Project Topic/ Summary: **Explore Swarm Robotics algorithms to optimize congestion and navigation among autonomous systems.**

**Relevant Details/ Preference:** We will explore potential implementation of Swarm Robotics algorithms in autonomous systems for scenarios such as smart traffic management. Developing/ exploring swarm robotic algorithms targeted at reducing congestion and improving navigation among autonomous systems, and analyzing their performance through Agent Based Model (ABM). MESA Python will be used to build an Agent Based Model (ABM) to create, execute, and analyze models of swarm robotic systems.

Thought this article can be helpful:  
<https://www.frontiersin.org/articles/10.3389/frobt.2020.00083/full>

And this:  
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7256583/>

Repository of datasets on autonomous driving we can use for building our Swarm Robotics algorithm: <https://medium.com/analytics-vidhya/15-best-open-source-autonomous-driving-datasets-34324676c8d7>

Potential applications for congestion reduction using drones + robots (STC):

* **Public safety**: They can be used to disseminate emergency alerts or evacuation instructions to specific areas experiencing congestion due to accidents or other incidents.
* **Traffic management**: Drones or robots equipped with STC capabilities can broadcast real-time traffic updates, rerouting instructions, or warnings to individual vehicles, helping drivers make informed decisions and optimize their routes.
* **Logistics and delivery**: Targeted communication with delivery vehicles can optimize routes, reduce congestion caused by unnecessary stops and starts, and improve delivery efficiency.
* Agriculture: great potential (John Deere, CAT)
* PROBLEMS: BAD CROPS; WHERE TO PUT PESTICIDES
* Use satellite data as an alternative for drone data (but will be lower res)
* Can use drones to identify areas of high / low crop yield on farmlands (once drone identifies, the ground robots can work to fix up the bad areas or gather more data on those areas)
* Can create a proof of concept / demo of how the communication system would work
* Airport logistics: regulatory challenges
* CV: ground/aerial robots classifying crops; once once robots figure out bad crops, other swarm robots zeroes in to the area

Combining swarm robotics and STC

While not currently implemented in real-world applications, there's potential for combining STC and swarm robotics for congestion reduction by:

* **Swarm robots collecting data**: They could gather real-time traffic information and communicate it to an STC system.
* **STC system sending targeted messages**: Based on the data, the STC system could broadcast targeted messages to individual vehicles or groups, suggesting route changes or providing congestion warnings.

Google Gemini LLM Data Sets suggestions ​​<https://g.co/gemini/share/25a69b490008>

**Define milestones in the project proposal; who does what. Proposal should serve as a weekly roadmap. For Agricultural use case have:**

* **Aerial model**
* **Ground model**
* **CV model**
* **10-20 examples to use as a benchmark**
* Have reasons why you pursed the idea

<https://www.researchgate.net/publication/320634426_Monitoring_and_mapping_with_robot_swarms_for_agricultural_applications>

Aerial side - surveying and modeling

Need to outline:

* Agent
* State
* Rules
* Interactions

Need to find use cases in agricultural context

Finding datasets for the 3 models

What would some of the challenges be

**Computer Vision datasets:**

Weed detection:

<https://universe.roboflow.com/augmented-startups/weeds-nxe1w>

<https://www.sciencedirect.com/science/article/pii/S0168169920312709>

Disease identification:

<https://universe.roboflow.com/artificial-intelligence-82oex/detecting-diseases>

Agricultural Vision:

<https://paperswithcode.com/dataset/agriculture-vision>

<https://data.mendeley.com/datasets/nj4vtk4tt6/1>

* **Agricultural research databases:**
  + USDA National Agricultural Library: <https://www.nass.usda.gov/datasets>
  + AgData Commons: <https://www.nal.usda.gov/services/agdatacommons>
* **Drone research repositories:**
  + OpenDroneMap: <https://community.opendronemap.org/>
  + PX4 Autopilot: <https://px4.io/>

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A Systematic Review of Swarm Robots

<http://repository.futminna.edu.ng:8080/jspui/bitstream/123456789/11538/1/30719-Article%20Text-57596-2-10-20200618%2024-07-2021%20at%2017.58.49.pdf>

Path Planning and optimization

<https://www.researchgate.net/publication/343400583_MULTI-AGENT_PATH_PLANNING_OF_ROBOTIC_SWARMS_IN_AGRICULTURAL_FIELDS>

UAV for agriculture

<https://knepublishing.com/index.php/KnE-Engineering/article/view/1459/3522>

Summary of agricultural swarm robots technologies.

<https://edisciplinas.usp.br/pluginfile.php/7955652/mod_resource/content/1/Swarm%20robots%20in%20mechanized%20agricultural%20operations.pdf>

agriculture, reinforcement learning

<https://www.sciencedirect.com/science/article/pii/S2667241323000241>

SAGA: Swarm robotics for Agricultural Applications

<http://laral.istc.cnr.it/saga/wp-content/uploads/2016/09/saga-dars2016.pdf>  
<http://laral.istc.cnr.it/saga/index.php/research/>  
<https://echord.eu/experiments/agricultural-and-food-robotics/index.php.html>

Multi-Agent Based Prototyping of Agriculture Robots  
[https://www.researchgate.net/publication/4246795\_Multi-Agent\_Based\_Prototyping\_of\_Agriculture\_Robot](https://www.researchgate.net/publication/4246795_Multi-Agent_Based_Prototyping_of_Agriculture_Robots)

AgriRobots (Thesis)  
<http://essay.utwente.nl/88141/1/Bunte_MA_BMS.pdf>

Swarm Robotics: Simulators, Platforms and Applications Review  
[Computation | Free Full-Text | Swarm Robotics: Simulators, Platforms and Applications Review](https://www.mdpi.com/2079-3197/10/6/80)

Deep reinforcement learning-based multi-agent area coverage control for smart agriculture  
<https://www.sciencedirect.com/science/article/abs/pii/S0045790622003445>

Autonomous Robot Path Planning: Sustainable Agricultural Applications  
<https://www.mdpi.com/2076-3417/12/3/943>

Adaptive Swarm Robotics Could Revolutionize Smart Agriculture

<https://today.tamu.edu/2021/11/15/adaptive-swarm-robotics-could-revolutionize-smart-agriculture/>

<https://texasfarmbureau.org/swarm-robotics-could-help-farmers-and-ranchers/>

Paper on various use cases of Computer Vision in Agriculture:

<https://www.sciencedirect.com/science/article/pii/S2214317319301751#b0175>

<https://www.sciencedirect.com/science/article/pii/S0168169920312709>

Problem statements to solve using Swarm robotics + drones

* Weed detection and control:
  + <https://www.kaggle.com/datasets/fpeccia/weed-detection-in-soybean-crops>
  + <https://github.com/AlexOlsen/DeepWeeds>
  + <https://github.com/cwfid/dataset>
  + <https://github.com/josemenber/image-based-crop-anomaly-detection>
* Plant disease:
  + <https://www.kaggle.com/code/aryanml007/plant-disease-resnet50/notebook>
* Classification:
  + <https://www.kaggle.com/code/mushfirat/rice-classification-99-2-accuracy/comments>
* Fruit detection:
  + <https://drive.google.com/drive/folders/1CmsZb1caggLRN7ANfika8WuPiywo4mBb>
  + <https://www.sciencedirect.com/science/article/pii/S2352340919308698?via%3Dihub>

<https://www.mdpi.com/1424-8220/23/13/6082>

<https://paperswithcode.com/dataset/m2dgr>

## Suggestions from ChatGPT

1. **Precision Farming**: Simulate the deployment of swarm robots for tasks like planting, watering, and fertilizing, focusing on the precise application of resources to each plant based on its specific needs. This can include testing different strategies for optimizing resource use and crop yield.
2. **Weed Detection and Removal**: Model the ability of swarm robots to identify and remove weeds from crops. This could involve simulating various sensing technologies (e.g., computer vision) and mechanical methods (e.g., targeted herbicide application or physical removal) to manage weeds effectively without damaging crops.
3. **Pest Monitoring and Control**: Use ABM to simulate how swarm robots can monitor pest levels across different parts of a farm and apply targeted pest control measures. This can help in exploring the effectiveness of different pest control strategies and their impact on crop health and yield.
4. **Soil Analysis and Amendment**: Simulate the use of swarm robots for collecting soil samples and analyzing them for nutrients and moisture content. This can help in understanding how best to amend the soil with fertilizers or irrigation to optimize crop growth.
5. **Crop Health Monitoring**: Model the deployment of swarm robots equipped with sensors to monitor crop health indicators such as leaf color, plant size, and signs of disease or stress. This use case can help in developing early warning systems for crop health issues and testing interventions.
6. **Harvesting**: Simulate the use of swarm robots for harvesting crops, focusing on optimizing the timing of harvest and minimizing damage to plants. This can include modeling different types of crops and harvesting methods.
7. **Data Collection and Analysis for Precision Agriculture**: Use ABM to explore how swarm robots can collect and analyze data on various factors affecting crop growth, such as soil conditions, weather, and crop health. This can help in refining precision agriculture practices and improving decision-making.
8. **Resilience to Environmental Changes**: Model how swarm robotics can adapt to environmental changes, such as weather variations or unexpected pest outbreaks. This can help in developing strategies for making agricultural practices more resilient to climate change and other environmental challenges.
9. **Integration with Farm Management Systems**: Simulate the integration of data collected by swarm robots with farm management systems, focusing on how this integration can improve the efficiency of farm operations and decision-making.
10. **Sustainability Practices**: Explore how swarm robotics can support sustainable farming practices, such as reducing chemical use, conserving water, or enhancing biodiversity. This can include modeling the impact of different farming practices on environmental indicators.

## Suggestions from Copilot

* Crop monitoring: Swarm robots can be used to collect data on crop growth, soil moisture, pest infestation, and environmental conditions. [The data can be used to create a simulation model that can help farmers optimize their crop management and yield1](https://www.mdpi.com/2079-3197/10/6/80)[2](https://www.mdpi.com/journal/agriengineering/special_issues/SwarmRoboticsLS).
* Weed control: Swarm robots can be used to detect and remove weeds from crop fields, using different methods such as mechanical, thermal, or chemical. [The simulation model can help evaluate the performance and efficiency of the swarm robots and their weed control strategies3](https://direct.mit.edu/isal/article/doi/10.1162/isal_a_00229/99214/Applying-Social-Network-Analysis-to-Agent-Based)[4](https://www.routledge.com/Agent-Based-Modeling-and-Simulation-with-Swarm/Iba/p/book/9781138033702).
* Harvesting: Swarm robots can be used to harvest crops such as fruits, vegetables, grains, and nuts. [The simulation model can help design and test the swarm robots and their harvesting algorithms, taking into account factors such as crop type, ripeness, location, and quality5](https://hal.science/hal-03183415/document)[6](https://doi.org/10.3390/computation10060080).
* Precision farming: Swarm robots can be used to apply fertilizers, pesticides, and irrigation to crops in a precise and targeted manner, based on the data collected by the crop monitoring swarm robots. The simulation model can help optimize the swarm robots and their precision farming techniques, reducing costs and environmental impacts .

## Biggest pain points for farmers that SWARM + STC can solve <https://g.co/gemini/share/5aa38f527122>

**1. Labor Shortages and Rising Labor Costs:**

* **Swarm robotics:** Automating tasks like planting, weeding, and monitoring can reduce reliance on manual labor, addressing chronic labor shortages and associated cost pressures.
* **STC with drones:** Enables communication and coordination with fewer human operators, potentially optimizing labor utilization and reducing overall labor costs.

**2. Precision and Efficiency in Farm Management:**

* **Swarm robotics:** Precise control over individual robots allows for targeted tasks like applying fertilizers or pesticides only where needed, minimizing waste and optimizing resource utilization.
* **STC with drones:** Enables real-time data collection and communication, facilitating informed decision-making for optimizing irrigation, crop management, and overall farm operations.

**3. Improved Crop Monitoring and Yield Optimization:**

* **Swarm robotics:** Robots equipped with sensors can continuously monitor crop health, identify potential issues like pests or diseases early on, and enable timely intervention.
* **STC with drones:** Enables efficient data collection and analysis from large fields, providing valuable insights into crop health, growth patterns, and potential yield variations.

**4. Environmental Sustainability and Reduced Impact:**

* **Swarm robotics:** Precise application of resources like fertilizers and pesticides minimizes environmental impact compared to traditional broad-scale techniques.
* **STC with drones:** Enables targeted monitoring of environmental factors like soil moisture and nutrient levels, allowing for data-driven decisions to optimize resource use and reduce environmental footprint.

**5. Data-Driven Decision Making and Farm Automation:**

* **Swarm robotics and STC with drones:** Both technologies generate valuable data that can be integrated into farm management systems, enabling data-driven decision making for optimizing various aspects of farm operations and gradually automating tasks for improved efficiency and productivity.

**Challenges and considerations:**

* **Technology adoption costs:** Initial investment in these technologies can be high, posing a challenge for smaller farms.
* **Technical expertise:** Operating and maintaining these technologies might require additional training and expertise for farmers.
* **Regulatory frameworks:** Legal and regulatory frameworks for autonomous robots and drone operation in agriculture need to be established and clarified.

[Gemini Breakdown of Project Summary and Timeline](https://g.co/gemini/share/10746c193013)

**Initial Project Summary:**

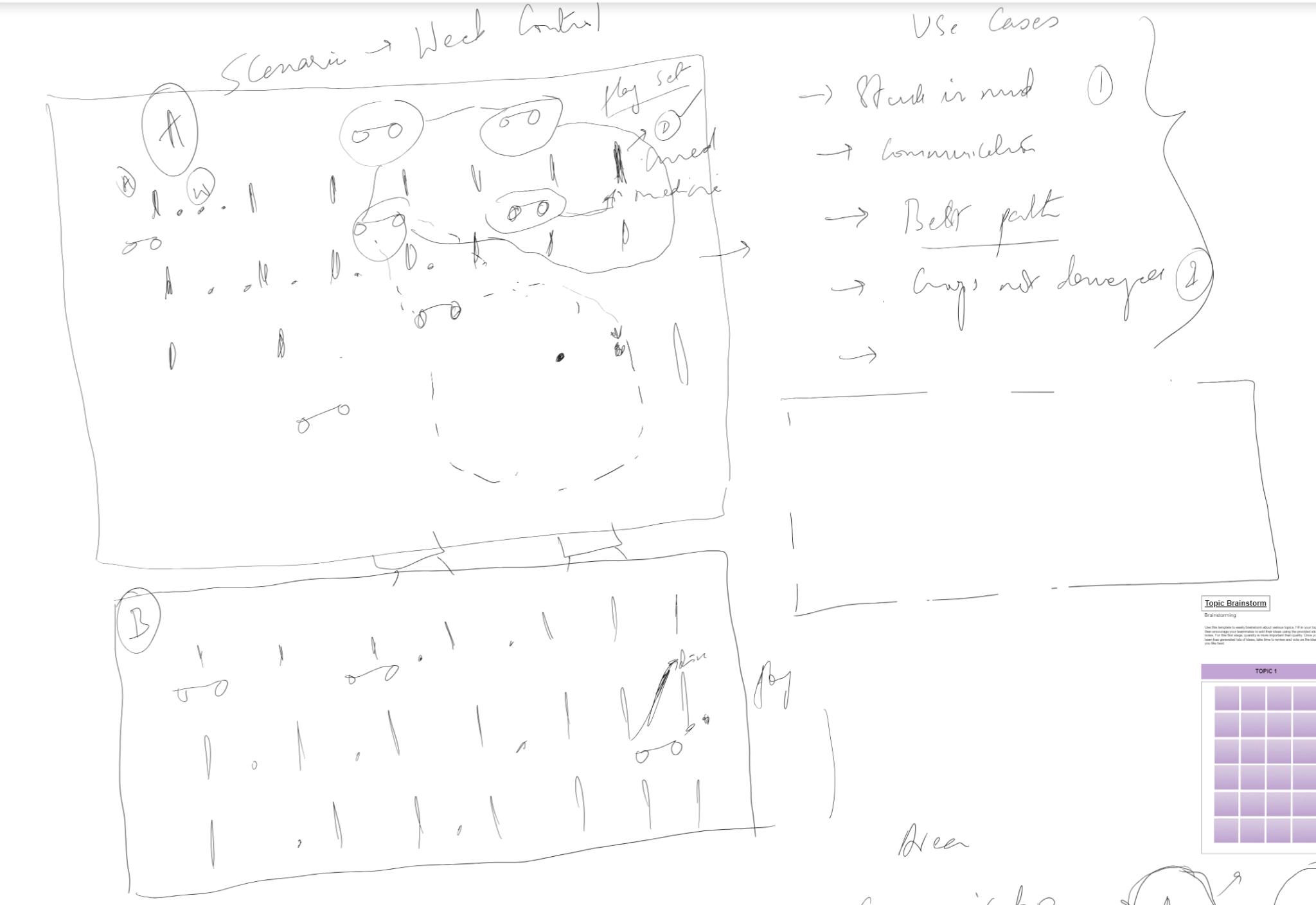
Using Swarm Robotics and STC in an Agent-Based Model to improve crop monitoring and yield optimization.

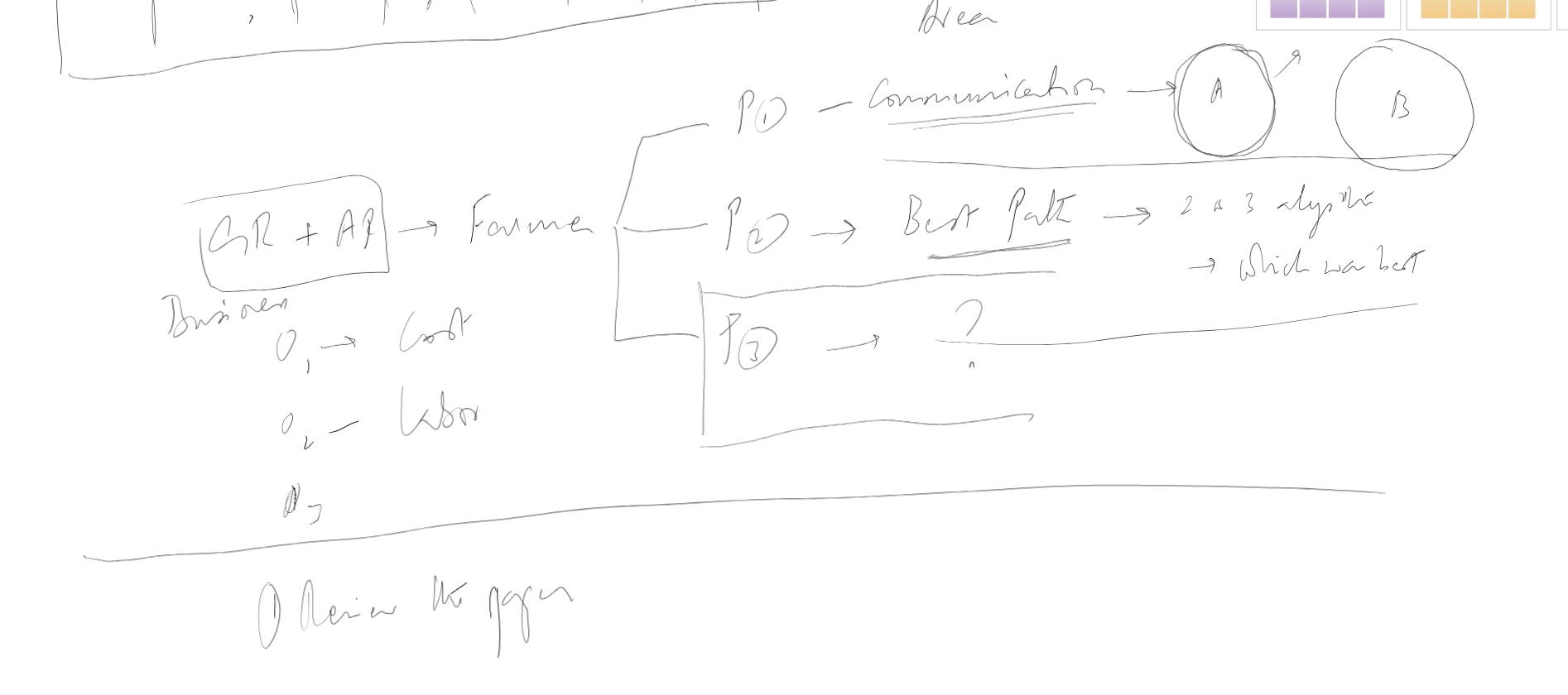
Swarm robotics: Robots equipped with sensors can continuously monitor crop health, identify potential issues like pests or diseases early on, and enable timely intervention.

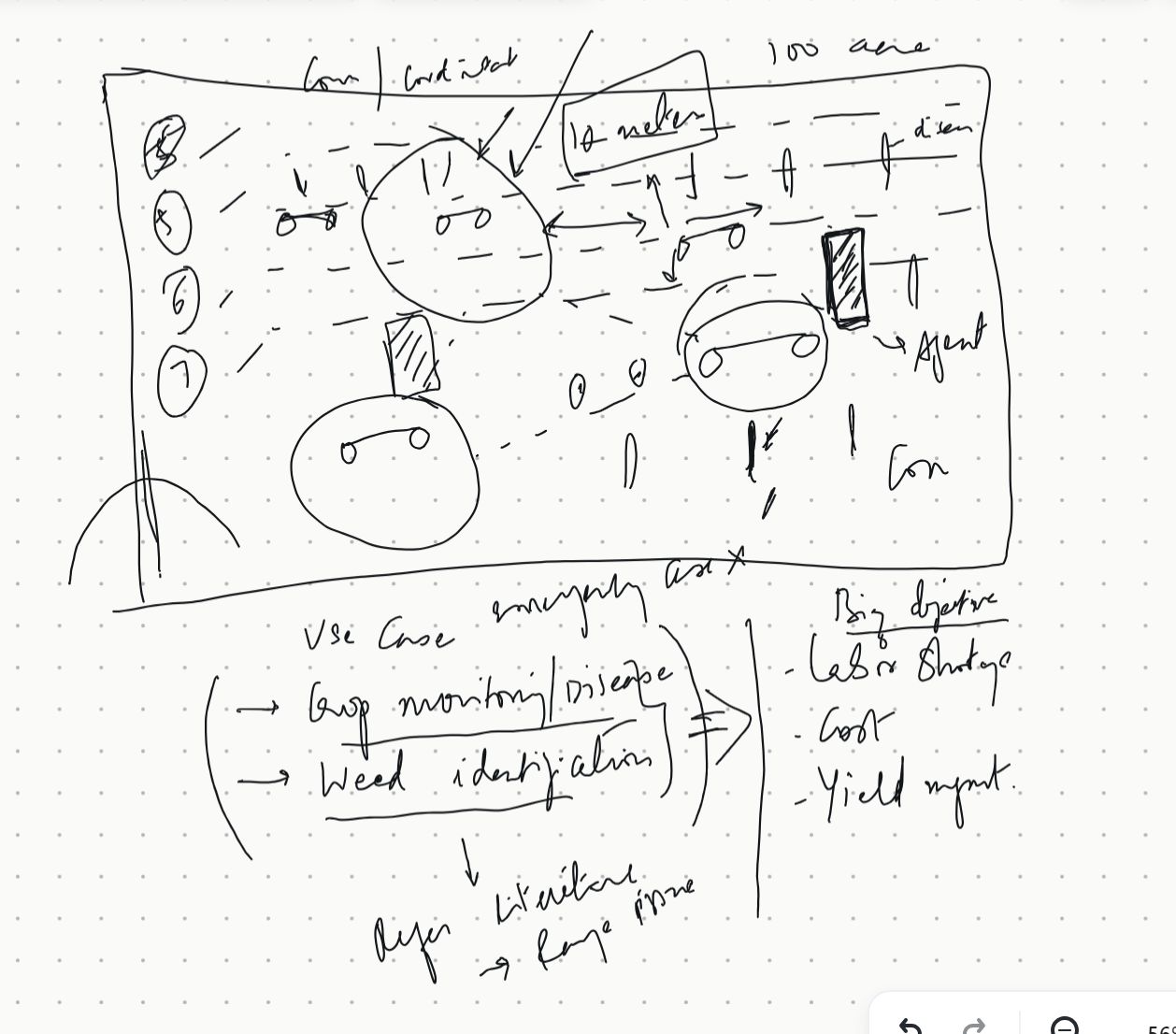
STC with drones: Enables efficient data collection and analysis from large fields, providing valuable insights into crop health, growth patterns, and potential yield variations.

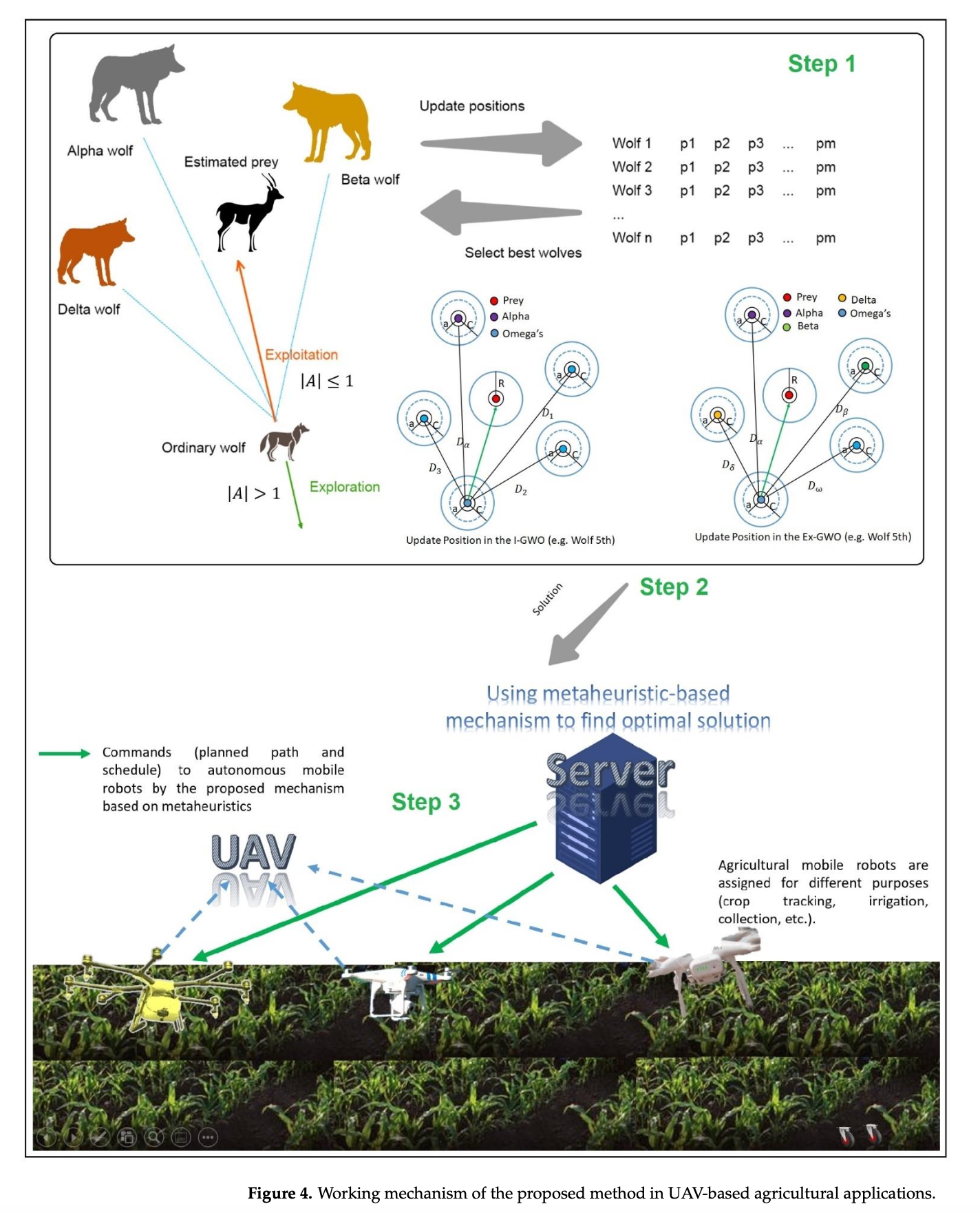
Developing/ exploring swarm robotic algorithms targeted at reducing congestion and improving navigation among autonomous systems, and analyzing their performance through Agent Based Model (ABM). MESA Python will be used to build an Agent Based Model (ABM) to create, execute, and analyze models of swarm robotic systems.

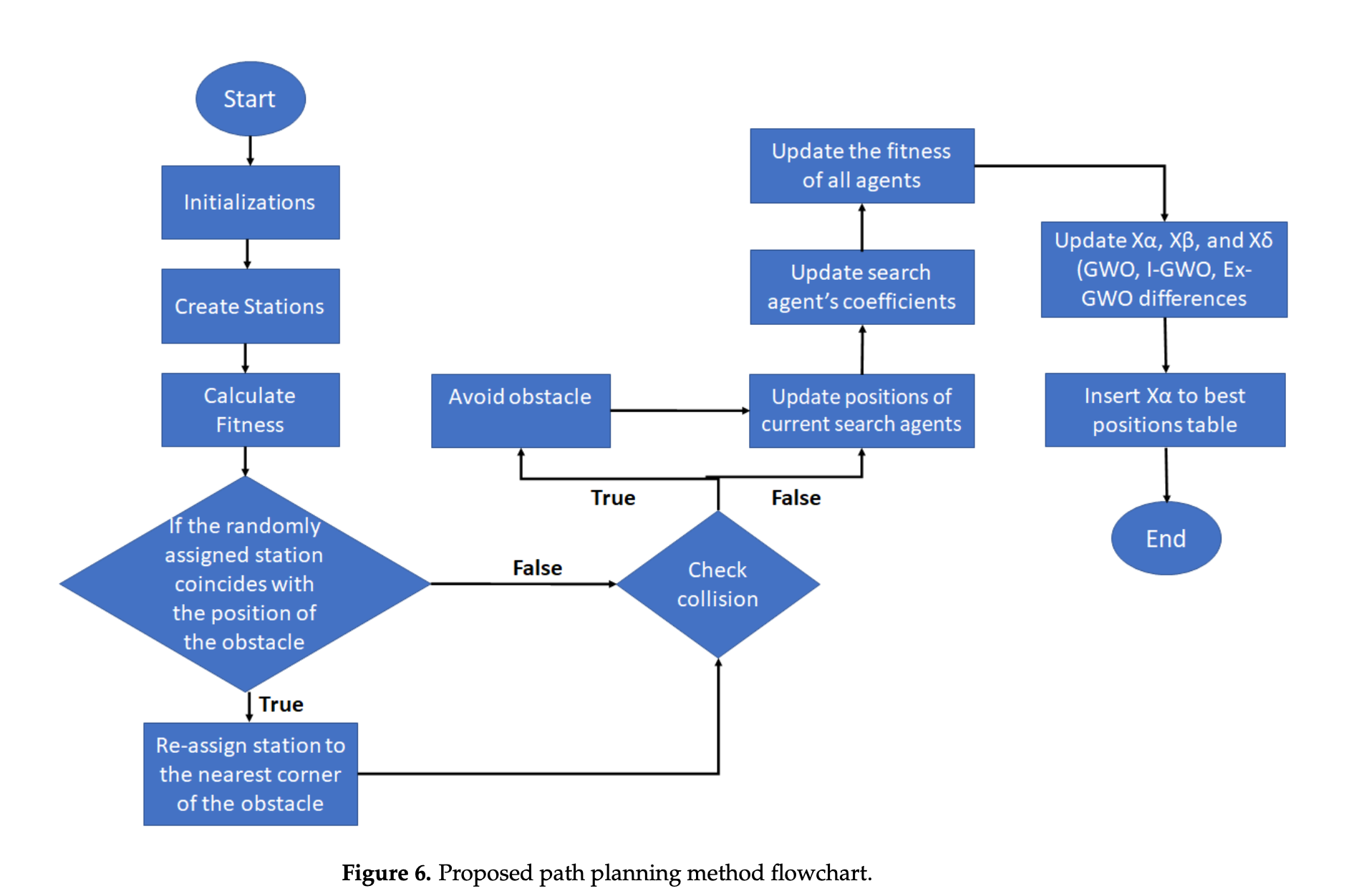
## Discussion Screenshots











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## Literature Review Segmentation:

**Bethlehem**

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## Data Set Segmentation:

**Bethlehem**

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