University of Strathclyde
Advanced Space Concepts Laboratory

Micro-rover workshop
Brown Uni – Strathclyde Uni

frontier research on visionary space systems

Advanced Space Concepts Laboratory

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Scottish...
& PROUD OF IT!
23213554-8
SCOTLAND
The Brave
215548216-01
0068456637-12

Micro-rovers in planetary exploration

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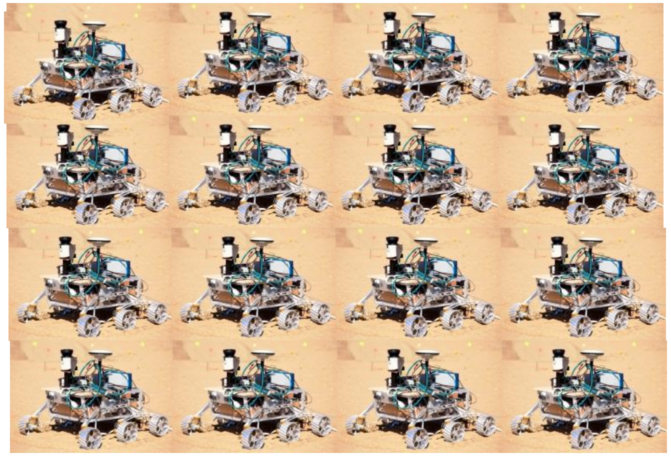
Smaller BUT deployed in larger numbers

- Maximum performance capabilities in minimum size
- Limitation in telecoms



- Multiple site of interest may be studied simultaneously
- Unit costs may be lower due to economies of higher production volumes
- Spare rovers for higher risk operations

Planetary micro-rovers autonomy

University of Strathclyde

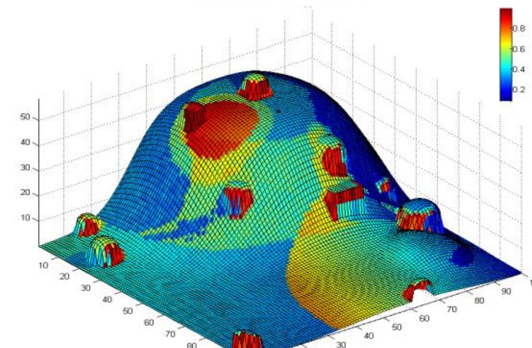
Smaller | Larger numbers | Planetary exploration

Autonomy

- Delay in data transmission
- Telecoms window availability
- Time spent idling waiting commands from Earth

Swarm control

- Multiple rover control
- Path planning



Exploration

- Environment is not known, thus contingencies and uncertainties must be considered by the planner
- Create map of interesting targets
- Goal reallocation is required

Giuliano Punzo

Dr. Derek Bennet

Dr. Malcolm Macdonald

Prof. Colin McInnes

MICRO-ROVER AUTONOMY WITH ARTIFICIAL POTENTIAL FIELD

Bifurcating artificial potential fields

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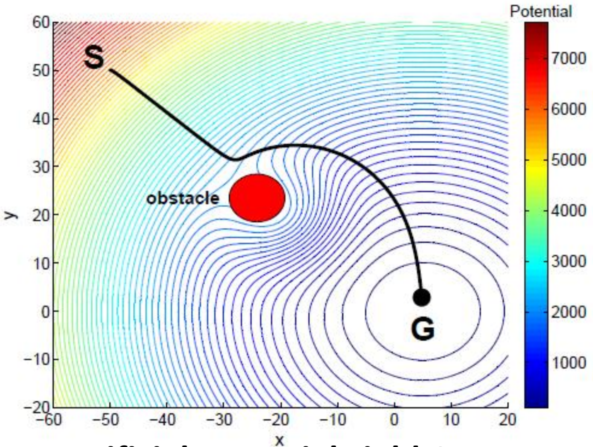
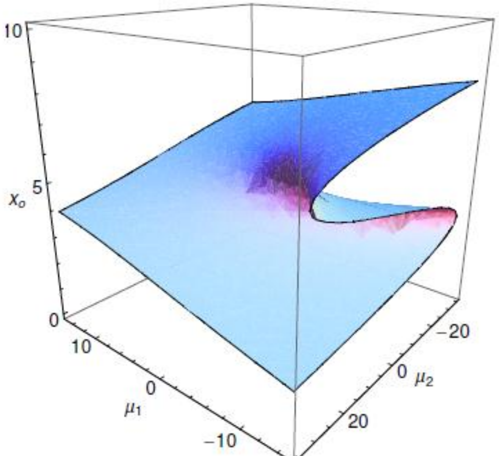
- Autonomous behavioural control architecture to control a swarm robotic system
- Method uses new approach of **Bifurcating Artificial Potential Field**
  - minimum point of potential is the point of attraction of the system
  - classical bifurcation theory is used for reconfiguration of the swarm
- Real safety critical application – stability must be assured
  - method uses **Lyapunov Stability Theory** to verify swarming behaviour



Artificial Potential Field Contour

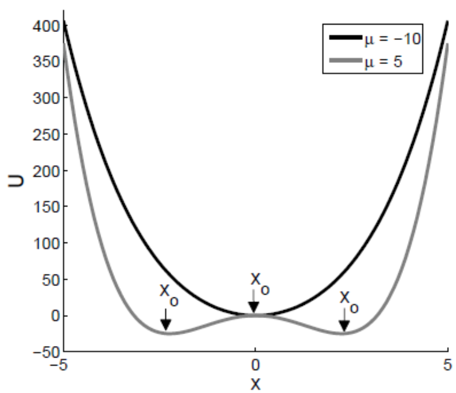


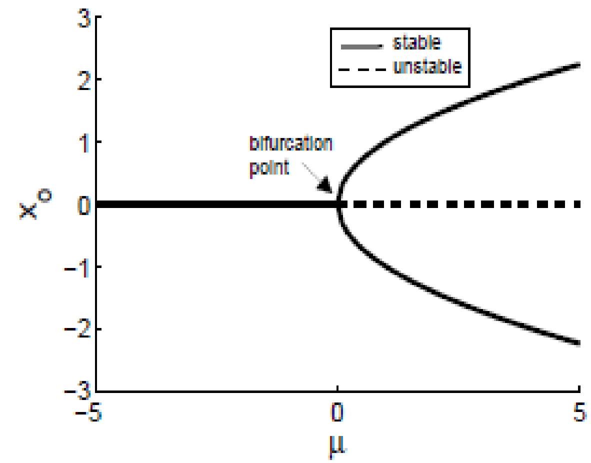
Cusp Bifurcation

Bifurcating artificial potential fields

- Both static and dynamic bifurcation theory considered
- Pitchfork Bifurcation (static) :

$$U = \frac{1}{4}(x-r)^4 - \mu(x-r)^2$$

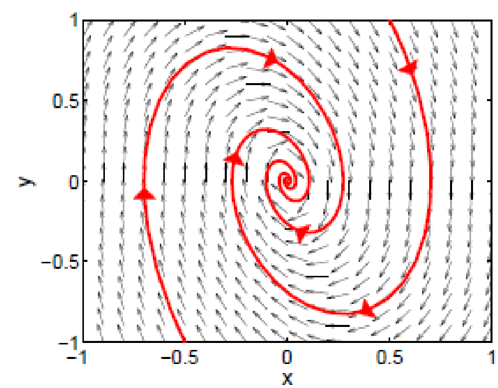




- Lyapunov Stability Theory:

$$L = E_{total}$$

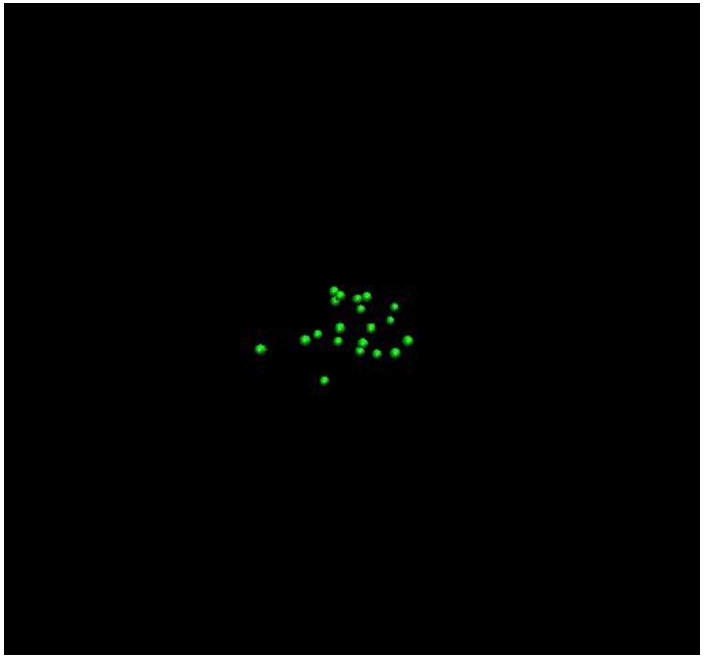
$$\frac{dL}{dt} \leq 0$$



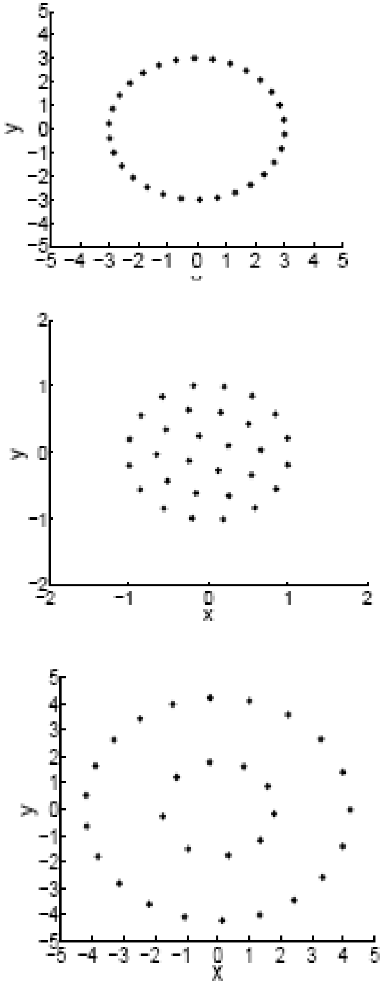
Bifurcating artificial potential fields

RESULTS: AUTONOMOUS SWARM FORMATION

- Simple parameter change (bifurcation) leads to reconfiguration of pattern

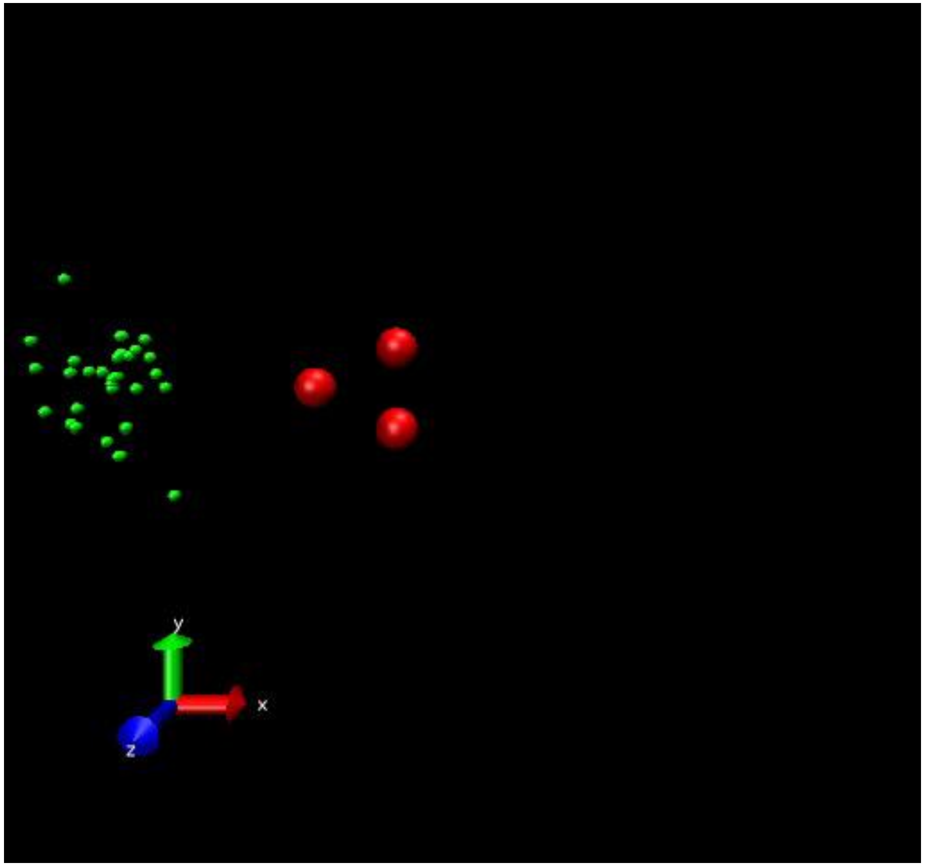


Transitions between simple swarm patterns

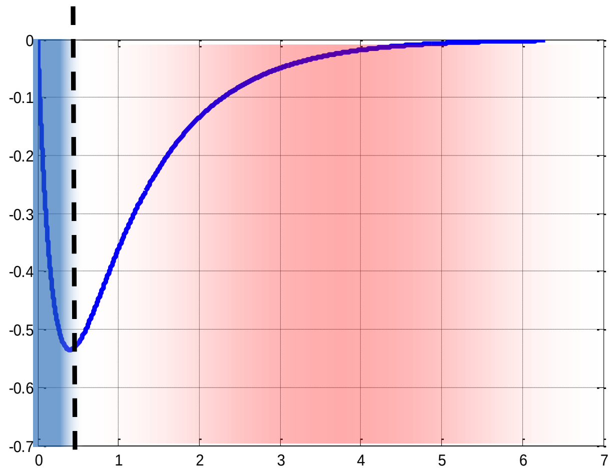


Bifurcating artificial potential fields

OBSTACLE AVIODANCE

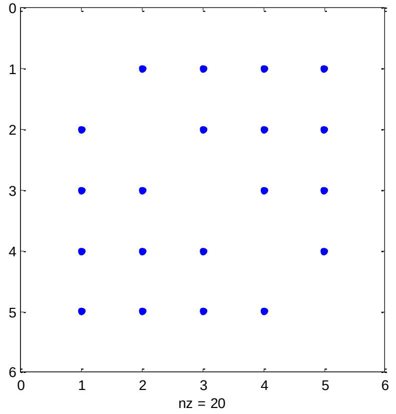


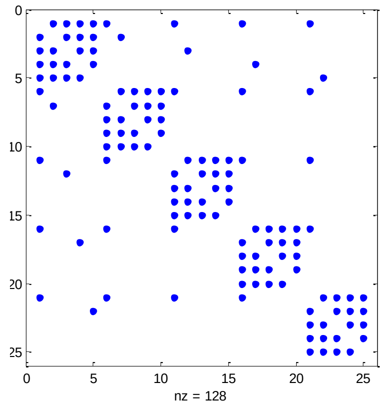
Towards heterogeneous and reliable multi robot exploration



Control relies **Morse Artificial potential** with an asymmetric interaction that produce one single minimum energy configuration while keeping provability of the method.

$$v_i = -\sum_j a_{ij} \nabla U^a\left(x_{ij}\right) + a_{ij} \nabla U^r\left(x_{ij}\right)$$





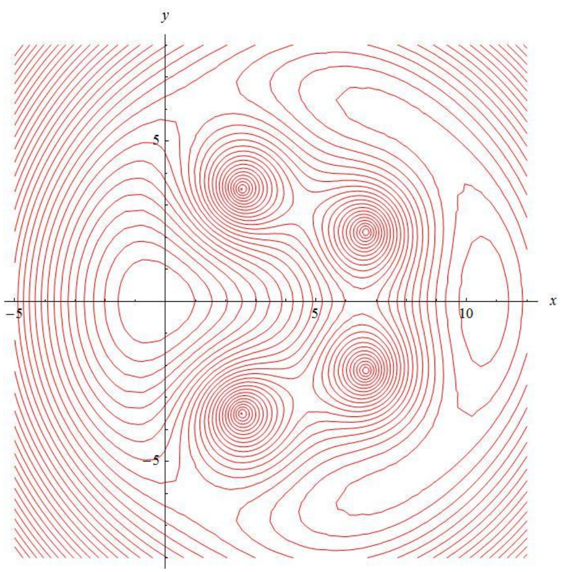
The connection network is carved and allows all-to-all communications for small groups only and more articulated network emerge as the number of agents increases.

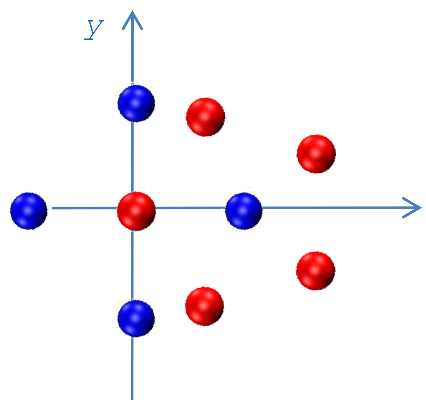
Heterogeneous potentials

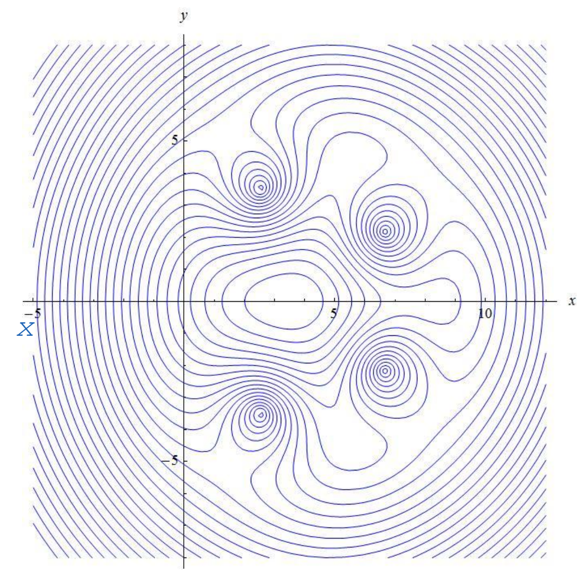
The switching is “provable” and depends on one single agent

$$\frac{dU_1}{dx} = 2\frac{C_a}{l_a}\left(e^{\frac{-d_x}{l_a}}\cos(\alpha) + e^{\frac{-d_{2x}}{l_a}}\cos(\beta)\right) - 2\frac{C_r}{l_r^*}\left(e^{\frac{-d_x}{l_r^*}}\cos(\alpha) + e^{\frac{-d_{2x}}{l_r^*}}\cos(\beta)\right)$$

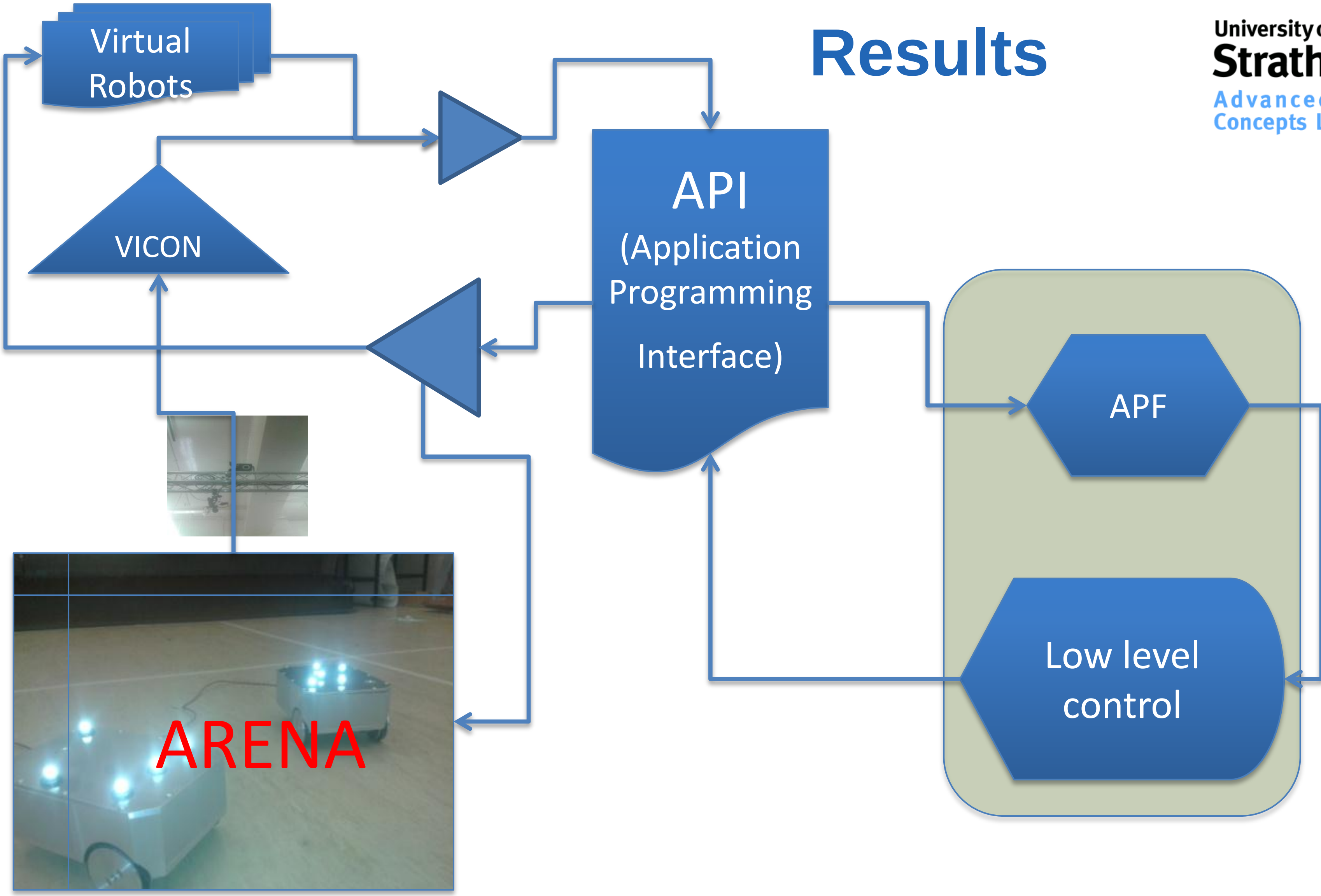
$$\frac{\frac{dU_1}{dx}}{dl_r^*} < 0 \qquad \frac{\frac{dU_1}{dx}}{dC_r} < 0$$



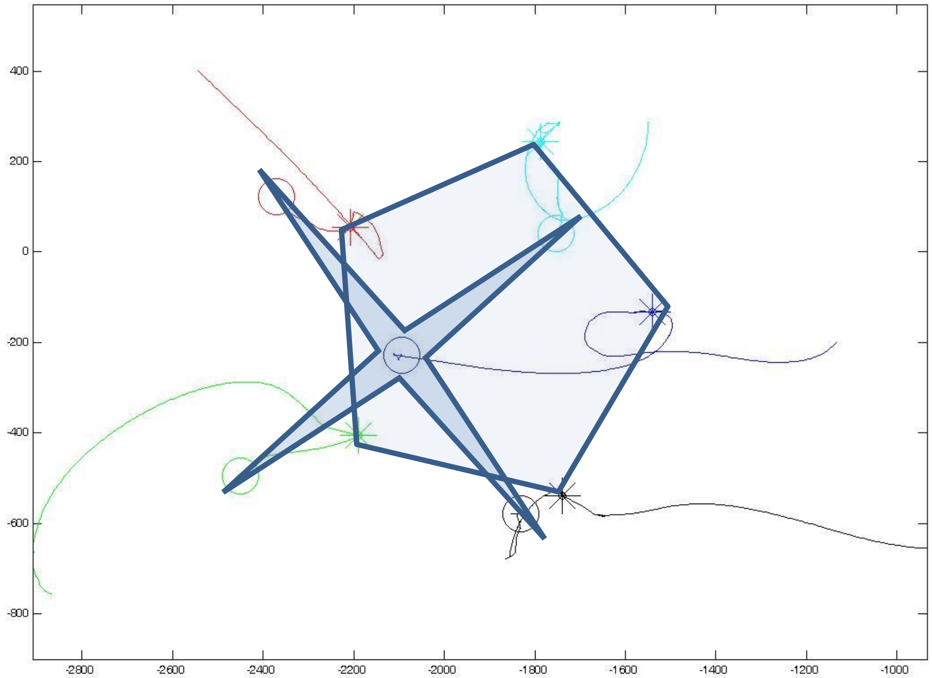




Results


Virtual
Robots
VICON
API
(Application
Programming
Interface)
APF
Low level
control
ARENA

Results



- Convergence within 30mm for a 900 mm cross
- The system is scalable
- Virtual robots can be included in the system to simulate the presence of more agents

Gordon Dobie, Research Centre for Non-Destructive Evaluation

MICRO-ROVER AUTONOMY FOR STRUCTURAL INSPECTION

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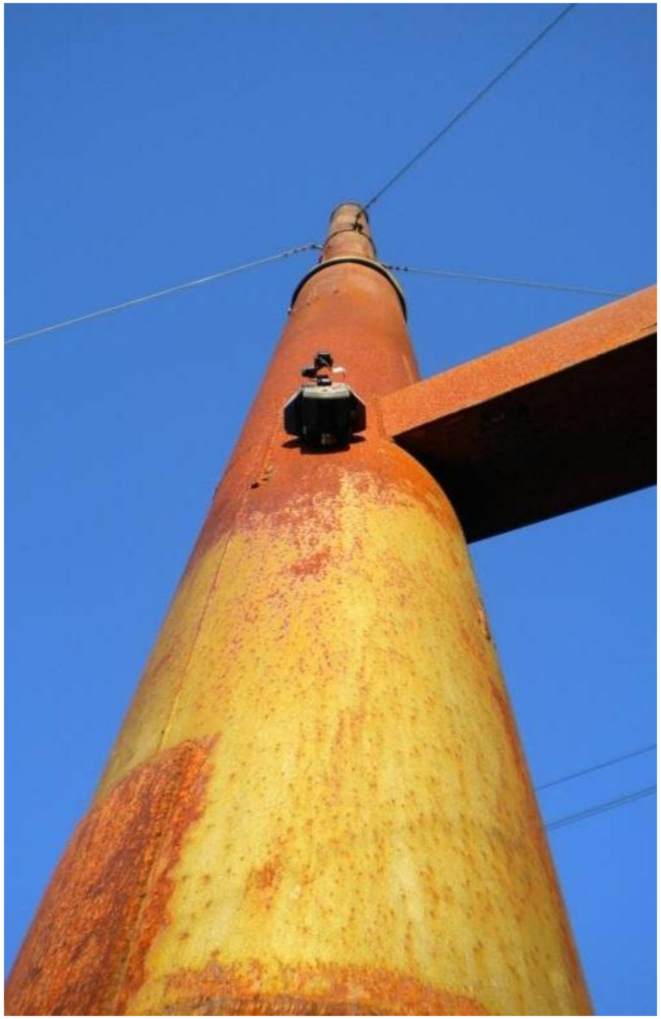
Research Goals

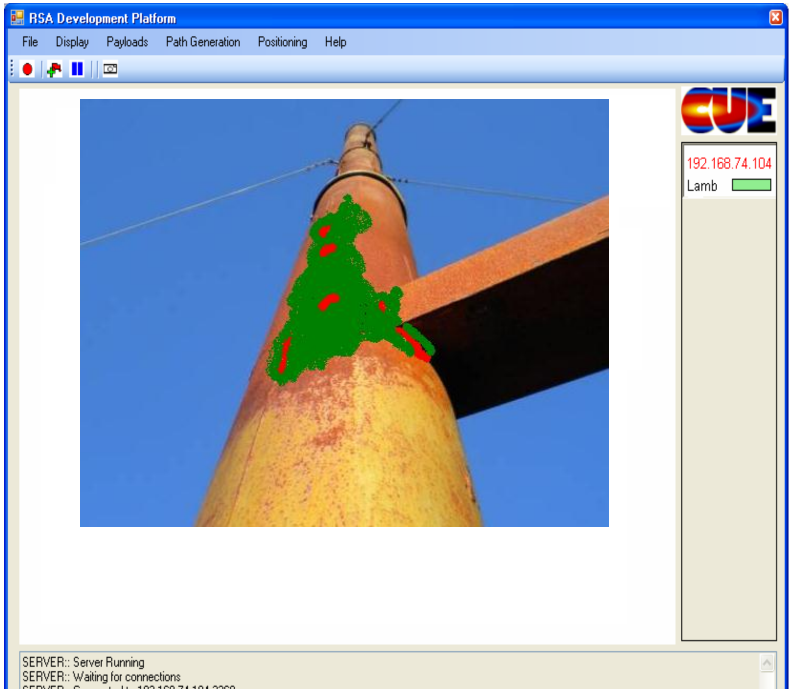
- Inspection with autonomous, miniature robotic vehicles enables:

1. Inspection of restricted access areas
2. Effective coverage of large areas




The Concept




RSA Development Platform
File
Display
Payloads
Path Generation
Positioning
Help
192.168.74.104
Lamb
SERVER:: Server Running
SERVER:: Waiting for connections

Path Planning Requirements

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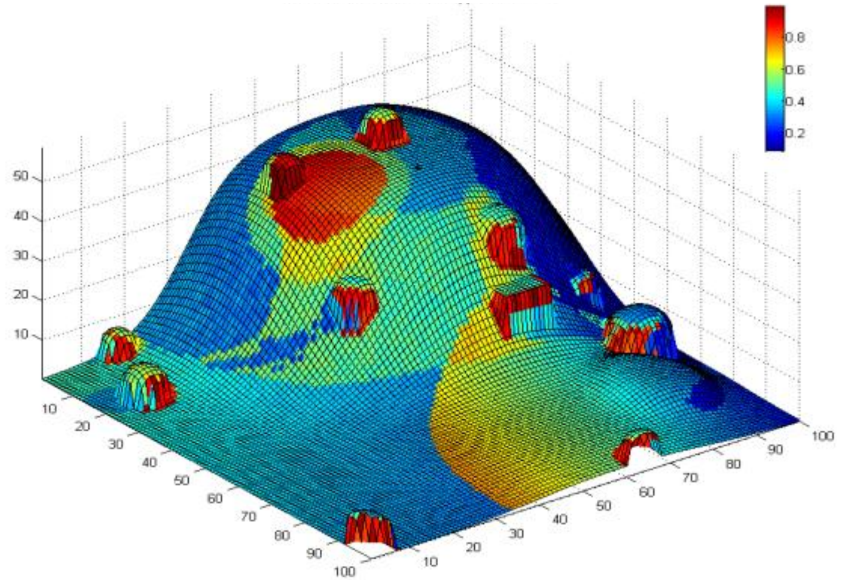
Multi-agent path planning over relatively complex geometries

Full surface coverage

Ability to avoid other agents and obstructions

Tolerance to robot positional uncertainty



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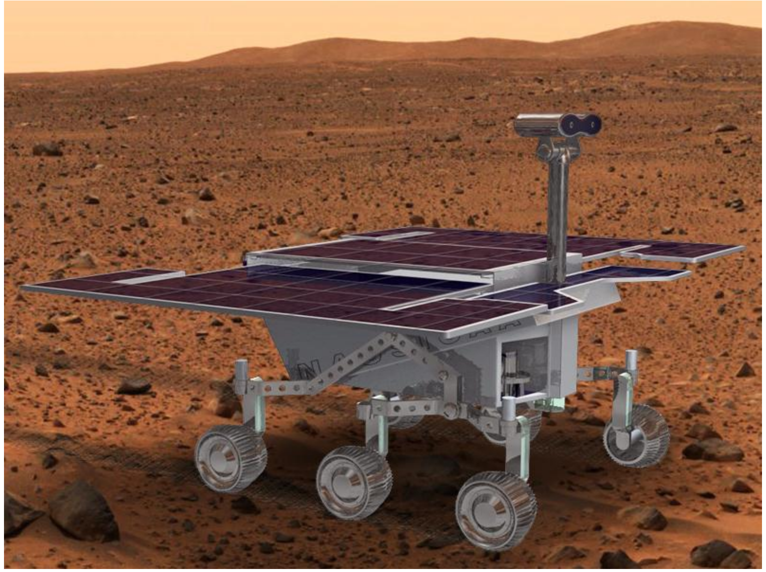
Matteo Ceriotti, Max Vasile, Giovanni Giardini, Mauro Massari

BIO-INSPIRED AUTONOMY FOR UNKNOWN ENVIRONMENTS

Wisdom

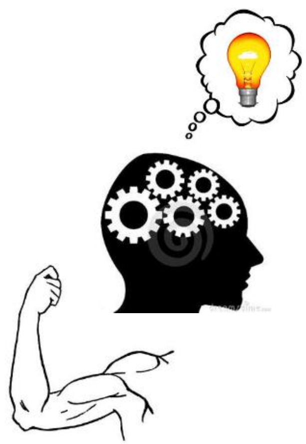
- The Wisdom system is a non-deterministic, deliberative-reactive system for rover autonomy in harsh, unknown environments
- Autonomous goal transformation and reallocation
  - Extremely important in poorly known environments
  - Define mission goals
  - How to reach a given set of goals
  - Cope with contingencies autonomously

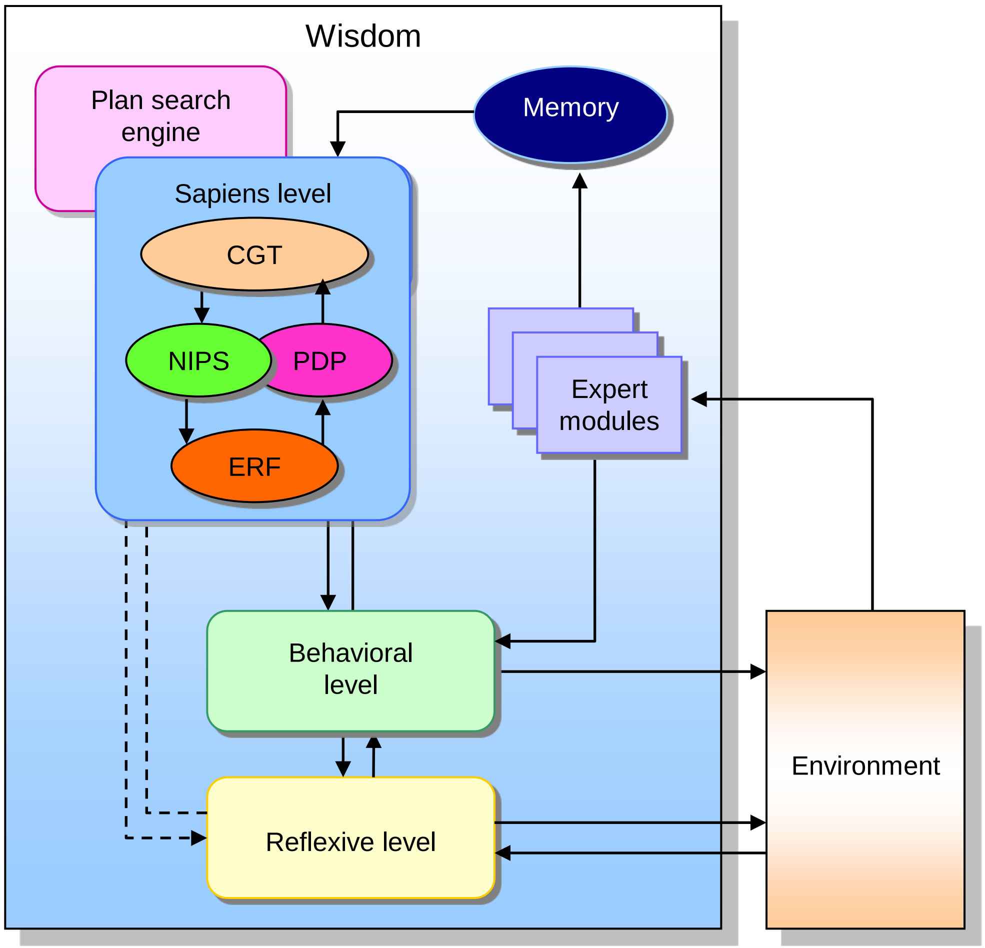


- Developed at Politecnico di Milano, Milan, Italy

Wisdom

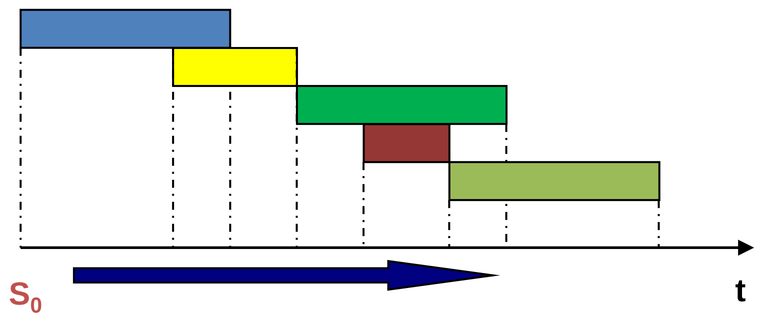
- Bio-inspired autonomy system for unknown environments
- 3 layers:
  - Sapiens
  - Behavioral
  - Reflexive
- Expert modules deal with specific subsystems

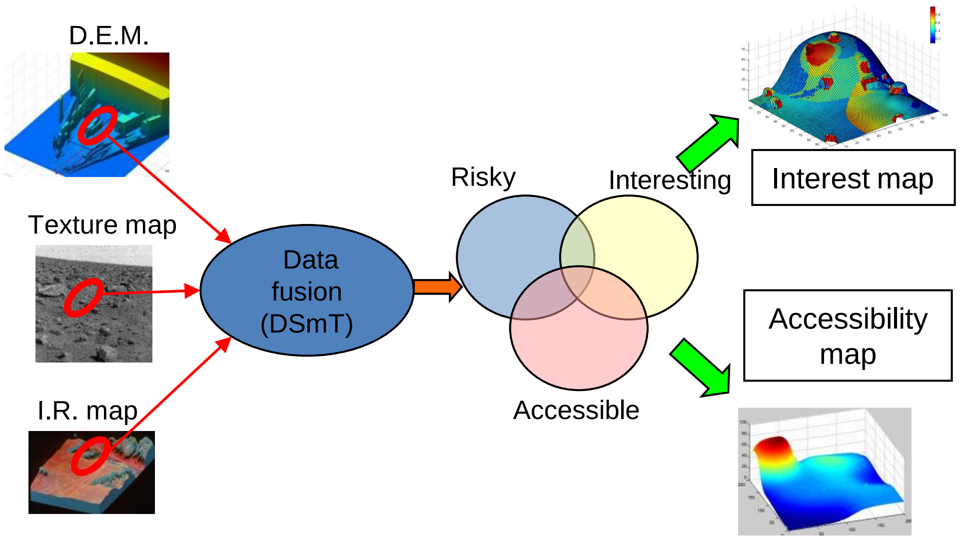




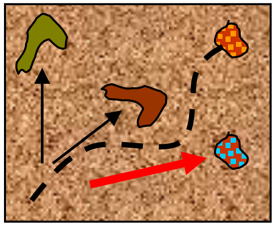
Sapiens layer

- The sapiens layer is a non-deterministic contingency planner based on a coevolutionary multiobjective search engine



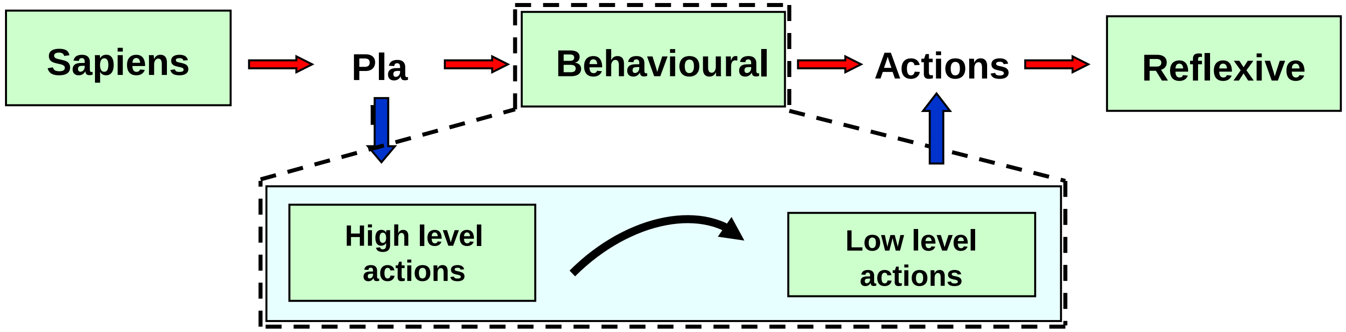


- Data fusion with Theory of Paradoxical Reasoning (DSmT) is used to create interest maps and accessibility maps, to define mission goals

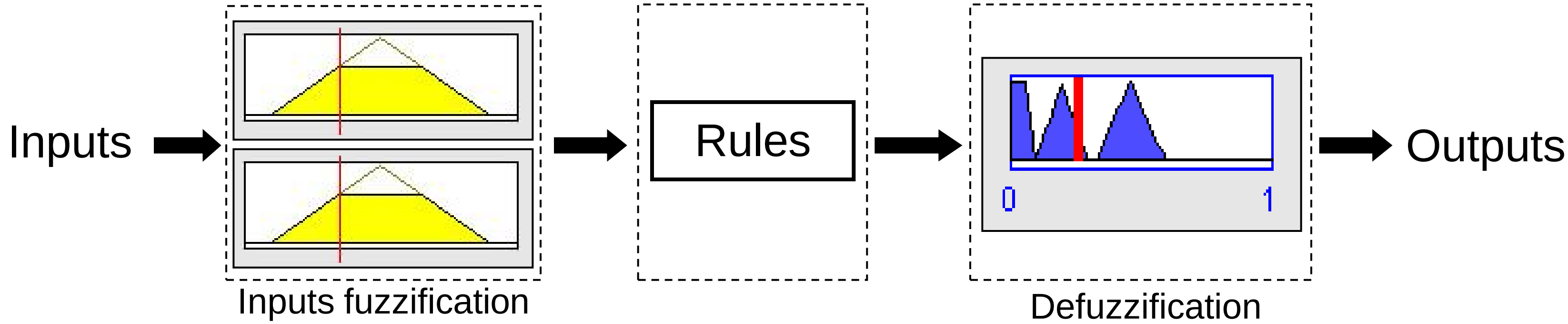


Behavioural layer

- Generate the low level actions in order to accomplish the high level actions that compose the plan

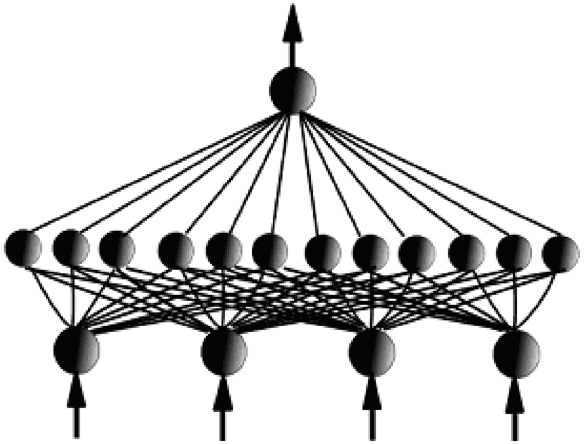


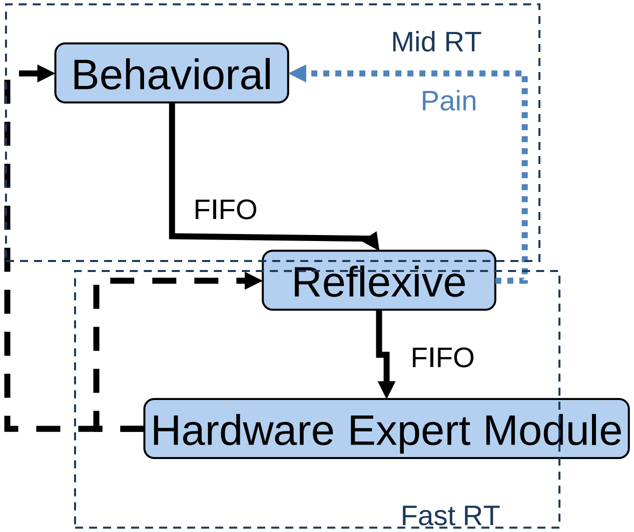
- The high level actions are translated in a set of input suitable for the fuzzy logic control system
  - Rules combine one or more inputs to one or more outputs



Reflexive layer

- Artificial Neural Network (ANN) for hardware interface and control
- Implementation of actions requested by behavioural layer
  - Hardware command trough feedback control
  - Replace PID regulator





- Implementation of reflexive action on short time term
  - Wait command from higher layer
  - Pain-action mechanism for unexpected events

Some references

Micro-rover autonomy using artificial potential field

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Bio-inspired autonomy for unknown environments

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Website: http://www.strath.ac.uk/

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Special thanks to Centre for Ultrasonic Engineering for hosting the link!

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Thank you for you attention!

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