

# MOBILITY MODELS FOR UAV GROUP RECONNAISSANCE APPLICATIONS

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*IEEE lecture 2006*

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# Plan

- Context
- Problematic
- Study of existing
- Our article
- Models of our study
- Experiments
- Comparison of 2 models
- Our Implementation
- Conclusion

# Context

- UAV
- Swarm of UAVs
- Mobility models

➔ How do they move ?

# Problematic



**Figure 1** . Source : "<http://www.swiss-uav.com> "

## How well scan an area ?

*As much and as quickly possible, in a limited time and at least, once every hour.*

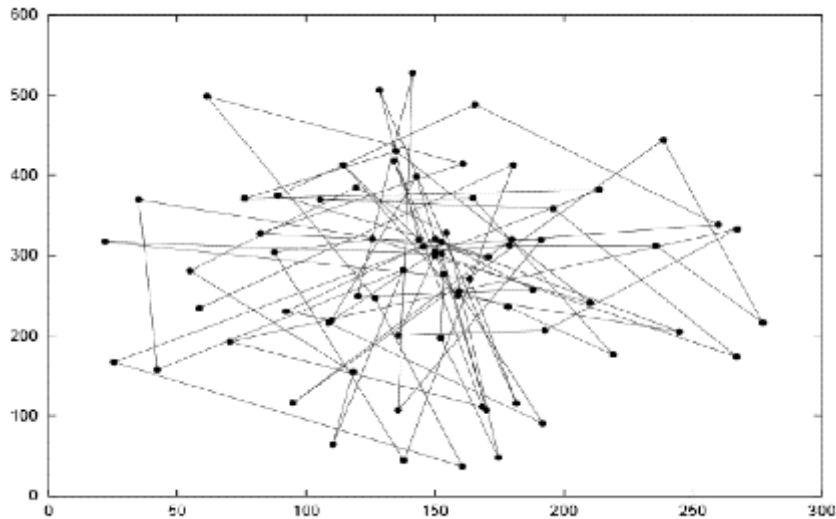


**Figure 2**. Source : " <http://technorati.com> "

# Study of existing

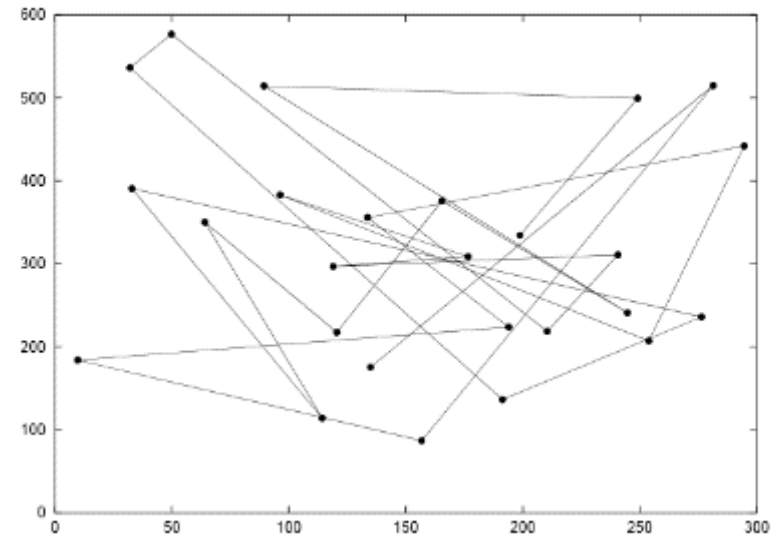
## Existing Models

- Random Walk



[1] : Result pattern of Random Walk

- Random WayPoint

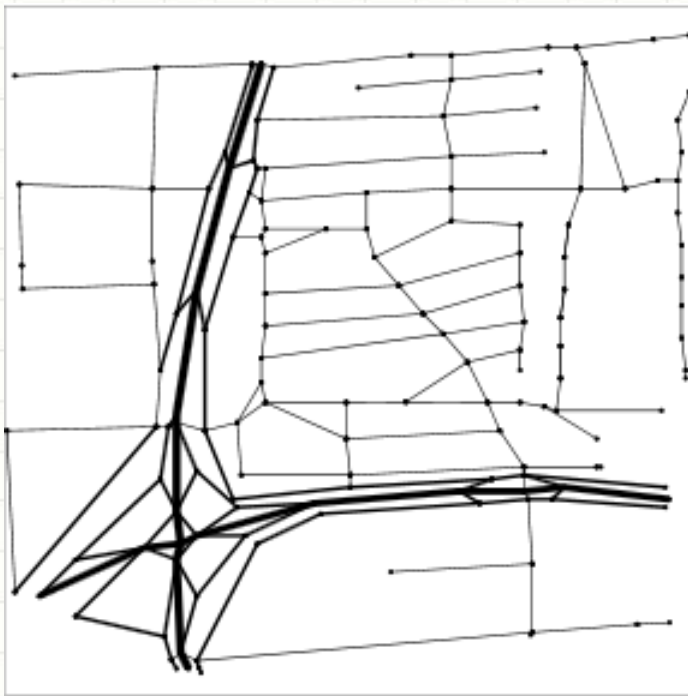


[2] : Result pattern of Random Walk



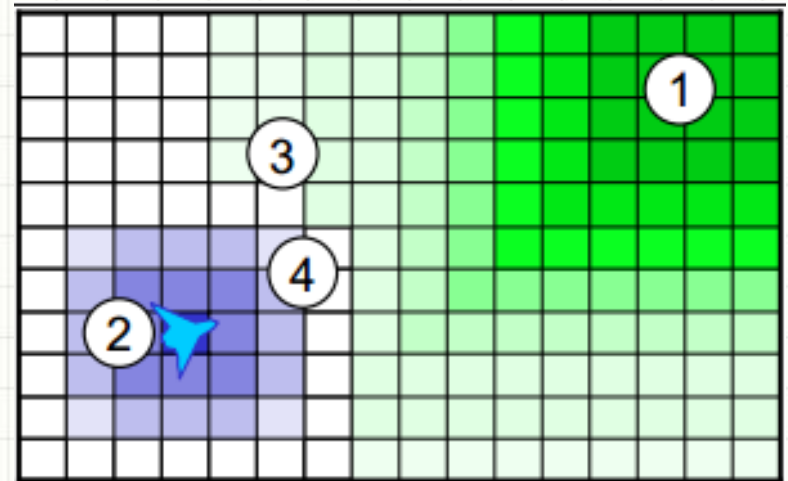
# Study of existing

- City Section



[3] : (b) **Region B**: Street scenario corresponding to a square area of size 1900 m×1900 m

- Distributed Pheromone Repel



[4] : Attractive and Repulsive Pheromones For Surveillance

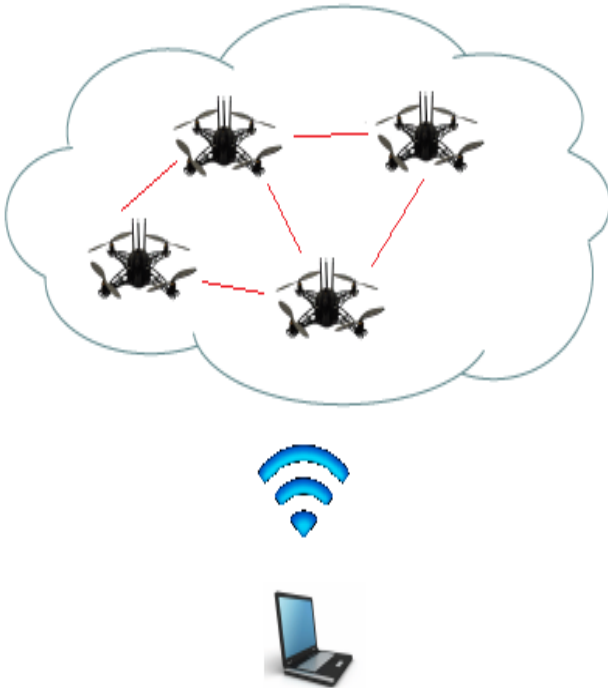
Blue : repulsive

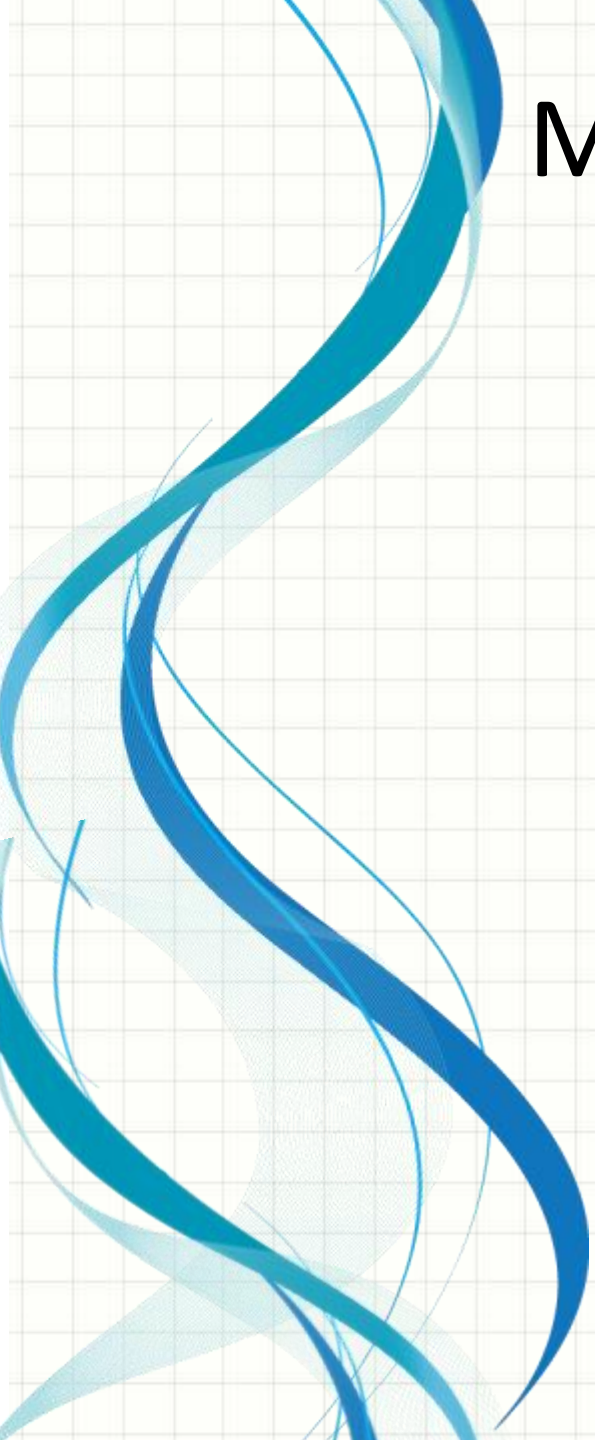
Green : attractive

# Our Article

## Introduction

- MANET
  - Mobile Ad Hoc Network
  - Networks of mobile entities
  - Collect, process and transmit data
- UAV
  - Application of mobility models with UAVs
- 2 different mobilities models
  - Random Waypoint
  - Distributed Pheromone Repel





# Models of our study

## Random Waypoint model

- Each drones are independant
- No backup position
- Random target



# Models of our study

## Random Waypoint model

**Table 1. UAV random action table.**

Last action	Probability of action		
	Turn left	Straight ahead	Turn right
Straight ahead	10%	80%	10%
Turn left	70%	30%	0%
Turn right	0%	30%	70%

*From : “Mobility Models for UAV Group Reconnaissance Applications”*

*By : E. Kuiper and S. Nadjm-Tehrani.*



# Models of our study

## Distributed Pheromone Repel model

- Coordination of UAVs thanks to pheromones
- Dynamic UAV



# Models of our study

## Distributed Pheromone Repel model

- One pheromone map per UAV
- Marks the areas when they have been scanned
- Broadcast regularly a local area pheromone map (when a distance is inferior to 8 km)

# Models of our study

## Distributed Pheromone Repel model

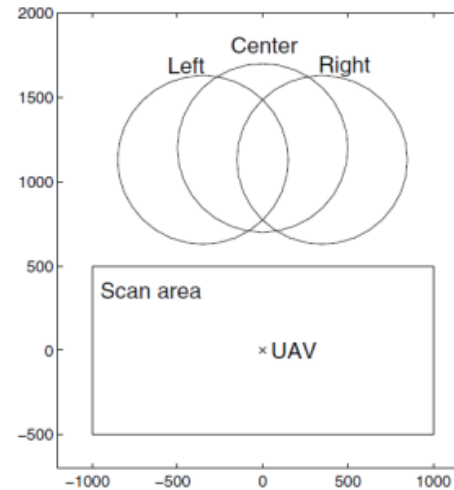


Figure 2. Pheromone search pattern

Table 2. UAV pheromone action table.

Probability of action		
Turn left	Straight ahead	Turn right
$(\text{Total} - \text{Left}) / (2 * \text{Total})$	$(\text{Total} - \text{Center}) / (2 * \text{Total})$	$(\text{Total} - \text{Right}) / (2 * \text{Total})$

**From :** “Mobility Models for UAV Group Reconnaissance Applications”

**By :** E. Kuiper and S. Nadjm-Tehrani.



# Experiments

## Scenarios for the 2 models

- Characteristics
  - Square with a side length of 30 Km
  - 10 UAVs per run
  - Fixed wing aircraft
- Requirements
  - Data must be returned to the C&C
  - No excessive use of bandwidth (communication of 1 message/s/UAV)



# Experiments

Expected results :

Scan the area in 18 min

Obtained results :

Mobilities Models	RandomWayPoint	Pheromone
Time to scan the area	80% of the area in 120 min	90% of the area in 50 min
Connectivity	Low	Low



# Experiments

## Limitations

- Speed and shift (direction)
- Coverage and connectivity of communications are two conflicting objectives.
- Absolutely unrealistic !!!!!

# Comparison of 2 models

## Scan characteristic

Both models manage quite well to avoid rescanning a recently scanned area.

**Table 3. Never scanned area**

	<b>Max</b>	<b>Median</b>	<b>Min</b>
<b>Random</b>	16.2%	3.2%	0.5%
<b>Pheromone</b>	0.21%	0.03%	0.01%

***From : “Mobility Models for UAV Group Reconnaissance Applications”***

***By : E. Kuiper and S. Nadjm-Tehrani.***



# Our Implementation

## All models

- Everything was done
- 10 nodes/models
- Margin calculation
- Percentage of scan
- Tracking display

## Pheromone model

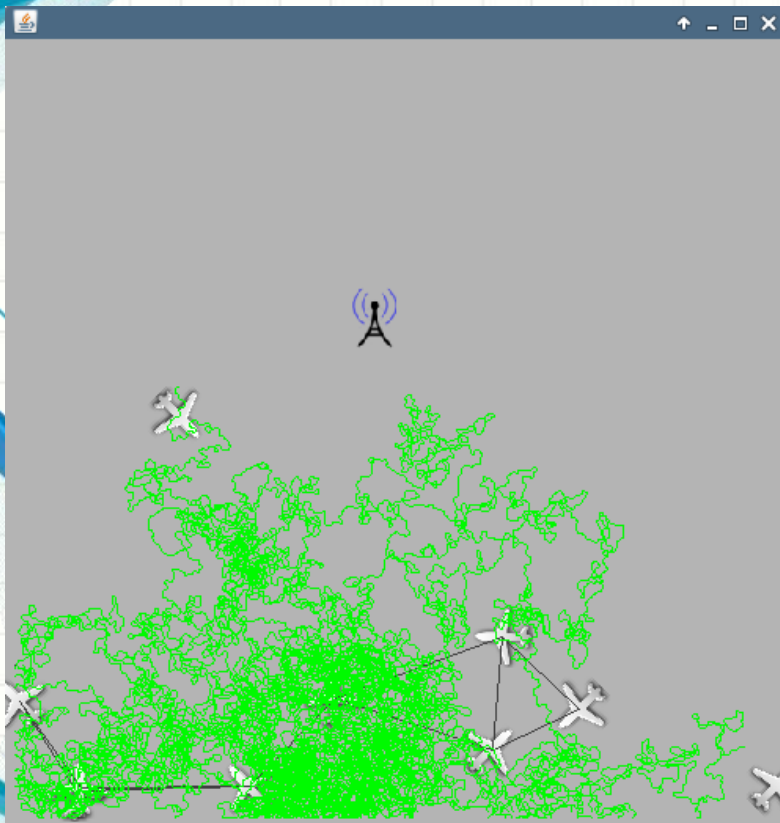
- Presence of C&C does not move
- Communication



# Our Implementation

JBotSim

Pheromone model



Problems @ Javadoc Declaration Console

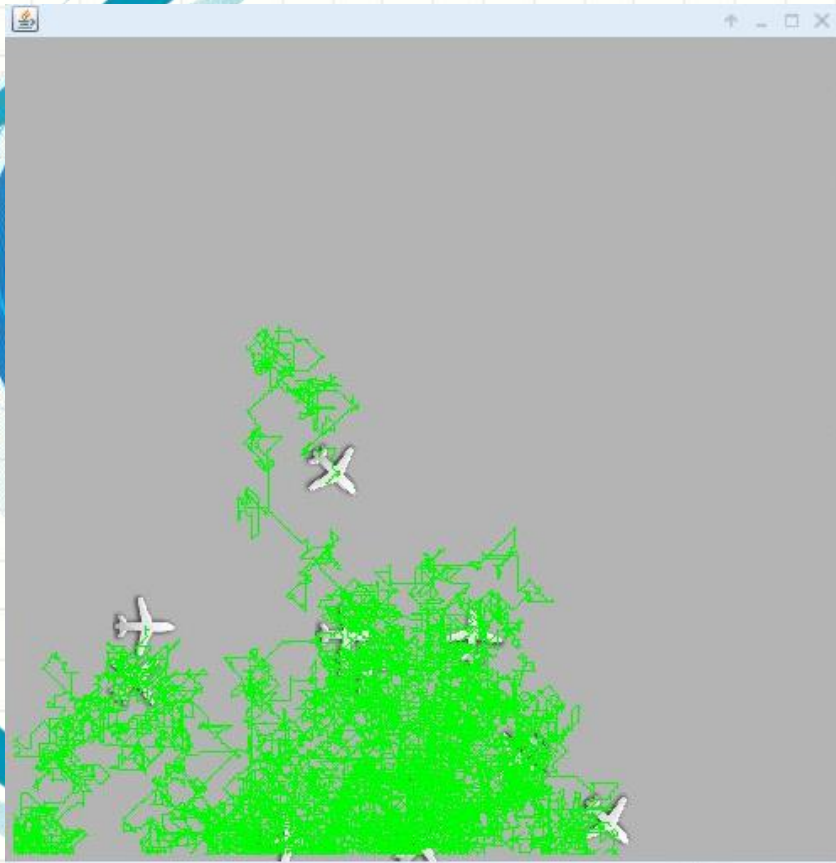
```
<terminated> Main [Java Application] /usr/lib/jvm/jdk-7-  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.305705955851728% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec  
Scan : 18.306122448979593% during 2 min 0 sec
```



# Our Implementation

JBotSim

Random Walk model



Problems @ Javadoc Declaration Console

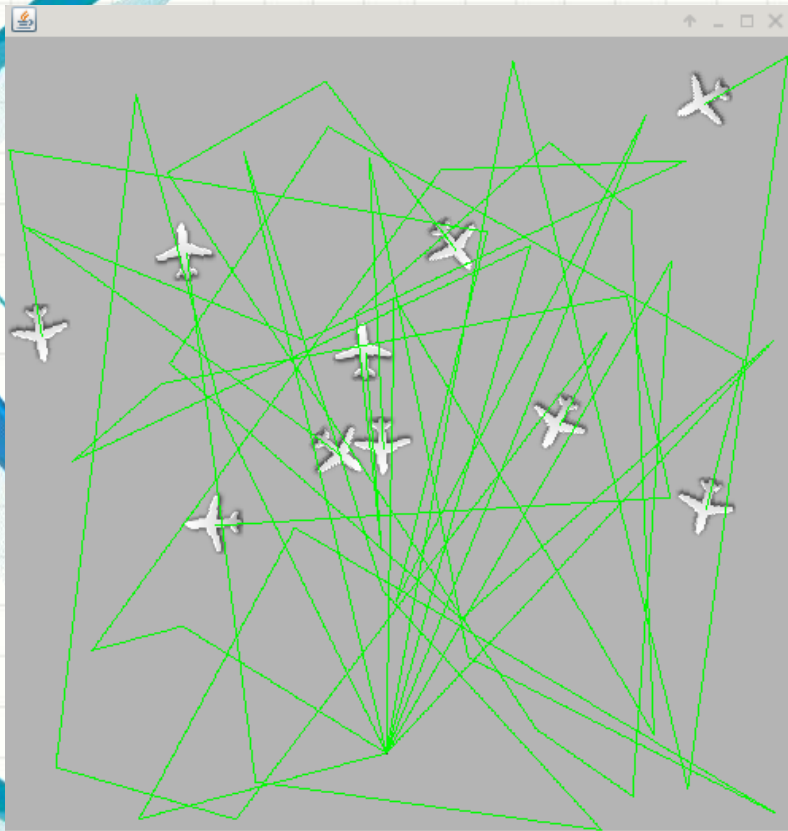
Main (2) [Java Application] /usr/lib/jvm/jdk-7-oracle-x64/t

```
Scan : 22.65264473136193% during 2 min 0 sec
Scan : 22.65264473136193% during 2 min 0 sec
Scan : 22.65264473136193% during 2 min 0 sec
Scan : 22.653061224489797% during 2 min 0 sec
Scan : 22.653061224489797% during 2 min 0 sec
Scan : 22.65347771761766% during 2 min 0 sec
Scan : 22.653894210745523% during 2 min 0 sec
Scan : 22.65431070387339% during 2 min 0 sec
Scan : 22.65431070387339% during 2 min 0 sec
Scan : 22.65431070387339% during 2 min 0 sec
Scan : 22.654727197001247% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655143690129112% during 2 min 0 sec
Scan : 22.655560183256977% during 2 min 0 sec
```

# Our Implementation

JBotSim

Random Waypoint model



Problems @ Javadoc Declaration Consol

Main (1) [Java Application] /usr/lib/jvm/jdk-7-oracle-x64/b

```
Scan : 35.723958333333336% during 2 min 0 sec
Scan : 35.724392361111114% during 2 min 0 sec
Scan : 35.724826388888886% during 2 min 0 sec
Scan : 35.725260416666664% during 2 min 0 sec
Scan : 35.725260416666664% during 2 min 0 sec
Scan : 35.725694444444444% during 2 min 0 sec
Scan : 35.725694444444444% during 2 min 0 sec
Scan : 35.725694444444444% during 2 min 0 sec
Scan : 35.725694444444444% during 2 min 0 sec
Scan : 35.726128472222222% during 2 min 0 sec
Scan : 35.726128472222222% during 2 min 0 sec
Scan : 35.7265625% during 2 min 0 sec
Scan : 35.726996527777778% during 2 min 0 sec
Scan : 35.727430555555556% during 2 min 0 sec
Scan : 35.727430555555556% during 2 min 0 sec
Scan : 35.727864583333336% during 2 min 0 sec
Scan : 35.727864583333336% during 2 min 0 sec
```



# Our Implementation

## Interpretation of results

- At the beginning, Random model more efficiency
- Pheromone : sharp increase because of C&C communication
- At the end, random models are stable
- Pheromone model is more effective that the others models to reach 100% of scan.



# Our Implementation

## Comparison with article

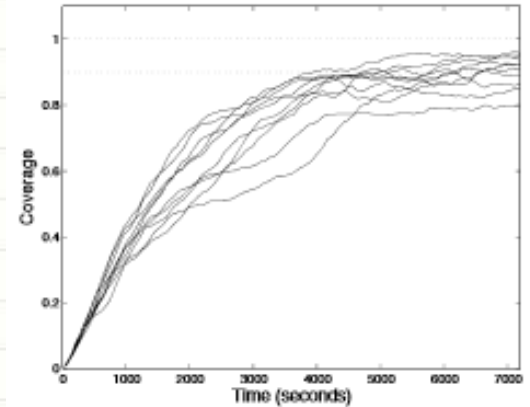
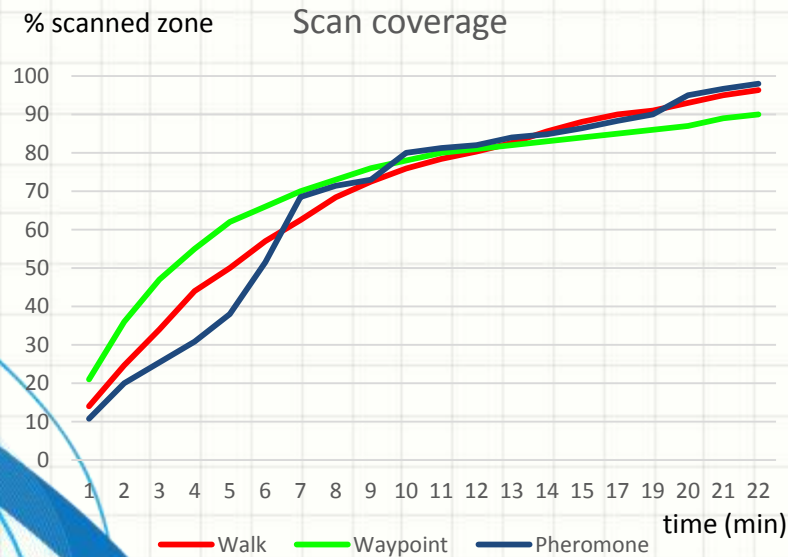


Figure 3. Random mobility coverage

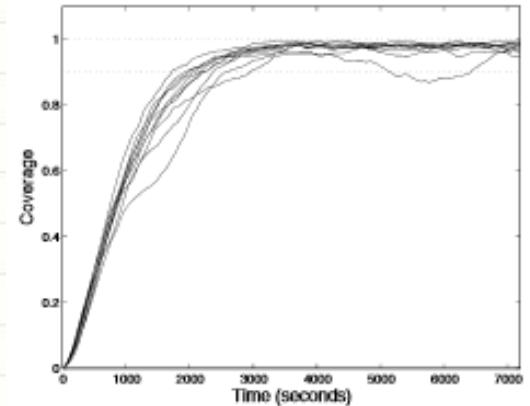
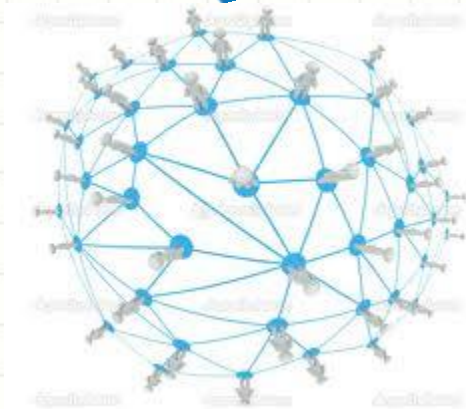


Figure 4. Pheromone mobility coverage.

# Conclusion

- Good model for scan coverage and reconnaissance scenario.
- Absolutely unrealistic
- Possibility amelioration is to temporary storage data and relax the limited bandwidth.



**Figure 4.** Source : " <http://fr.depositphotos.com> "



**Figure 3.** Source : " <http://www.vikingaero.com> "





Figure 5. Source : " <http://titanaerospace.com> "

# DO YOU HAVE ANY QUESTIONS ?



Figure 6.

# Ressources

- E. Kuiper and S. Nadjm-Tehrani.

*Mobility models for uav group reconnaissance applications. In Wireless and Mobile Communications, 2006. ICWMC '06. International Conference on, page 33, July 2006.*

"<http://dept-info.labri.fr/~desbarat/PER/sujets/Autefage1-article.pdf> "

[1] && [2] : A. Jardosh, E. M. Belding-Royer, K. C. Almeroth, S. Suri. Towards Realistic Mobility Models for Mobile Ad Hoc Networks. 9th annual International Conference on Mobile Computing and Networking. September 2003. ACM Press

[3] A. K. Saha, D. B. Johnson. Modeling Mobility for Vehicular Ad Hoc Networks. First ACM Workshop on Vehicular Ad Hoc Networks. October 2004. ACM Press

[4] J. A. Sauter, R. Matthews, H. V. D. Parunak, S. A. Brueckner. Performance of Digital Pheromones for Swarming Vehicle Control. Fourth International Joint Conference on Autonomous Agents and Multi-Agent Systems. July, 2005. ACM Press