TIRAMISU

Toolbox Implementation for Removal of Anti-personnel Mines, Submunitions and Uxo

Energy Efficient Terrain Coverage Using an Autonomous Mobile Robot

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SEVENTH FRAMEWORK PROGRAMME

Outline

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- Problem Definition
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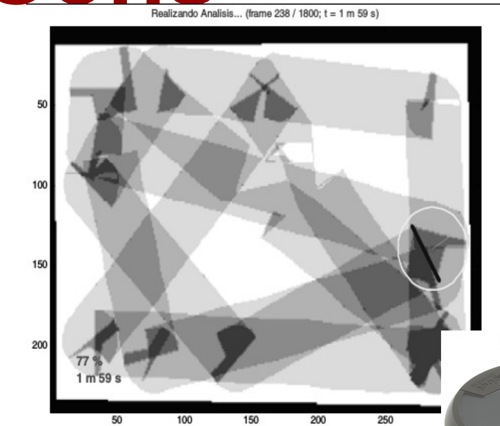
Coverage Path Planning (CPP)

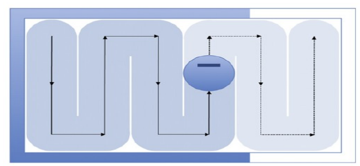
- Pass through each point of an area with a small sensor/actuator
- Lawn mowing
- Farming (soil preparation, collecting crops, spraying…)
- Mine/UXO detection

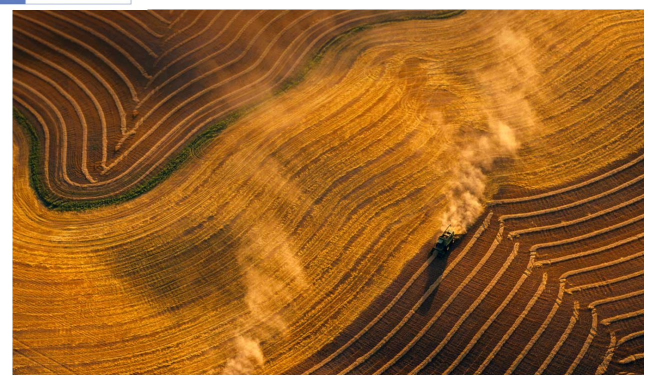
How to CPP? Pros vs Cons

- Floor cleaning & lawn mowing robots
  - Random, Semi-Random
  - Small, energy & time infinite, small area,
  - Limited sensing abilities, task is error-tolerant
  - Not feasible for large robots, or areas, or away from energy sources

- Soil Processing, Harvesters, De-miners
  - Have to cover all space, not error tolerant
  - Uniform
  - Zigzag/back-forward
  - Spiral







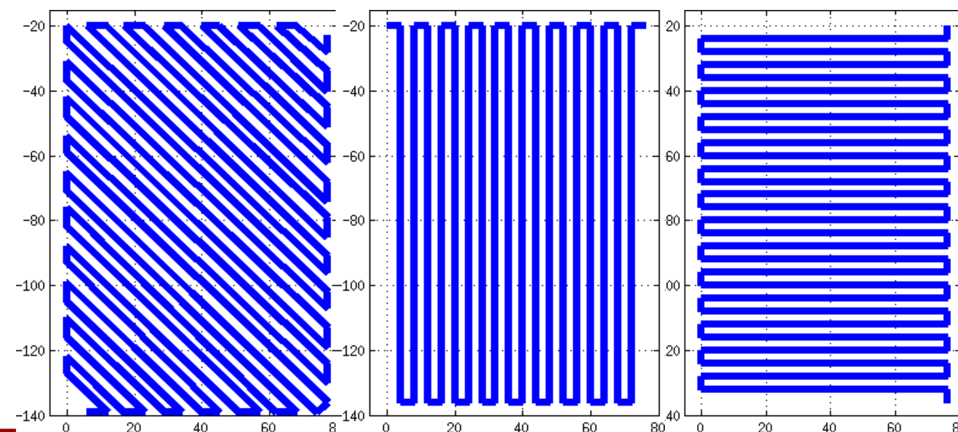
Motivation

- De-mine large outdoor areas, with uneven terrain.
- Farm uneven terrain.

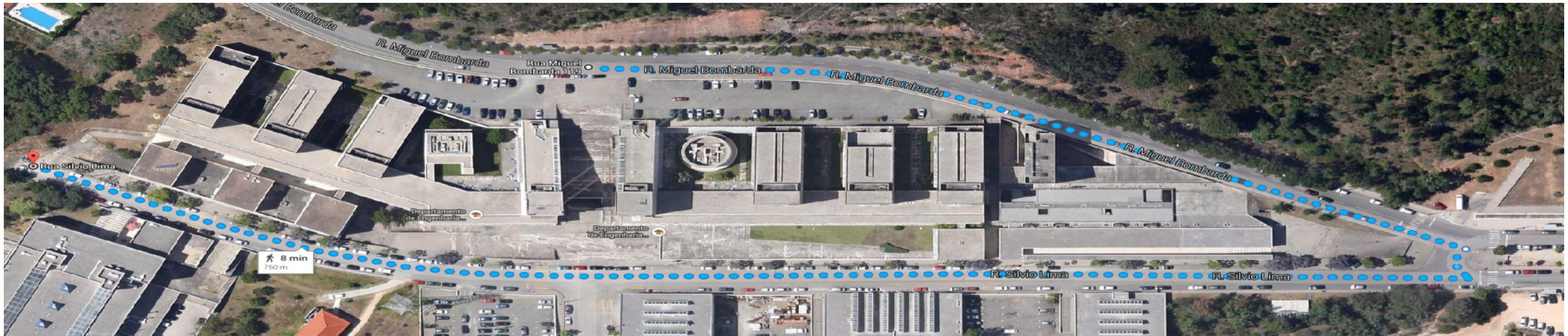
Problem Definition (1)

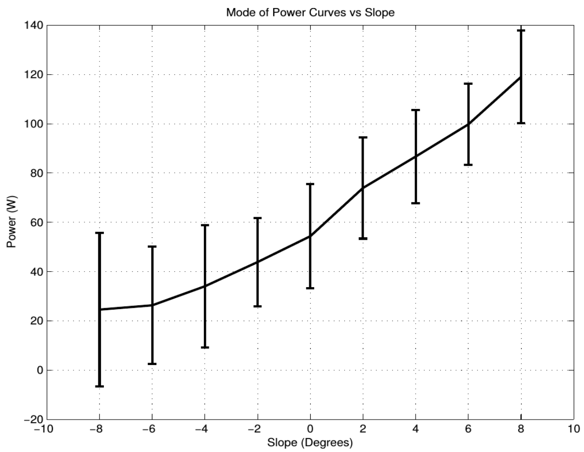
- Q: What is the total energy spent traversing (ignoring corners)
  - along the slope?
  - perpendicular to the slope?

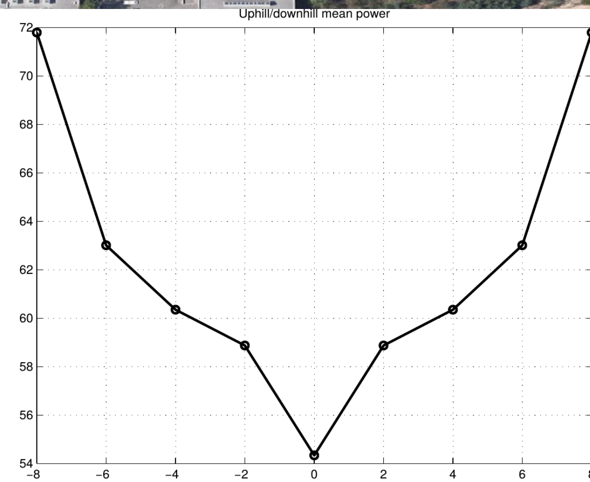
- A(1): Ideally the same.
- A(2): It depends on the motor type as well.

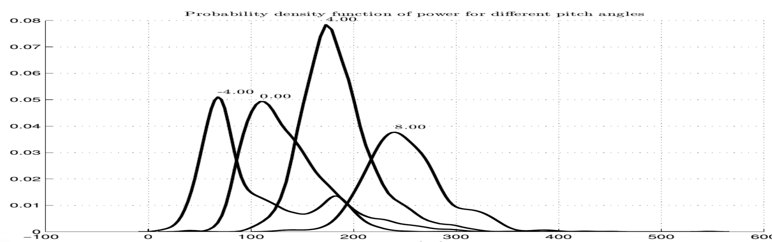


Problem Definition (2) – Power measurements on the field



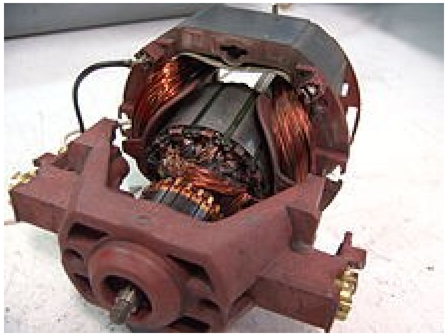






Problem Definition (3) - Mathematics

- For a DC motor:



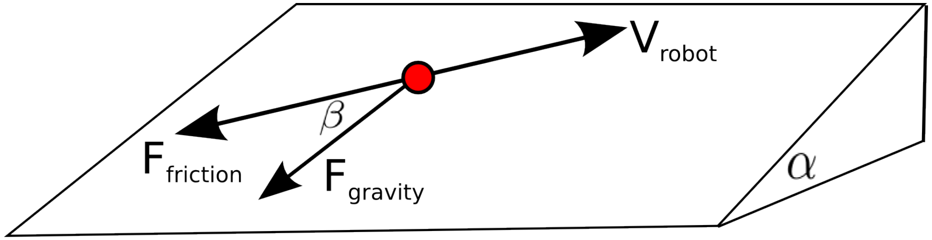
$$P_m = R_m I_a^2 + E_b I_a$$

$$T = K_1 I_a \quad F = rT$$

$$P_{losses} = K_2 F^2$$

$$F_{up} = F_{gravity} + F_{friction}$$

$$F_{down} = |F_{gravity} - F_{friction}|$$

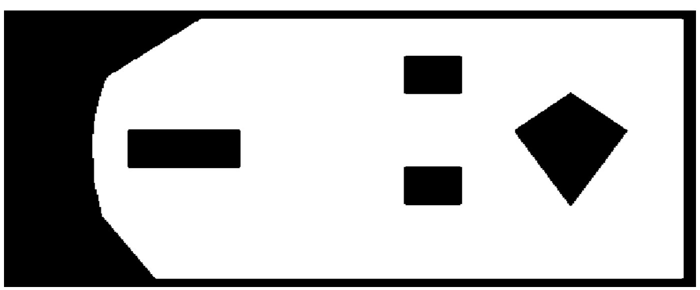


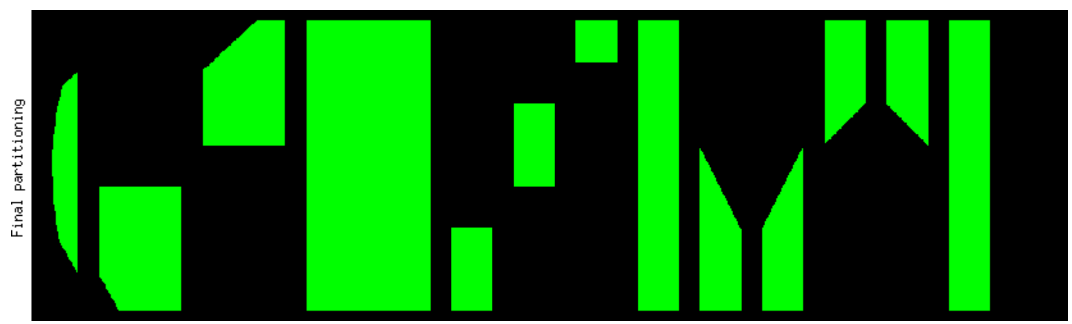
$$F_{gravity} = mg \sin\alpha \sin\beta \quad F_{friction} = \mu mg \cos\alpha$$

$$\begin{aligned} P_{losses} &= K_2(F_{gravity}^2 + F_{friction}^2) \\ &= K_2 m^2 g^2 (\sin^2\alpha \sin^2\beta + \mu^2 \cos^2\alpha) \end{aligned}$$

Method – Decomposition

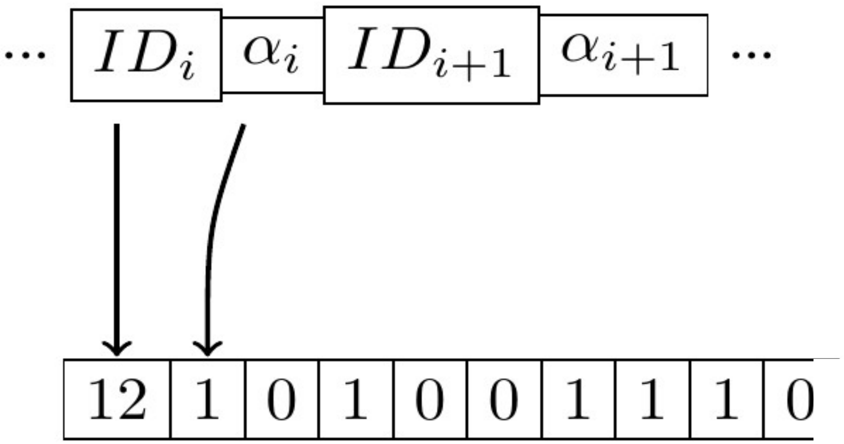
- *gradient* ← gradient of the given terrain
- *map2d* ← obstacle map of the environment
- *map2d'* ← gradient & map2d
- *partitions* ← decompose(map2d')
  - ...

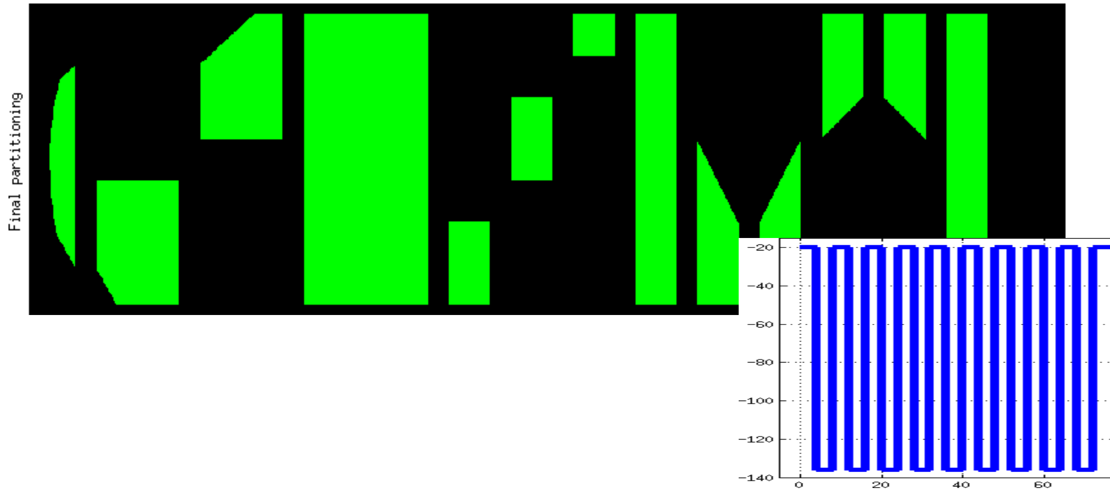




Method – Genetic Algorithm (1)

- Chromosome ← sequence of partition IDs with the orientation of their templates





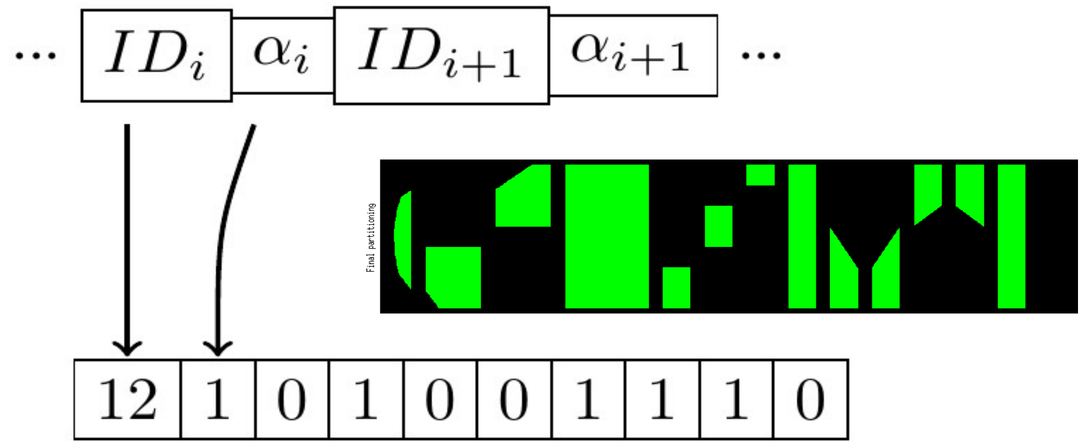
$$\text{Cost} = K_1 \int P \, \mathrm{d}s + K_2 \int \left|\frac{\partial \beta}{\partial s}\right| \mathrm{d}s$$

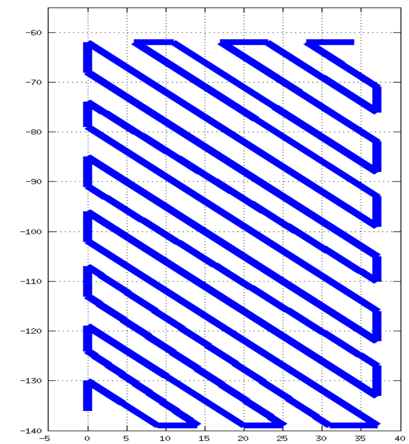
$$P = k(\sin^2 \alpha \sin^2 \beta + \mu^2 \cos^2 \alpha + \mu \sin 2\alpha \sin \beta)$$

Method – Genetic Algorithm (2)

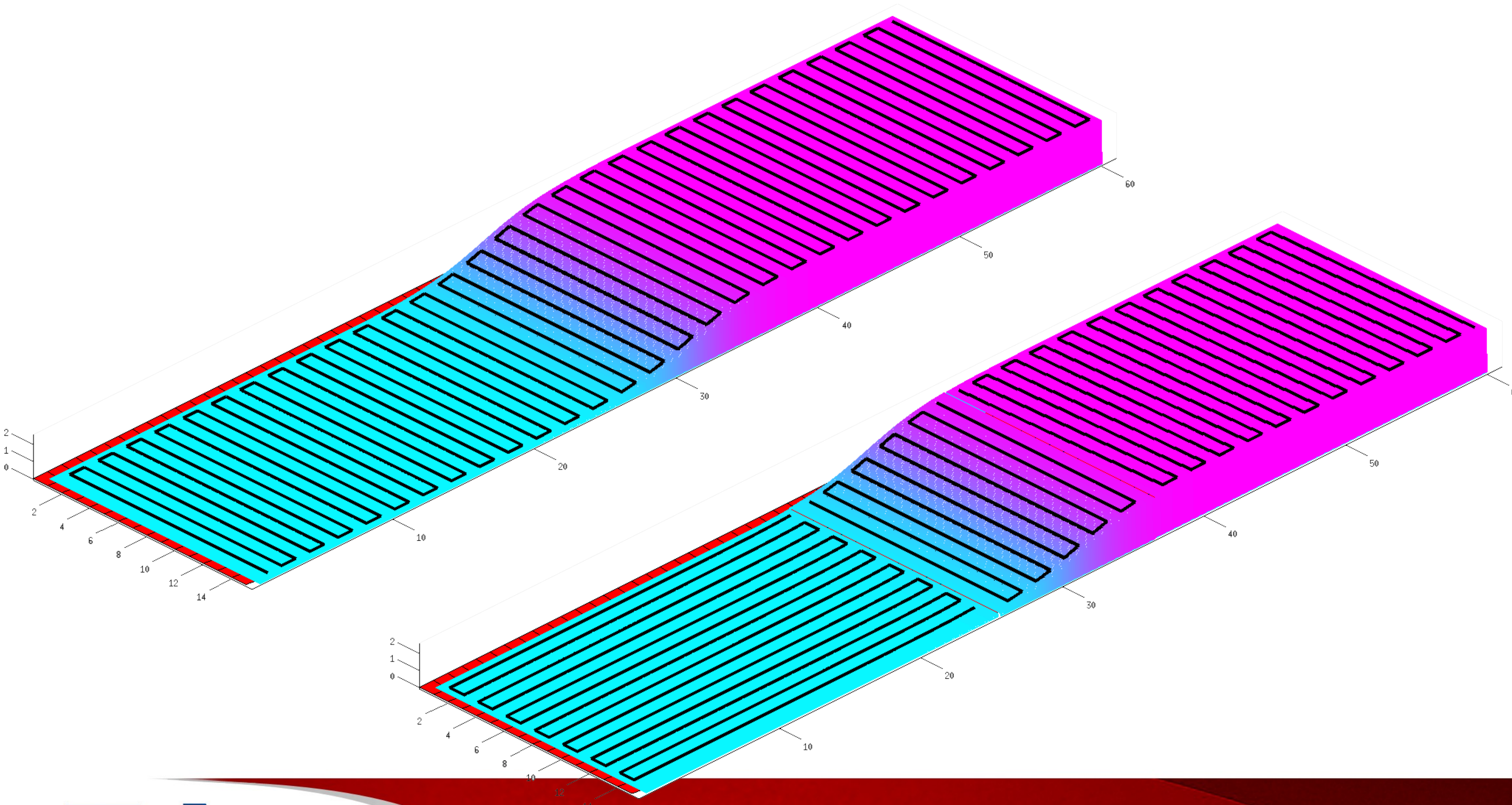
- Crossovers:
  - Blocks (SCX)

    If sequence is invalid,
    get the next closest
  - Angles
- Mutations:
  - Bit flip angle
  - Invert angle
  - Replace two blocks

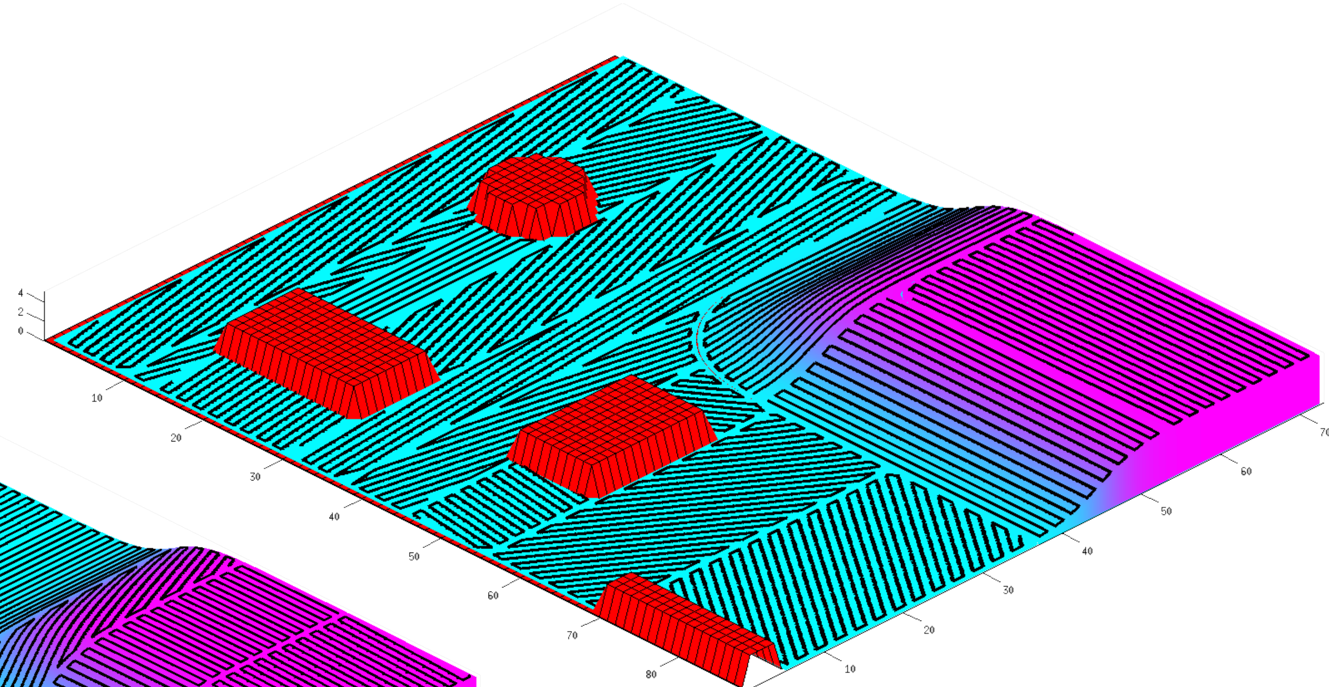


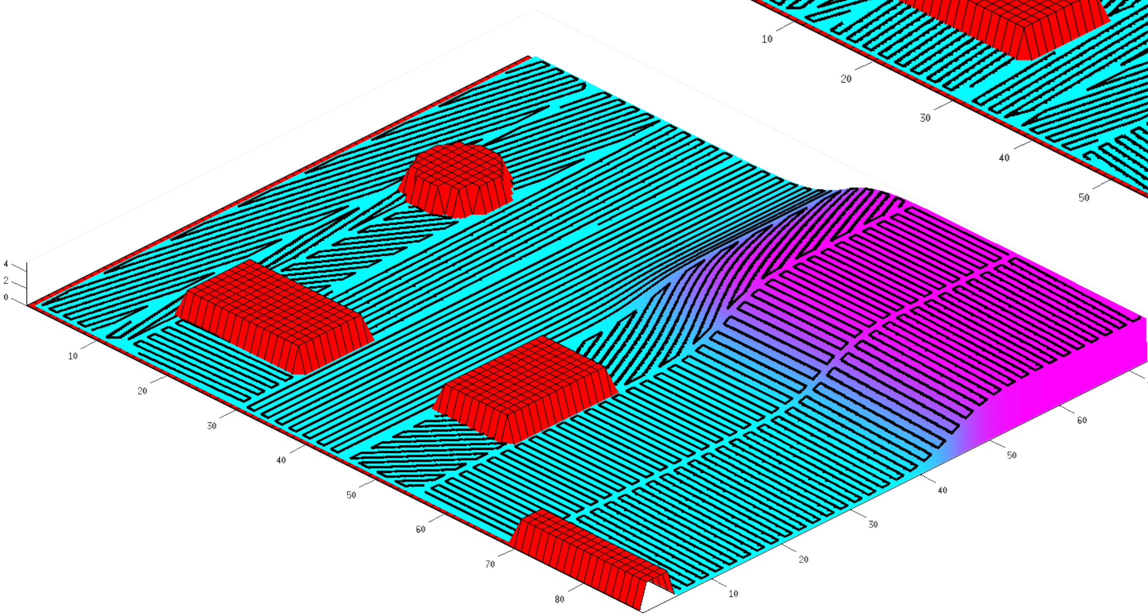


Results – Example (1)

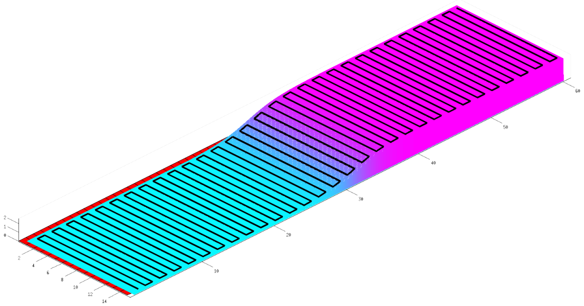


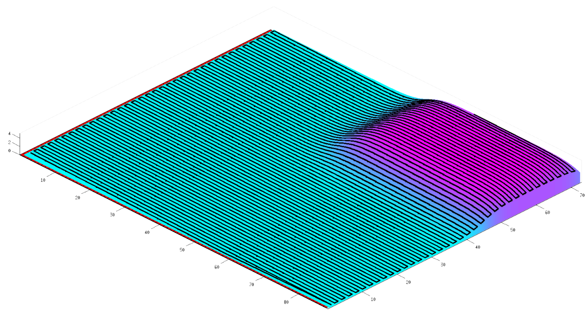
Results – Example (2)

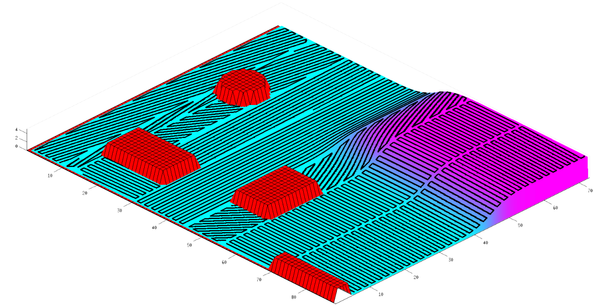




Results - Comparisons







Terrain	Total Area	Num Partitions Before	Num Partitions After	Total Cost Before[1]	Total Cost After[2]
Terrain 1	15x60	1	3	652 kJ	573 kJ
Terrain 2	72x88	1	7	15428 kJ	8545 kJ
Terrain 3	72x88	11	15	7218 kJ	6573 kJ

- **1**: Without taking the slope into account during the decomposition
- **2**: Taking into account the slope during the decomposition

Conclusion

- We have presented an efficient Coverage Path Planning algorithm that works by integrating the slope into the decomposition.
- The algorithm uses genetic algorithms with few types of cross over and mutation operators.
- The method is applicable to all terrain, but needs the elevation map.
- We are planning to improve our model and do field tests.

Thank You

Any Questions?

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