U.S. Army Research, Development and Engineering Command

Constructing a Movement Model for a Small Unit

ARL

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Overview

1. **The Autonomous Squad Member (ASM) Project is a research effort that provides a robot with intelligence to work with humans as teammates.**
2. **Anomaly Detection capabilities takes evidence from disparate sources to draw information from external environment.**
3. **A* is used to predict normal expected spatio-temporal characteristics of mission movement which is affected by THREE general factors:**
   - *MissionFactors*
   - *Terrain Factors*
   - *Human Factors*
4. **The method bounds the area where the small unit will be located at a particular time.**

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Autonomous Squad Member

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From robots as tools ….

Require detailed supervision

Confined to benign terrain

Tedious tele-operation through complex interfaces

… to robots as teammates

Understand tactical commands

Operate in various terrain

Reason about battlefield events

From The RCTA Vision: Achieving Foundational capabilities of Autonomy, Jan 2013

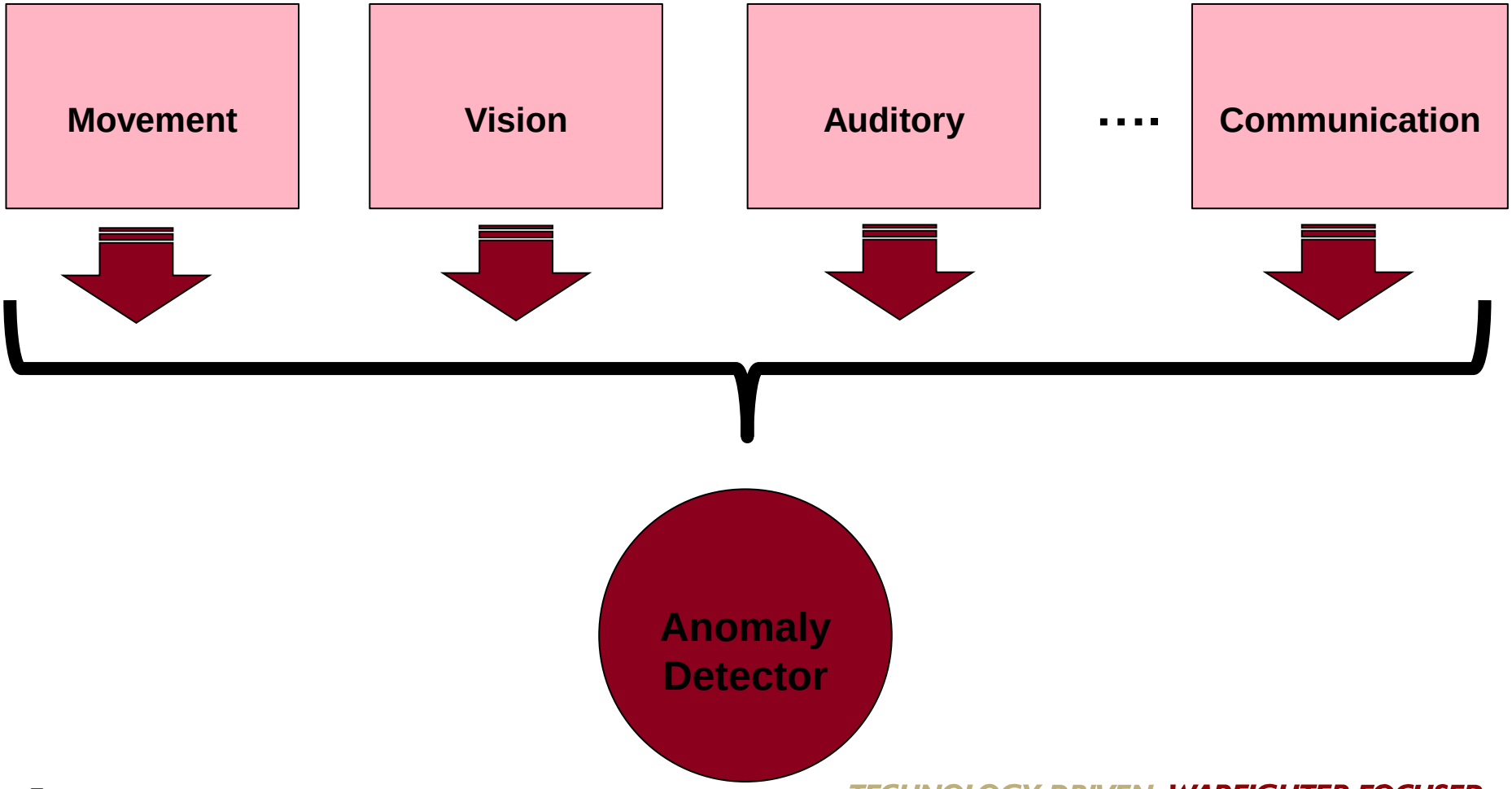
ASM Goals

- Develop a semantic understanding of objects and events in the environment
- Recognize anomalous situations
- Formulate new goals that respond to unanticipated situations and support the squad's goals
- Communicate effectively with squad mates

Detecting Abnormal Situations

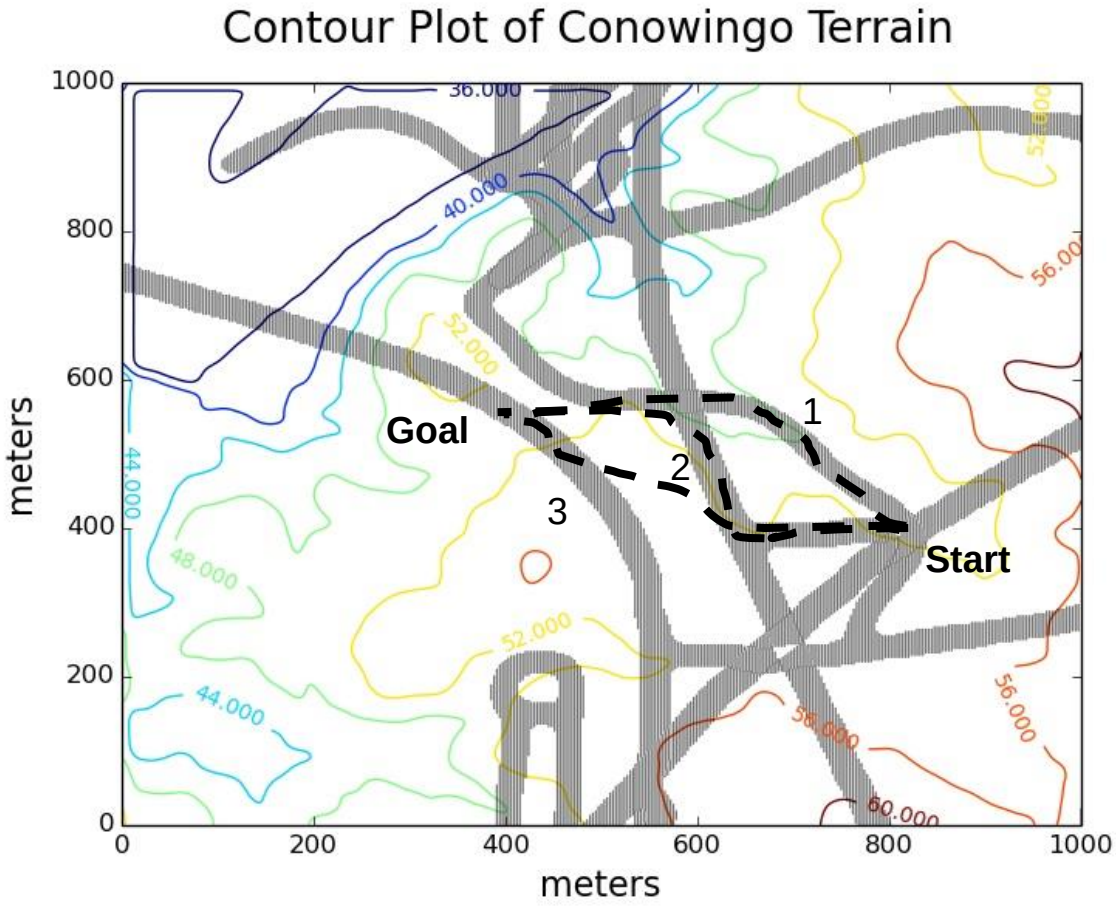
Recognize the transition from normal to off-normal operations using:

Evidence

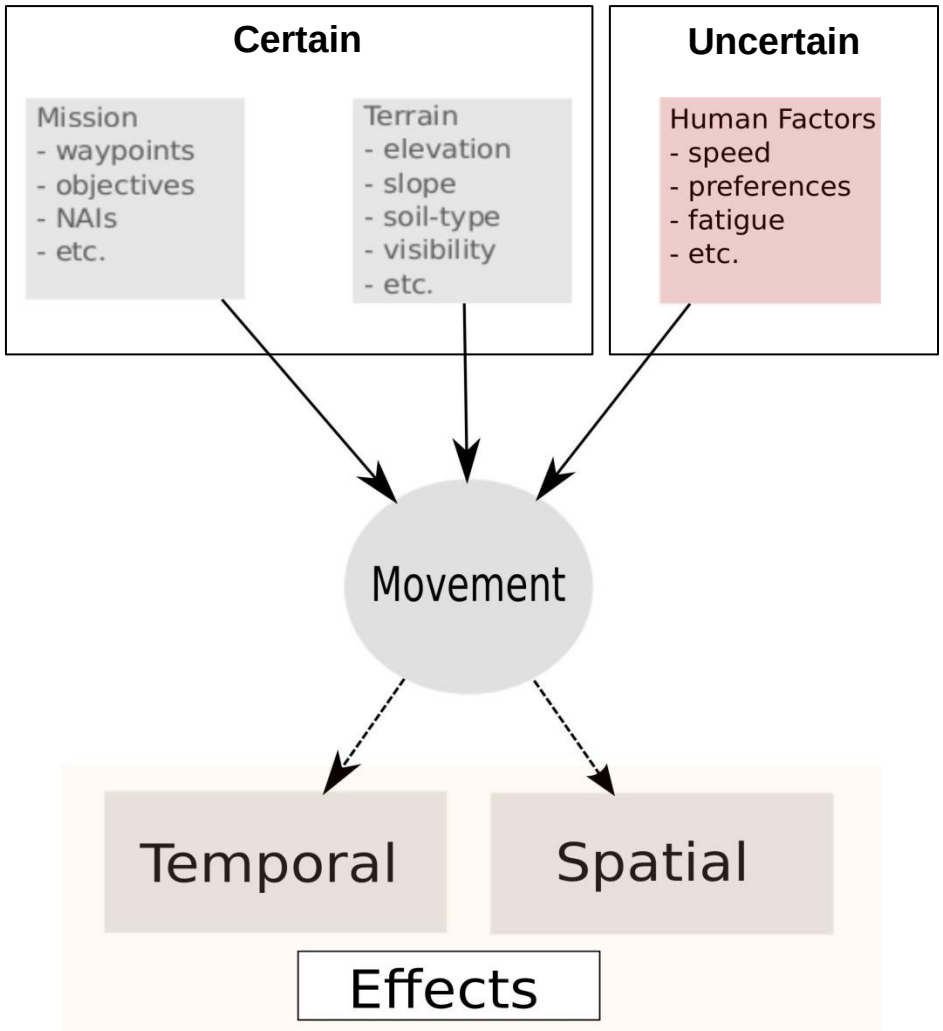


Problem Statement

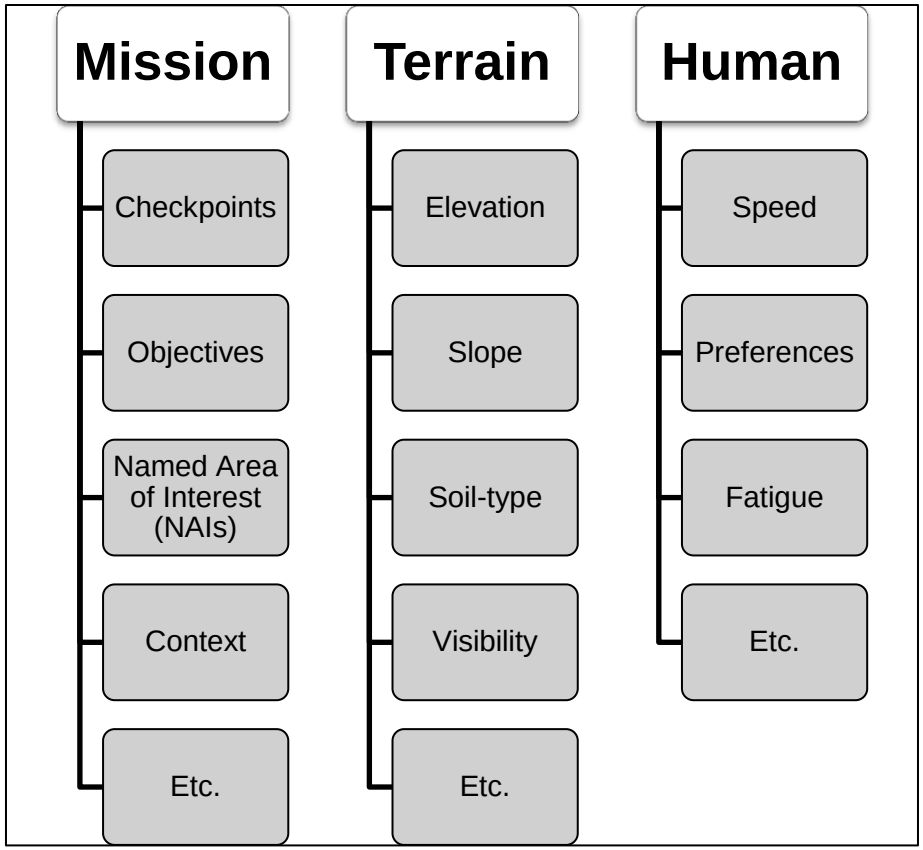
- **Given the Mission Factors and the Terrain Factors, can we reason about the movement of a small unit?**



Small Unit Movement Model

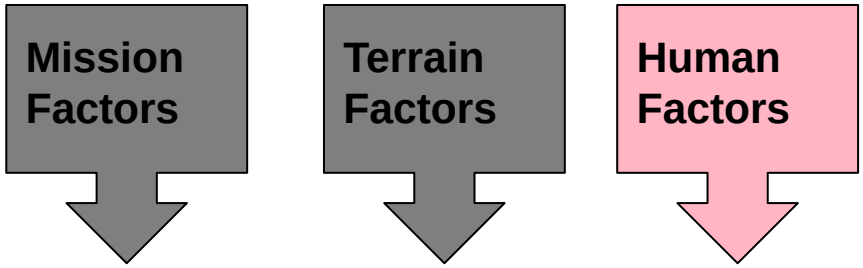


Movement Variables



Methods

- **Goal: Create a model to estimate the time-dependent location of the squad members**
- **General Approach:**
  1. **Sample uncertain human factors**
  2. Generate a portfolio of likely paths
  3. Estimate the time to arrival for each node.



Methods

- **Goal: Create an area where squad members are likely located**
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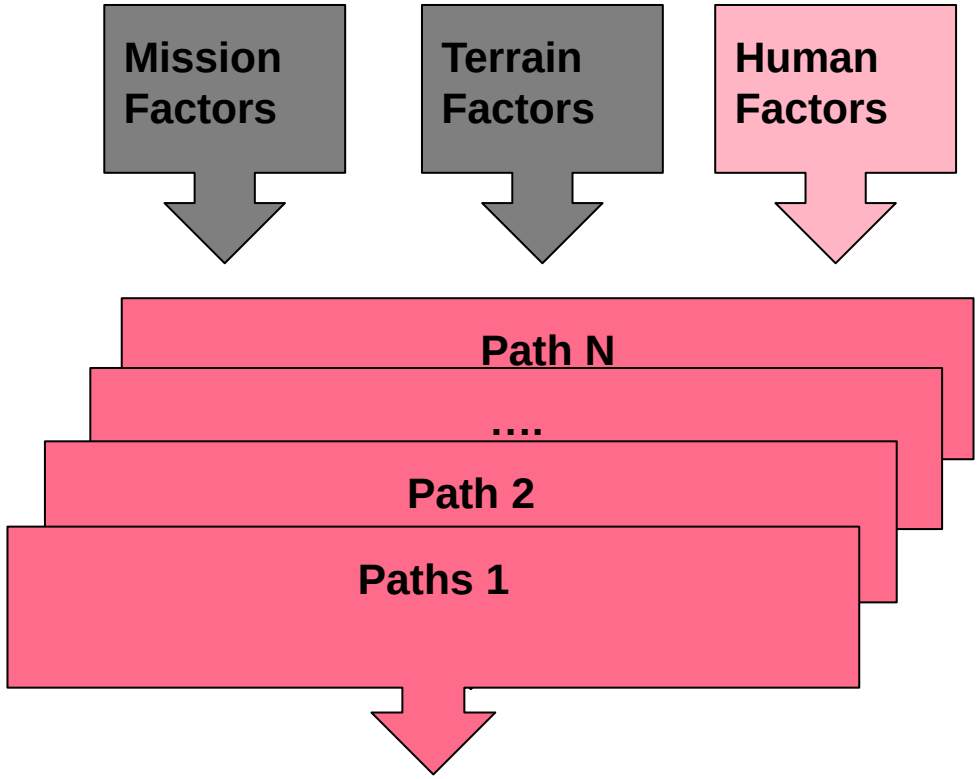

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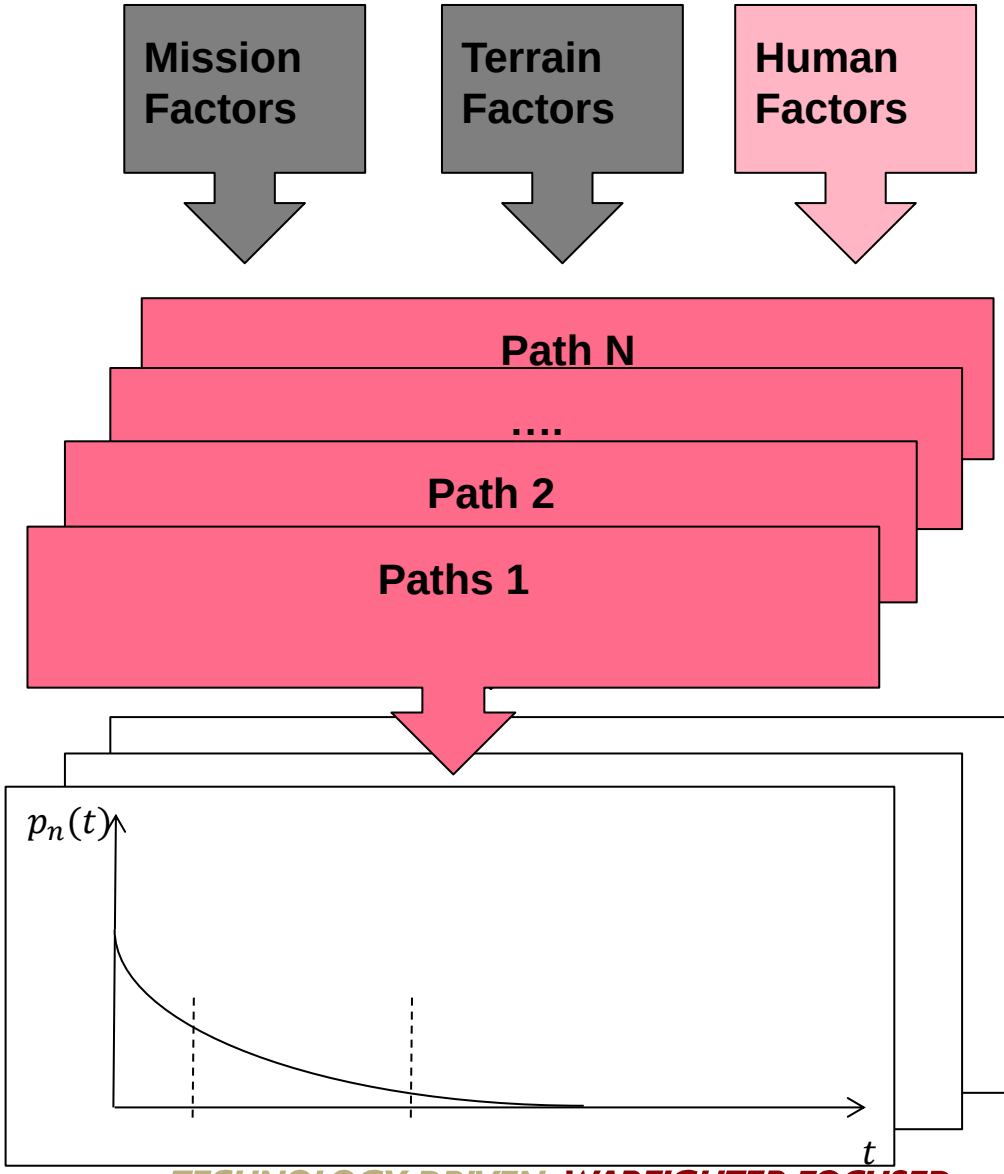


Background

Sample uncertain human factors | Generate portfolio of likely paths | Estimate time of arrival.

- **A* search algorithm**
  - Popular algorithm widely used in path-finding and graph traversal (Hart, P.E. 1968)
  - Searches for the minimum cost path for a given deterministic cost function:
    - $G(x, y)$ ≔ Cost to arrive at node (x, y)
    - $H_d(x, y)$ ≔ Heuristic cost
      - straight-line distance between the current node and the goal node

$$F(x, y) = G(x, y) + H_d(x, y)$$

Methods

Sample uncertain human factors | Generate portfolio of likely paths | Estimate time of arrival.

- **Terrain Variables:**
  - Distance Travelled, v_1
  - Slope, v_2
  - Type, v_3
  - Visibility, v_4
- **Mission Variables:**
  - Initial point, (x_0, y_0)
  - Checkpoint, (x_T, y_T)
- **Human Variables:**
  - Preferences, $\boldsymbol{\lambda}$:
    - Distance, λ_1
    - Slope, λ_2
    - Soil-Type, λ_3
    - Visibility, λ_4

Human Factors **Terrain Factors** **Mission Factors**

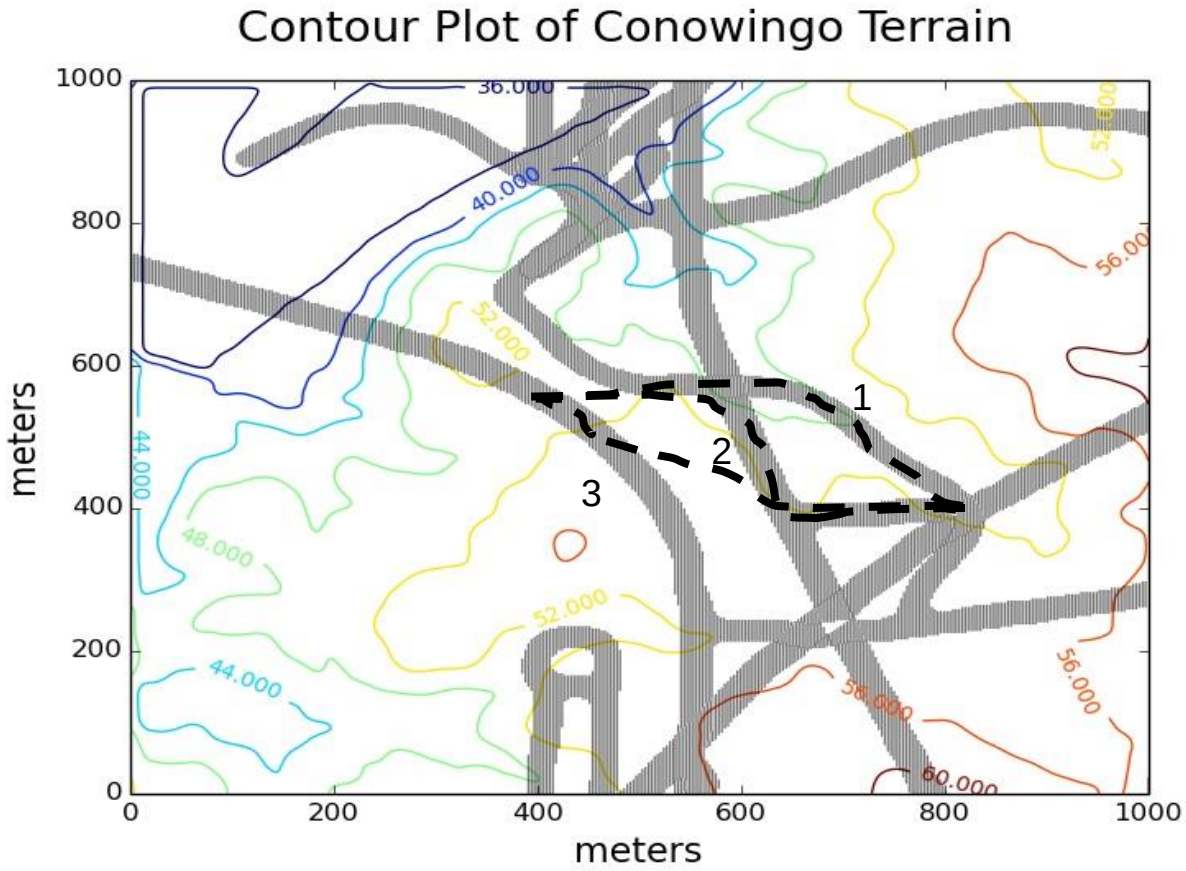
$$\boldsymbol{F_\lambda(x, y, v) = \sum_{i=1}^{k} \lambda_i G(x, y, v_i, x_0, y_0) + H_d(x, y, x_T, y_T)}$$

Such that

$$\sum \lambda_i = 1 \quad , \forall i$$

Methods

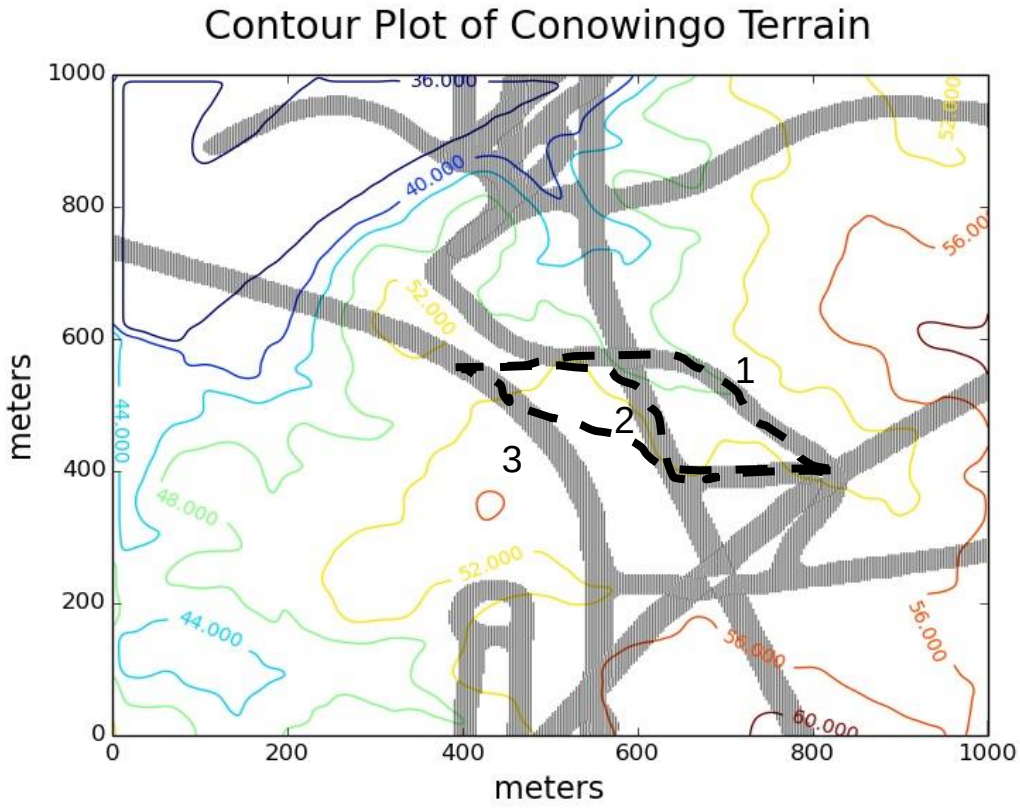
Sample uncertain human factors | Generate a portfolio of likely paths | Estimate time of arrival.



Methods

Sample uncertain human factors | Generate a portfolio of likely paths | Estimate time of arrival

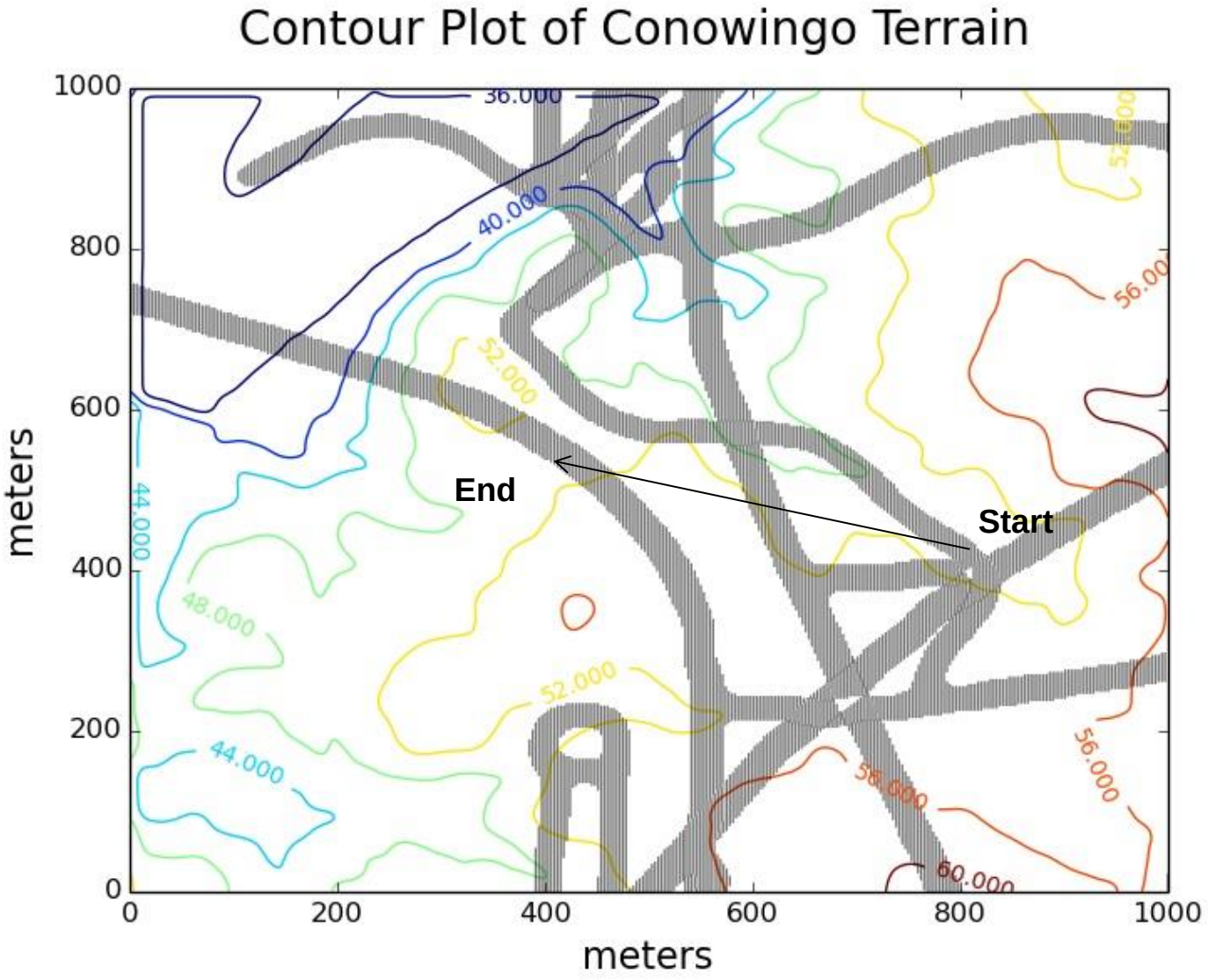
- **Terrain Variables:**
  - Distance, z_1
  - Slope, z_2
  - Type, z_3
- **Mission Variables:**
  - Initial point, (x_0, y_0)
  - Checkpoint, (x_T, y_T)
- **Human Variables:**
  - Speed, s, Uncertain



$$T(x, y; z; s) = t(x, y; z; s) + T(x_p, y_p; z_p).$$

Time to Arrival at node (x, y) = **Time to arrival at parent node** + **Time to arrival from parent node to node (x, y)**

Results: Spatial Aspect



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Results: Spatial Aspect

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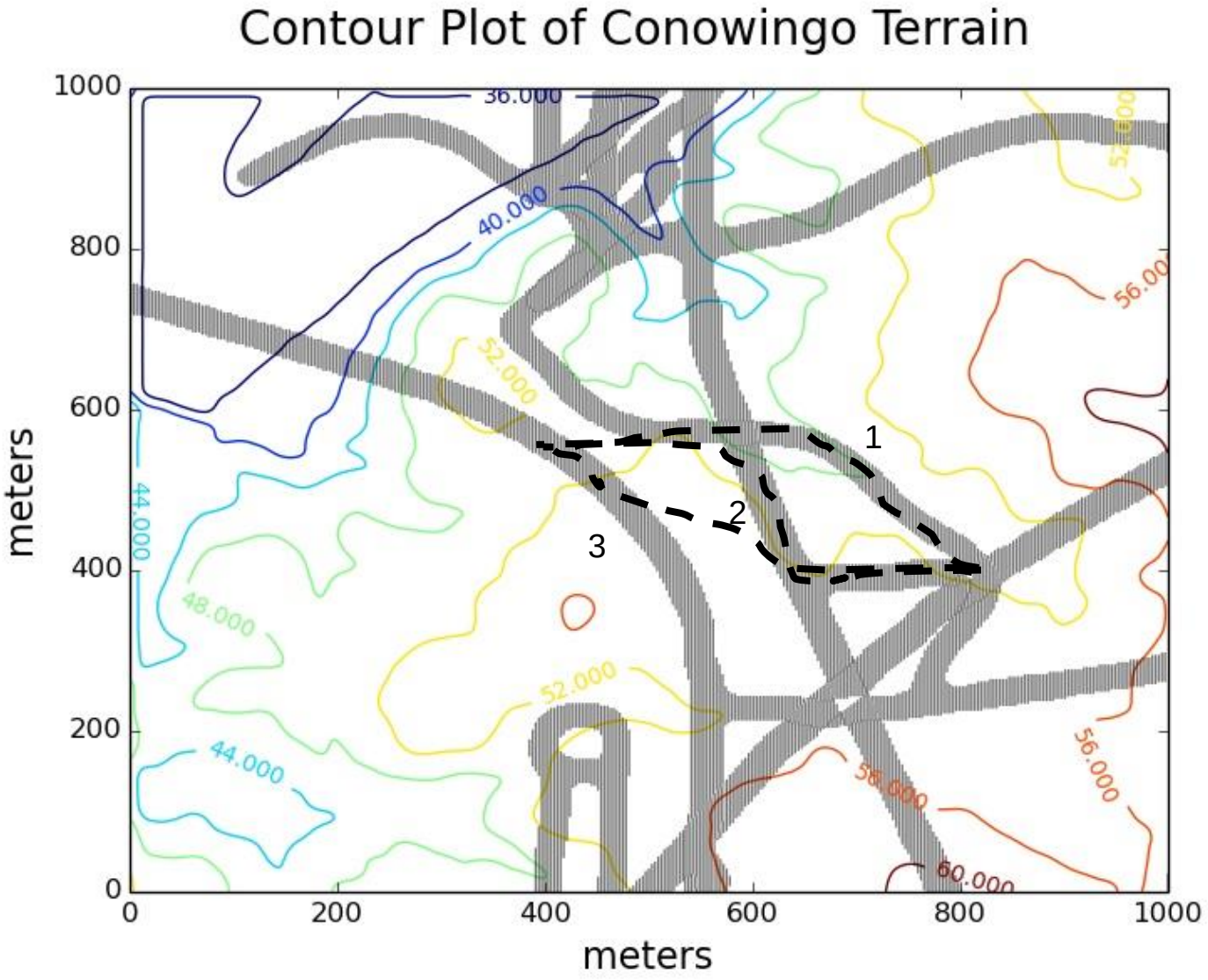

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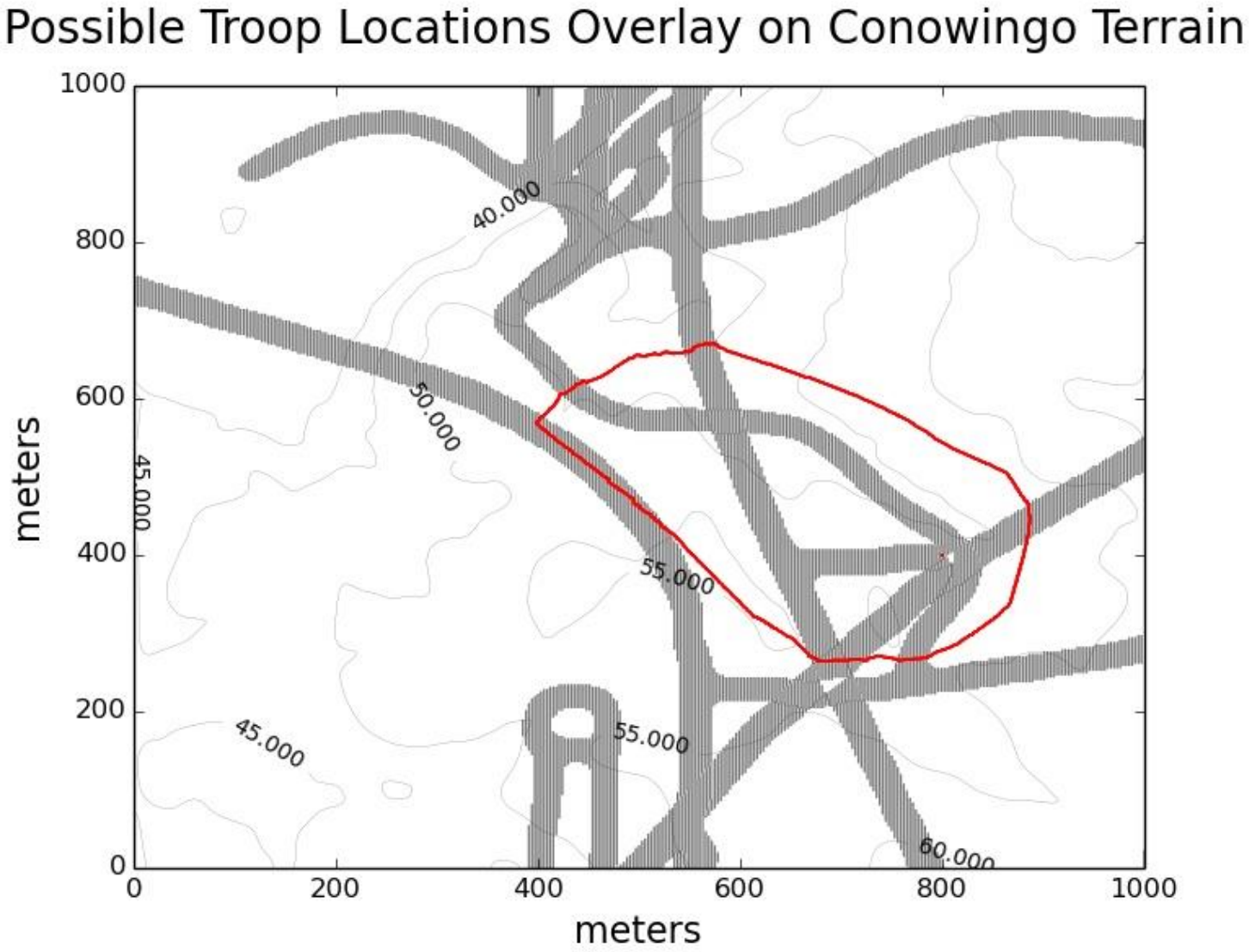

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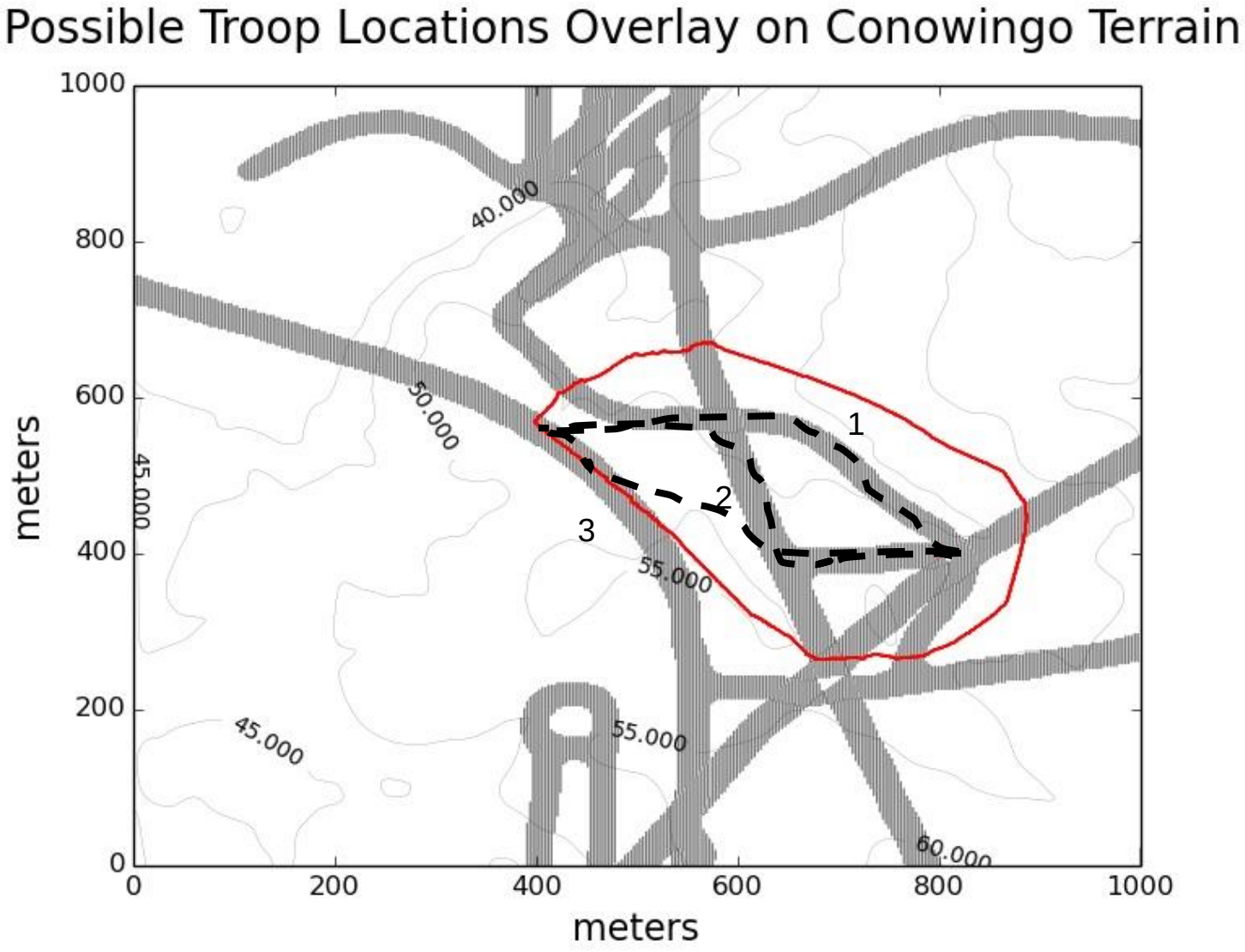
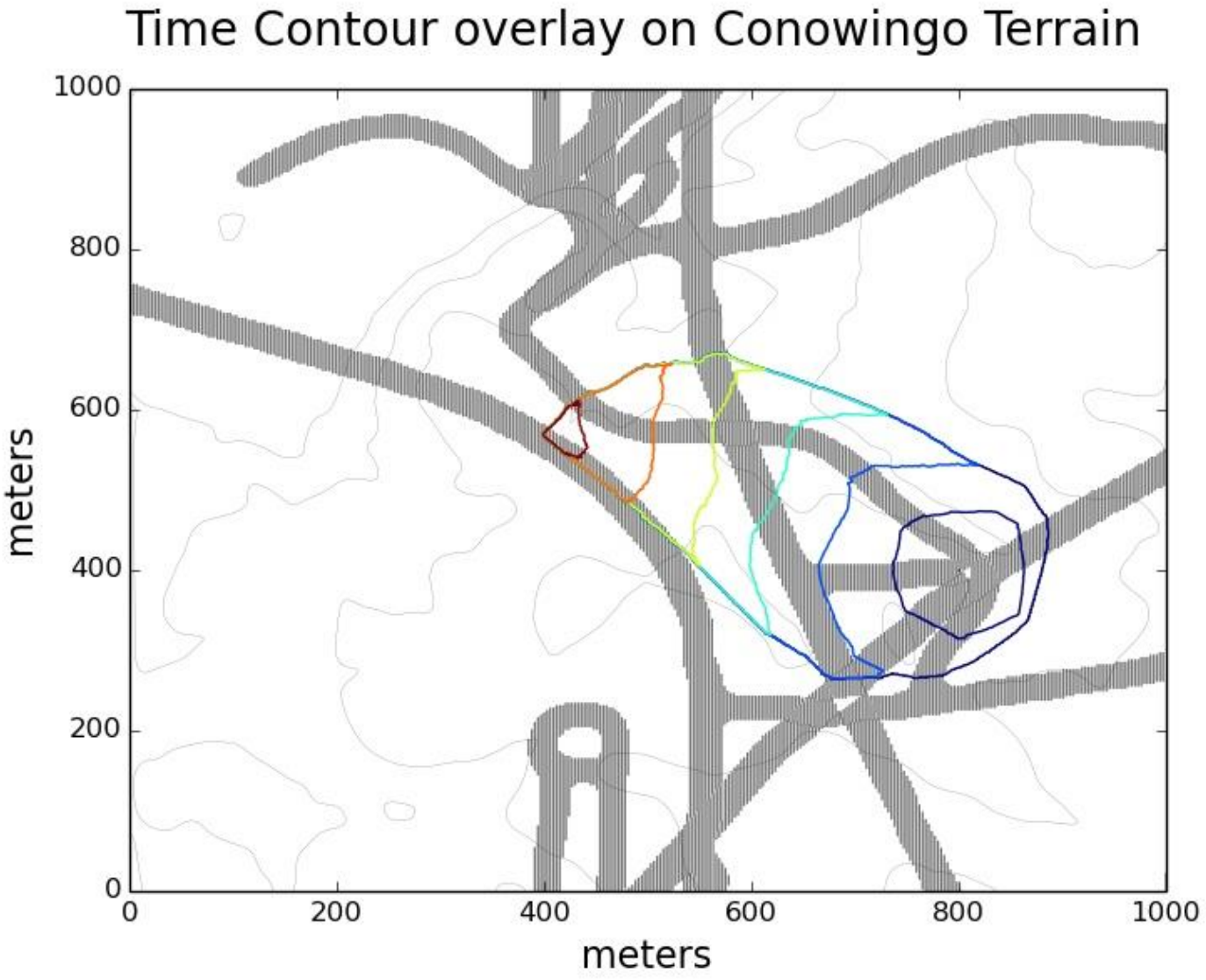
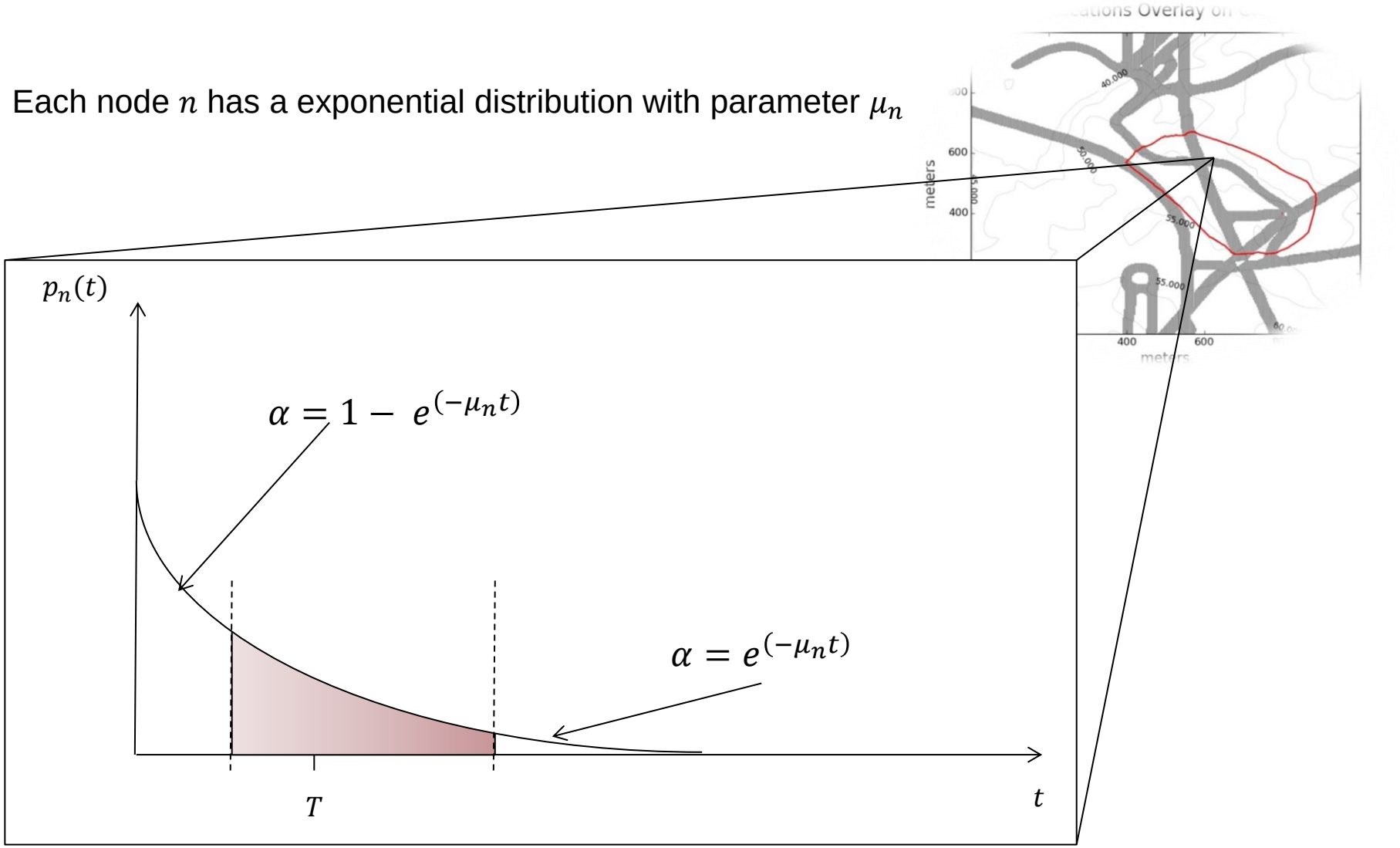


Results: Temporal Aspect



Results: Temporal Aspect

Each node n has a exponential distribution with parameter μ_n



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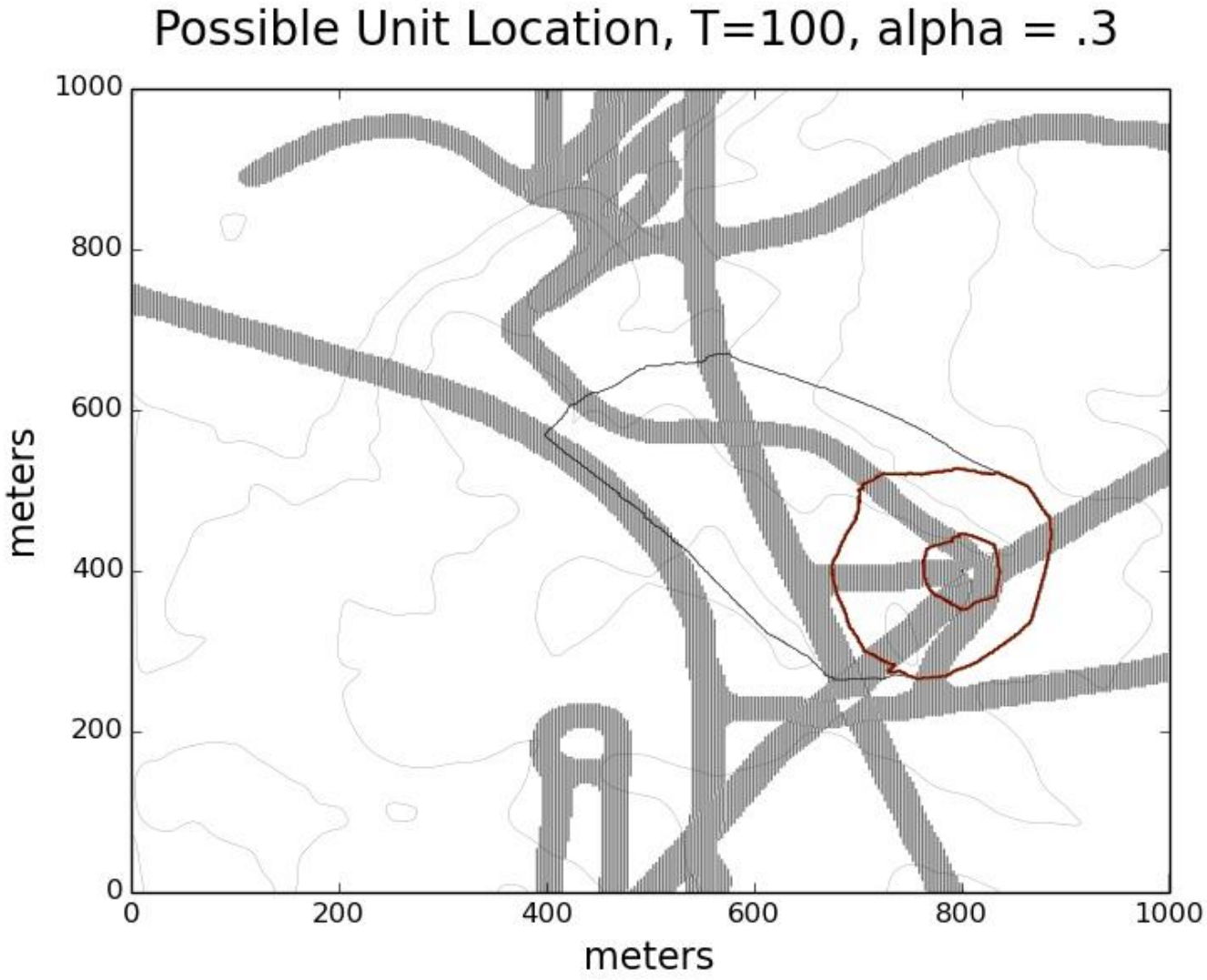

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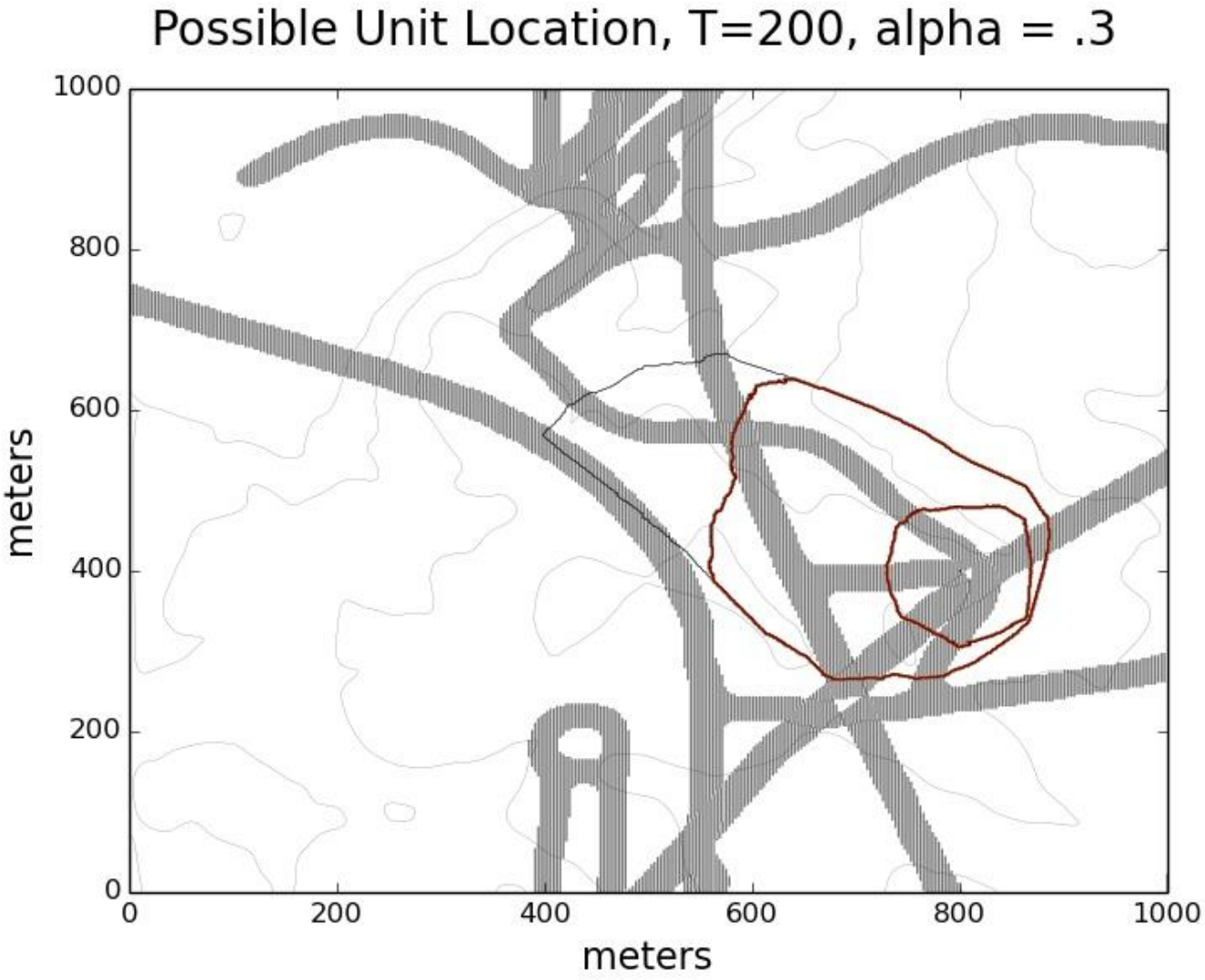

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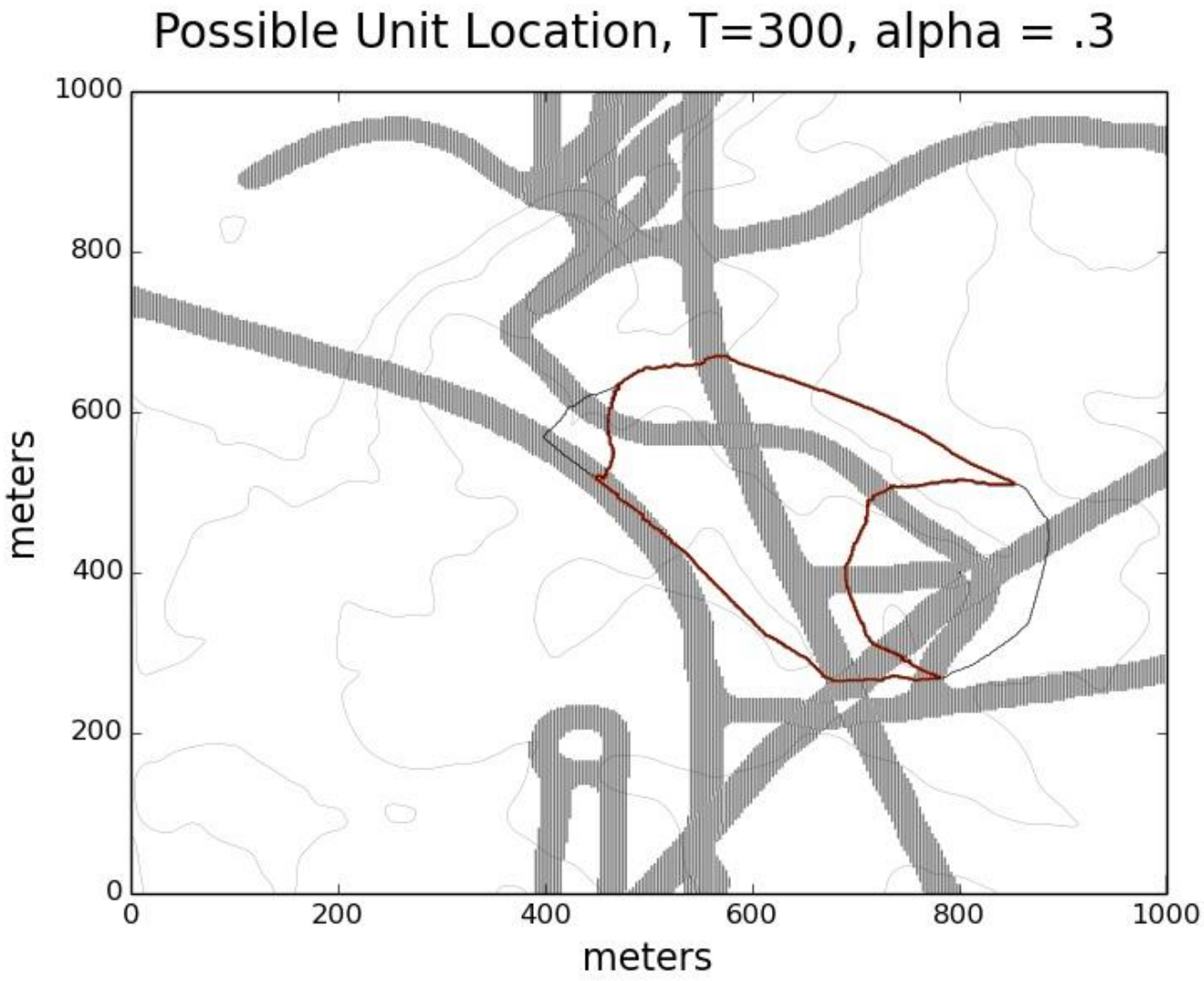

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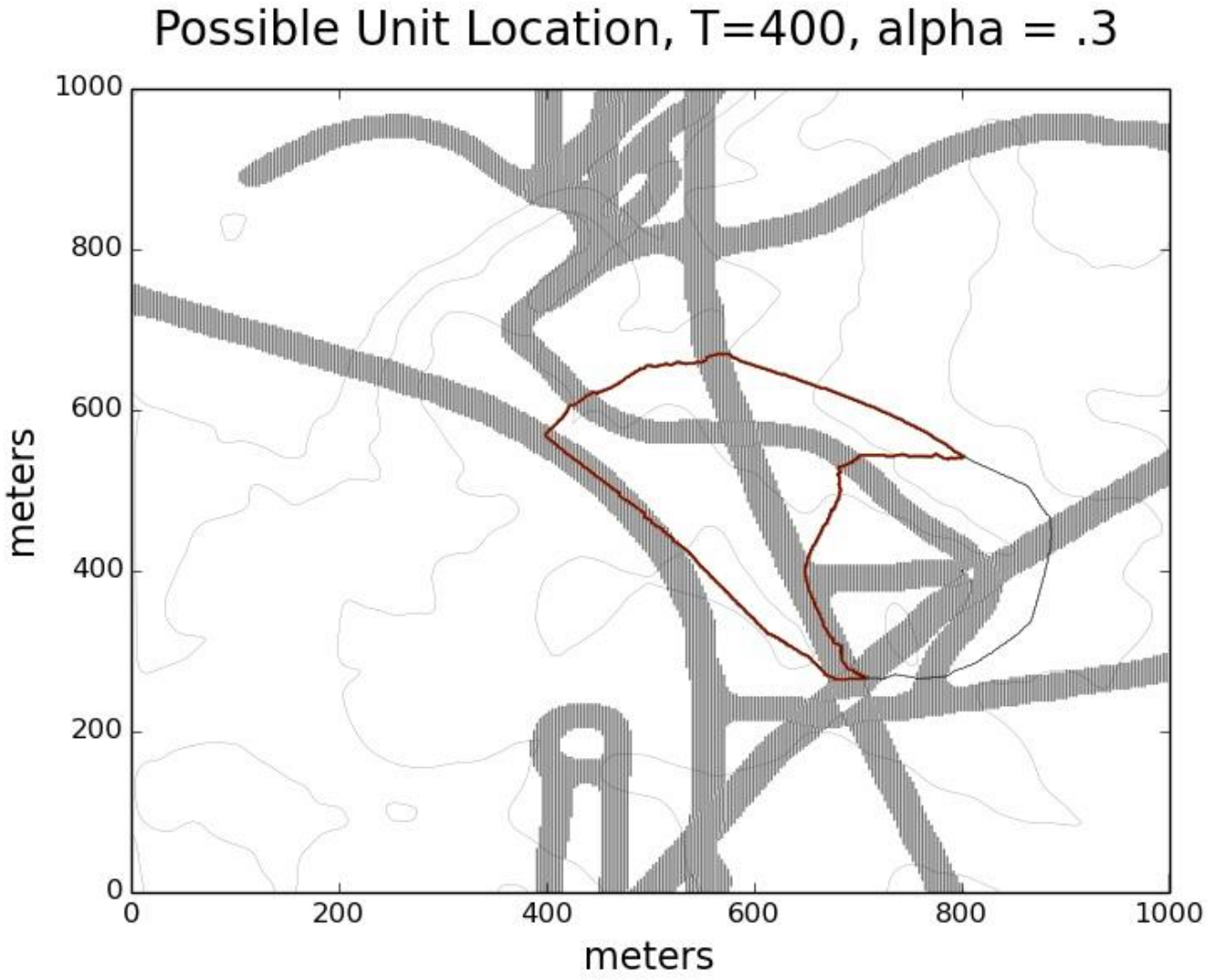

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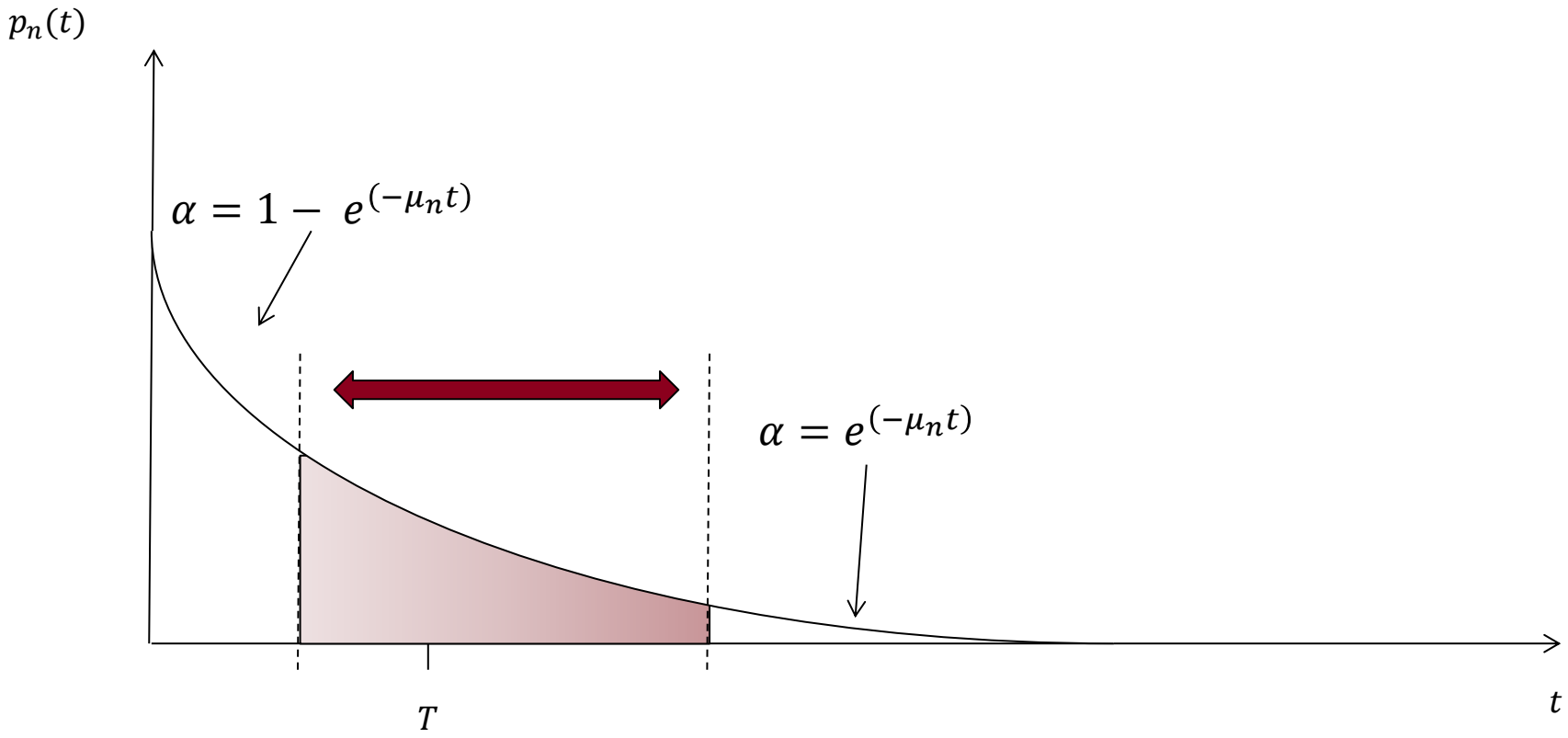
Results: Confidence Interval



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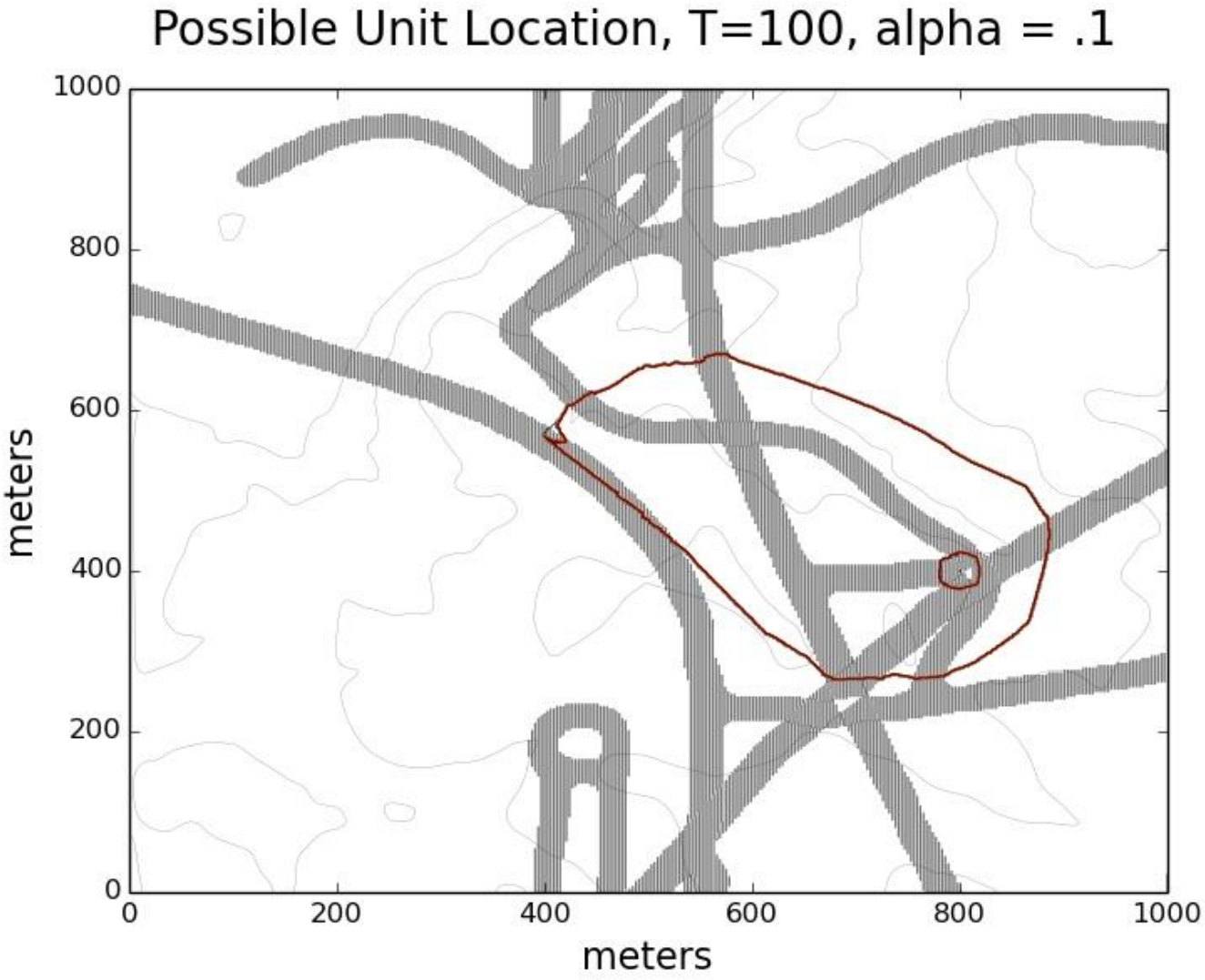

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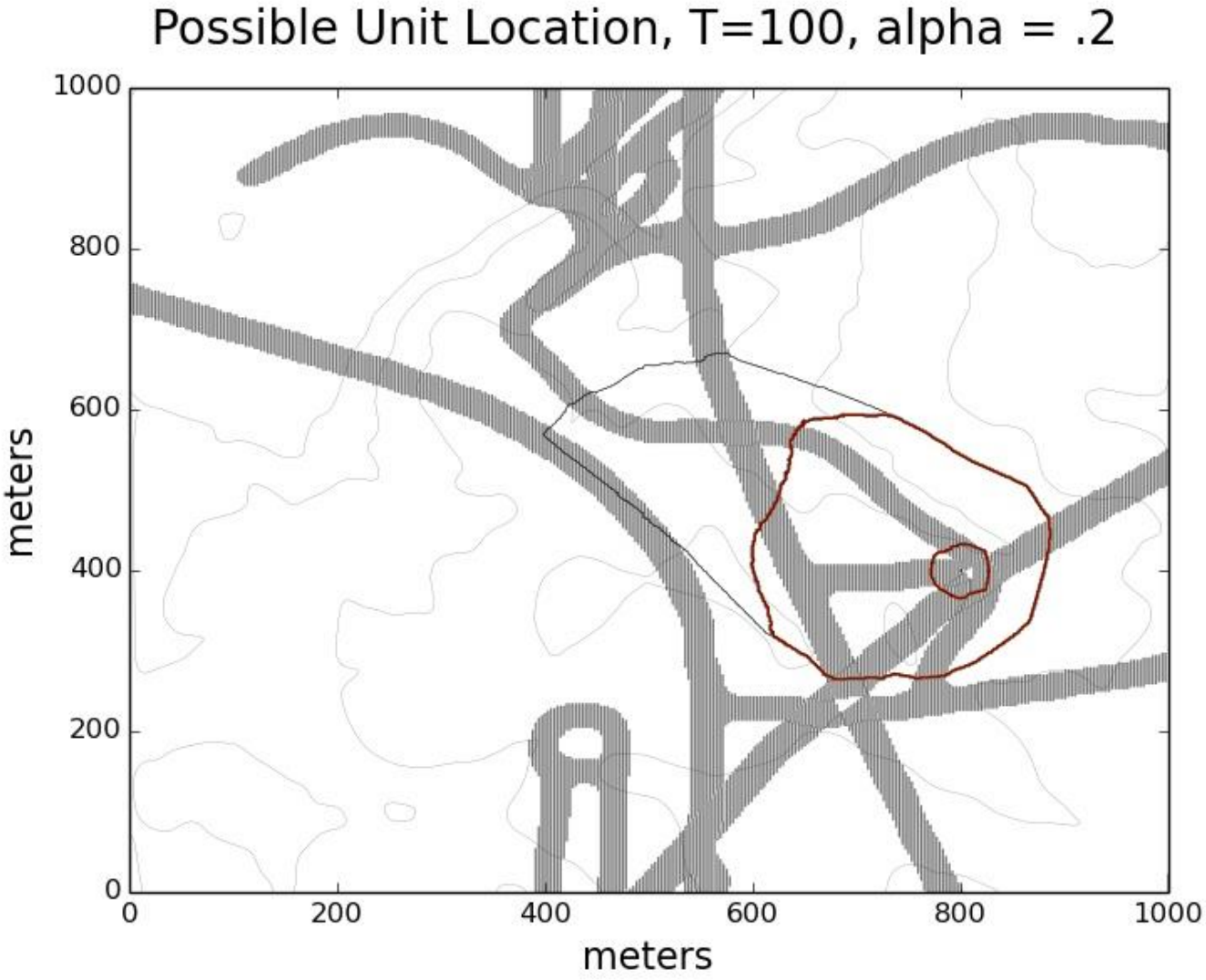

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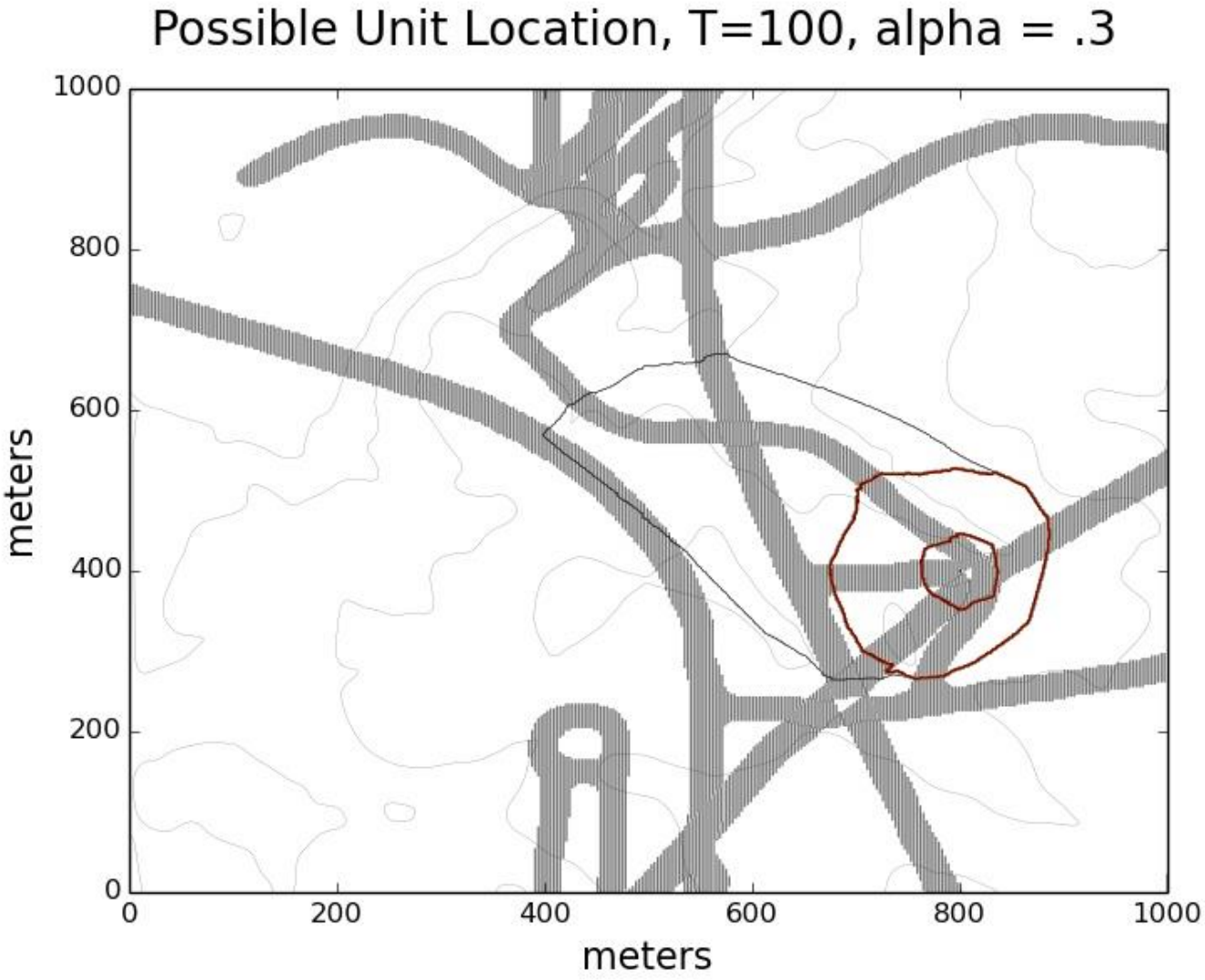

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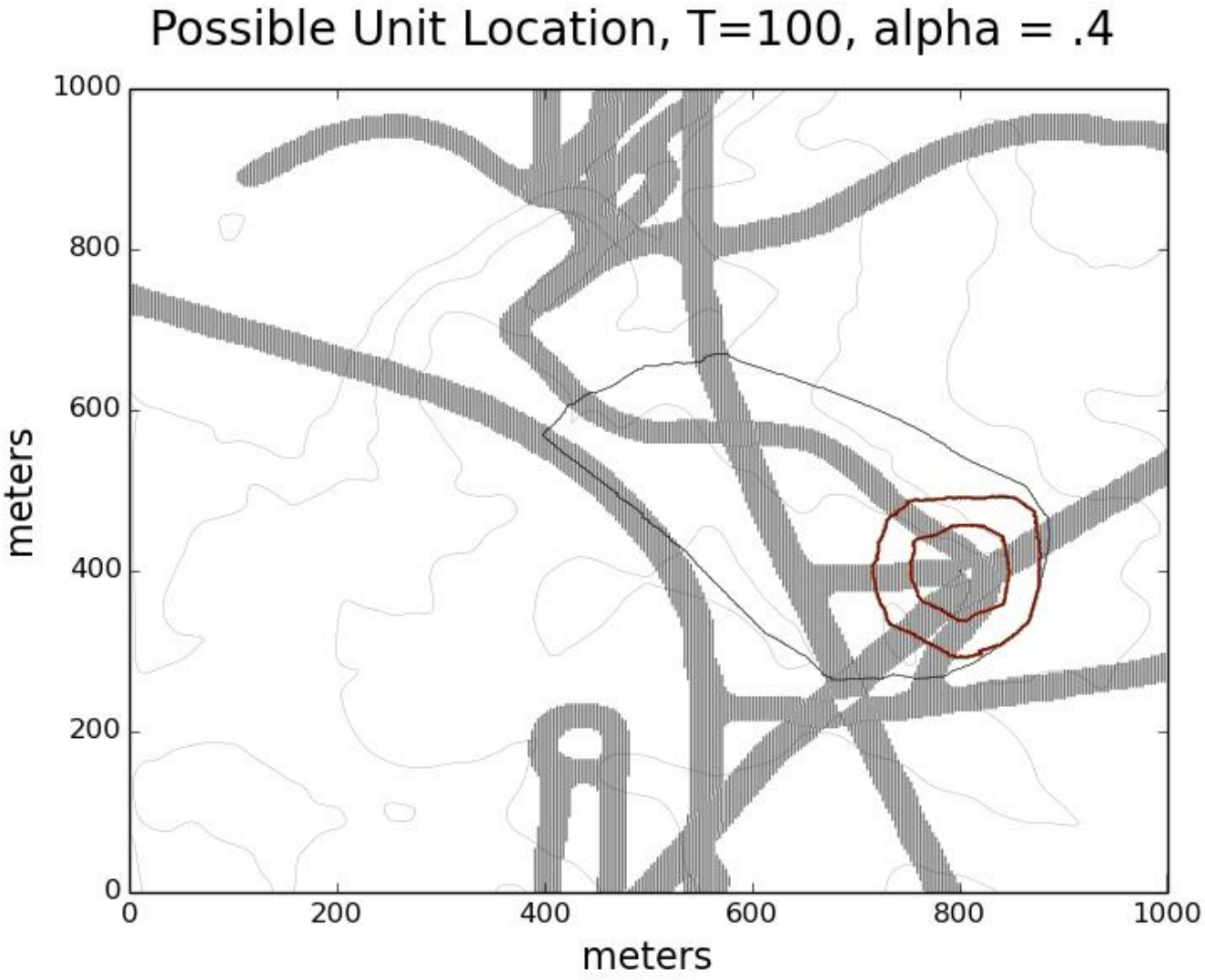

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Conclusion

- We constructed a model to estimate expected locations for a small unit in order to reason about troop movement.
- Movement is part of the set of information used to detect anomalies.
- Anomaly detection is an important ability for an Autonomous Squad Member (ASM) in order to effectively perform as a teammate.

Future Work

- **Future Work:**
  - Collaboration with other organization to build a better movement model
  - Increase model complexity by adding factors
    - Adversarial Factors
  - Improved Time of Arrival Distribution

Thank you!

Questions

Contact:
j.vincepulido@virginia.edu

A* SEARCH ALGORITHM

- **A* search algorithm**
  - Popular algorithm widely used in path-finding and graph traversal
  - Searches for the minimum cost path for a given cost function
  - Assumes deterministic cost path:
    - Cost to reach a node
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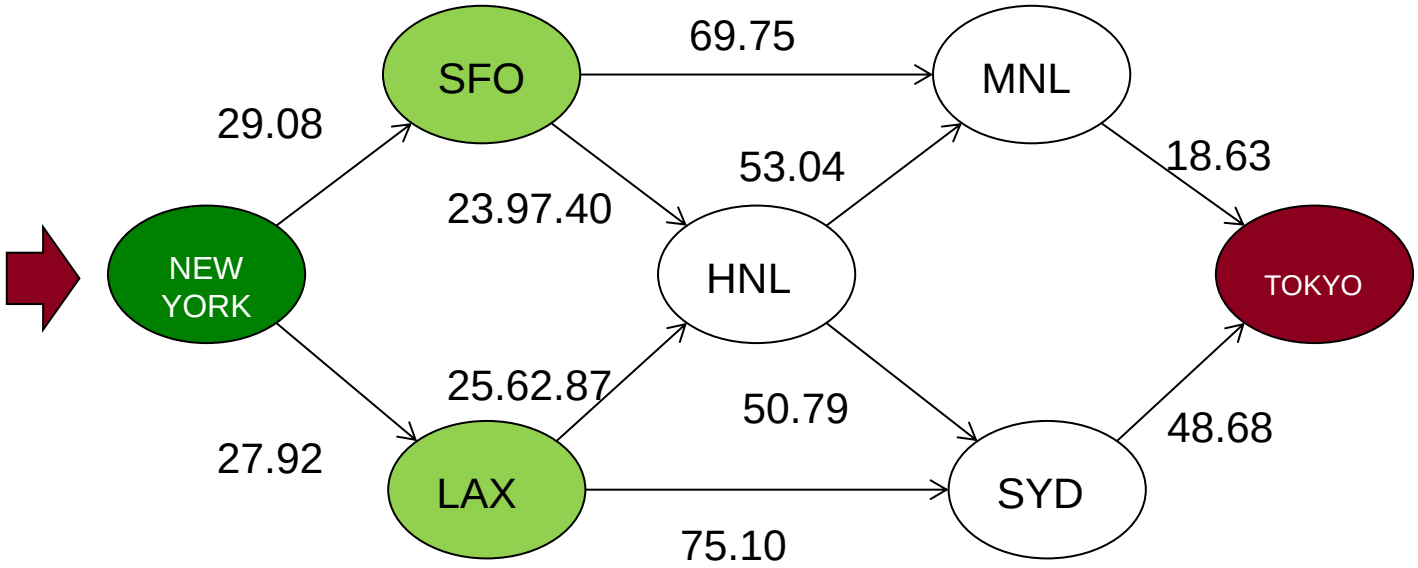

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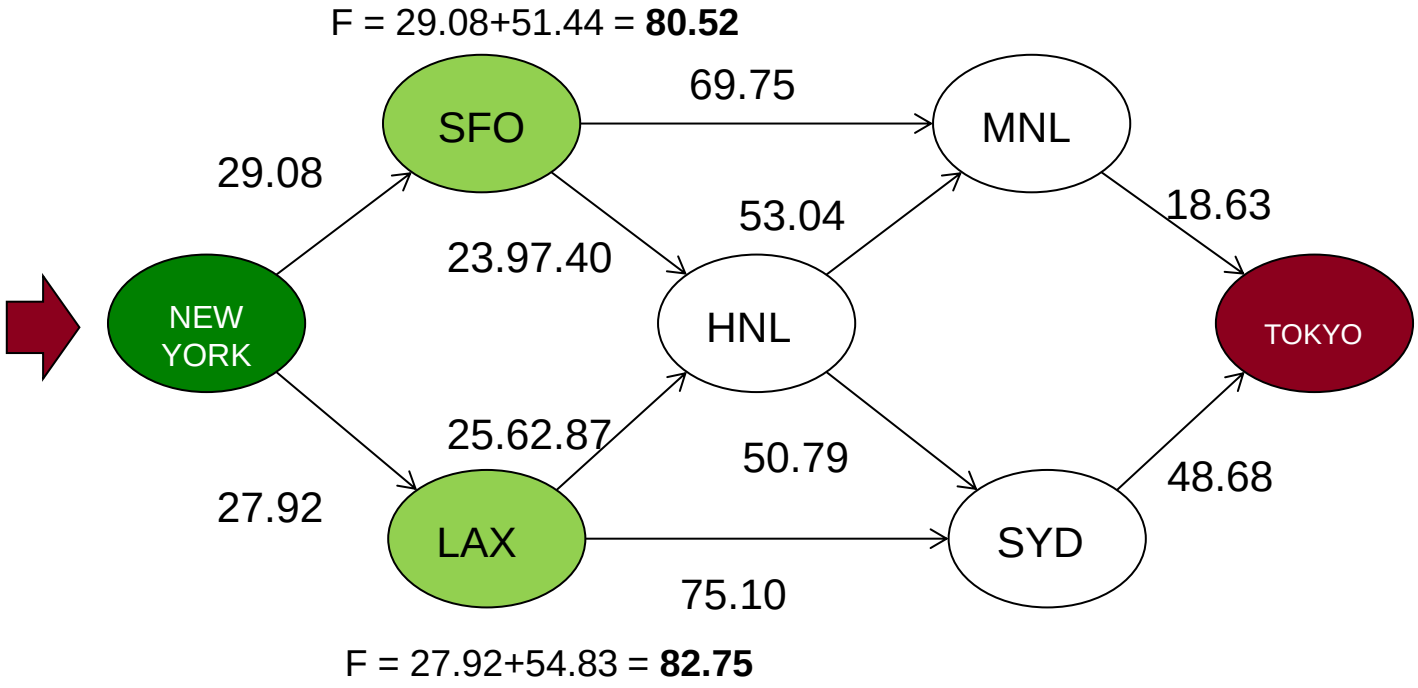

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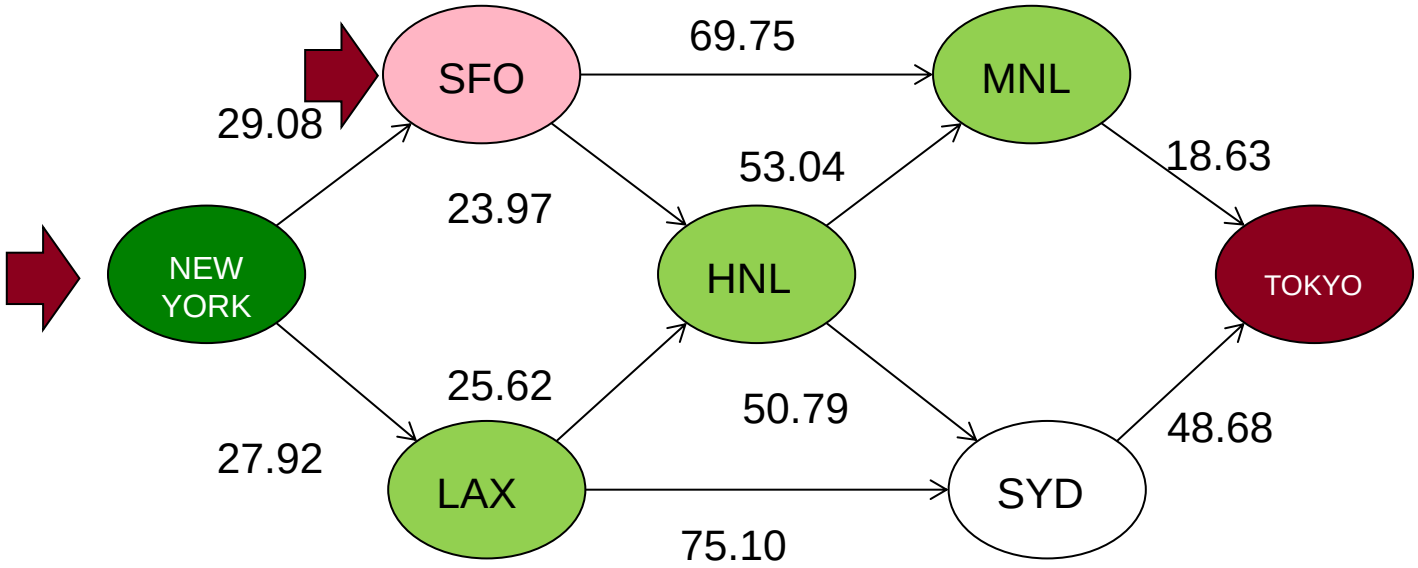

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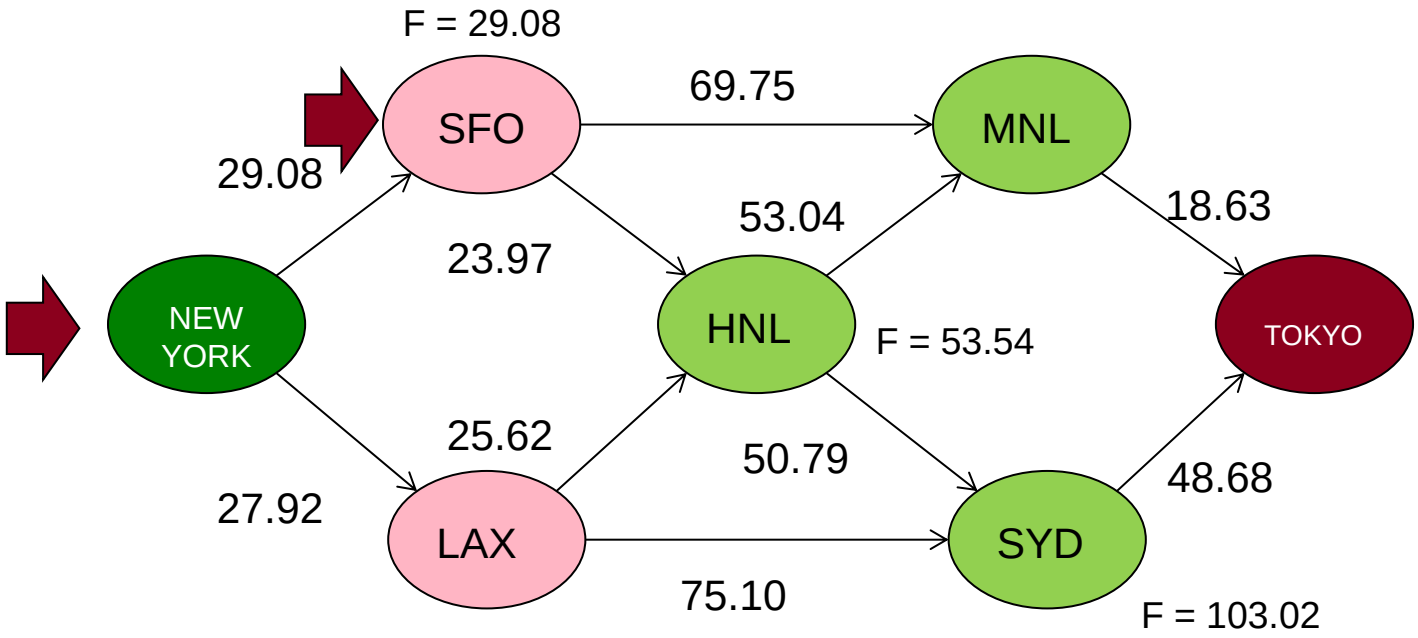

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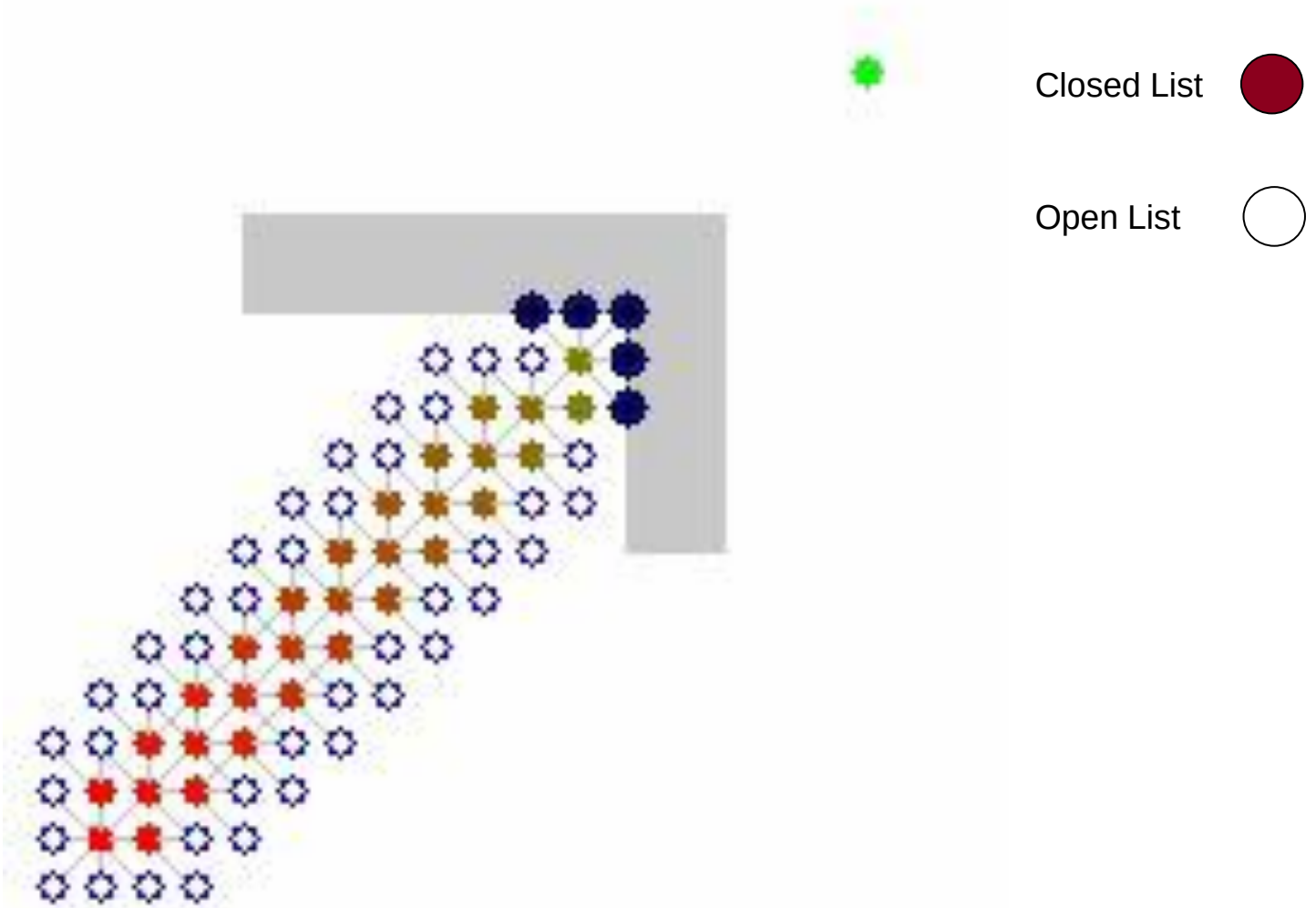
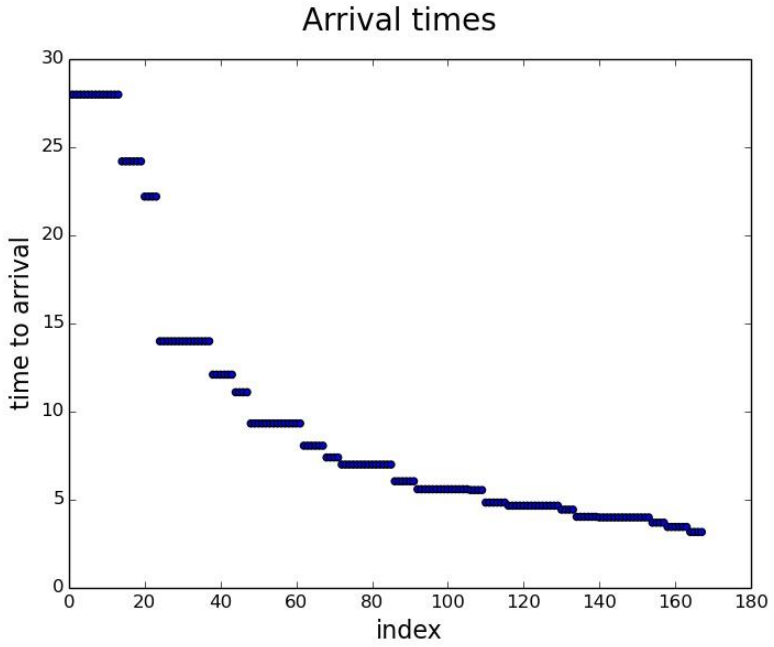


http://en.wikipedia.org/wiki/A*_search_algorithm#mediaviewer/File:Astar_progress_animation.gif

Example Nodes

x=404, y=802



x=531, y=559