

Multi-objective Capacitated Arc Routing Problem

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Abstract. The Capacitated Arc Routing Problem (CARP) is a very hard vehicle routing problem raised for instance by urban waste collection. In addition to the total route length (the only criterion minimized in the academic problem), waste management companies seek to minimize also the length of the longest trip. A bi-objective genetic algorithm is presented for this more realistic CARP, never studied before in literature. Based on the NSGA-II template, it includes two-key features: use of good constructive heuristics to seed the initial population and hybridization with a powerful local search procedure. This genetic algorithm is appraised on 23 classical CARP instances, with excellent results.

The capacitated arc routing problem

Graph $G=(V,A)$

- n nodes, m arcs
- a fleet of identical vehicles (capa. W)
- based at a depot
- for each arc (i,j)
 - a traversal cost c_{ij} , a collecting cost k_{ij} ,
 - a quantity to be collected q_{ij}

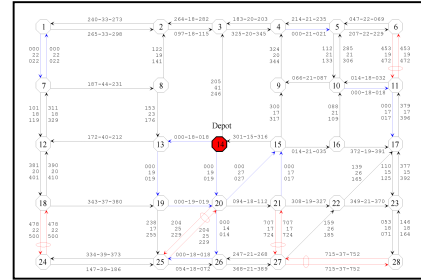
CARP is *NP-Hard* in a strong sense for a single objective

Instances

- Golden, De Armon and Baker
- 23 files from OR-Library
- from 7 to 27 nodes
- from 11 to 55 edges

Objectives

- Minimizing the total duration of the trips
- Minimizing the longest trip



- Circles on arcs indicates that both sides are collected simultaneously
- Arcs are valued by q_{ij} , c_{ij} and k_{ij}

Application of NSGA-II with improvements

Chromosome representation

- permutation (giant tour)
- exact evaluation through a shortest path algorithm in an auxiliary graph

Initial solutions

- Path-Scanning [Golden *et al.* 1983]
- Augment-Merge [Golden & Wong, 1981]
- Ulusoy' s heuristic [Ulusoy, 1985]

Local search

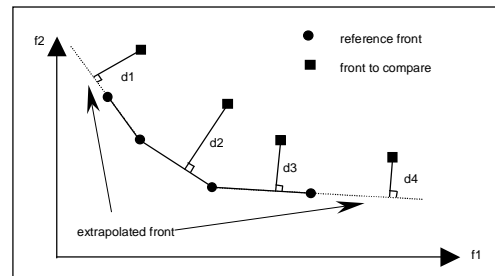
- improvement in each direction of the objectives or both
- Applied under probability after each crossover operation

- five types of moves:
 - inverse the traversal direction of a task in its trip
 - move one task after one other
 - move two adjacent tasks after one other
 - swap two tasks
 - perform 2-opt moves

Evaluation of the quality of a solution

Distance measure

- a front is used as a "reference front" (here a front w/o Local Search)
- it is a piecewise linear front
- the front is extrapolated
- a distance is measured between a solution and its projection to the extrapolated reference front
- distances are cumulated
- distance can be normalized when dividing by the number of efficient solutions



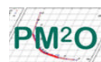
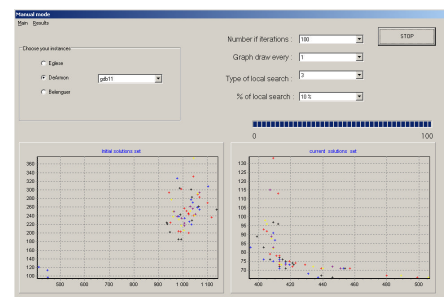
Computational results

Parameters

- population size: 60
- crossover operator: Std. OX
- max. iterations: 100
- local search: both directions
- local search rate: 10%

Results

- Average $|E| = 3.76$
- Measure Std. = - 22.82, Norm. = - 6.48
- Objective total duration
 - dev. from LB = 0.56%
 - # opt. found = 16
- Objective total duration
 - dev. from LB = 22.07 %
 - # opt. found = 11



Multiple Objective Metaheuristics

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