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Chapter 1

Protocol

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**
Term1	Train	Path optimization	Bee colony optimization	Transit	Artificial intelligence	Multi agent	Routing	Neo4j
Term2	Plane	Scheduling optimization	Particle swarm optimization	Transportation	AI			Graph database
Term3	Bus	Route optimization	Swarm intelligence	Traffic	Machine Learning			
Term4	Delivery	Planning	Ant colony optimization	Vehicle				
Term5		Multimodal	BCO					
Term6			PSO					
Term7			ACO					

Table 1.1: Matrix of search terms

1.1 Search Terms

- Group 1: Train, plane, bus, delivery
- Group 2: Path optimization, Scheduling Optimization, Route Optimization, Planning, Multimodal

- Group 3: Bee colony optimization, Particle swarm optimization, Swarm intelligence, Ant colony optimization, BCO, PSO, ACO
- Group 4: Transit, Transportation, Traffic, Vehicle
- Group 5: Artificial Intelligence, ai, Machine Learning
- Group 6: Multi-agent
- Group 7: Routing
- Group 8: Neo4j, Graph database

1.2 Complete Search Term

(train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi-agent" AND routing)

1.3 Research Questions

To conduct a structured literature review it is vital to decide the problem to be solved, referred to as P, and the constraints used to guide the search, referred to as C.

One of the goals for the environment package for transportation in Trondheim, "Miljøpakken", is to reduce percentage of people travelling with cars from 58 % to 50 % by 2018 (Miljøpakken, 2014). If this goal is reached, it will be an increased need for public transportation in Trondheim. There has never been done any optimization of the bus routes in Trondheim, the existing solution is purely based on experience. The problem formulation for this thesis was therefore based on the idea to improve todays solution by optimizing the bus routes using AI-methods. (And as a result of this satisfy the same amount of users today with less resources.)

- **P:** "Optimizing the bus routes in Trondheim using AI-methods. " This problem can be characterized as a *General Pickup and Delivery Problem (GPDP)* (Ferrucci, 2013, p.22-25).
- **C:**
    1. To optimize the bus routes in Trondheim we wanted to explore the possibility using methods from swarm intelligence. This idea came from an initial, non-structured literature review were we did a broad search among different artificial intelligence methods and route optimizing.

2. We believe that a part of solving the problem, P, is how we choose to represent the network of the bus routes in Trondheim. The chosen algorithms to optimize the routes with respect to minimize the number of resources used will use this representation. We have some experience with the graph database Neo4j. Neo4j has several benefits that we believe we can take advantage of when solving P, including a natural node-edge-structure and the possibility of saving information to both the nodes and edges. We envision that the nodes will represent bus stops, and the edges will represent the connectivity between the stops.

This gives us the following research questions:

1. What are the existing solutions to this problem?
2. Which swarm intelligence methods is best suited for optimizing?
3. Is it practicle to represent and work with this route network as a graph database for this kind of methods?
4. Does this solution help optimize the bus routes?

1.4 Inclusion Criteria

To exclude irrelevant literature, some inclusion criterias were decided to ensure a level of relevance to the very first pool. First of all, duplicate literature, book of chapters, book of abstracts, book of references, literature not written in english, books, and literature with cleary irrelevant titles (for example literature from different research areas) were removed based on title. After that, we decided to filter out relevant literature based on the abstracts. Because we had relatively many sources to related literature after the initial filtering (367), we decided that we wanted the abstracts (or the keyword section) to explicitly mention swarm intelligence or algorithms associated with swarm intelligence, while it also described a problem connected to vehicle routing. For our literature review we decided to use the inclusion criterias solely on the title, abstract and keywords. After a discussion and reading a few abstracts we landed on the following inclusion criterias:

- The main concern is route optimization focusing on vehicles.
- The study focuses on the use of swarm intelligence.
- The literature must contain an abstract.
- The literature must still excist (some literature were removed from its original source).
- The literature must be free of charge.

After the inclusion criteria filtering, we had 42 sources to related literature, including scientific papers and master theses.

1.5 Quality Criteria

1. How relevant is it?
   (a) Is the problem of the research a vehicle routing problem?
   (b) Is swarm intelligence the main optimization method?
2. Is there is a clear statement of the aim of the research?
3. Is the study put into context of other studies and research?
4. Are system of algoritmic design decisions justified?
5. Is the test data set reproducible?
6. Is the study algorithm reproducible?
7. Is the experimental procedure thoroughly explained and reproducible?
8. Is it cleary stated in the study which other algorithms the study‘s algorithm(s) have been compared with?
9. Are the performance metrics used in the study explained and justified?
10. Are the test results thorougly analysed?
11. Does the test evidence support the findings presented?
12. Has the architecture been implemented (and published)?
13. Is the amount/quality of citation satisfactory? ($< \frac{1}{3}$ self-citation and > 10 citations)

1.5.1 Scoring

Point 1-13 was given a score, with the granularity of 0 (no), $\frac{1}{2}$ (partly), and 1 (yes). For this structured literature review we wanted to emphasize on the quality criteria that covered the relevance. We read some literature that were quite good regarding to the example structure and composition, but not relevant for our thesis. Therefore, we chose to multiply the 1a and 1b quality criteria with 3.

1.6 Selecting the final literature

When selecting the final literature we decided to do this solely based on the quality criteria scores. The average score of the read literature was $13.1 \approx 13$. We decided that literature given a score ≥ 1.5 above average were selected. After this sorting we ended up with 14 final literature. These 14 literature are going to create the foundation of our thesis. Table 1.2 shows the selected literature.

Title	**Author**
"Adapt-Traf: An adaptive multiagent road traffic management system based on hybrid ant-hierarchical fuzzy model"	Kammoun et al.
"An ant based algorithm approach to vehicle navigation"	Salehi-nezhad and Farrahi-Moghaddam
"An Ant Based Simulation Optimization for Vehicle Routing Problem with Stochastic Demands"	Tripathi et al.
"An Ant System application to the Bus Network Design Problem: an algorithm and a case study "	Poorzahedy and Safari
"An improved Ant Colony algorithm for Urban Transit Network Optimization"	Jiang et al.
"An Inverted Ant Colony Optimization approach to traffic"	Dias et al.
"Ant colony optimization for best path planning"	Hsiao et al.
"Ant dispersion routing for traffic optimization"	Alves
"A parallel ant colony algorithm for bus network optimization"	Yang et al.
"A simultaneous transit network design and frequency setting: Computing with bees"	Nikolić and Teodorović
"Computing with bees: Attacking complex transportation engineering problems"	Panta and Du San Teodorovi
"Dynamic Fuzzy Logic-Ant Colony System-Based Route Selection System"	Salehinejad and Talebi
"Solving the open vehicle routing problem by a hybrid ant colony optimization"	Sedighpour et al.
"Solving the Urban Transit Routing Problem using a particle swarm optimization based algorithm"	Kechagiopoulos and Beligiannis

Table 1.2: Final literature

Chapter 2

Search Engines and Search Strings

In this structured literature review we decided to do searches in seven different search engines. The process of deciding which search engines to use was strongly influenced by the paper about how to do a structured literature (Kofod-Petersen, 2014). The complete search term [section 1.2] is built up of terms from seven different groups. In addition to the search of the complete search term from section, a search consisting of one additional group (group 8) was done in each of the different search engines. Group 8 consists of the words "neo4j" and "graph database". This additional search was done to investigate if the combination of swarm technology and graph databases to solve a route optimization problem was already studied. The results from our search shows that our search term combined with "neo4j" or "graph database" gave zero findings.

2.1 ACM Digital Library

Notes: ACM Digital Library did not support a mix of ANDs and ORs in its initial input field, but this was possible in advanced search. The search string was not modified, and the first search gave a satisfactory number of results.

Queries:

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing

Date of search: 2014-11-10
Results: 19

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing AND ("graph database" OR neo4j)

Date of search: 2014-11-10
Results: 0

2.2 ScienceDirect

Notes: In ScienceDirects advanced search it was only possible to perform a full text search. The first search was within "all sciences" and this retrieved 100 results. The next search was therefore just within "Computer Science", which gave less, but a lot more relevant literature. In addition to this books were excluded from the results.

Queries:

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing

Date of search: 2014-11-10
Results: 60

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing AND ("graph database" OR neo4j)

Date of search: 2014-11-10
Results: 0

2.3 CiteSeer

Notes: In CiteSeer you cannot perform a search within title, abstract and keywords at the same time. It was therefore conducted a full text search by adding the element text:() to the query. Some of the retrieved literature had an unknown title with unknown authors, so theese were excluded from the results.

Queries:

- text:((Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing)

  Date of search: 2014-11-10
  Results: 27

- text:((Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing) AND ("graph database" OR neo4j)

  Date of search: 2014-11-10
  Results: 0

2.4 SpringerLink

Notes: In SpringerLinks advanced search it was only possible to find literature with either all the words, the exact phrase or at least one of the words in the search string. For this reason the whole boolean search string was used in the initial input field. The first search gave 200 results, so the next search was only conducted within "computer science" and "engineering". In addition to this only results within "articles" were selected.

Queries:

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing

  Date of search: 2014-11-10
  Results: 28

- (Train OR plane OR bus OR delivery) AND ("path optimization" OR "scheduling optimization" OR "route optimization" OR planning OR multimodal) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR bco OR pso OR aco) AND (transit OR transportation OR traffic OR vehicle) AND ("artificial intelligence" OR ai OR "machine learning") AND "multi agent" AND routing AND ("graph database" OR neo4j)

Date of search: 2014-11-10
Results: 0

2.5 IEEE Xplore

Notes: The search is done in full text, including metadata. The search string had to be changed to fulfill IEEE's criteria that the string only should contain 15 search terms.

Queries:

- ("public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization")

Results: 45
Date of search: 2014-11-10

- ("public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization") AND neo4j)

Results: 0
Date of search: 2014-11-10

- ("public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization") AND "graph database")

Results: 0
Date of search: 2014-11-10

2.6 ISI Web of Knowledge

Notes: In Web of Knowledge you cannot perform at full text search, and must choose to search in "Topic", "Title", "Author", "Author Identifiers", "Editor", "Group Author", "Publication Name", "DOI" or "Year Published". We decided to use "Topic", "Title" and "Publication Name" because it seemed the most relevant to our search terms. The search was done in "All databases", but only in the "COMPUTER SCIENCE" research area. The original search string (see table 1.1) had to be modified, because it gave no results in Web Of Knowledge. A few terms were therefor excluded, and a few AND's were switched with OR's.

Queries:

- ("public transportation" OR traffic OR transportation OR transit OR "scheduling optimization" OR "path optimization" OR "route optimization" OR planning OR multimodal OR routing) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR pso OR aco OR bco) AND ("artificial intelligence" OR ai OR "machine learning")

  Results: 47 (Topic) + 0 (Title) + 0 (Publication Name)
  Date of search: 2014-11-11

- ("public transportation" OR traffic OR transportation OR transit OR "scheduling optimization" OR "path optimization" OR "route optimization" OR planning OR multimodal OR routing) AND ("bee colony optimization" OR "particle swarm optimization" OR "swarm intelligence" OR "ant colony optimization" OR pso OR aco OR bco) AND ("artificial intelligence" OR ai OR "machine learning") AND (neo4j OR "graph database")

  Results: 0 (Topic) + 0 (Title) + 0 (Publication Name)
  Date of search: 2014-11-11

2.7 Google Scholar

Notes: Google Scholar only allows very short search strings, and we were therefor forced to split the query into smaller pieces and do mulitple search, for so to add the results togheter. The original search string had to be modified for making the splitting tolerable and effective.

Queries:

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND "bee colony optimization"

Results: 21
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND "bee colony optimization" AND neo4j

Results: 0
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND "bee colony optimization" AND "graph database"

Results: 0
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal)AND(transit OR traffic)AND("artificial intelligence" OR ai OR "machine learning")AND routing AND "particle swarm optimization"

Results: 78
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal)AND(transit OR traffic)AND("artificial intelligence" OR ai OR "machine learning")AND routing AND "particle swarm optimization" AND neo4j

Results: 0
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal)AND(transit OR traffic)AND("artificial intelligence" OR ai OR "machine learning")AND routing AND "particle swarm optimization" AND "graph database"

Results: 0
Date of search: 2014-11-10

- "public transportation" AND ("path optimization" OR "route optimization" OR planning OR multimodal) AND (transit OR traffic) AND ("artificial intelligence" OR ai OR "machine learning") AND routing AND "swarm intelligence"

Results: 76
Date of search: 2014-11-10

- “public transportation” AND (“path optimization” OR “route optimization” OR planning OR multimodal) AND (transit OR traffic) AND (“artificial intelligence” OR ai OR “machine learning”) AND routing AND “swarm intelligence” AND neo4j

Results: 0
Date of search: 2014-11-10

- “public transportation” AND (“path optimization” OR “route optimization” OR planning OR multimodal) AND (transit OR traffic) AND (“artificial intelligence” OR ai OR “machine learning”) AND routing AND “swarm intelligence” AND “graph database”

Results: 0
Date of search: 2014-11-10

- “public transportation” AND (“path optimization” OR “route optimization” OR planning OR multimodal) AND (transit OR traffic) AND (“artificial intelligence” OR ai OR “machine learning”) AND routing AND “ant colony optimization”

Results: 119
Date of search: 2014-11-10

- “public transportation” AND (“path optimization” OR “route optimization” OR planning OR multimodal) AND (transit OR traffic) AND (“artificial intelligence” OR ai OR “machine learning”) AND routing AND “ant colony optimization” AND neo4j

Results: 0
Date of search: 2014-11-10

- “public transportation” AND (“path optimization” OR “route optimization” OR planning OR multimodal) AND (transit OR traffic) AND (“artificial intelligence” OR ai OR “machine learning”) AND routing AND “ant colony optimization” AND “graph database”

Results: 0
Date of search: 2014-11-10

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