I. IDENTIFICATION DATA

Thesis name:	Learning Based Solution to Routing Problems
Author's name:	Bc. Petra Fridrichová
Type of thesis :	master
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis supervisor:	prof. Ing. Jan Faigl, Ph.D.
Supervisor's department:	Department of Computer Science

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment   challenging
Evaluation of thesis difficulty of assignment.

The thesis's topic is from a relatively well-studied domain of routing problems with many existing approaches, including recent advancements in learning-based methods. Besides, extending the existing methods to more general routing problems than the traveling salesman problem (TSP) is ambitious. Therefore, the assignment is considered challenging.

Satisfaction of assignment   fulfilled
Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.

The original idea of general routing problems such as non-Euclidean, multi-vehicle instances, or considering time windows have been quickly abandoned because the early review of the related work and evaluation of the existing solutions to the TSP showed a relatively poor performance even in the Euclidean TSP from the TSPLIB. Therefore, we agreed to focus on the solution of the instance of the TSP to improve existing learning-based methods. The proposed concept of reusing existing solutions to determine the initial solution combined with the solution improvement based on combinatorial metaheuristic has been implemented and thoroughly validated in random and TSPLIB instances showing better results than using the original learning-based methods solely. Thus, the assignment is considered fulfilled.

Activity and independence when creating final thesis   B - very good.
Assess whether the student had a positive approach, whether the time limits were met, whether the conception was regularly consulted and whether the student was well prepared for the consultations. Assess the student's ability to work independently.

The student has been active during the work on the thesis. She started by reviewing the existing approaches and evaluated their performance in random and later realistic TSP instances from the TSPLIB. We regularly discussed possible approaches and how to handle relatively extensive evaluation results. However, performing the evaluation results would deserve more attention, but in the end, the student has been able to fix found issues. The text was created gradually, and the student worked independently.

Technical level   B - very good.
Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

The student exploited existing and available solutions and built her solutions on top of the existing work, which enabled her to evaluate several approaches and design a novel solution pipeline. The student proposed architecture to exploit a set of available instances with optimal solutions from which the most similar instance is determined using embedding the attention model for the TSP. Then, an initial solution of the new instance is constructed using the solution of the similar instance that can be further improved by a combinatorial metaheuristic employed as an improving heuristic. The greedy construction of the initial solution showed to provide poor performance. Therefore, an existing unsupervised learning-based method for routing problems has been adopted as the so-called feasible solution creator. The proposed approach provides better results than the original methods used solely as the TSP solvers. The employed combinatorial metaheuristic was initially adopted from the existing work for routing with profits and neighborhoods. Later on, it was reconsidered and implemented simplistically. Results in Fig. 6.5 indicate it deserves further investigation to figure out relatively poor exploration capability in the requested 2000 iterations, which, on the other hand, might be considered relatively low.

Formal and language level, scope of thesis — B - very good.

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.

The text typesetting meets the thesis standards with illustrative figures and readable presentations. A few typos, such as FSC vs. FCS, have yet to be revealed that are supposed to stand for feasible solution creator.

Selection of sources, citation correctness — B - very good.

Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.

The proposed solution is based on the literature view using relevant sources that are all correctly cited. However, the literature review on unsupervised and supervised learning-based methods in routing problems can be more extensive.

Additional commentary and evaluation

Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.

During the work on the thesis, we found out that some of the recently proposed learning-based methods have not been evaluated on the TSPLIB instances nor compared with well-established traditional combinatorial heuristics. Therefore, the further added value of the thesis, in addition to the proposed solution pipeline, are evaluation results of the existing attention model and graph neural networks-based approaches in selected TSPLIB instances where the methods show relatively poor performance outperformed by simple greedy heuristics in several cases.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.

The master thesis is based on a literature review and evaluation of the existing solutions from which a novel concept of reusing existing solutions of the TSP instances is proposed and validated. The developed solution provides better results than the original learning-based methods used solely. Besides, it scales better with the increasing size of the instance. It provides significantly better results in realistic TSP instances of the TSPLIB than the existing learned models published in the literature and evaluated only on random instances. The proposed method and developed solution are presented in a suitable form in the text of the thesis, and I have no doubt that the student has demonstrated the ability to independently study the problem, design her solution, and verify and present the achieved results in the actual text of the thesis.

I evaluate handed thesis with classification grade **B - very good.**

Date: **16.6.2023**   Signature: