Optimization result reporting:

**Dynamic Increasing of Low Mutation Ratio/Decreasing of High Crossover Ratio (ILM/DHC)** was found to be more effective with smaller populations (25 and 50 individuals), where higher mutation rates later in the search process introduced necessary diversity, helping the algorithm avoid local optima. **Dynamic Decreasing of High Mutation Ratio/Increasing of Low Crossover Ratio (DHM/ILC)** performed better with larger populations (200 and 400 individuals), where a higher crossover rate towards the end of the search allowed for the generation of stronger offspring, leveraging the diversity already present in the population.(Hassanat et al., 2019)

***Example for selection of mutationa and crossover weight value:***

*The values of mutation and crossover rates are calculated according to the generation level number. If the generation level is 500, the maximum generation is*=1600*, and the population size is*=100*, then the value of mutation and crossover rates according to the previous equations are:*

𝐿𝐺=500

𝐺𝑛=1600

𝑀𝑅=1−(500/1600)=0.69

𝑀=0.69∗100=69*individuals are to be mutated in generation level 500.*

*For Crossover rate:*𝐿𝐺=500,𝐺𝑛=1600*,*𝐶𝑅=(500/1600)=0.31

𝐶=0.31∗100=31*individual are to be used for the crossover process at generation level 500.*

Computing infrastructure used: Google colab T4 GPU

**Earth Model we choose:**

The WGS 84 datum surface is an [oblate spheroid](https://en.wikipedia.org/wiki/Oblate_spheroid) with equatorial radius *a* = 6378137 m at the equator and [flattening](https://en.wikipedia.org/wiki/Flattening) *f* = 1⁄298.257223563. The refined value of the WGS 84 [gravitational constant](https://en.wikipedia.org/wiki/Standard_gravitational_parameter) (mass of Earth's atmosphere included) is *GM* = 3.986004418×1014 m3/s2. The angular velocity of the Earth is defined to be *ω* = 72.92115×10−6 rad/s (Agency, 1987).

Our objective:

1. Minimize revisit time O\_1(x)
2. Maximize dwell time O\_2(x)

In **multi-objective optimization**, we need to minimize both objectives. However, since were trying to **maximize** the dwell time, we need to **transform** this into a **minimization** problem.

Mathematically,

* **Minimizing** O\_1(x): We want to minimize the revisit time directly.
* **Maximzing O-2(x): We want to maximize the dwell time. However, since DEAP’s optimizer minimizes by default, we must transform this into a minimization problem. To do that, we minimize the negative of dwell time:**

O\_2(x)\_maximizing = maximize O\_2(x). # dwell time

= minimize - O\_2(x)

The weights define whether to minimize or maximize an objective. (w1, w2) = (-1.0, -1.0) represents the fitness function as,

Fitness(x) = w1 \* O\_1(x) + w2 \* O\_2(x)

= -O\_1(x) + O\_2(x)

minimizing the fitness, results in minimization of revisit time and minimization of -ve of dwell time.

* Optimization of inclination angle (i), and raan for the constellation of 3-plane and 12 satellites using NSGA3, for minimum cumulative revisit time and maximum cumulative dwell time of constellation.

Number of objectives = 2

Fitness / evaluation function = -1 \* cumulative revisit time (CRT) -1 \* ( - cumulative dwell time (CDT))

Optimizing parameter = Inclination (i), and RAAN

Population size = 20,

NGen = 15

Number of plane = 3

Number of satellite per plane = 4

Fitness weight = (-1, -1)

Crossover weight = 0.7

Mutation weight = 0.2

Results:

A graph with numbers and a blue dot

Description automatically generated

Figure1: final population fitness nsga3-20P15G

Best 5th individual (inclinations, raan) for each plane:

[[21.711890082943626, 84.1511867209388, 15.255350281208214], [168.27944861745772, 288.7786064367185, 223.71299670259702]]

Best fitness cumulative revisit time 75060.0 seconds and cumulative dwell time 9750.0 seconds

A graph with blue dots

Description automatically generated

Fig : Pareto front of NSGA-III

A map of the earth

Description automatically generated

Fig : resulted constellation of optimized using NSGA3 for 3plane 4 satellite per plane, constellation where genetic algorithms applied with population size 20 for 15 generation

Analysing the earlier batch experiment, We can expect the right plane to detect the area of our interest within the range as for inclination angle ranges from 0 to 90, and for RAAN angle ranges from 100 to 250 degrees.

**Future studies:**

Further studies includes the research and experiment over Earth's gravity field, measurements such as the geoid, gravity anomalies, deflections, and dynamic Doppler effect.

AGENCY, U. S. D. M. 1987. *Department of Defense World Geodetic System 1984: its definition and relationships with local geodetic systems*, Defense Mapping Agency.

HASSANAT, A., ALMOHAMMADI, K., ALKAFAWEEN, E. A., ABUNAWAS, E., HAMMOURI, A. & PRASATH, V. S. 2019. Choosing mutation and crossover ratios for genetic algorithms—a review with a new dynamic approach. *Information,* 10**,** 390.