Bachelor Thesis Proposal:

Applying heuristic search strategies to plan with reconfigurable multi-robot systems

by Rahul B. Shrestha,
Computer Science Student at Jacobs University Bremen

1. Introduction

Reconfigurable robots can physically merge to create dynamic robotic systems, leading to additional degrees of freedom. Temporal Planning for Reconfigurable Multi-Robot Systems (TemPl) is a constrained-based mission planner for reconfigurable multi-robot systems. This planner introduces a mission description as a generalisation of the Vehicle Routing Problem (VRP).

TemPl translates a mission description into a multicommodity min-cost flow problem to identify a locally optimal plan. This optimization is solved as linear integer problem (LP) which can be solved using existing linear integer program solvers [1]. The size of the multicommodity min-cost flow problem as a linear program depends upon the size of the temporally expanded network, as well as the number of active mobile and immobile agents that need to be routed. The scalability of this planning approach is limited by this optimal planning approach and the used LP solvers.

To tackle this limitation this thesis aims to explore and evaluate the use of heuristic search strategies such as Tabu Search[2] or Very Large Neighbourhood Search (VLNS)[3] which could possibly optimise the planner.

2. Definition of goals

The goal of this thesis is to select, implement, test and evaluate heuristic search strategies to improve the mission planner TemP. The comparison of different strategies for planning will be based on a set of evaluation criteria:

The major criteria for the evaluation of the heuristic search strategies are:

- quality of plans, based on the combination of following metrics:
    - distance travelled
    - operation time
    - consumed energy
    - safety
- planning time

- scalability / size of the supported planning problem

3. Task Description

3.1 Task description

The project is divided into the following tasks:

Evaluate state of the art / Familiarize with the available planning system TemPl in parallel to sota

The initial task consists of two parallel activities. The first activity focuses on the field of combinatorial optimization and the Vehicle Routing Problem, which is a broad and active field of research. I will read papers and collect the state of the art on heuristic search strategies to identify mature approaches that can be embedded into the planner.
As second activity I will familiarize myself with the available planning system TemPl to be capable to develop an integration approach as following activity.

Develop an integration approach for heuristic search strategies

To permit the evaluation of the heuristic search algorithms within TemPl, I will implement an integration approach and define an interface to replace the existing LP-based local optimizer.

Select heuristic search strategies to embed and plan metrics

After my evaluation of state-of-the art and preparing the integration into TemPl, I will pick heuristic search strategies that are most relevant to solving the planning problem. Metrics will be devised so that the different strategies can be ranked properly.

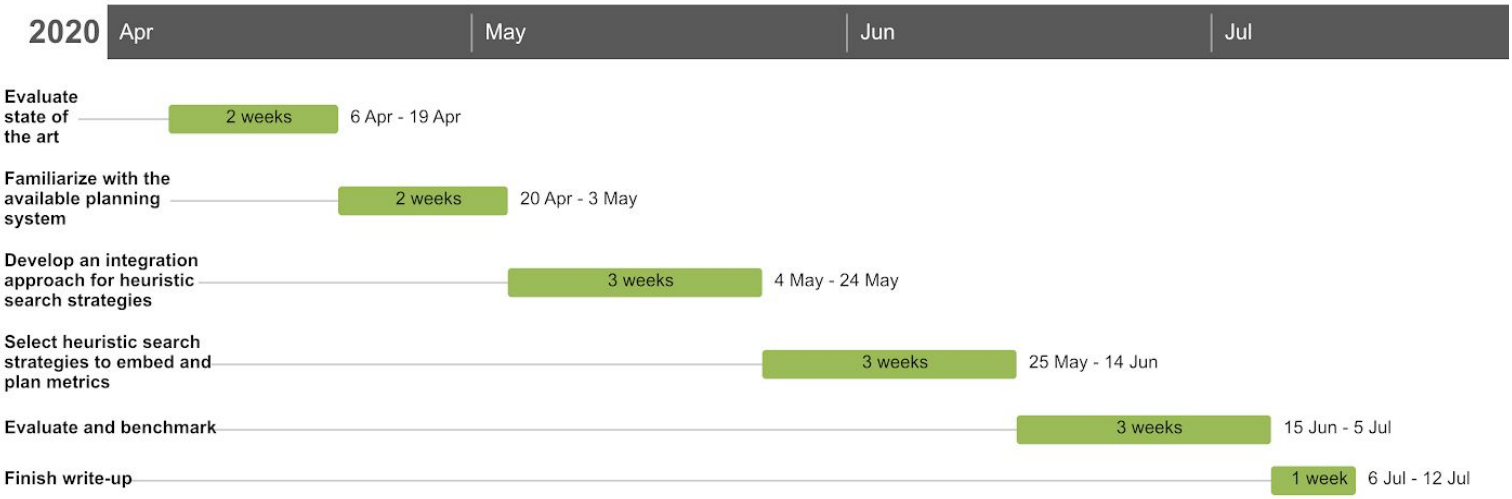
Evaluate and benchmark

The performance of the heuristic search strategies will be evaluated against a set of representative missions. To generate a variety of missions a generator will be implemented, which will allow to benchmark the planner according to the criteria previously mentioned.

Writeup

The write up will happen during all stages of this project. I intend to leave some time after the final task to review my results and come up to a conclusion.

4. Time Schedule



5. Supervisor

Jacobs University Bremen: Dr. Francesco Maurelli
University of Bremen: Prof. Dr. Dr. h.c. Frank Kirchner
Mentor: Dr. Thomas Röhr

7. References

[1] Roehr, T. (March 2019). *Autonomous Operation of a Reconfigurable Multi-Robot System for Planetary Space Missions*. http://elib.suub.uni-bremen.de/edocs/00107698-1.pdf
[2] Gendreau, M., Hertz, A., & Laporte, G. (1994). A tabu search heuristic for the vehicle routing problem. *Management science*, *40*(10), 1276-1290.
[3] Ahuja, R. K., Orlin, J. B., & Sharma, D. (2000). Very large-scale neighborhood search. *International Transactions in Operational Research*, *7*(4-5), 301-317.