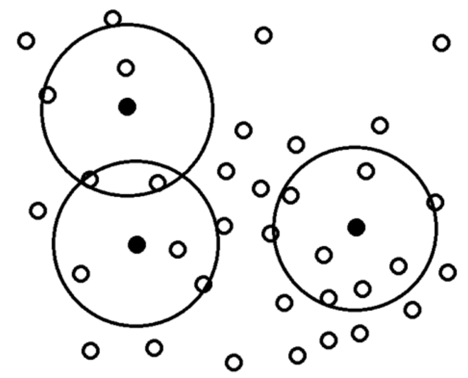
Solving Probabilistic Maximal Covering Location-Allocation Problem Using Artificial Bee Colony Algorithm with Local Refinement

Subhrajit Das

Supervisors:
Dr. Priya Ranjan Sinha Mahapatra
Dr. Soumen Atta

Department of Computer Science and Engineering
University of Kalyani

Introduction to the problem



- Introduced by Marianov and Serra [1998], the probabilistic maximal covering location-allocation problem (PMCLAP) is a renowned NP-hard problem in operations research which is a modified and constraints imposed on the maximal covering location problem (MCLP) proposed by Church and ReVelle [1974]. The application of this problem is enormous for example locating places for first aid centres, hospitals, fire stations, locating electric vehicle (EV) charging stations, stores of fast food chains, placing ATMs, etc.
- This problem can be simply defined as:
  - Suppose in a country with many cities with respective population, we directed to open k facilities in distinct k cities such that
    - Each facility in a city has a circular service radius of r serving other cities within the radius
    - One city can only be served by only one facility at max
    - There will be max waiting time of T in each facility or, There will be a waiting queue of length of max b clients
  - We have to maximize the total population served (Objective)

Mathematical Formulation

To model the PMCLAP, we define two sets of binary variables: one of location and the other for one for allocation decisions. Variables y_j are equal to one if and only if location j $\in$ N is opened, and variables x_{ij} are equal to one if and only if the demand of node i is associated with facility j, i,j $\in$ N. The problem can be formulated as follows:

$$maximize \sum_{i\in N}\sum_{j\in N_i} d_i x_{ij} \quad (1)$$

subject to

$$\sum_{j\in N_i} x_{ij} \leq 1, \quad i \in N \quad (2)$$

$$\sum_{i\in N} y_j = p \quad (3)$$

$$x_{ij} \leq y_j, \quad i \in N,\ j \in N \quad (4)$$

$$\sum_{i\in N} f_i x_{ij} \leq \mu \sqrt[b+2]{1-\alpha} \quad j \in N \quad (5)$$

$$\sum_{i\in N} f_i x_{ij} \leq \mu + \frac{1}{\tau}\ln(1-\alpha), \quad j \in N \quad (6)$$

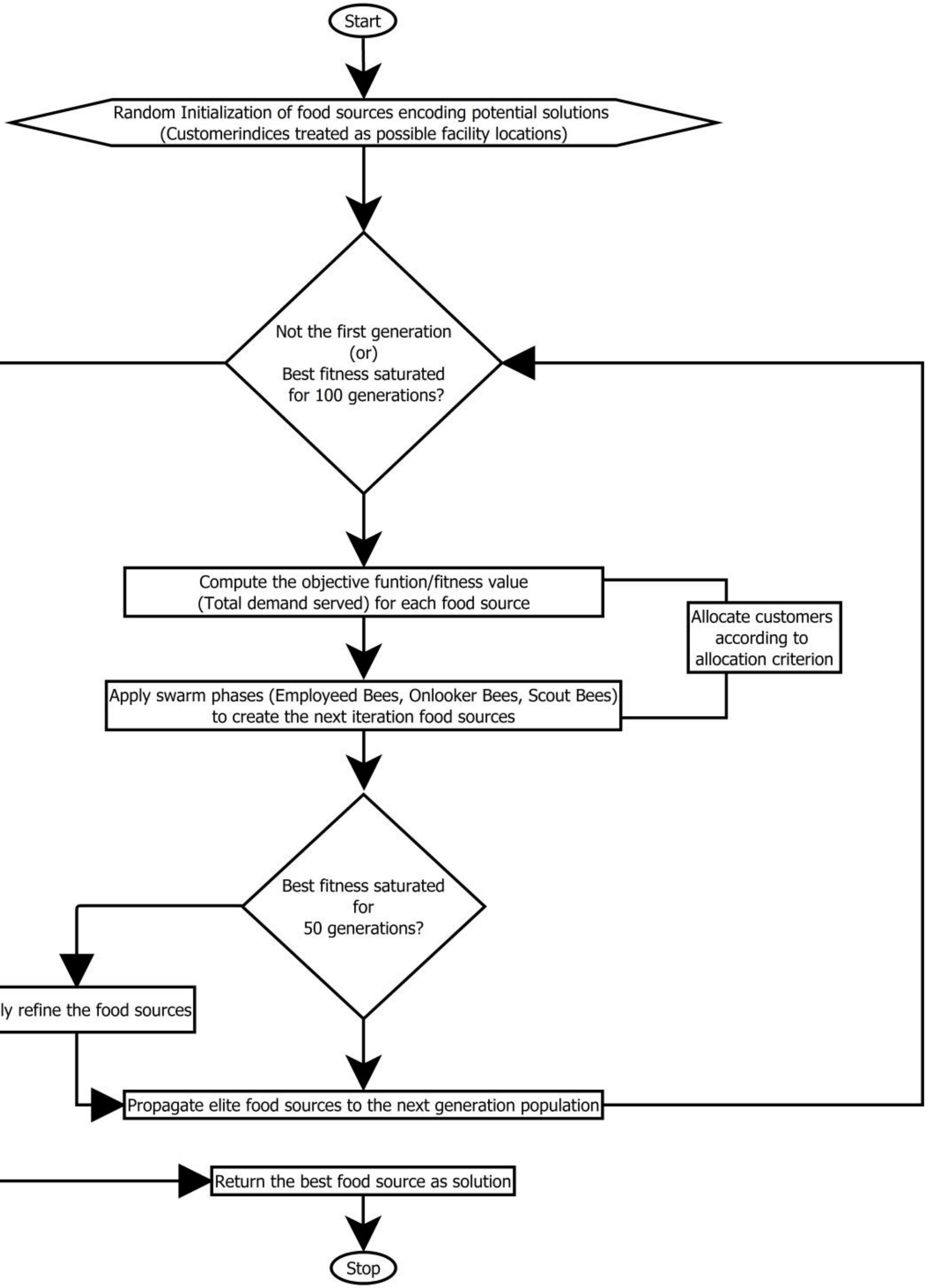
$$y_j, x_{ij} \in \{0,1\}, i \in N, j \in N \quad (7)$$

Experimental Methodology

Solving using Artificial Bee Colony Algorithm with Local Refinement

Initialization Phase
REPEAT
- Employed Bees Phase
- Onlooker Bees Phase
- Scout Bees Phase
- Local Refinement
- Allocate Customers to Facilities
- Elitism

UNTIL (Max Fitness Value Converged for last 100 generations)


Start
Random Initialization of food sources encoding potential solutions
(Customerindices treated as possible facility locations)
Not the first generation
(or)
Best fitness saturated
for 100 generations?
Compute the objective funtion/fitness value
(Total demand served) for each food source
Allocate customers
according to
allocation criterion
Apply swarm phases (Employeed Bees, Onlooker Bees, Scout Bees)
to create the next iteration food sources
Best fitness saturated
for
50 generations?
Locally refine the food sources
Propagate elite food sources to the next generation population
Return the best food source as solution
Stop

Software used

- Matlab R2021a
  - Machine Configuration-> i5 7th Gen, 8GB Ram

Experimental Results

	ANLS			MS_Heuristic		CS			GRASP			CPLEX		ABC WITH LOCAL REFINEMENT						
Instance	Best	Average	Time	Best	Time	Best	Average	Time	Best	Average	Time	Best	Time	Best	Average	Standard Deviation	Current Gap (%)	Earlier Gap (%)	Earlier Gap(%)	Time(s)
30_2_0_0_85	**3700**	3700	12.333	**3700**	0.000	**3700**	3700	0.009	**3700**	3700	0.007	**3700**	0	**3700**	3700	0	**0**	**0**	0	16.72
30_2_0_1_85	**5100**	5100	9.000	4630	0.000	5090	5090	0.018	5090	5090	0.016	**5100**	0	5090	5075	15	0.19	0.19	0.19	17.30
30_2_0_2_85	**5210**	5210	4.667	4780	0.000	**5210**	5210	0.016	**5210**	5210	0.015	**5210**	0	**5210**	5201	21	**0**	**0**	0	20.76
30_2_0_2_95	**4520**	4520	11.333	4470	0.000	**4520**	4520	0.015	**4520**	4520	0.013	**4520**	0	**4520**	4520	0	**0**	**0**	0	18.44
30_3_0_0_85	**5390**	5390	5.000	5210	0.000	**5390**	5390	0.025	**5390**	5390	0.025	**5390**	0	**5390**	5377	26.09	**0**	**0**	0	28.55
30_3_0_1_85	**5390**	5390	3.000	5210	0.000	**5390**	5390	0.024	**5390**	5390	0.024	**5390**	0	**5390**	5390	0	**0**	**0**	0	28.60
30_3_0_1_95	**5270**	5270	44.667	5080	0.000	5240	5240	0.024	5240	5240	0.024	**5270**	6	5260	5251	11.5	0.18	0.18	0.56	25.85
30_3_0_2_85	**5390**	5390	3.667	5210	0.000	**5390**	5390	0.023	**5390**	5390	0.022	**5390**	1	**5390**	5390	0	**0**	**0**	0	29.35
30_3_0_2_95	**5390**	5390	3.667	5230	0.000	**5390**	5390	0.027	**5390**	5390	0.023	**5390**	0	**5390**	5390	0	**0**	**0**	0	29.32
30_4_0_1_95	**5390**	5390	8.333	5260	0.000	**5390**	5390	0.026	**5390**	5390	0.022	**5390**	0	**5390**	5390	0	**0**	**0**	0	35.31
30_5_0_0_95	**5330**	5330	288.667	5210	0.000	**5330**	5317.6	0.041	**5330**	5312.8	0.032	**5330**	13	**5330**	5330	0	**0**	**0**	0.56	40.61
30_6_0_0_95	**5410**	5410	62.333	5390	0.000	**5410**	5391	0.037	5390	5390	0.029	**5410**	1	5400	5391	3	0.18	0.36	0.36	49.87

Type of fitness evaluation	**Number of times called (aggregated)**	**Percentage(%) Used**
Allocating to Least Congested Facility	41460253	~98
Allocating to Random Facility	845822	~2
Allocating to Nearest Facility	16	~0
Allocating as per Max Demand/Distance	383	~0

Experimental Results

	ANLS			MS_Heuristic		CS			GRASP			CPLEX		ABC WITH LOCAL REFINEMENT						
Instance	Best	Average	Time	Best	Time	Best	Average	Time	Best	Average	Time	Best	Time	Best	Average	Standard Deviation	Current Gap (%)	Earlier Gap (%)	Earlier Gap(%)	Time(s)
324_10_0_0_85	**37180**	37180	1255.333	37081	0.220	37173	37163.2	3.460	37157	37155.8	2.24	**37180**	13	37160	37094.70	61.50	0.02	0.08	1.02	323.01
324_10_0_0_95	**21460**	21460	865.667	21386	0.140	21455	21447.2	3.160	21446	21441.2	2.05	**21460**	9	21441	21381.70	64.40	0.08	0.14	1.56	346.67
324_10_0_1_85	**51000**	51000	1435.000	50750	0.200	50948	50946.3	3.410	50948	50946.3	2.30	**51000**	22	50928	50722	126.37	0.14	0.245	2.08	335.87
324_10_0_1_95	**35360**	35360	857.000	35250	0.160	35359	35354.6	3.170	35339	35336.5	2.06	**35360**	14	35351	35322.40	18.42	0.02	0.05	0.67	379.19
324_10_0_2_85	**59740**	59740	987.667	59598	0.200	59693	59688.5	3.330	59693	59688.5	2.24	**59740**	22	59628	59453	144.98	0.18	0.17	1.92	336.81
324_20_0_0_85	**74360**	74357.7	6191.667	73981	0.830	74165	74106.7	9.710	74165	74106.0	4.80	**74360**	198	73752	73452.90	160.62	0.81	0.94	2.93	811.24
324_20_0_0_95	**42920**	42919.7	3936.333	42714	0.730	42840	42804.9	9.370	42813	42792.2	4.24	**42920**	22	42738	42608.60	124.73	0.42	0.35	4.48	819.53
324_20_0_1_85	101978	101974	7212.667	100628	1.020	101374	101177.4	9.070	101374	101177.4	4.88	**102000**	612	99771	99079.50	511.43	2.16	2.41	2.94	787.73
324_20_0_1_95	**70720**	70720	4417.333	70368	0.740	70656	70628.2	9.060	70561	70529.8	4.43	**70720**	55	70536	70456.60	63.84	0.26	0.31	2.12	700.33
324_20_0_2_85	119455	119447.3	6388.000	118451	0.770	118771	118613.6	8.990	118771	118613.6	4.86	**119740**	10804	117455	116917.70	496.44	1.67	1.81	4.91	505.41*
324_20_0_2_95	**90780**	90780	6667.333	90424	0.810	90556	90521.2	9.400	90550	90518.9	4.64	**90780**	74	90084	89620.90	232.61	0.76	0.80	3.29	528.46

Type of fitness evaluation	**Number of times called (aggregated)**	**Percentage(%) Used**
Allocating to Least Congested Facility	16,85,47,219	~97
Allocating to Random Facility	50,16,308	~2.88
Allocating to Nearest Facility	884	~0
Allocating as per Max Demand/Distance	343,55	~0.12

Conclusion

- It proposed an approach to solve the Probabilistic Maximal Coverage Location-Allocation Problem using the Artificial Bee Colony algorithm with local refinement strategy. Three allocation subproblems were solved using different strategies, resulting in promising results for the 30 node dataset.
- However, for larger datasets of 324 and 818 nodes, the benchmark results were missed by a small margin.
- Future work will focus on making appropriate changes to achieve benchmark results while maintaining faster computational time. Overall, this study provides insights into solving the PMCLAP problem and opens up avenues for further research in this area