Poznań University of Technology
Faculty of Computing Science
Institute of Computing Science

Master's thesis

ROAD TO SOLVING QUADRATIC ASSIGNMENT PROBLEM USING PHYSARUM MACHINES

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Acknowledgements

The scientific man does not aim at an immediate result. He does not expect that his advanced ideas will be readily taken up.

His work is like that of the planter — for the future.
His duty is to lay the foundation for those who are to come, and point the way.

NIKOLA TESLA

Abstract

Contents

Chapter 1

Introduction

Nowadays, computing science intertwined with a various field of studies posing new challenges for the people of this industry. Every aspect of science is dominated by technology, just like the everyday lives of humans across the world.

A good example of such interdisciplinary connection is that the companies' managers sometimes are trying to answer a very difficult question. These businesses mostly consist of different branches, which require transferring of goods between them, such as production lines. Each element of the product could be manufactured in a various department and needed in the last part of the assembly in the main office. It could be easier to say that they should produce the whole product in one location, yet seldom it is better to divide the responsibility for specialists in each sector. Although, this process generates great costs for the company. It would be crucial minimizing the expenses during assignment of the branches to the locations. Trying to resolve this by hand could be a long process due to the complexity of the problem. However, with a usage of computers, it could be answered in shorter time. The result may not be the optimal one in each case, but it should meet all assumptions, which is enough to put it into real life.

In computer science, the dilemma is named the quadratic assignment problem (QAP). The QAP is a combinatorial optimization problem, which was presented by Koopmans and Beckmann in 1957, and is a generalization of assignment problem. It is np-hard thus finding results even for small instances is done by approximate methods.

The QAP can be formulated as follows: Given n different facilities (F) and n different locations (L), a weight function $w : F \times F \mapsto R$ between facilities and a distance function $d : L \times L \mapsto R$ between locations, find the assignment minimizing this cost function:

$$min \sum_{a,b \in P} w(a, B) * d(f(a), f(b)) \tag{1.1}$$

Over the years, a number of methods for solving this problem were established. Nevertheless, there is still a place for improvement and experts are searching for new ways of resolving that. Inspired by their works this thesis tries to find an innovative method using physarum organisms.

The physarum polycephalum, also known as slime mold, is a plasmodial organism of yellow color. Its single cell body is considered the biggest in the world. Taking into account current classification it belongs to the Kingdom Protista, however, this is frequently changed due to the fact that it does not exactly match any of the recognized kingdoms. The organisms move very slowly and in a pattern similar to tree branches in order to find new food sources. It ingests bacteria, fungal spores and during the experiments - oatmeals.

1.1 Motivation

The motivation for this thesis was indirect interest in topics related to computer science, but also of the world around us. The behavior of physarum, which is often compared to a simple machine, creates many opportunities to unveil a biological side of computer science making the topic fascinating.

Nowadays, scientists put great emphasis on discovering and analyzing the nature. It is done to improve the world surrounding us. Generally, two ways of development of this field of study could be distinguished. The first one focuses on improving the biological flaws of humans and animals. A good case is studies related to the creation of natural prosthetics that make life easier for the people without limbs. The second one is a transmission of the known naturally patterns to the computing environment. Observing the nature leads to logical algorithms, which usage can solve issues seemingly unrelated to originally presented problems and often gives much better solution than working it out greedy. For example, thanks to such research, the ant algorithm was implemented, which shows the behavior of an ant colony searching for the best path between their home and food. These unconventional methods of inventing algorithms allow excellent results for hitherto very complicated mathematical problems.

The physarums have great potential in both, the first and the second case. Until now, several studies linked to these organisms were conducted, though, it still remains a mystery to many experts. One example of an experiment carried on slime molds was solving the maze. The organism found the shortest path between two oatmeals in the environment with walls, thus finding the solution for the maze. More detailed description and more cases are presented in the later chapter of this thesis. Nonetheless, these interesting achievements were the reason behind the choice of the subject.

Also, the thesis focuses on the quadratic assignment problem, which is a challenging topic. It reflects the real difficulties faced by the managers of logistics companies. They need optimal results, however, the complexity of the dilemma makes it almost impossible to resolve in a reasonable time. This demand urges scientists to explore this issue further and try to look for a reliable way of solving the problem.

The QAP could be a great challenge for inventing a new unconventional algorithm based on the behavior of physarum.

1.2 Goal

This thesis presents the road to solving quadratic assignment problem (QAP) using physarum machines. In order to reach meaningful conclusions, it is needed to analyze deeply each part of the main dilemma.

The first task is to carry out the detailed investigation of the behavior and capabilities of physarum. Without the understanding of organisms, it is not possible to replicate its operations. For this purpose, the living physarums will be observed and described, which will mainly consist of the schemas of ways of moving to find food. This will be studied in order to extract similar patterns and facilitate the creation of their mathematical model, which could be transported into the computer environment. Additionally, it will determine whether they fit into QAP.

Furthermore, not only the direct observation of their behavior is needed here, but also a careful examination of previous studies. It will show already discovered characteristics, which could have been unnoticed on our own research.

In order to properly inspect the organisms, there must be implemented a method, which facilitates observations. The physarum are moving gradually and changes may not be always noticed by a human being. For this reason, the digital camera will be used. Later, the recorded image will be interpreted by a computer. This way the description of changes over time will be more accurate, which allows for more specific description of phyrasum's behavior.

Next, the analysis of the research related to the QAP will be required leading to better understanding of the problem and showing the current practices for resolving it. Recognizing the dilemma will make it easier to fit algorithm based on slime molds to the QAP.

The key element of this thesis is applying physarum methods for solving QAP. This step will consist of adapting the mechanisms, implementation of simulation and reading its results. It will summarize the previously acquired theoretical knowledge in a practical task.

And last, but not least, our aim will be to create the innovative method for solving QAP.

1.3 Chapters

The thesis is divided into five chapters and includes one appendix.

- Chapter two describes the physarum organisms characteristics such as a position in the hierarchy, basic information about the species, basics of operations, emerging behavior and previous research.
- Chapter three outlines the quadratic assignment problem (QAP). It consists of a different interpretation, practical usages, current exact solution and current heuristic.
- Chapter four presents the algorithm, which will be proposed as the result of this thesis. It will be a pseudophysarum machine providing working metaheuristics based on observed behavior.
- Chapter five summarizes the research and is focusing on future work ideas.
- Appendix A includes description of hardware-software platform, which is used for examination of physarum.

Work Distribution

Chapter 2

Background

Intro goes here

2.1 Physarum Polycephalum

The organism being a subject for this work is *Physarum Polycephalum* also called the many-headed slime mould. It is a member of the *Physaridae* family of slime moulds, in order of *Physarales*, class *Myxogastria*, phylum *Myxomycete*, supergroup *Amoebozoa* in *Protista* kingdom. While current position in taxology is well defined, presented characteristics will justify why scientists used to have problems with classification of the Physarum [SS+94].

In order to make the thesis readable, terms *Physarum Polycephalum*, *Physarum* or *the slime mould* will be used interchangeably as the subject is unambiguously defined.

2.1.1 Biological characteristics

lorem

2.1.2 Observations

lorem

2.1.3 Emerging computational possibilities

lorem

2.1.4 Interaction

lorem

2.2 Quadratic Assignment Problem

Chapter 3

Project

Chapter 4

Conclusion

Appendix A

Physarum Maintenance Protocol

Appendix B

Benchmark Results

Appendix C

TSP Results

Bibliography

[SS+94] Steven L Stephenson Stephenson, L Steven, et al. *Myxomycetes; a handbook of slime molds.* Number 04; QK635. A1, S8. 1994.

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