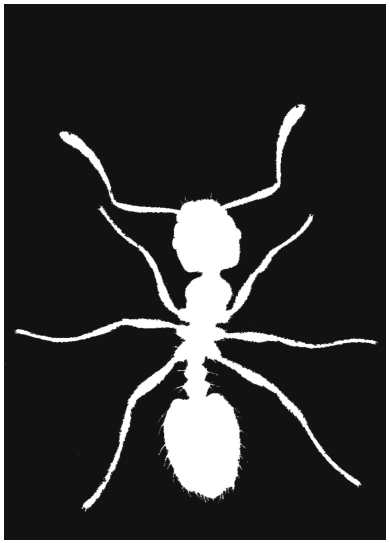
Virtual Ant Colonies per la segmentazione di oggetti



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CAD for Lung Cancer? (y 2003)

- **5 years survival rate for lung cancer: 14% (US), 10-15% (EU)**
- **no improvement in the past 20 years**

  - Low dose CT: 6 times more efficient than Chest X-Ray (CXR) in the detection of state I malignant nodules

  - **CAD methods are being explored**

  - **Gurcan et al., Med. Phys. 29(11), Nov. 2002, 2552:**

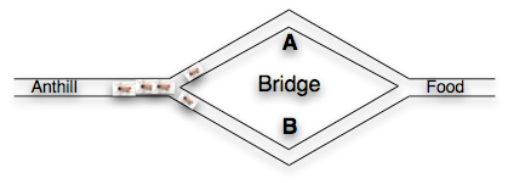
"...computerized detection for lung nodules in helical CT images is promising... large variations in performance, indicating that the computer vision techniques in this area have not been fully developed. Continued effort will be required to bring the performances of these computerized detection systems to a level acceptable for clinical implementation."

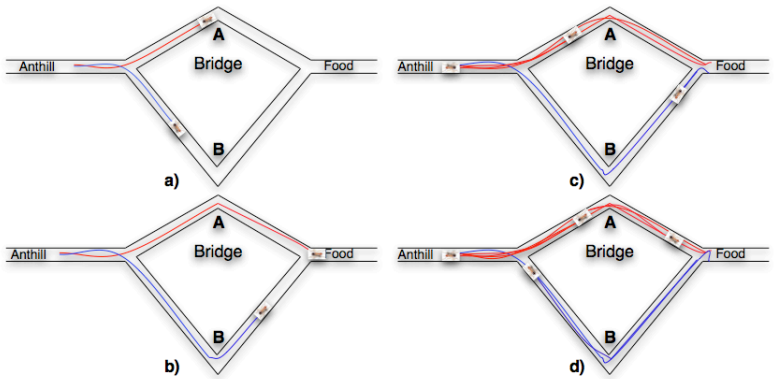
What is a Virtual Ant Colony?

- **Virtual Ant** - an independent agent that evolves in the environment according to some (biological) rules
- **Virtual Ant Colony** - community of individuals & **Queen**

- Ants ***do not*** interact with each other directly
- Ants communicate through modifications of the environment - i.e., ***pheromones deposition***

- Ants live in a *n-dimensional* world where they can:
  - **Sense and release pheromones**
  - **Move**
  - **Reproduce**
  - **Die**

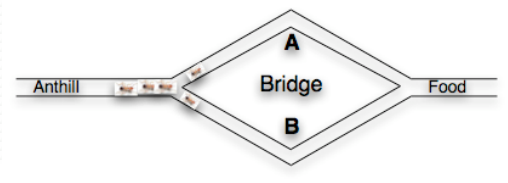


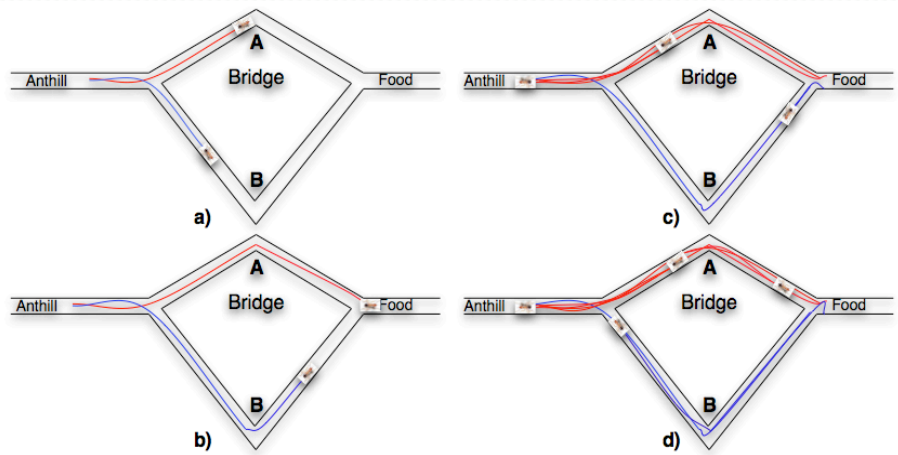


What is a Virtual Ant Colony?

- The colony evolves according to its (biological) rules
- There is no central control on the colony
  - the Queen only implements the rules

- An Ant Colony is an efficient, robust and flexible NON LINEAR system



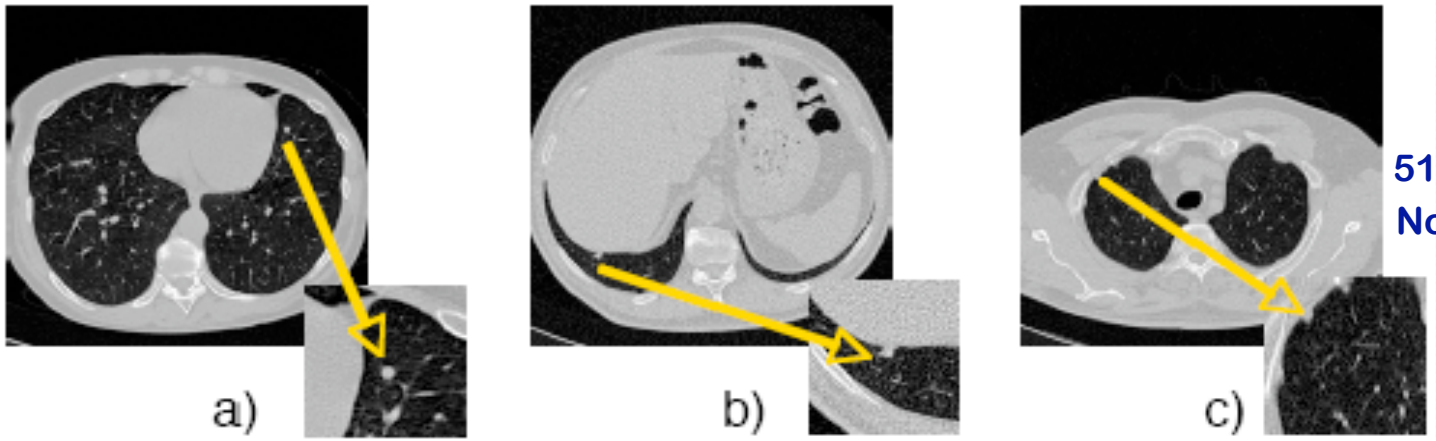


Why Virtual Ant Colonies?

- Ants in nature show an ability to
  - detect structures
  - find the shortest (i.e., most efficient) way to reach them

- Virtual Ants can be used to segment the vascular/bronchial trees in lung CTs
  - … once identified, the trees are removed and a filter can look for nodules in a more friendly environment (i.e., with much less possible false positives)

- The final goal is a Computer Assisted Detection system



Lung CT
150 - 450 slices
512x512 pixels/slice
Nodules > 3mm size

Virtual Ant Colonies

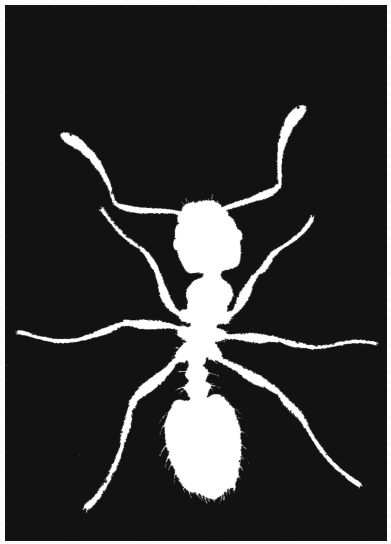
- **Virtual Ant models existed in 2D**

- **… we developed a new model, called Channeler Ant Model (CAM), for a 3D environment:**

  - **Definition of the model rules for the colony evolution**
  - **Model deployment on known structures**
  - **Performance validation**
  - **Results on lung CTs**

The Channeler Ant Model

- **The Queen**
  - Sets the anthill position
  - Keeps the global knowledge
  - Extinguishes the colony



- **The Ants**
  - Move
  - Sense and Release pheromones
  - Change their energy (birth, life, death)

The Channeler Ant Model

- **Moving rules**
  - **Only neighbouring free voxels are possible destinations**
  - **Voxels exceeding the maximum amount of pheromone are forbidden**
  - **The probability for a voxel to be selected is a function of the amount of pheromones in that voxel**
  - **The actual choice is made by a *roulette wheel* extraction**

$$P_{ij}(v_i \rightarrow v_j) = \frac{W(\sigma_j)}{\sum_{n=1}^{26} W(\sigma_n)}$$

σ Pheromone density

β Osmotropotaxis sensitivity

$1/\delta$ Sensory capacity

$$W(\sigma_j) = \left(1 + \frac{\sigma_j}{1 + \delta \cdot \sigma_j}\right)^{\beta}$$

$\beta = 3.5$
$\delta = 0.2$

Values from literature

The Channeler Ant Model

- **Pheromones release**
  - **Before moving to another voxel, ants release pheromones according to the following rule**

$$T = \eta + H_{fac} \cdot \Delta_{ph}$$

$\eta = 0.01$
$H_{fac} = 2.0$

η is the minimum released amount of pheromone
(only to distinguish visited pixels from others)

H_{fac} is an amplifying constant
(related to the required algorithm speed)

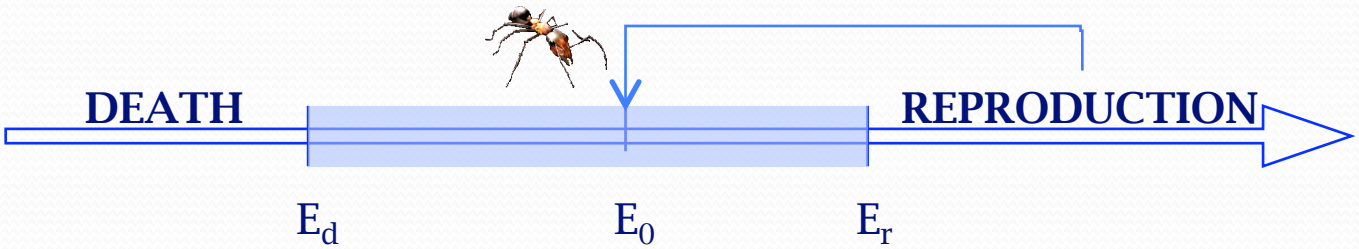
Δ_{ph} is related to the **local properties**, i.e. the voxel intensity

for Lung CTs $\Delta_{ph} = I(v_i)$

The Channeler Ant Model

- **Birth, life, reproduction, death**
  - At birth, the ant energy is set to a default value $E_0 = 1 + \alpha$
  - At each step, the energy changes according to the environment properties $\alpha = 0.2$
  - Below the minimum energy, ants die
  - Above the maximum energy, ants reproduce and their energy is reset

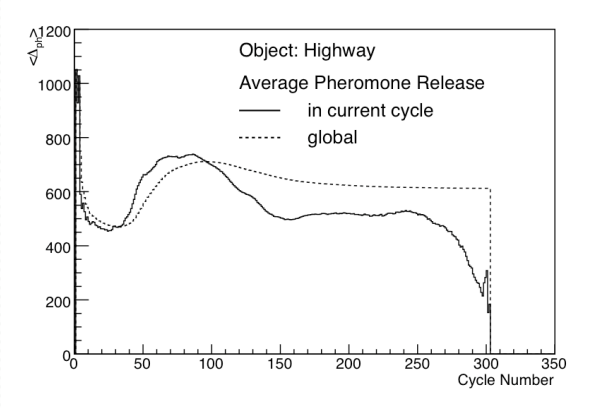
$E_d = 1.0$
$E_0 = 1.2$
$E_r = 1.3$



The Channeler Ant Model

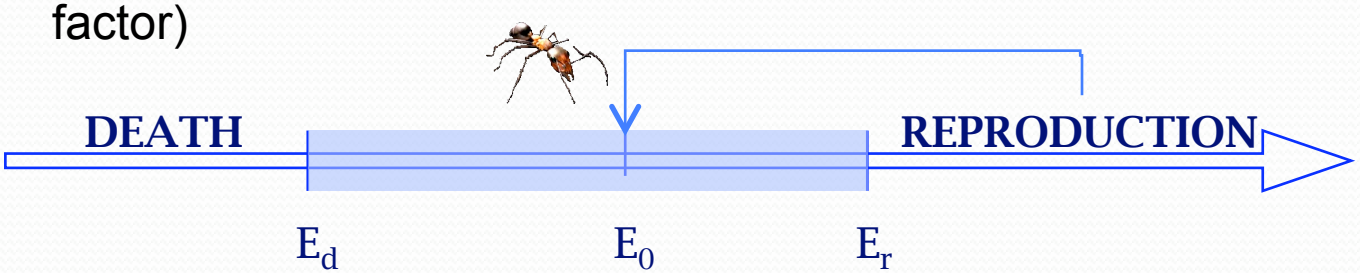
- **Birth, life, reproduction, death**
  - **The energy variation for ant *k* goes as follows**

$$E_{i+1}^{k} = E_{i}^{k} - \alpha + \alpha \cdot \frac{\Delta_{ph}^{k}(i+1)}{< \Delta_{ph} >_{tot}}$$

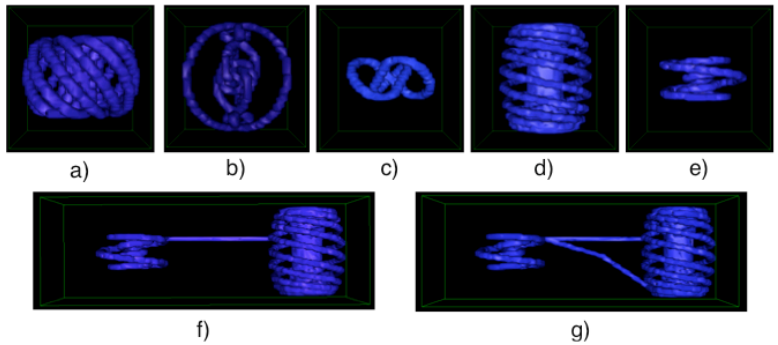


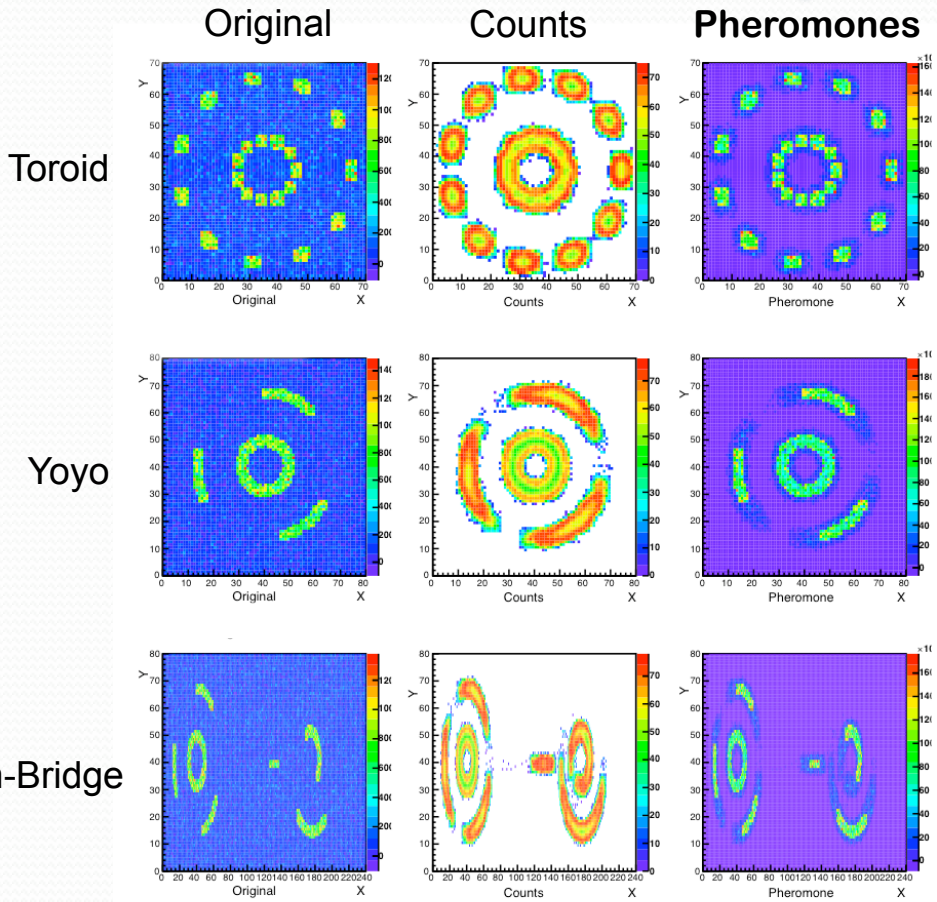
$\Delta_{ph}^{k}(i+1)$ is the pheromone release in the current cycle

$< \Delta_{ph} >_{tot}$ is the average pheromone release, since the colony started to evolve (i.e., a normalisation factor)



Model Deployment





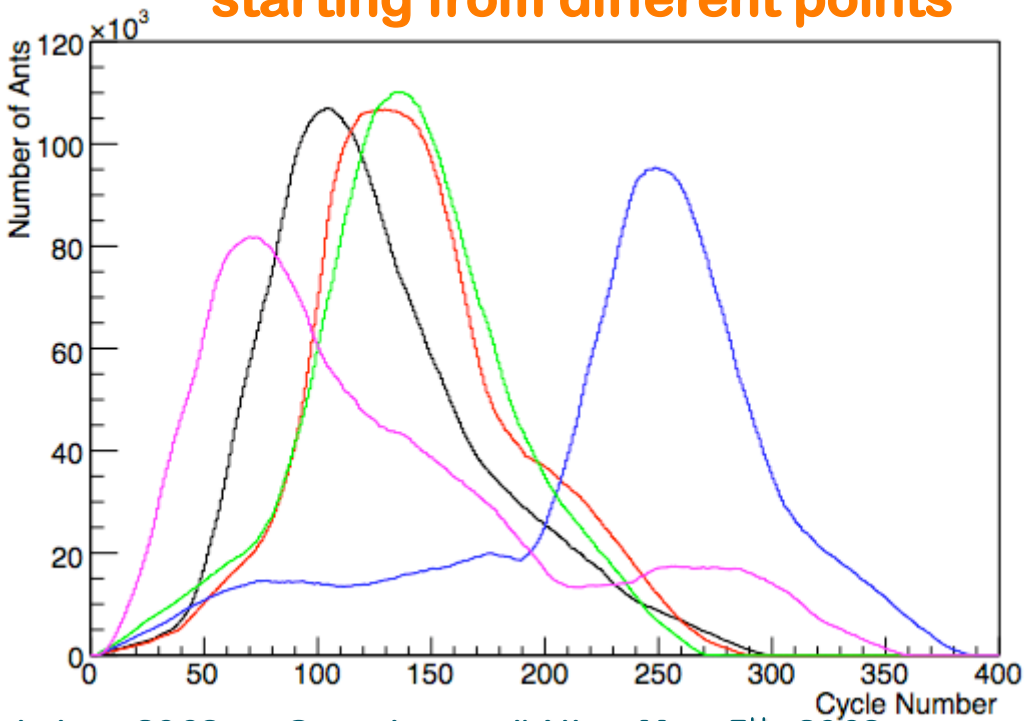
- **On known structures of different**
  - **shape**
  - **dynamic range**
  - **background levels**

	Signal	Background
A)	Flat	no
B)	Gaussian	no
C)	Gaussian	Gaussian

Results

- **The segmentation is independent of the anthill position although the evolution pattern is different**

Segmentation of a 2-Arm-Bridge starting from different points

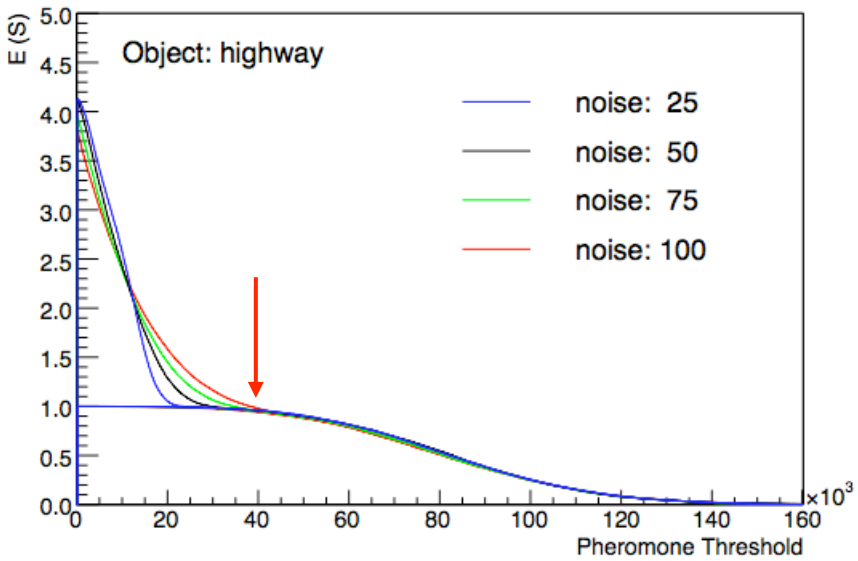


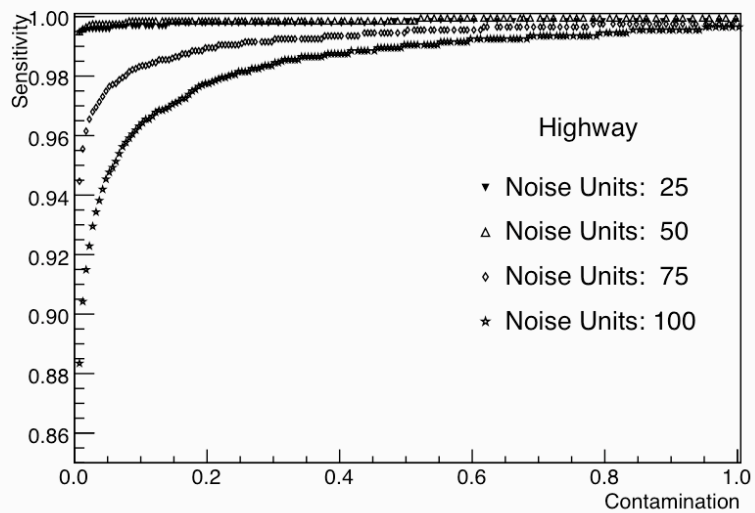
Results

- **The "contamination" (segmented voxels not belonging to the object) decreases with the pheromone threshold and depends on the noise level**

Segmentation of a highway with different noise levels

Exploration (E)
Sensitivity (S)

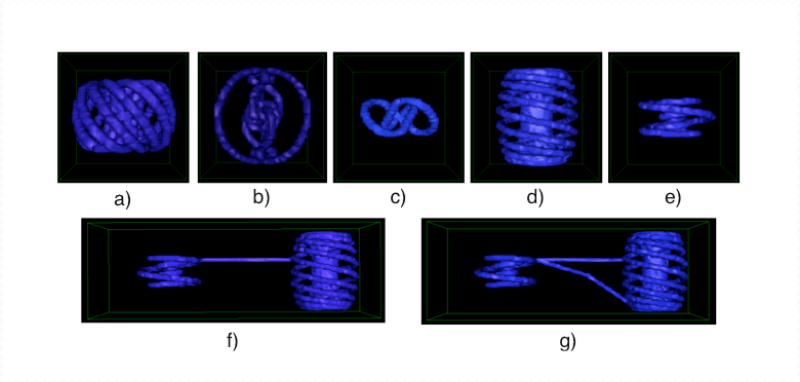


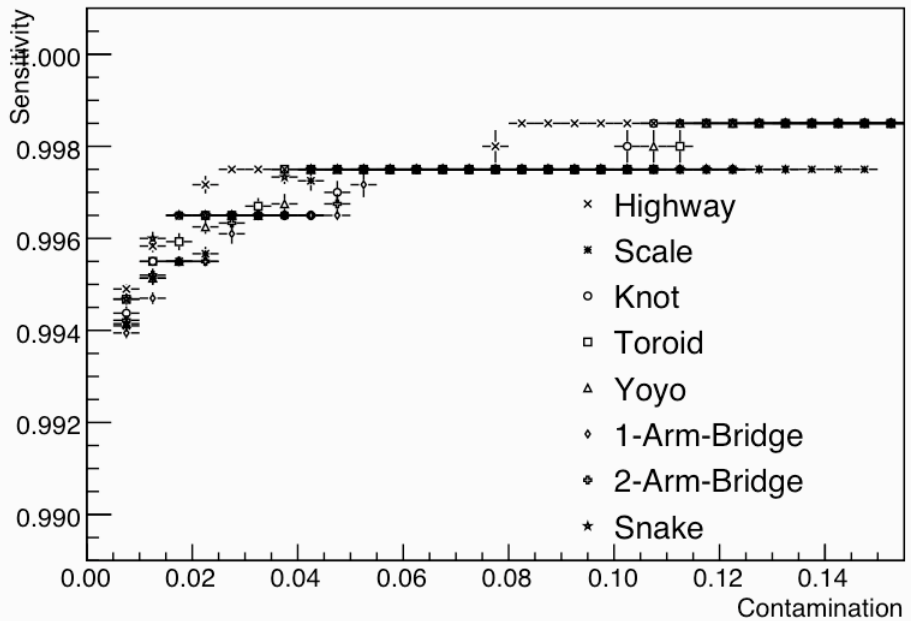


Results

- **The performance does NOT depend significantly on the object shape**

Segmentation of a objects with different shapes

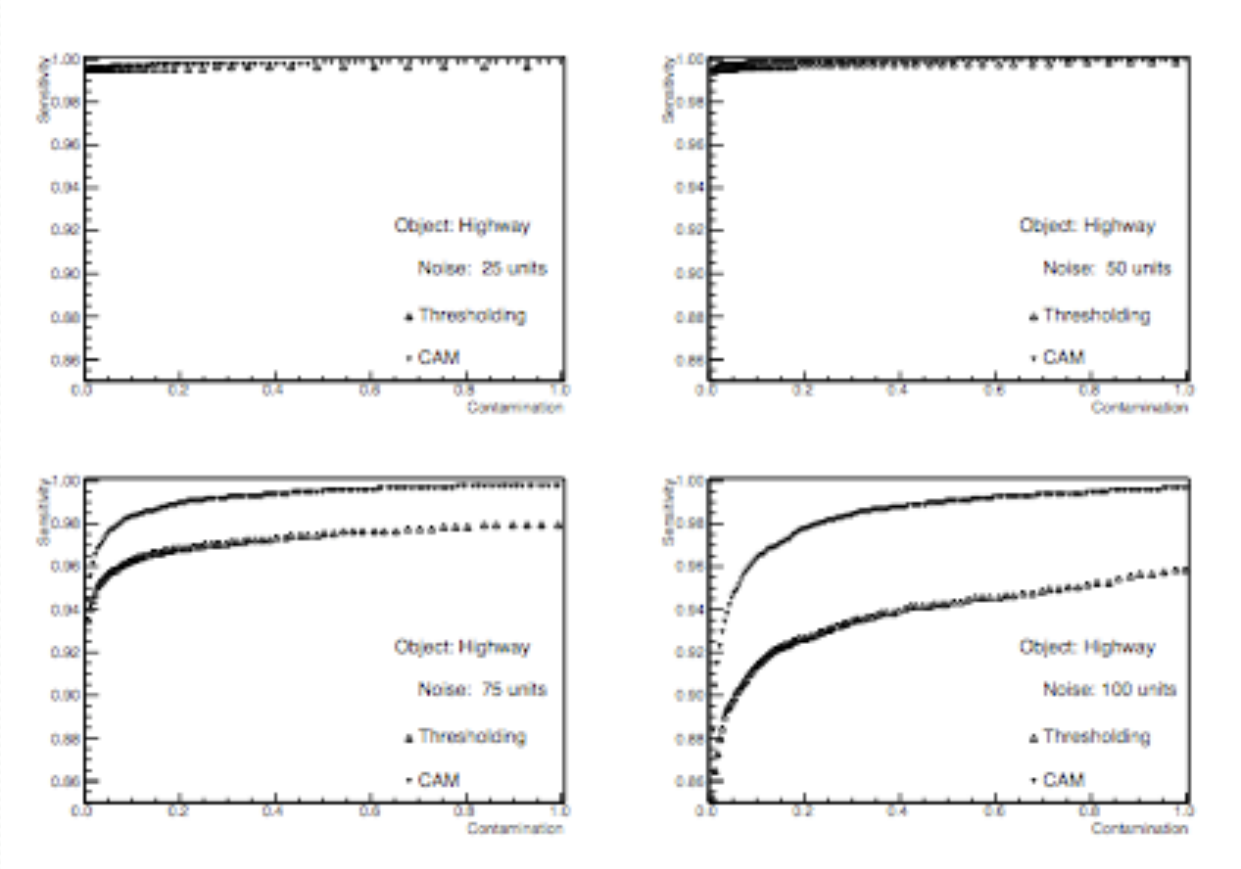




Results

- **Is the CAM better than other methods?**

Comparison of CAM
With Simple Thresholding



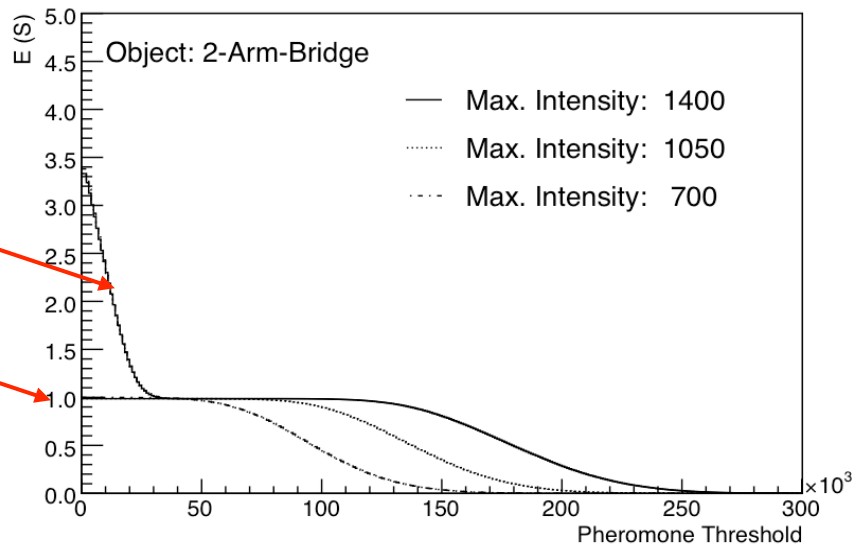
Results

- **The "contamination" (C = E – S, segmented voxels not belonging to the object) decreases with the pheromone threshold and does not depend on the intensity range**

Segmentation of a 2-Arm-Bridge with different intensity ranges

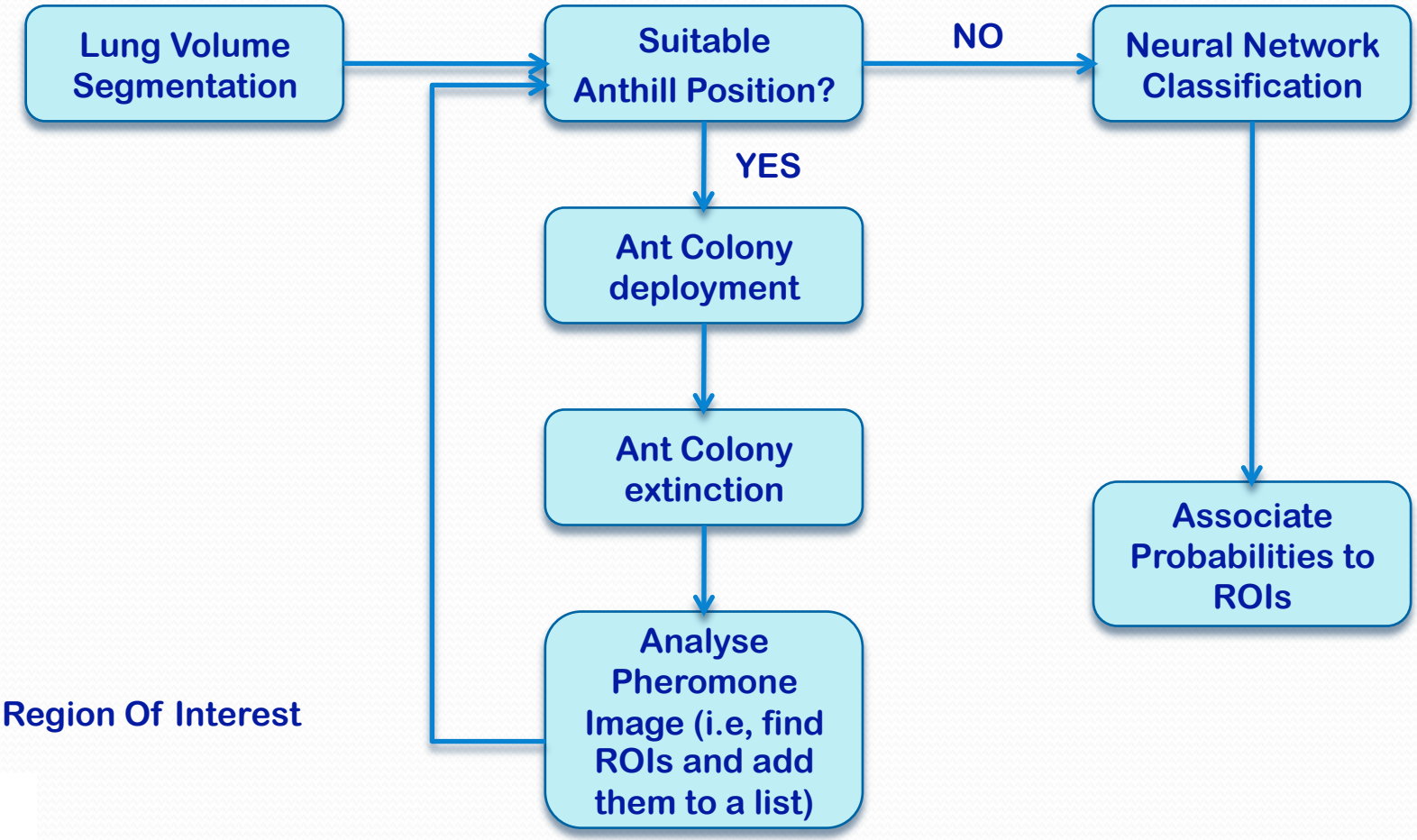
Exploration (E)

Sensitivity (S)



Virtual Ants in a lung CT

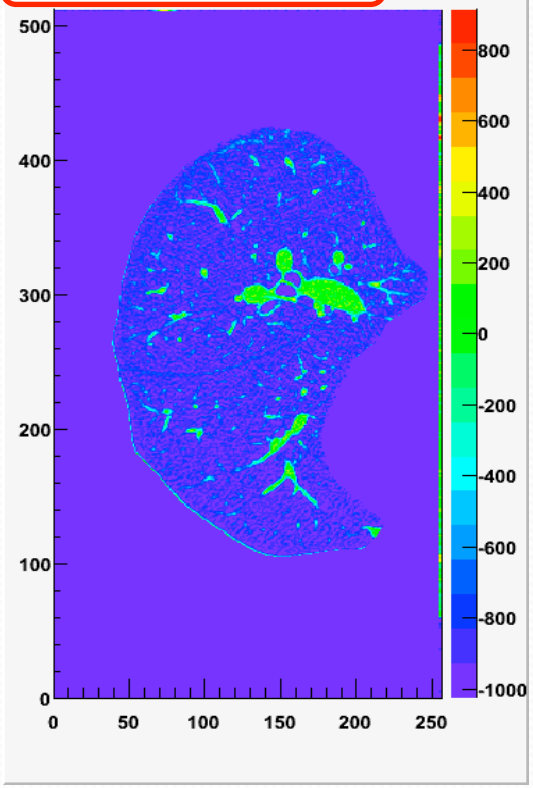
- **The algorithm structure for lung CT analysis**



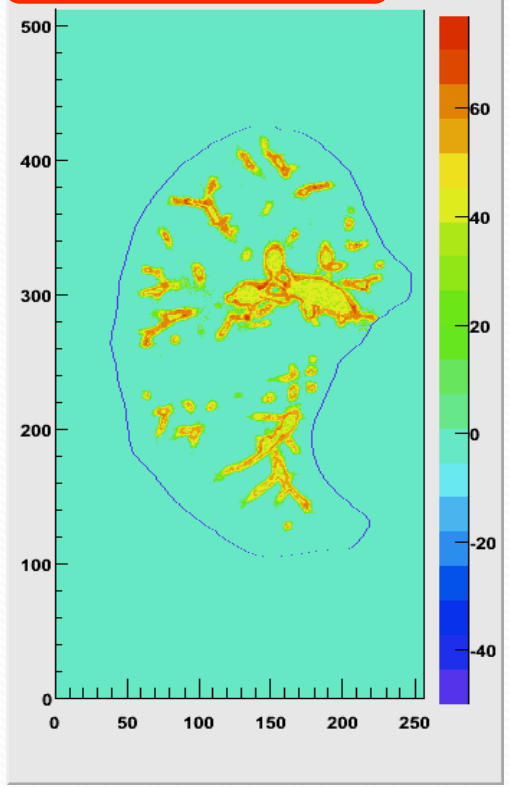
ROI : Region Of Interest

Virtual Ants in a lung CT

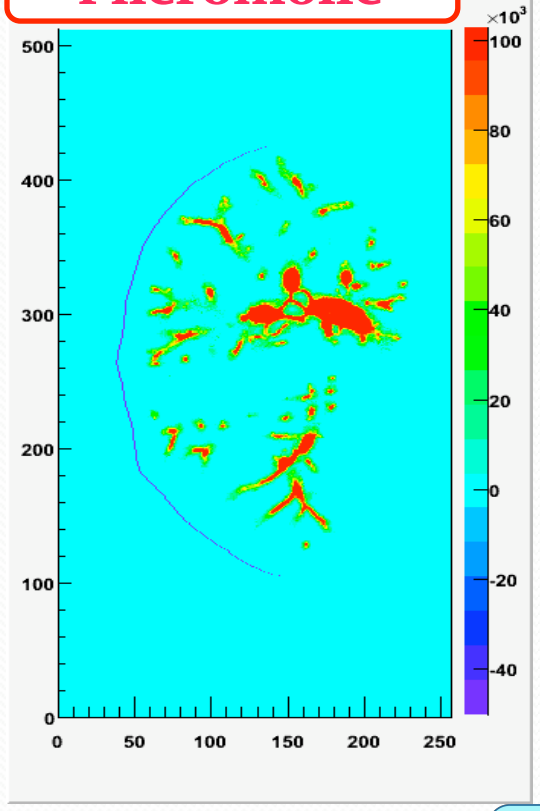
Original



Counts

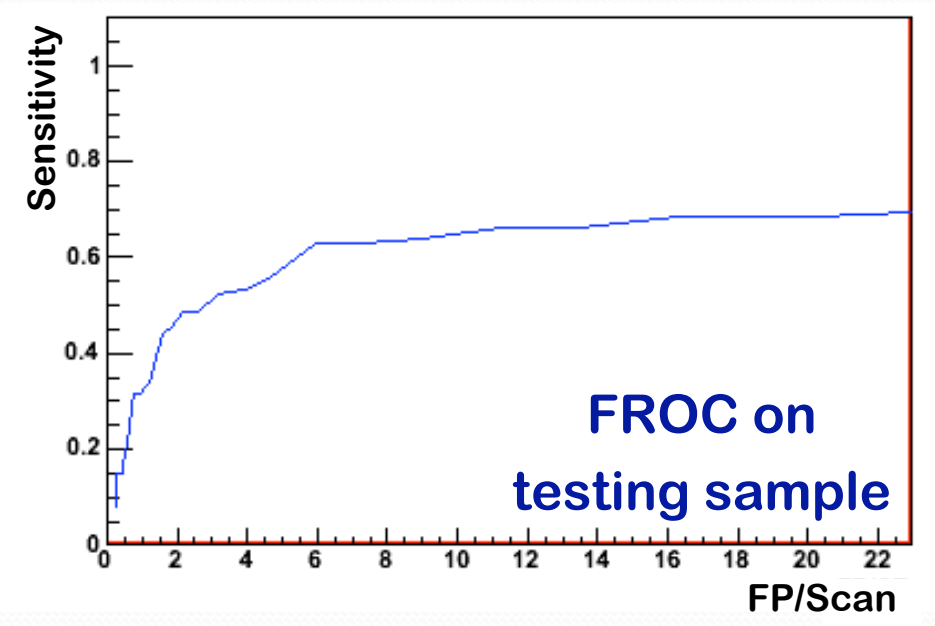


Pheromone



Virtual Ants in lung CTs

- **On the MAGIC-5 Database**
  - **Training sample**
  - **50 scans (testing sample)**



Virtual Ants in lung CTs

- On the ANODE Database
  - 5 known (for testing)
  - 50 unknown scans
  - Open international competition

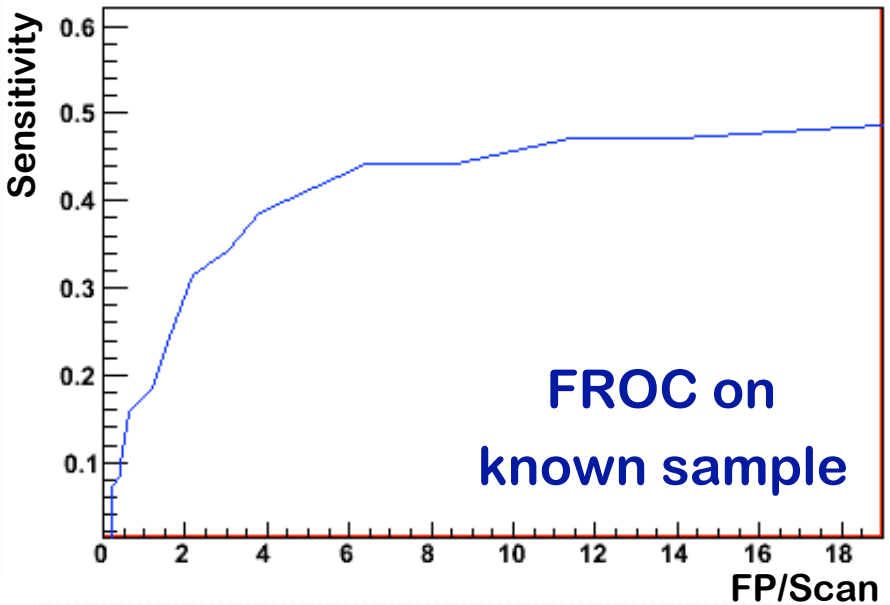


Figure of merit:
S(1/8) + S(1/4) + S(1/2) + S(1) + S(2) + S(4) + S(8)

Ants score on unknown sample:
1.82 (3rd)
Top score: 2.10
(also MAGIC-5 ☺)

Summary

- The **Channeler Ant Model** is a general tool for the investigation of complex systems (i.e., images)
  - lung CTs
  - vehicles flow optimisation
- It is designed in a general way
  - few free parameters
  - intrinsic normalisation
- It is (already) competitive at the international level as a CAD for lung CTs
  - … and there is room for improvements ☺

- Is it meaningful to use it for fiber tracking?