Vehicle Routing Problem With Time Windows

— Computational Intelligence —

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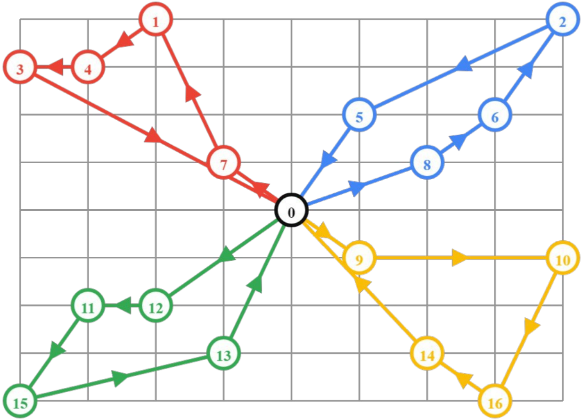
Overview

Description

- Set of cities V and set of customers C
- Constraints
- Objective function



Genetic algorithm

- Pseudocode

Algorithm 1 Genetski algoritam

```
Create initial population
Evaluate population
while Termination criterion is not met do
    Select good individuals for reproduction
    Perform crossover operation on said individuals
    Perform mutation operation on children individuals with probability P_m
    Evaluate new population
end while
```

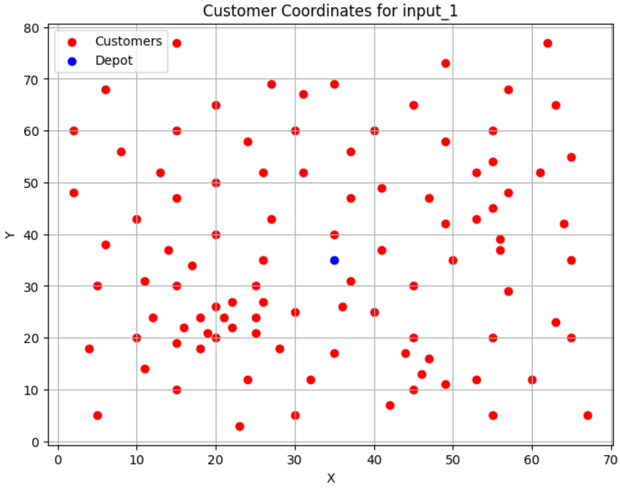
Genetic algorithm

```python
population = [Individual(data, capacity, num_of_vehicles, service_time) for _ in range(population_size)]
new_population = deepcopy(population)

best_solutions = []
for i in range(num_generations):
    population.sort(key = lambda x: x.fitness)
    best_solutions.append(population[0])
    new_population[:elitism_size] = population[:elitism_size]

    for j in range(elitism_size, population_size, 2):
        parent1 = selection(selection_params, population[:elitism_size])
        parent2 = selection(selection_params, population)

        while(parent1 == parent2):
            parent2 = selection(selection_params, population)

        crossover(params, parent1, parent2, new_population[j], new_population[j+1])

        new_population[j].solution = deepcopy(mutation(params, new_population[j], mutation_prob))
        new_population[j+1].solution = deepcopy(mutation(params, new_population[j+1], mutation_prob))

        offset = min(i/400, 0.25)
        insertion_based_repair(new_population[j], offset)
        insertion_based_repair(new_population[j+1], offset)

        new_population[j].fitness = new_population[j].calc_fitness()
        new_population[j+1].fitness = new_population[j+1].calc_fitness()

        new_population = check_and_update_num_of_vehicles(j, j+1, new_population)

    population = deepcopy(new_population)

print("Number of vehicles after for loop: ", population[0].num_of_vehicles)
return min(population, key = lambda x: x.fitness), best_solutions
```

Parameters

```
POPULATION_SIZE = 300
ELITISM_SIZE = 60
MUTATION_PROB = 0.25
TOURNAMENT_SIZE = 50
NUM_GENERATIONS = 30
CAPACITY = 200
SELECTION = [random_selection, tournament_selection, roulette_selection, rang_selection]
MUTATION = [swap_mutation, invert_mutation, shaking_mutation]
CROSSOVER = [order_crossover, partially_mapped_crossover, best_route_better_adjustment_crossover]
NUM_OF_VEHICLES = 50
SERVICE_TIME = 10
```

Dataset

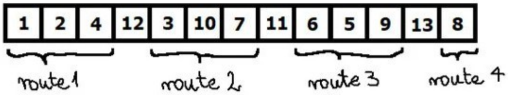


- Marius M. Solomon
- R101

Chromosome initialization

Algorithm 2 Inicijalizacija hromozoma

```
Create remaining customers list from available customers
routes = []
last visited = Depot
current route = []
while Remaining customers list is not empty do
    Create list of feasible customers and sort it according to distance from last visited customer
    if List of feasible customers is empty then
        last visited = Depot
        Append current route to routes list
        current route = []
        continue
    end if
    if random[0, 1] ≤ randomizing parameter then
        Choose a random feasible customer and add it to current route
        Remove said customer from feasible customers list
        Update last visited customer
    else
        Choose a nearest customer from feasible customer list and add it to current route
        Remove said customer from feasible customers list
        Update last visited customer
    end if
end while
```



- Nearest Neighbour heuristic
- How to achieve a diverse initial population?

Chromosome initialization

```python
def generate_feasible_routes(self, routes, remaining_cities, prob) -> [[int]]:
    for route in routes:
        while True:
            if not route:
                feasible_cities = self.get_feasible_cities(remaining_cities, 0, 0, self.capacity)
            else:
                _, current_time, remaining_capacity = self.route_fitness(route)
                feasible_cities = self.get_feasible_cities(remaining_cities, route[-1], current_time, remaining_capacity)

            if not feasible_cities:
                break

            if random.random() < prob:
                city_index = random.choice(feasible_cities)[0]
            else:
                city_index = feasible_cities[0][0]

            remaining_cities.remove(city_index)
            route.append(city_index)

            is_unfeasible, _ = self.is_route_unfeasible(route)
            if is_unfeasible:
                route.pop(-1)
                remaining_cities.append(city_index)
                continue
```

Fitness function

```
def route_fitness(self, route) -> (float, float, float):
    if not route:
        return 0, 0, self.capacity

    fitness = 0
    current_time = 0
    previous_city = 0
    remaining_capacity = self.capacity

    for current_city in route:
        current_city_data = self.data[current_city]
        distance = self.distance_between_cities[previous_city][current_city]

        if round(current_time + distance + self.service_time, 3) > current_city_data["due_time"] + self.tolerance:
            fitness += (current_time + distance + self.service_time - current_city_data["due_time"])*self.time_penalty

        if remaining_capacity < current_city_data["demand"]:
            fitness += (current_city_data["demand"] - remaining_capacity)*self.capacity_penalty

        current_time += distance + self.service_time
        previous_city = current_city
        remaining_capacity -= current_city_data["demand"]

    fitness += current_time + self.distance_between_cities[previous_city][0]
    fitness /= len(route) # fitness normalization
    fitness = round(fitness, 3)

    return fitness, current_time, remaining_capacity
```

- Penalization
- Normalization

Optimal operators combination

```
ga_all_combinations.sort(key = lambda x : x[-1][-1].fitness)
best_selection, best_mutation, best_crossover, best_individual_all_comb, best_solutions_all_comb = ga_all_combinations[0]

print('Best selection:', best_selection)
print('Best mutation:', best_mutation)
print('Best crossover:', best_crossover)
print('Best fitness:', best_solutions_all_comb[-1].fitness)

# for s, m, c, p, sol in ga_all_combinations:
#     print(s, m, c, sol[-1].fitness)
```

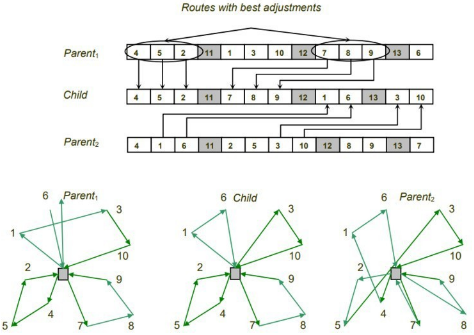
```
Best selection: random_selection
Best mutation: swap_mutation
Best crossover: best_route_better_adjustment_crossover
Best fitness: 567.904
```

Random Selection

```python
def random_selection(population):
    return random.choice(population)
```

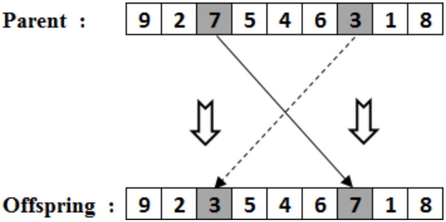
Best Route Better Adjustment Crossover

```python
def best_route_better_adjustment_crossover(parent1, parent2, child1, child2):
    # n/2 best from parent1 into first n/2 of child1
    # the rest elements are from parent2

    def create_child(p1, p2, ch):
        p1_routes = p1.get_routes()
        p1_routes.sort(key = lambda route: p1.route_fitness(route)[0])

        offspring = []
        route_idx = 0
        while route_idx <= len(p1_routes) / 2:
            offspring.extend(p1_routes[route_idx])
            route_idx += 1

        p2_routes = p2.get_routes()

        for route in p2_routes:
            for city in route:
                if city not in offspring:
                    offspring.append(city)

        ch.solution = offspring

    create_child(parent1, parent2, child1)
    create_child(parent2, parent1, child2)
```



Swap mutation

```python
def swap_mutation(individual, l, r):
    if l == len(individual.solution):
        l -= 1

    if r == len(individual.solution):
        r -= 1

    individual.solution[l], individual.solution[r] = individual.solution[r], individual.solution[l]
    return individual.solution
```



Insertion Based Repair

```python
def insertion_based_repair(individual, offset):
    if (individual.is_feasible()):
        return individual

    routes = individual.get_routes()
    cities = range(1, individual.num_of_cities + 1)
    removed_cities_list = []

    # get unvisited cities
    for city in cities:
        if city not in individual.solution:
            removed_cities_list.append(city)

    # get unfeasible routes
    unfeasible_routes = []
    for route in routes:
        is_unfeasible, _ = individual.is_route_unfeasible(route)
        if is_unfeasible:
            unfeasible_routes.append(route)

    # get feasible routes
    feasible_routes = []
    for route in routes:
        if route not in unfeasible_routes:
            feasible_routes.append(route)

    routes = deepcopy(feasible_routes)
```

Insertion Based Repair

```python
# remove excess routes
if len(routes) > individual.num_of_vehicles:
    routes.sort(key = lambda route: individual.route_fitness(route)[0])
    while len(routes) > individual.num_of_vehicles:
        route = routes.pop(-1)
        removed_cities_list.extend(route)

# remove unfeasible routes
for i, _ in enumerate(unfeasible_routes):
    unfeasible_routes[i].sort(key = lambda x: (individual.data[x]["ready_time"], individual.data[x]["due_time"]))

    # find and eliminate unfeasible cities
    while True:
        is_unfeasible, unfeasible_city = individual.is_route_unfeasible(unfeasible_routes[i])
        if not is_unfeasible:
            break

        removed_cities_list.append(unfeasible_city)
        unfeasible_routes[i].remove(unfeasible_city)
    routes.append(unfeasible_routes[i])
```

Insertion Based Repair

```python
# first try: insert if possible in existing route
if len(removed_cities_list) > 0:
    for removed_city in removed_cities_list:
        is_inserted = False
        for route_index, _ in enumerate(routes):
            for city_index, _ in enumerate(routes[route_index]):
                route_copy = deepcopy(routes[route_index])
                route_copy.insert(city_index, removed_city)

                is_unfeasible, _ = individual.is_route_unfeasible(route_copy)
                if not is_unfeasible:
                    routes[route_index] = deepcopy(route_copy)
                    is_inserted = True
                    removed_cities_list.remove(removed_city)
                    break

            if is_inserted:
                break
```

Insertion Based Repair

```
# second try: create new routes
if len(removed_cities_list) > 0 and individual.num_of_vehicles - len(routes) > 0:
    new_routes = [[] for _ in range( individual.num_of_vehicles - len(routes) )]
    generated_routes = individual.generate_feasible_routes(new_routes,
                                                           removed_cities_list,
                                                           0.25 - offset)

    routes = routes + generated_routes

individual.solution = individual.create_solution(routes)
```

Parameter optimization for optimal operators

```
POPULATION_SIZE = list(range(500, 1000, 100))
ELITISM_SIZE = list(range(70, 140, 14))
MUTATION_PROB = 0.25
TOURNAMENT_SIZE = 50
NUM_GENERATIONS = list(range(30, 50, 5))
CAPACITY = 200
SELECTION = globals().get(best_selection)
MUTATION = globals().get(best_mutation)
CROSSOVER = globals().get(best_crossover)
NUM_OF_VEHICLES = 50
SERVICE_TIME = 10
```

```
Best population size: 700
Best number of generations: 35
Best elitism size: 70
Best fitness: 541.695
```

Parameter optimization for optimal operators

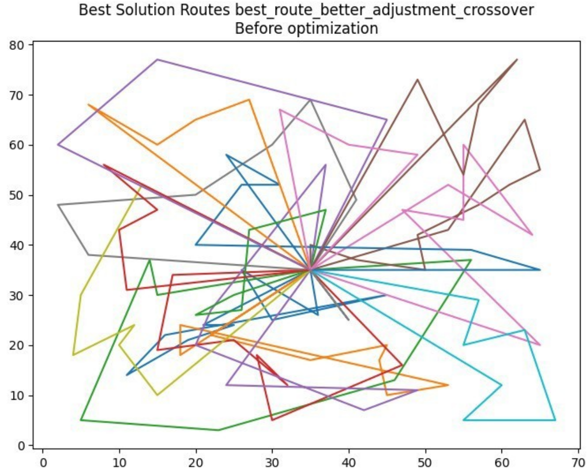
```
ga_analysis(best_crossover, best_individual_all_comb)
```

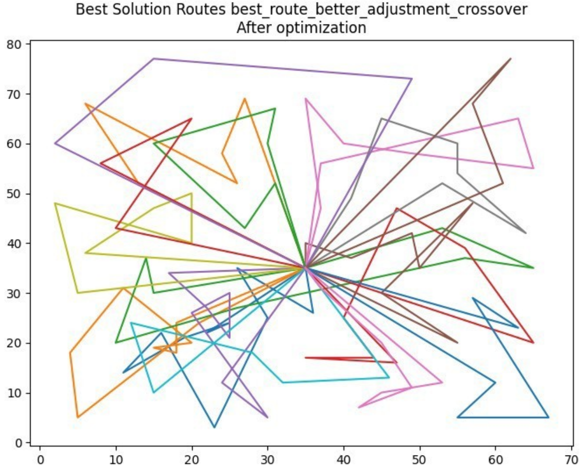
```
best_route_better_adjustment_crossover - is feasible
best_route_better_adjustment_crossover - num of non empty routes: 18
best_route_better_adjustment_crossover - total num of routes: 18
best_route_better_adjustment_crossover - fitness: 567.904
```

```
ga_analysis(best_crossover, best_individual_opt)
```

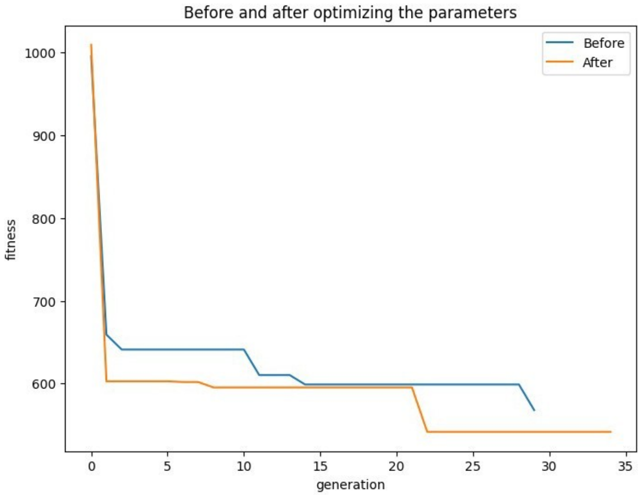
```
best_route_better_adjustment_crossover - is feasible
best_route_better_adjustment_crossover - num of non empty routes: 17
best_route_better_adjustment_crossover - total num of routes: 17
best_route_better_adjustment_crossover - fitness: 541.695
```

Parameter optimization for optimal operators





Parameter optimization for optimal operators



Thank you!