה? במנגנון חיפוש באינטרנט היום שולחים פיסות תוכנה הנקראות בוטים, שמחפשות משהו רלוונטי. כשאתה מפזר מיליון בוטים על פני הרשת הלא מוכרת, בעיית הפיזור לא כל כך שונה מנמלים המחפשות מזון בסביבה לא ידועה".

פרופ' בקשטיין מזכיר את הפתגם המתבקש ממשלי: "'לך אל נמלה עצל, ראה דרכיה וחכם: אשר אין לה קצין, שוטר ומושל'. המשל מתאר את האופי האמיתי של הנמלה. אין הירדכיה במערכת הזאת. עלינו ללמוד מכך כיצד לבנות מערכות שבהן סוכנים פשוטים מפעילים אלגוריתמים עם אינטראקציה פשוטה, שמובילים אותנו להתנהגות הגלובלית הרצויה".

תצלום: גטי אימג'ס

נמלים הצליחו להגיע למזון בדרך הקצרה ביותר כשעמדו לרשותן עשרות אלפי דרכים