Multi-objective Priority Based Heuristic Optimization for Region Coverage with UAVs

Kemal Ihsan Kilic, Orhan Gemikonakli, Leonardo Mostarda

Computer Science Division, University of Camerino

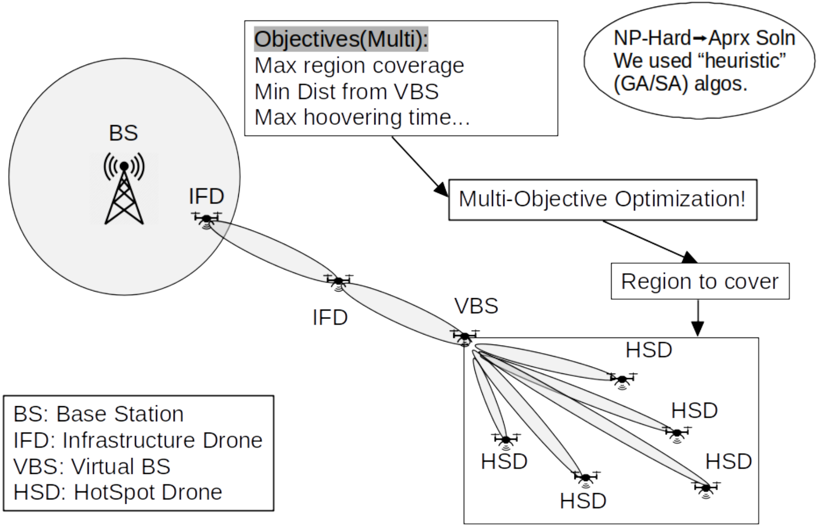
kemal.kemal@unicam.it

April XX, 2020

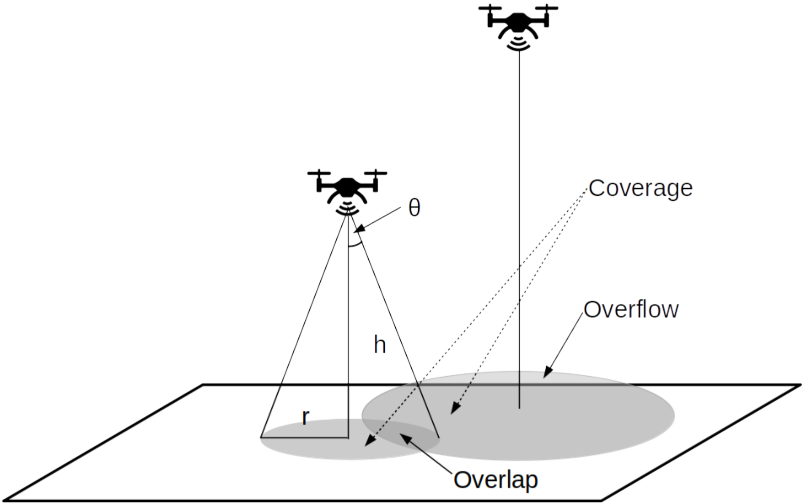
Outline

- Problem
- Approaches
- Proposed Framework
- Benchmarks, Results, and Conclusion

Drone Configuration



Drone Parameters



Summary of approaches so far

- Mostly “target coverage” considered
- Mostly “single objective optimization” considered
- Mostly “integer linear programming” utilized
- Few articles presented optimum drone config. figures

Novelties proposed

- Different application scenarios listed
- Priorities for multi objectives (based on scenario type) offered
- Circle-packing algo. for "initial solution": "Good" for "evolutionary" algos.

Approaches for Multi-objective Optim.

- **Generally people do Pareto Optimization**: Lets make all the goals happy!
- But sometimes "Jack-of-all-trades-master-of-none" case
- Priorities! Lets use weights and pick objectives to optimize some more

Priority based multi-objective scoring

$$\text{Score} = W_c \times CP + W_l \times OlpP + W_f \times OfwP + W_d \times TotDP$$

NOVELTY!

Scenarios for coverage

Table 1: Application cases and proposed set of weights for objectives.

Application type (Scenario)	$\boldsymbol{W}_c$	$\boldsymbol{W}_l$	$\boldsymbol{W}_f$	$\boldsymbol{W}_d^\dagger$
S1: Max coverage with no compromise	+	0	0	0
S2: Max coverage with only overlap/overflow penalty	+	-	-	0
S3: Max coverage with overlap/overflow penalty and min total distance of drones from VBS	+	-	-	+
S4: Max coverage with only min total distance of drones from VBS	+	0	0	+

†: Normalized total distance differences from the max distance in the mission region from all drones.

NOVELTY!

Benchmarking 3 Algorithms in R

- GA: Genetic Algorithm
- GenSA: Generalized Simulated Annealing
- DEoptim: Differential Evolution algorithm for global optimization

Table 2: Parameters used in benchmarking.

Parameter	**Value**
Region length	400m
Region width	300m
Min height for drones	5m
Max height for drones	150m
Theta angle for drones	30°
Number of drones	2, 4, 6, 8, 10, 12

- DEoptim was the quickest algorithm
- GA was the best in finding more "compact" (drones closer to VBS) coverage configuration although the coverage percentage was not highest
- GenSA was the best in finding highest coverage percentage

Example Optimizations

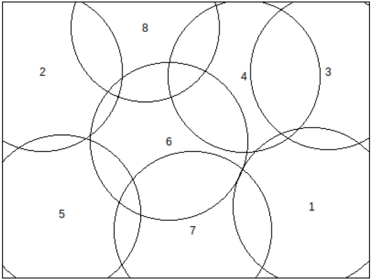


Figure 1: A: S1, GA, overflow-overlap ignored, max region coverage, no compromise. 99.24%, 2431m

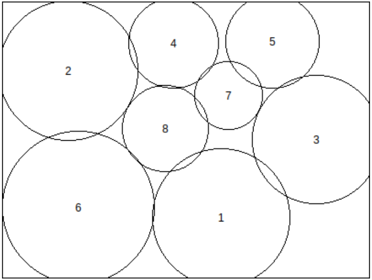


Figure 2: B: S3, GA, overflow-overlap penalty and minimizing drone distance from BS(0,0). 80.6%, 2228m

NOVELTY!

Thanks!
Any questions?

Table 3: Benchmark results for running time, coverage, and total distance of drones from VBS for each scenario.

Drones	Scn	Time(sec)					Cov(%)						TDist(m)					
		DO	GA		SA		IS	DO	GA		SA		IS	DO	GA		SA	
			With	No	With	No			With	No	With	No			With	No	With	No
2	S1	13.82	209.3	361.92	743.39	729.64	21.94	40.05	40.05	40.05	40.05	40.05	475.6	565.26	564.74	596.96	666.55	597.95
	S2	15.27	196.86	207.18	712.06	719.62	21.94	40.05	40.05	40.05	40.05	40.05	475.6	652.55	608.76	627.69	636.88	540.39
	S3	39.78	163.48	178.62	716.18	699.62	21.94	40.04	37.74	40.05	40.04	40.04	475.6	508.32	500.19	509.66	507.35	508.7
	S4	30.9	202.51	226.14	711.26	710.78	21.94	39.56	39.36	39.13	39.56	39.56	475.6	493.09	488.73	484.75	493.21	493.42
4	S1	166.32	153.86	153.47	1000.78	1000.75	57.24	76.33	76.12	75.36	76.48	76.48	1322.59	1212.75	1215.67	1185.11	1232.22	1233.37
	S2	155.98	308.28	157.75	1001.01	1000.71	57.24	73.5	74.62	71.82	75.74	75.74	1322.59	1161.65	1177.85	1180.21	1201.64	1223.76
	S3	189.84	200.94	225.61	1000.92	1000.77	57.24	71.23	65.85	66.34	70.9	72.43	1322.59	1177.95	1083.5	1045.09	1097.27	1129.37
	S4	197.45	175.2	153.91	1001.12	1001.65	57.24	76.1	76.11	75.09	76.16	76.14	1322.59	1187.73	1194.66	1160.29	1185.27	1185.03
6	S1	427.51	511.38	577.94	1000.73	1000.75	69.59	95.86	95.8	95.38	96.42	96.43	1760.01	1880.97	1828.03	1851.19	1854.81	1853.23
	S2	378.26	251.65	236.42	1000.74	1000.72	69.59	87.65	83.69	86.43	87.1	89.48	1760.01	1841.02	1859.63	1753.23	1795.94	1793.11
	S3	390.51	325.48	425.98	1000.72	144.12	69.59	84.73	77.55	77.93	72.73	82.43	1760.01	1673.83	1530.65	1517.62	1275.02	1413.54
	S4	416.64	481.24	281.81	1000.76	1002.13	69.59	95.02	95.18	87.69	96.09	96.12	1760.01	1807.89	1796.11	1693.77	1813.75	1812.89
8	S1	269.4	437.34	524.35	1000.76	1000.77	75.61	94.63	98.07	99.24	99.9	99.97	2457.35	2534.07	2483.6	2431.52	2510.69	2499.34
	S2	269.91	458.04	364.65	1000.94	1000.72	75.61	78.96	83.72	83.04	90.68	89.75	2457.35	2343.94	2402.89	2270.75	2462.48	2486.55
	S3	647.31	445.35	502.83	179.23	189.01	75.61	76.98	81.8	80.6	84.85	76.96	2457.35	1688.09	2306.31	2227.58	1985.03	1638.37
	S4	694.71	372.77	394.13	1000.84	1001.92	75.61	96.14	98.37	98.08	98.7	98.32	2457.35	2120.46	2423.06	2293.7	2218.2	2178.36
10	S1	935.31	789.75	1652.59	377.51	363.53	67.29	99.98	100	99.98	100	100	3112.84	3118.6	3109.22	2981.74	3018.26	3136.28
	S2	394.58	609.55	1439.43	1000.79	1000.81	67.29	81.67	84.91	86.08	89.91	89.02	3112.84	2699.96	2796.58	2854.54	3206.29	2998.3
	S3	532	203.99	878.5	110.4	78.42	67.29	85.91	85.37	80.36	85.19	85.29	3112.84	2335.38	2561.08	2501.69	2257.09	2310.3
	S4	742.62	554.54	894.4	604.63	201.47	67.29	98.03	99.08	99.51	99.26	98.49	3112.84	2690.57	2657.05	2763.19	2520.76	2439.56
12	S1	772.97	638.99	1230.49	274.62	240.81	73.98	99.92	100	99.91	100	100	3518.39	3882.51	3617.53	3399.39	3663.7	3655.72
	S2	278.42	657.43	1016.11	1000.92	1002	73.98	69.41	86.77	84.23	89.53	89.46	3518.39	2853.03	3438	3278.39	3367.15	3230
	S3	602.03	1156.61	341.71	145.89	236	73.98	85.36	85.47	82.56	89.66	84.48	3518.39	3011.19	3423.38	2719.09	2776.8	2669.1
	S4	1296.59	744.6	528.75	174.49	192.89	73.98	97.09	99.86	98.67	97.18	98.76	3518.39	2860.62	3268.05	2947.51	2755.3	2943.88
S1 # of 1^{st}		3	0	1	0	2	-	1	3	1	4	6	-	0	2	4	0	0
S2 # of 1^{st}		5	0	1	0	0	-	1	1	1	5	3	-	3	0	2	0	1
S3 # of 1^{st}		2	0	0	2	2	-	2	0	1	2	1	-	0	1	1	2	2
S4 # of 1^{st}		1	1	2	1	1	-	1	1	1	3	2	-	1	0	3	1	1
Tot # of 1^{st}		11	1	4	3	5	-	5	5	4	14	12	-	4	3	10	3	4