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Self-Organizing Sensor Node Sensing and the Constrained Shortest Path Problem Alternative for Biodefense

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Abstract

Numerous self-organizing systems can be found in nature that autonomously adapt to shifting circumstances without impairing the system's objectives. In order to conduct an energy-effective region sampling, we suggest a self-organizing sensor network that is modelled after actual systems. Using local data processing, mobile nodes in our network carry out certain rules. These principles give the nodes the ability to split the sampling duty so that they can self-organize to use less power overall and sample phenomena more accurately. The digital hormone-based model, which contains these regulations, offers a theoretical framework for analysing this group of systems. On cricket mote simulations, this model has been put into practise. Compared to a traditional model with fixed rate sampling, our findings show that the model is more efficient.

In transportation optimization, personnel scheduling, network routing, and other areas, the constrained shortest path (CSP) problem is frequently employed. As an NP-hard problem, it is still a matter of debate. The adaptive amoeba algorithm's fundamental mechanism is the foundation of the novel approach we provide in this paper. Two sections make up the suggested procedure. To resolve the shortest path problem in directed networks in the first section, we use the original amoeba approach. The Physarum algorithm and a rule with bio-inspired design.

Keywords: Hormone; Simulations; Optimization; Physarum

Introduction

One of the oldest and most prevalent problems is the shortest route problem (SPP), which finds application in a variety of areas including network optimization, navigation, and more. The constrained shortest path (CSP) problem seeks to establish the shortest path in a directed network between a known source node and a predetermined destination node while adhering to the restriction that it must be less than or equal to a predetermined upper limit. The classical shortest path issue is typically made NP-hard by limitations like these [1]. The tail assignment problem in aircraft scheduling, the quality-of-service routing in communications networks, and other situations are prominent examples of when CSP is used and frequently seen as a version of SPP.

Lagrangian relaxation methods, dynamic programming (DP), and path ranking methods are three broad categories that can be used to group CSP-solving techniques. The first strategy in CSP depends on the resolution of a Lagrangian dual issue and employs several strategies to bridge the duality chasm. A solution to the Lagrangian dual problem was put out by Handler and Zang. By employing the shortest pathways algorithm and concluding with the first path meeting the condition, they were able to close the duality gap. In addition, they suggested a technique that conducted a direction search. The improvement of this approach is that the resulting Lagrangian function was optimised, and the optimality gap was addressed by listing nearby shortest paths. open-ended shortest path algorithms [2].

On DP, a number of earlier works were based. The foundation of each of these techniques was a label-setting or label-correcting algorithm. Starting with Joksch's work, node labelling methods were thoroughly examined. This concept was expanded upon, and the issue was resolved, by Dumitrescu and Boland utilising preprocessing methods. They demonstrated how the label-setting method's effectiveness might be further enhanced by utilising all of the Lagrange multiplier data gathered in the initial phase of a Lagrangian relaxation. SkIt index structure was recently created by Likhyani and Bedathur [3]. It supported a variety of label constraints on paths and provided an estimate of the shortest path that complied with the requirements. All of the aforementioned techniques, nevertheless, had one drawback: they might not accurately predict very large networks.

Many researchers have been drawn to a slime mould called Physarum polycephalum. A network of tubular components was present in the body of the plasmodium of Physarum polycephalum, allowing for efficient circulation of nutrients and chemical signals. This organism was highly helpful for researching the dynamics and operation of natural adaptive networks since the tubes disassembled and reassembled in response to environmental changes over the course of a few hours. It was employed in a variety of applications, including road network structure, network optimization, amaze problem solving, and finding the quickest path. Due to the unpredictability in real-world applications, this approach is also used to find the shortest path in a challenging situation [4].

We combine the Physarum algorithm with a bioinspired rule to deal with the CSP, which is inspired by the amoeba's intelligence. The approach's central idea is to use the Physarum algorithm to identify the shortest path. Once the constraint has been satisfied, a check method is executed. A penalty function is applied when it fails to satisfy the condition [5]. As long as no path exists that satisfies the constraint, this method will continue to run.

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In event-based systems, such as sensor networks, a large number of sensor nodes that are constantly observing physical phenomena work together to gather data. A sensor network's primary goal is to accurately identify or estimate event attributes using the data provided by all of the sensor nodes. Therefore, this collective sensing idea, which is achieved through their networked deployment, overcomes the energy and consequently processing limits of small wireless sensor nodes. While the collaborative nature of sensor nodes offers important advantages over traditional sensing, such as greater accuracy, a wider coverage area, and the extraction of localised features, the spatiotemporal correlation among the sensor observations is another important and distinctive feature of the sensor networks that can be utilised to significantly improve the performance of the entire network [6].

The existence of spatial and temporal correlations offers significant potential benefits for the creation of effective communication protocols well suited for the sensor networks paradigm, in addition to the collaborative nature of sensor networks. Intuitively, for instance, data from spatially separated sensors is more valuable to the base station than highly correlated data from nearby nodes because to the spatial correlation [7]. A smaller number of sensor measurements may be sufficient to report the event features within a particular error level, hence it may not be essential for every sensor node to relay its data to the base station. The measurement reporting frequency, or the rate at which the sensor nodes broadcast their observations, can also be changed for a specific event monitoring application such that temporally

Using mobile nodes, we provide a method in this study for creating an autonomous system for spatiotemporal reconstruction of environmental phenomena. Our method's emphasis on energy efficiency through the use of adaptive sampling in both space and time will be a major component. As a result of the fact that message transmissions account for a sizable portion of overall power consumption, we optimise the quantity of messages that must be sent in order for nodes to collaborate. The most crucial goal, however, is to make the system self-organizing, which is accomplished by employing straightforward local rules. Such systems' key benefit is that it lessens the reliance on crucial nodes for proper operation. For instance, in the case of multisensor detection, if a fusion centre malfunctions, a new one will probably be elected.

Materials and Method

The shortest path can only be discovered using the original amoeba algorithm in undirected networks. We must resolve two issues in order to solve the CSP in directed networks. The first one concerns directed networks and how to determine the shortest path. The second is a modified amoeba algorithm for effectively solving CSP.

Shortest Path Problem in Directed Networks: Modified Amoeba Model.

Let $G = (N, E, W)$ be a directed network, where N stands for the set of n nodes, E for the set of directed edges, and W for the set of directed edge weights. We assume that there is only one direction in the network G between nodes I and j. Assume that nodes s and t are the relevant source and sink nodes. Finding a route from node s to node t that only consists of directed edges of E and has the least sum of edge weights is known as the network's shortest path problem [8].

Every arc is bidirectional in the original amoeba model. Therefore, the flux can move from node I to node j. Additionally, they are capable of flowing the other way. For the original amoeba model, it is the same; however, in directed networks, the direction must be clearly distinguished. In particular, network G only has one path between any two nodes. It implies that if the flux may move in one way, from node I to node j, it cannot move in the opposite direction.

A positive feedback loop exists in the amoeba model, the greater the pressure difference, the greater the flux. The pressure differential will increase as the flow increases. This approach causes the shortest path to gradually emerge as the iteration goes on. The positive feedback mechanism is also present in directed networks.

Proposed Method

An example from is given to demonstrate the general flow of the suggested method, as illustrated in Figure 1. The particular values can be derived. For example, the numbers (120 and 60) on the arc between nodes 1 and 2 indicate that the arc's length is 120 and its cost is 60. Finding the longest, shortest path that doesn't cost more than 200 from source node 1 to sink node 20 [9].

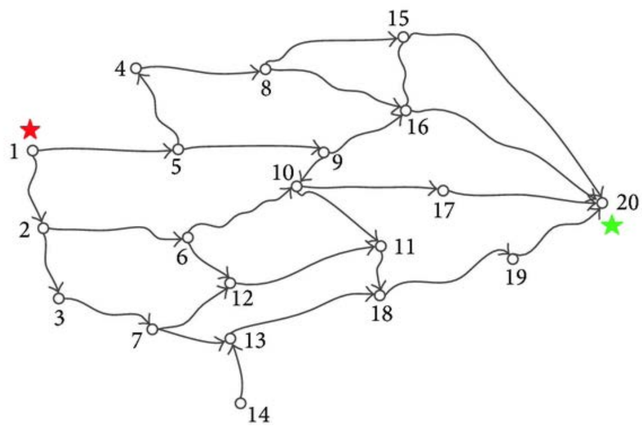

Figure 1: A network of 20 nodes for directed transit.

Guidelines for Hormone Reaction and Spread

Hormone signal transmission takes place in a two-dimensional space and is governed by the same rules that govern radio signal propagation. Although hormones spread by cellular interaction in living things, in mobile sensor nodes, hormone dispersion is aided by radio broadcast reception. As more nodes from far distant locations move closer to the target area, his effect will become more noticeable. Therefore, the sluggish cascading produced by our model delays the spread of hormones until the receiving node begins probing at the new target site. Additionally, by using this technique, the network's overall energy usage can be decreased. The above-mentioned model shows how distributed actuation and self-organization can be accomplished with the help of straightforward rules that just take into account local data. Even if the nodes perform the sensing function autonomously, the network's collective readings must still be compiled for further analysis. This will necessitate the nodes sending sensor readings to a base station on a regular basis [10].

Results

A simulator named Shimla was created to conduct tests on the amount of power used and the precision of signal reconstruction using the hormone-based model. Shimla executes both our digital hormone-based model and a straightforward probabilistic model at the same time to compare the power consumption of nodes as they move around. Shimla is a covert time machine.

Each of the several epochs that make up the full simulation period reflects a portion of the time that a node is in the Probe or Listen state. The inaccuracy in reconstructing a static and time-varying spatiotemporal signal is also calculated. Numerous parameters, including the number of nodes, the number of epochs, their initial positions, and the signal, can be changed to create simulations. The hormone model's implementation has largely been successful, with the exception of how long it takes a bot to settle down at the intended point. A digital compass and separate hardware for localization should be used to implement the model for deployment in a real-world environment. We created a Java coverage panel to show the sensor nodes' true locations in real time. .

The organising ideas of the Tiny OS operating system were implemented using nesC. The system was implemented using three different pieces of software. First, three motes were used as beacons while the firmware provided was uploaded. In order to use this firmware as a node running our model, a small modification was made. In order to display information in the coverage panel, a single node was configured as a packet forwarder and connected to the serial port. Between sensor nodes and the serial port of the computer, this packet forwarder serves as an interface. The nodes' self-deployment, localisation, event detection, and relocation have all been programmed into them.

Conclusion

We have shown that EDHM aids in striking a compromise between the degree of battery saving needed and the tolerance for reconstruction inaccuracy. The simulation results demonstrate how more nodes share the workload, boosting both efficiency and sampling. But we'd like to point out that our model is a little more biassed toward energy conservation than toward precisely sampling the area. However, in most situations, the utility U is more than one, with the exception of those in which the number of nodes is insufficient for effective collaboration. Our research supports the idea that there needs to be a sizable number of independent units in a self-organizing system for it to work.

From the discussion above, it is also clear that while simulations are a useful tool for confirming the accuracy of theoretical predictions, their real implementation may call for dealing with situations that are wholly unrepresentative. Nevertheless, in order for the system to function as intended, these problems must be fixed.

In this research, we present a novel approach to solve the CSP that makes use of the internal workings of the amoeba model. There are two aspects to the CSP solution.

First, we extend the Physarum algorithm to the directed network shortest path problem. Second, to address the CSP, we combine the Physarum algorithm with a rule that draws inspiration from biology. Additionally, we have demonstrated the viability of the suggested technique by contrasting it with other current methodologies using a case study of the DCLC problem.

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Conflict of Interest

The author has no known conflict of interest associated with this paper.

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