# Proposal of Bachelorarbeit – B.Sc. Informatik

**Thesis Proposal**

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## Introduction

This document shows a bachelor thesis proposal to be researched by the student Fernando Bombardelli da Silva (*Matrikelnummer* 364924) in the *Technische Universität Berlin* in the course of Computer Science (*Informatik*).

The proposed research subject has theoretical bases from the areas of multi-agent system, swarm intelligence and mathematical optimization. The context of the problem to be described involves themes of growing concern nowadays, such as transportation and traffic issues, like multi-modal mobility.

### Problem Description

In current urban areas, mainly in very populated cities, there is a huge number of mobility problems. These problems have been seen with much interest by the scientific community, which has been strongly contributing to the improvement of transportation and logistic networks, thus promoting advances towards a better mobility.

The here addressed problem is known as the dial-a-ride problem (DARP). Shortly, it consists of a system with a set of requests of pick up and delivery entered by customers and a fleet of vehicles. The goal is planning the route of the vehicles and the assignment of requests to them in a feasible way, since there are constraints from both the requests and the vehicles to which a solution is subject. These can be several conditions, like location and time limit for picking up and delivering or how much time each vehicle can operate. Besides, it is not only searched a feasible solution but an optimal one that minimizes the costs of the operation defined by a function.

Many difficulties are found when trying to solve the described problem, the combinatorial nature of its solution space make it hard to treat for large inputs because of the high complexity, it leads then to a special difficulty in building a scalable application.

### Problem Approach

The chosen approach to solve the problem in this work is considering this as the optimization of the cost function subject to the constraints. Moreover, in order to better evaluate the results, two different methods are proposed, namely,

- a mathematical program executed by a solver that delivers an exact optimal solution if there is one;
- an implementation of the swarming metaheuristic Firefly to obtain a near-optimal solution in polynomial time.

## Justification

It is expected that the results of this work may bring relevant contributions to the handling of the presented problem, and even of other ones. By having two distinct approaches it is possible to compare results regarding important features of the problem, such as scalability, feasibility and deviation to an optimal solution. Furthermore, the application of the relatively new firefly algorithm to the problem can show how it performs in a such a solution space.

In addition to the contributions to the understanding of the behavior of swarming metaheuristics applied to optimization problems of transportation, the new procedure of solving the problem serves as a prototype and brings a new perspective to commercial applications which seek constantly to treat the problem in a more efficient and scalable way.

With regard to the current cities' mobility, there is a growing demand for an efficient alternative to the classical means of transportation. The implementation of such a system improves the possibility of movement of the population and makes it more efficient, since it allows the decrease of the number of cars that drive through the urban network everyday causing traffic jams in big cities. Moreover, it helps to solve an demanding problem in today's society where there is an increasing number of elderly or handicapped people, who have the right to mobility and need assistance to travel in the town.

Also in an economical view this research contributes to the win of new markets by companies who aim to enter the branch of public transportation since its main goal is minimizing the

operation costs. With such a model a company can take great advantages against competitors in order to capture marketplace.

At last, the concerns of the proposed model shows also an ecological relevance by enabling the decrease of the emission of greenhouse gases in the urban area, directly, considering that in this case costs are direct proportional to the consume of fuel, and consequently to the emission of gases, such as $CO_2$, and indirectly by reducing the circulation of other automobiles.

## Literature Review

The Dial-a-ride Problem (DARP) is very similar to other problems studied in the scientific society, namely, it can be cited the Pickup and Delivery Vehicle Routing Problem (PDVRP) and the Vehicle Routing Problem with Time Windows (VRPTW), problems with application in logistics. According to Cordeau (2007, [1]), what basically differs the DARP from these other ones is the human perspective, by the fact that people are transported. It often appears presenting two goals, minimizing operation costs subject to the constraints and maximizing the availability and quality of the service. The quality criteria include frequently aspects like route duration, customer waiting and ride time, maximum vehicle ride time, among others and are usually treated in the constraints of the optimization.

Cordeau (2007, [1]) realized a survey on the subject, he presents three mathematical models that occur in the literature, two as formulation of a mathematical optimization and one as a scheduling problem. Therefore there are several other approaches made by other authors.

Although there are works handling the problem in an exact way, that tries to find an optimal solution, for instance, with the branch-and-cut algorithm, most of them focus on applying a determined heuristic in order to find a near-optimal solution in the search space, for example, tabu search, genetic algorithms or simulated annealing.

What has not been tried is using swarm-based metaheuristics to solve the problem, such as particle swarming optimization, ant colony or the firefly algorithm. Swarm intelligence is a technique applied in the computer science, more precisely in artificial intelligence and operations research, that is based on nature patterns or behaviors. In this point of view, these metaheuristics resemble the genetic algorithms, since these are also nature-based, but they differ by the fact that, genetic algorithms have mutation and crossover operators and are based on the theory of

evolution of the species, whereas swarm intelligence techniques are based on the observation of the behavior of swarms.

In this work we will study and apply the firefly algorithm (FA), that has been showing good results in the solution of nonlinear global optimization problems. Yang (2012, [5]) presents a theoretical analysis on swarm intelligence having as study cases the firefly algorithm and particle swarm optimization (PSO). Yang (2013, [6]) introduce the FA approaching parameter settings, complexity and applications in a didactic way with examples, at the end he draws a conclusion showing a growing application of the method in scientific articles and foreseeing an expansion in the subject and the improvement of such metaheuristic. Additionally, Yang (2009, [7]) compares the FA against the PSO running simulations in a variety of objective function and concludes affirming the superiority of the FA over the PSO and that it is potentially more powerful in solving NP-Hard problems.

## Methodology

The proposed work methodology is basically approaching the problem in two different ways, firstly it is wanted an exact solution through the solving of a mathematical optimization model with the help of a generic solver, secondly it is wanted a near-optimal solution capable of being computed in a shorter period and of being scalable. The sequence should be the following:

- describe the mathematical model of the integer optimization problem;
- transcribe the model into the AMPL language (A Mathematical Programming Language, [11])
- write a program implementing the firefly metaheuristic;
- determine the algorithm parameters empirically by means of experimentation;
- gather or generate data for test cases;
- solve the problem by executing the metaheuristic implementation and the mathematical problem with the GNU LPK (Linear Programming Kit, [16]);
- collect the results of both methods and evaluate them comparing against each other.

In addition, an iterative development will be followed, it means, the whole research process will be performed in several cycles of gradual progress in order have a more agile reaction to possible problems that may appear in the process. For that, it is intended to develop several prototypes throughout the research period.

A time schedule and a list of milestones have been made to control the evolution of the bachelor thesis, so that the project can succeed at the end.

## Time Schedule

| **Month** | 1 | | | | 2 | | | | 3 | | | | 4 | | | | 5 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Week** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Define the topic | • | • | • | • | | | | | | | | | | | | | | | | |
| Literature study | | | • | • | • | • | • | • | | | | | | | • | • | | | | |
| Problem definition | | | | | | • | • | • | • | | | | | | • | | | | | |
| Collect data | | | | | | | | • | • | • | | | | | | | | | | |
| Implementation | | | | | | | | | • | • | • | • | • | | • | • | • | • | | |
| Experiments | | | • | • | | | | | | • | | • | • | • | | | • | • | • | |
| Evaluation | | | | | | | | | | | | | • | • | | | | • | • | • |
| Document writing | | | | | | | | • | • | | | | • | • | | | | • | • | • |

## Milestones

Following are the milestones of the project, at each date is described the documentation or functionalities that must be ready.

| Milestone | Goals |
|---|---|
| **2nd November** | Well defined theme, problem description, goals, methodology<br>First prototype of the LP |
| **30th November** | Problem definition reviewed and reworked<br>Mathematical program written and executed in the solver<br>Creation of test cases, alternatively gahtering of test data<br>Partial documentation and sketch of the document to be delivered |
| **24th December** | Run of a first stable version of the metaheuristic implementation<br>First experimental evaluation of the method<br>Refined sketch of the document to be delivered |
| **24th January** | Concrete results and evaluations<br>Further documentation for the thesis<br>Adjusts in the model and in the implementation, if necessary |
| **14th February** | Final evaluation of results after adjusts and second run<br>Finalization of the written work |

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