Ants-Inspired Collective Problem Solving

仿螞蟻群體解題

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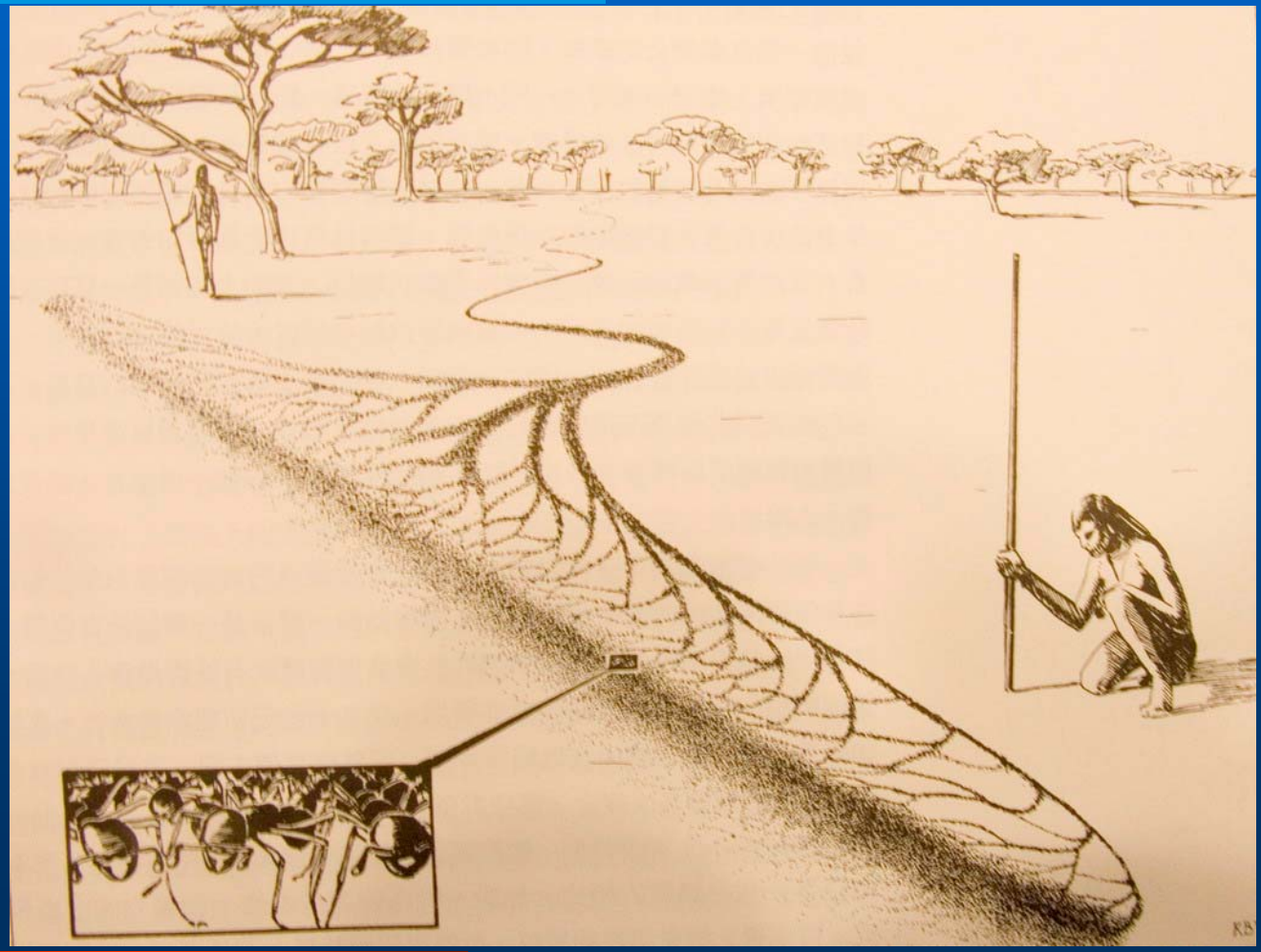
大綱

1. 螞蟻的群體行為(Collective Behavior in Ant Colony)
2. 仿螞蟻群體解題(Ant-inspired Collective Problem Solving)
3. 群體解題的科學認識論(Epistemology)和一點點哲學……

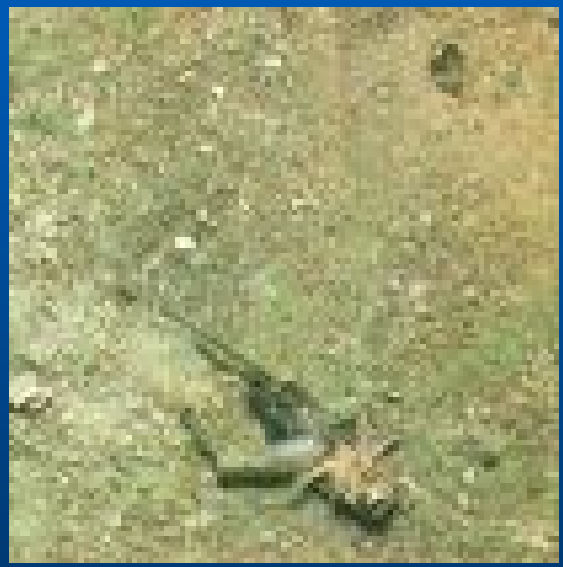
螞蟻的群體行為
Collective Behavior in Ant Colony

Super-Organism Model of Ant Colony

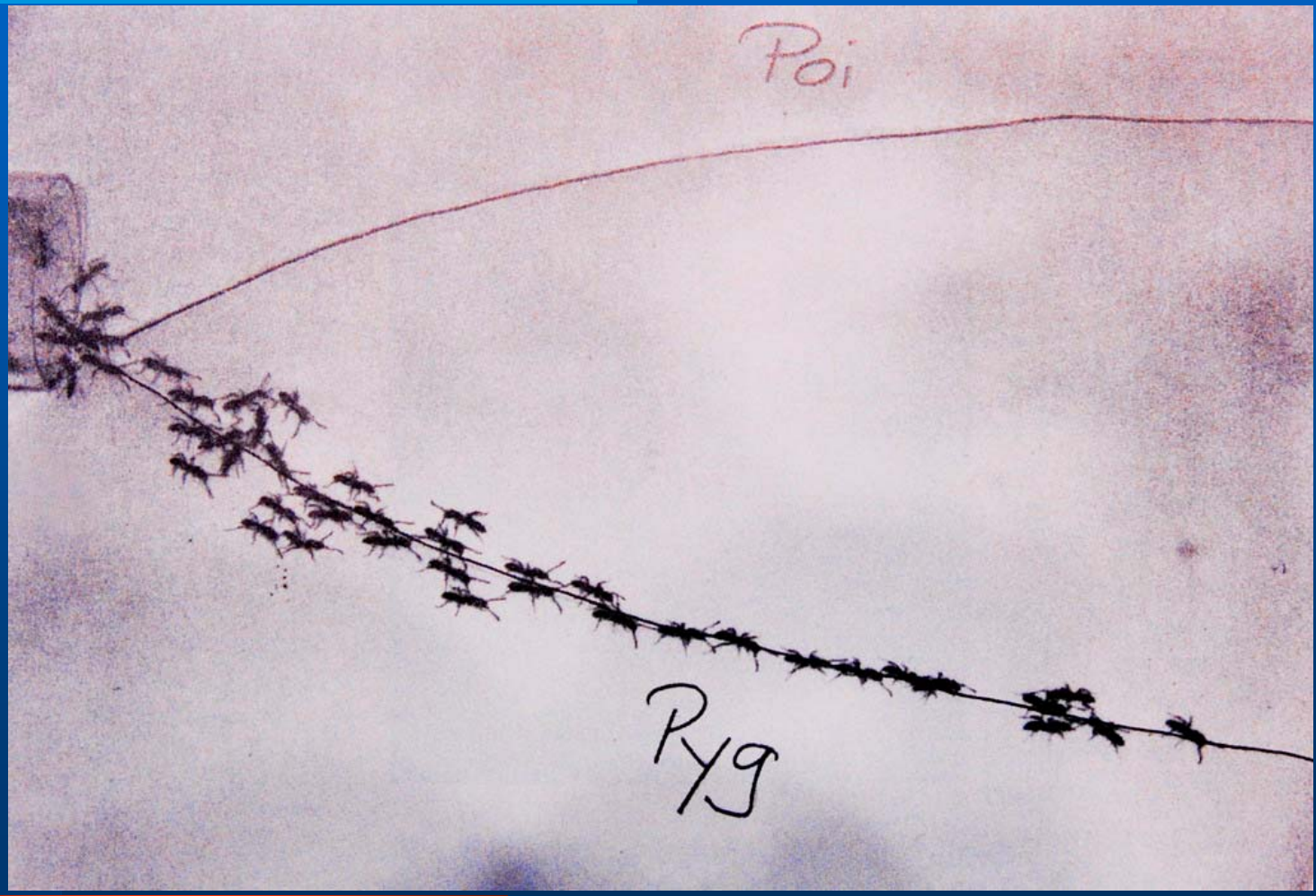


Ant and Ant colony

Problem Solving in Ant colony

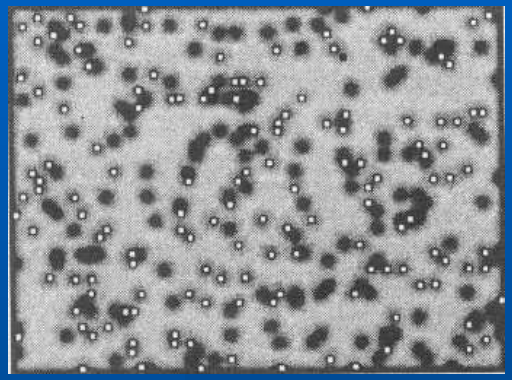


Communication System in Ant Colony

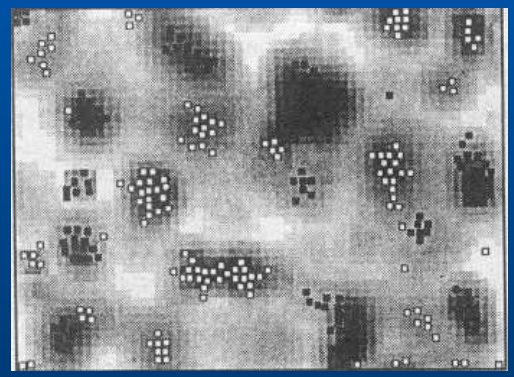


Gathering Behavior in Ant Colony

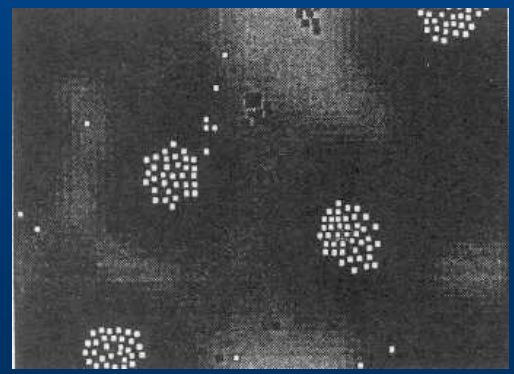
T_1



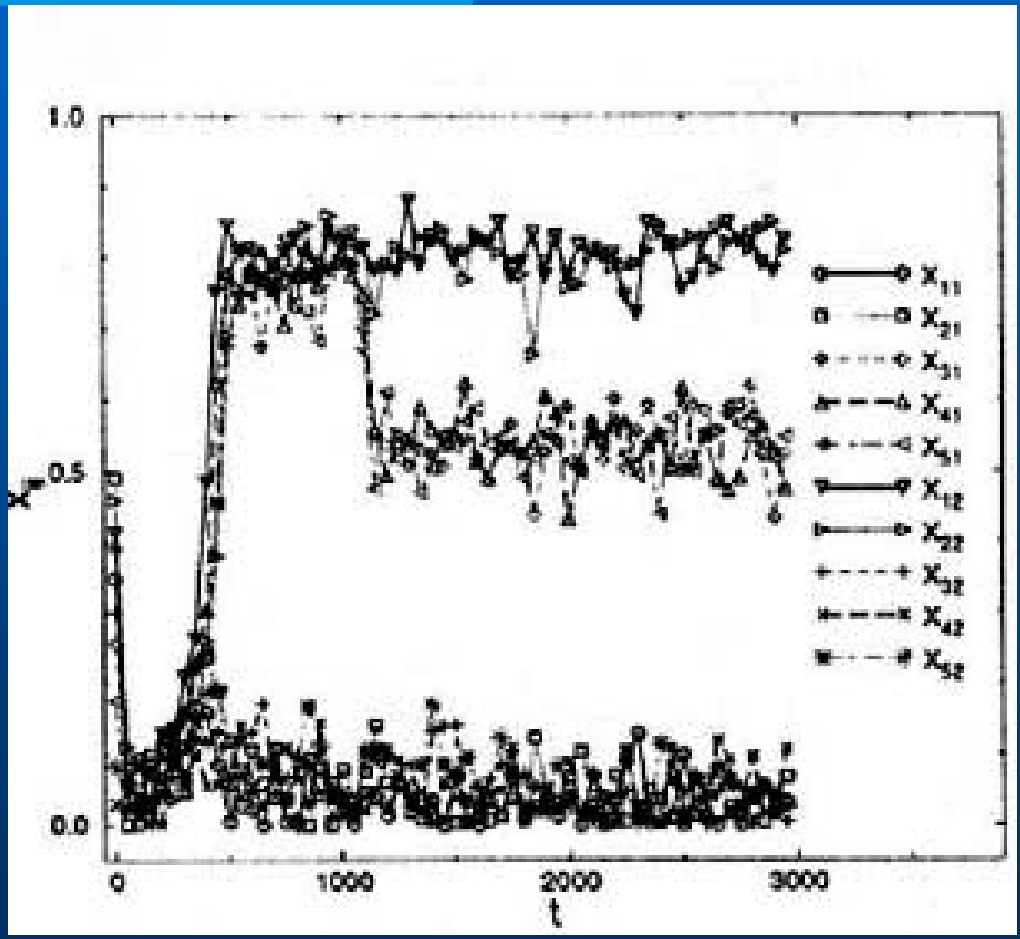
T_2



T_3



Task Allocation in Ant Colony



Nest Building in Ant Colony

Bridge Building in Ant Colony

Bridge Building in Ant Colony

仿螞蟻群體解題
Ant-inspired Collective Problem Solving

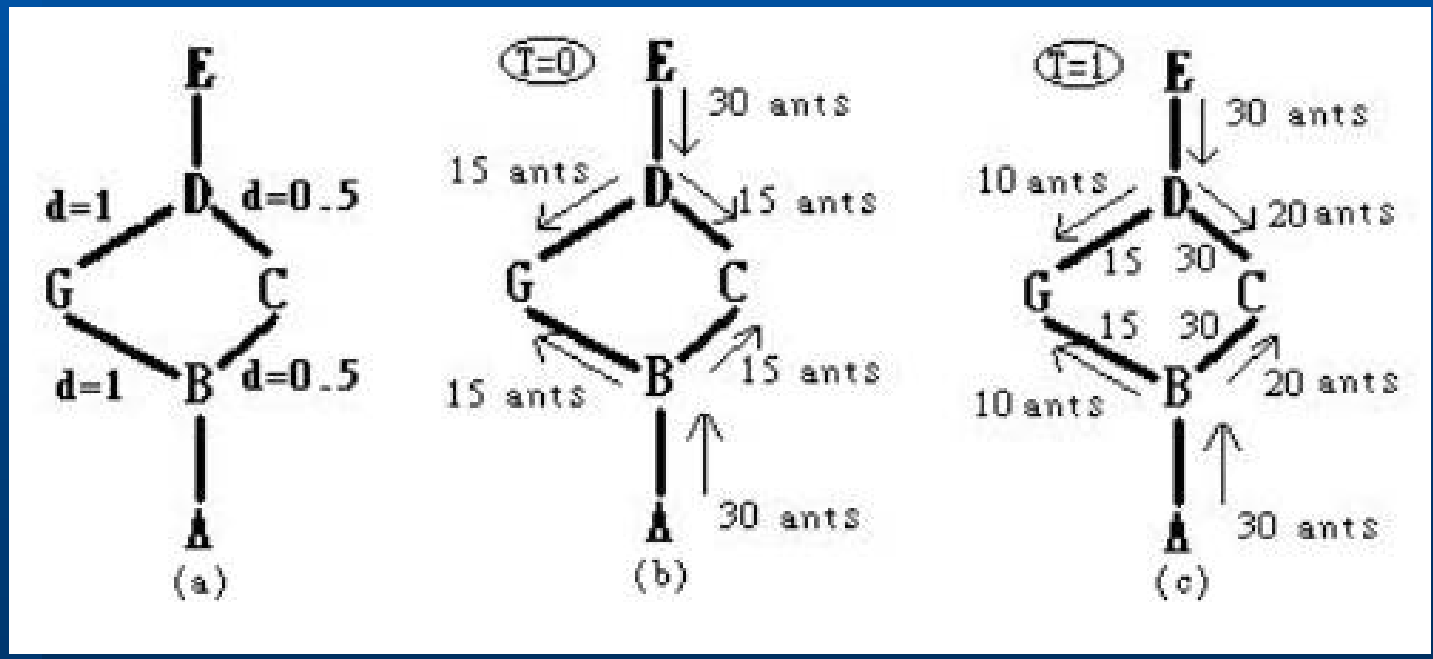
Collective Problem Solving

Collective Problem Solving :

由一群簡單功能的個體(ant)所形成的群體(ant colony)，能夠展現出高可靠度、高適應性的自主化的解決問題的能力。

Foraging Behavior of Ants

當螞蟻在食物和巢物之間來回行走時，會分泌一種化學物質：費洛蒙(pheromone)。當巢穴到食物之間有許多路徑可以選擇時，個別螞蟻將傾向於選擇費洛蒙較強的路徑。



Formalization of Ants foraging

費洛蒙更新

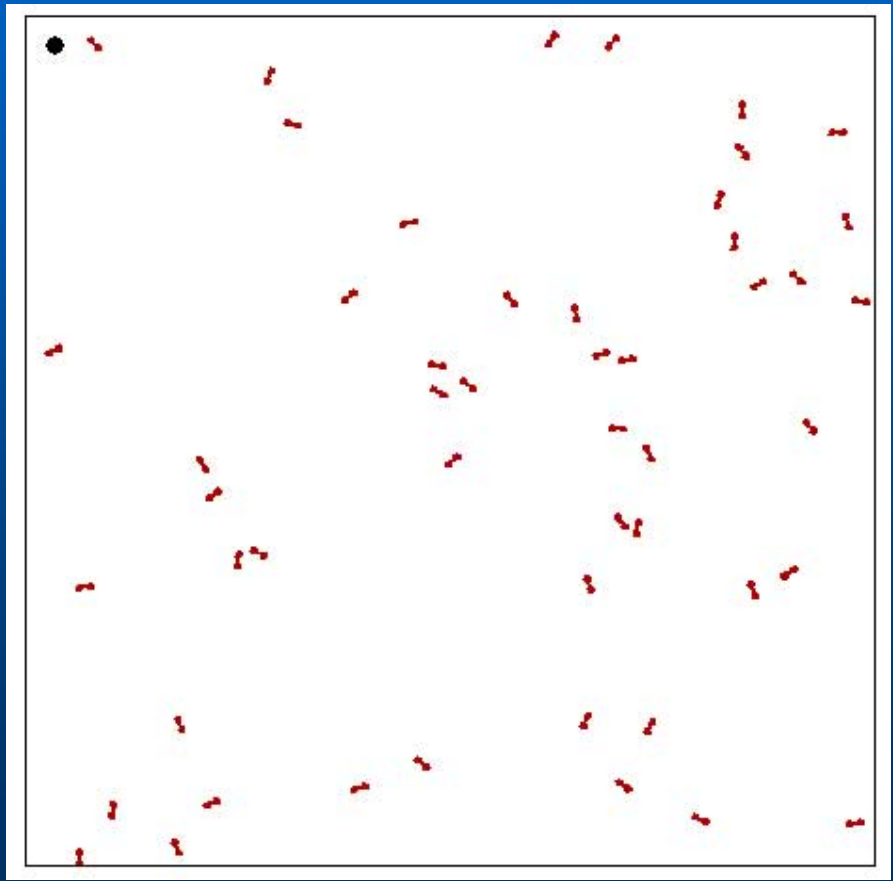
$$\tau_{ij}(t+n) = \rho * \tau_{ij}(t) + \Delta\tau_{ij}$$

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k}$$

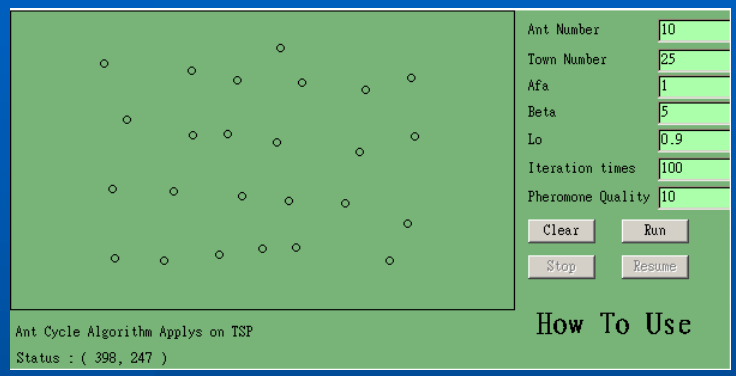
決策機率

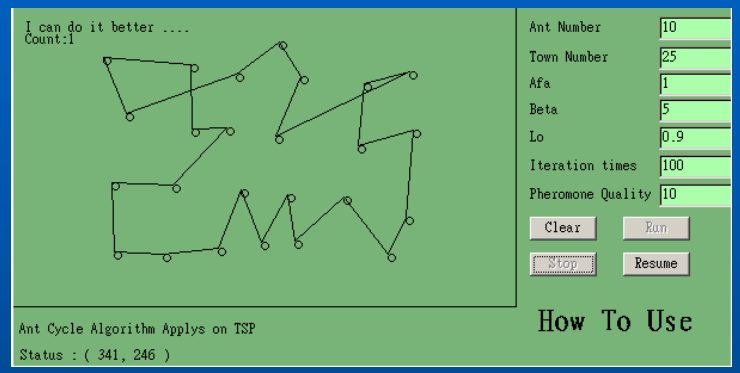
$$p_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum_{l \in \mathcal{N}_i^k} [\tau_{il}(t)]^{\alpha} \cdot [\eta_{il}]^{\beta}} \qquad \text{if } j \in \mathcal{N}_i^k$$

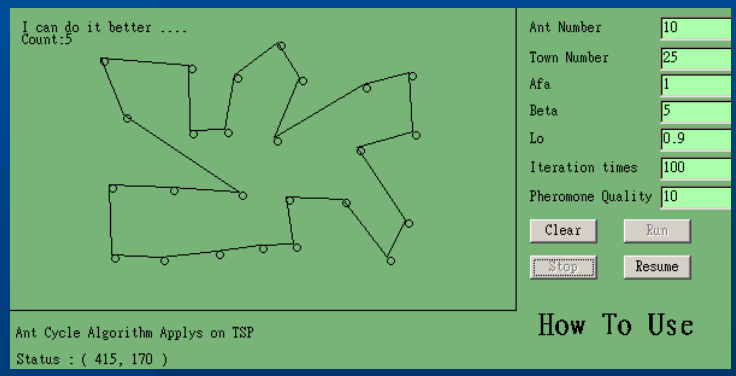
Simulation of Ants foraging

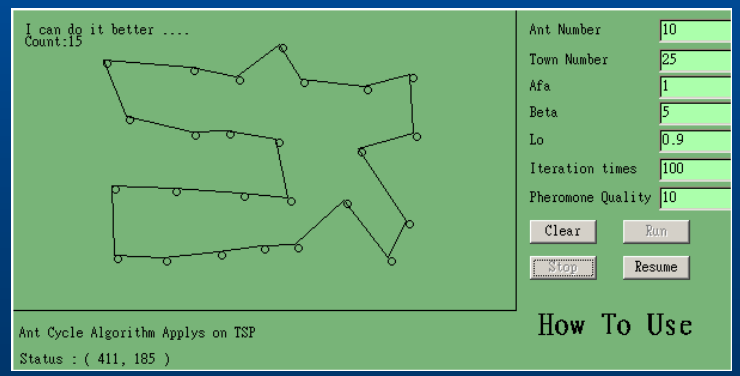


Ants foraging for TSP Optimization



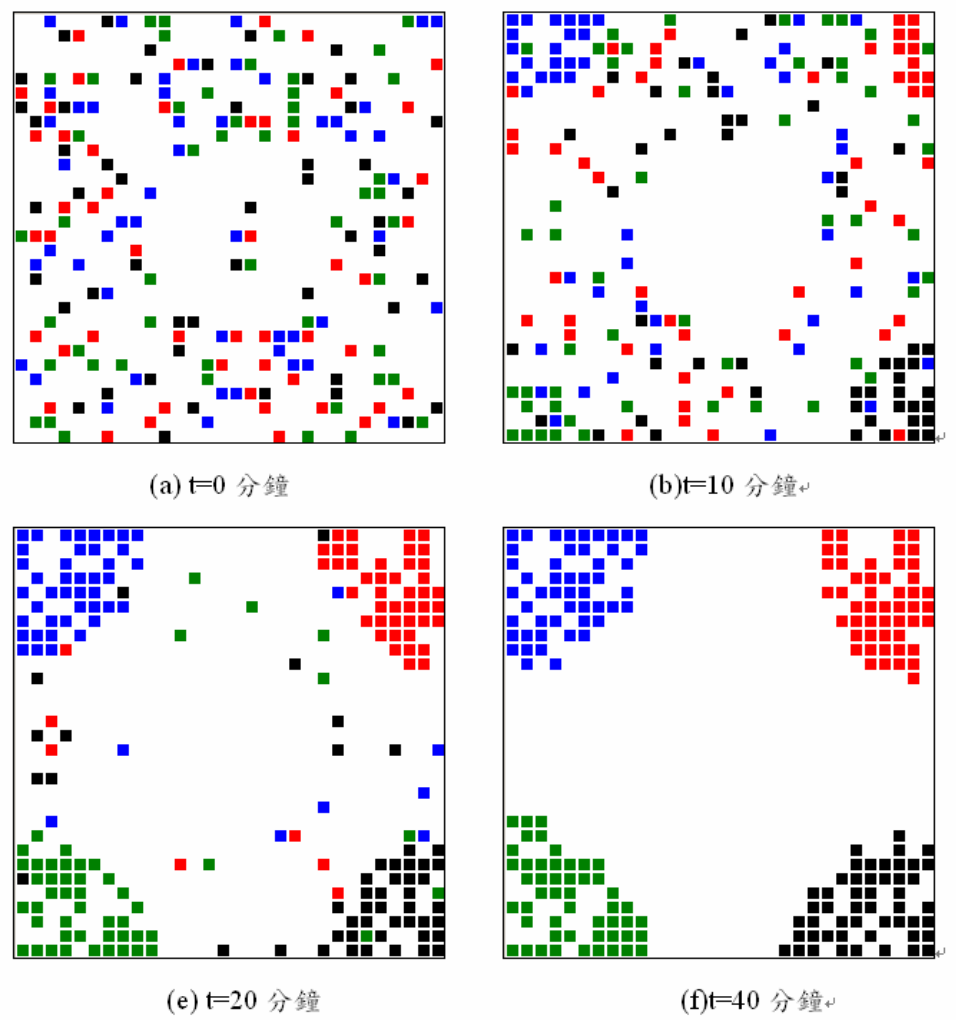






Ant-TSP DEMO

Self-Organizing Gathering(SOG)



(a) t=0 分鐘

(b)t=10 分鐘

(e) t=20 分鐘

(f)t=40 分鐘

Self-Organizing Gathering(SOG)

— 如果螞蟻正搬運一個物資，則牠在某位置x放下的機率與該物資與x周圍物資的同質性成正比。

— 如果螞蟻沒有搬運物資，則牠在某位置x把一個物資搬起的機率與該物資與x周圍物資的異質性成正比。

Formalization of SOG

感知

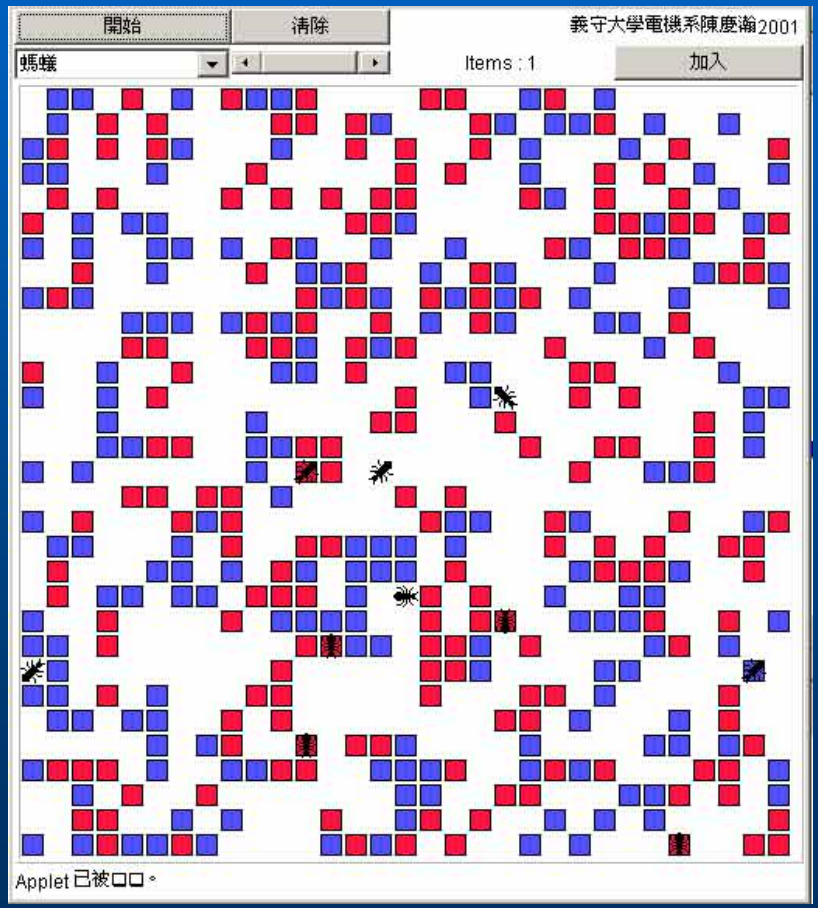
$$f(o_j) = \begin{cases} \frac{1}{s^2} \sum_{o_j \in Neigh(r)} \left[1 - \frac{d(o_j, o_k)}{\alpha} \right], if > 0 \\ 0, otherwise \end{cases}$$

决策

$$\text{proba(pick up)} = \left(\frac{k_1}{k_1 + \text{f}(o_j)} \right)^2$$

$$\text{proba(deposit)} = \left(\frac{k_2}{k_2 + \text{f}(o_j)} \right)^2$$

Simulation of SOG



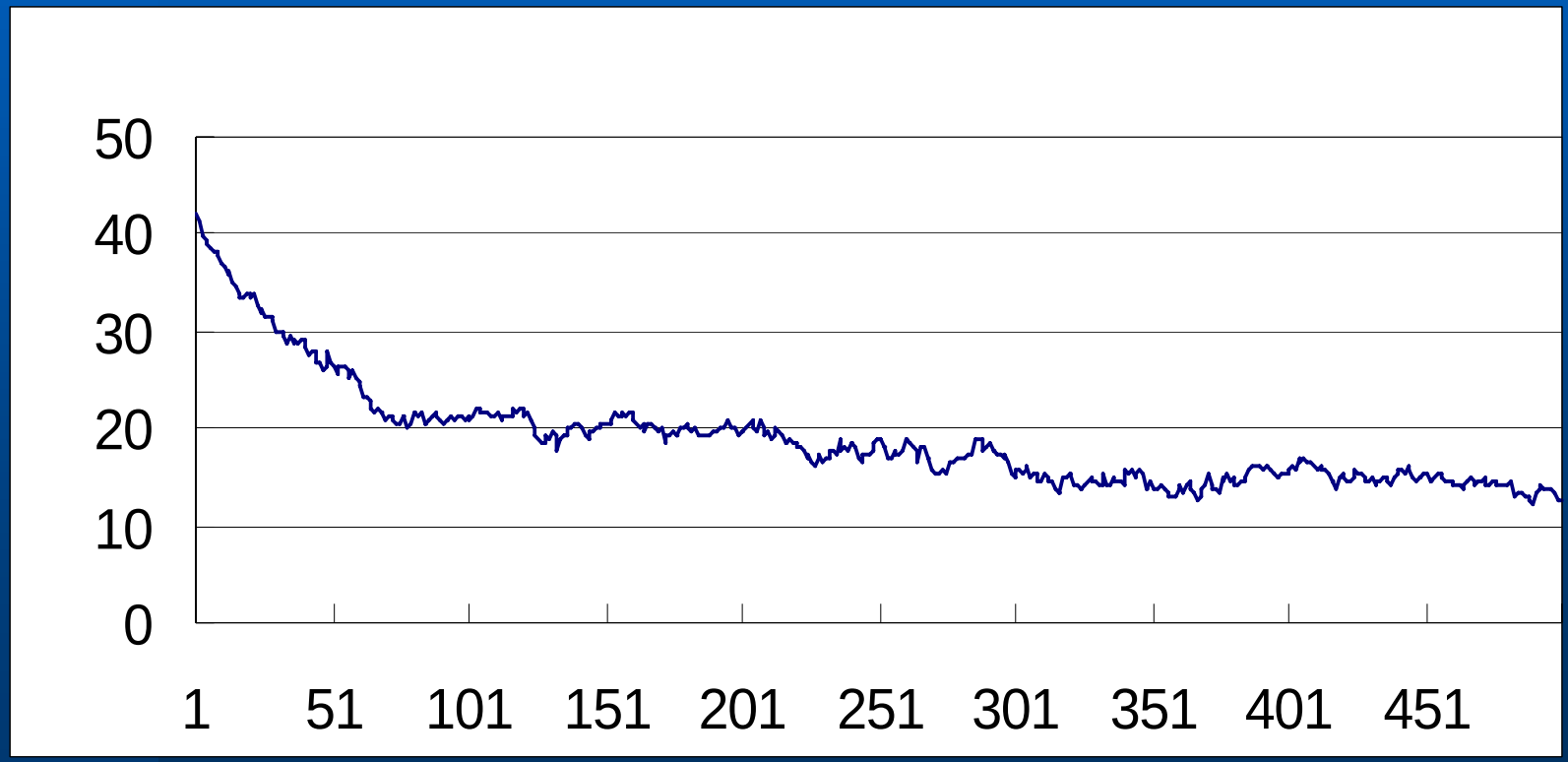
Spatial Entropy Measurement of SOG

以空間熵度量系統的收斂性

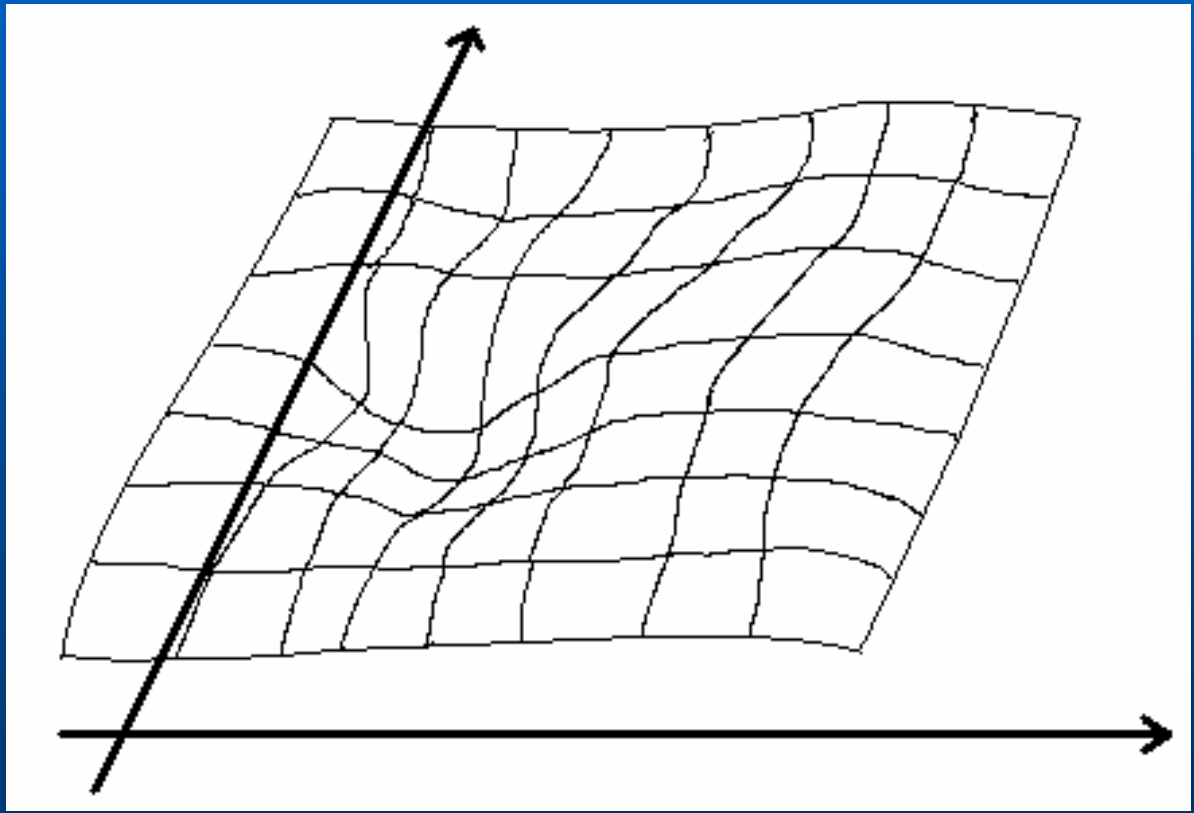
$$E_S = \sum_{I \in \{S\}} P_I \log P_I$$

Spatial Entropy Measurement of SOG

SOG系統的空間熵收斂曲線



Optimization as problem solving



Individual/Social Behavior Adaptation

個體經驗行為：

$$v_{j,d}(t) = v_{j,d}(t-1) + \phi_{j,d}^{(2)}(t)(x_{j,d}(t^{\#}) - x_{j,d}(t-1))$$

社會影響行為：

$$v_{j,d}(t) = v_{j,d}(t-1) + \phi_{j,d}^{(1)}(t)(x_{j,d}(t^{*}) - x_{j,d}(t-1))$$

Particle Swarm Optimization

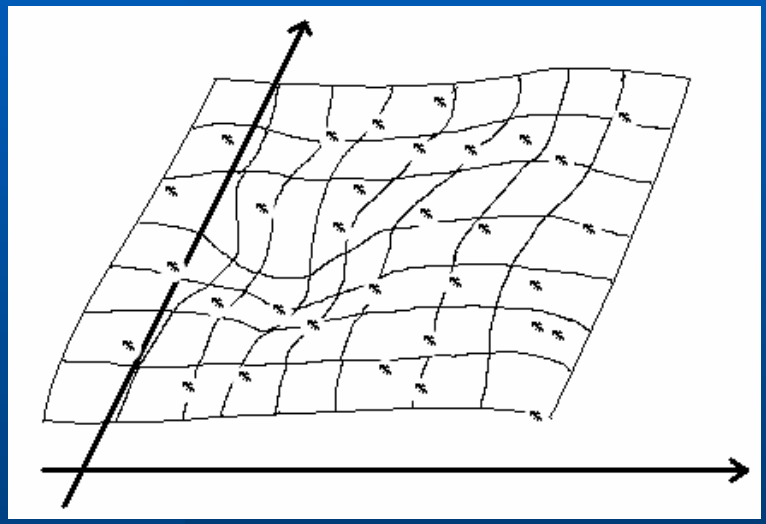
調整搜尋速度：

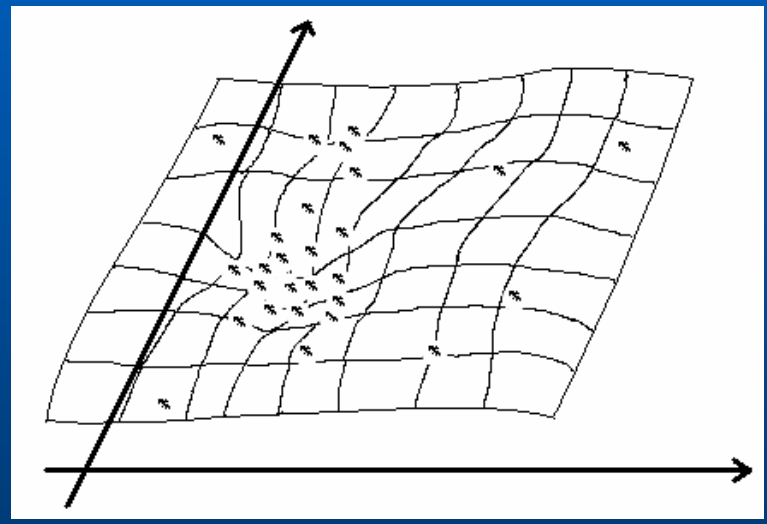
$$v_{j,d}(t) = v_{j,d}(t-1) + \phi_{j,d}^{(1)}(t)(x_{j,d}(t^*) - x_{j,d}(t-1)) + \phi_{j,d}^{(2)}(t)(x_{j,d}(t^{\#}) - x_{j,d}(t-1))$$

新的搜尋位置：

$$x_{j,d}(t) = x_{j,d}(t-1) + v_{j,d}(t)$$

Social Behavior for Optimization





展示程式

Characteristics of Ant-inspired Collective Problem Solving

Positive Feedback：

快速找到最佳解

Probabilistic Decision Making：

跳出區域性最佳解

Distributed Searching：

Anti-control的平行搜尋策略

Applications of Ant-inspired Collective Problem Solving

— Design Optimization

— Data Mining by Clustering

— Adaptive Task Allocation

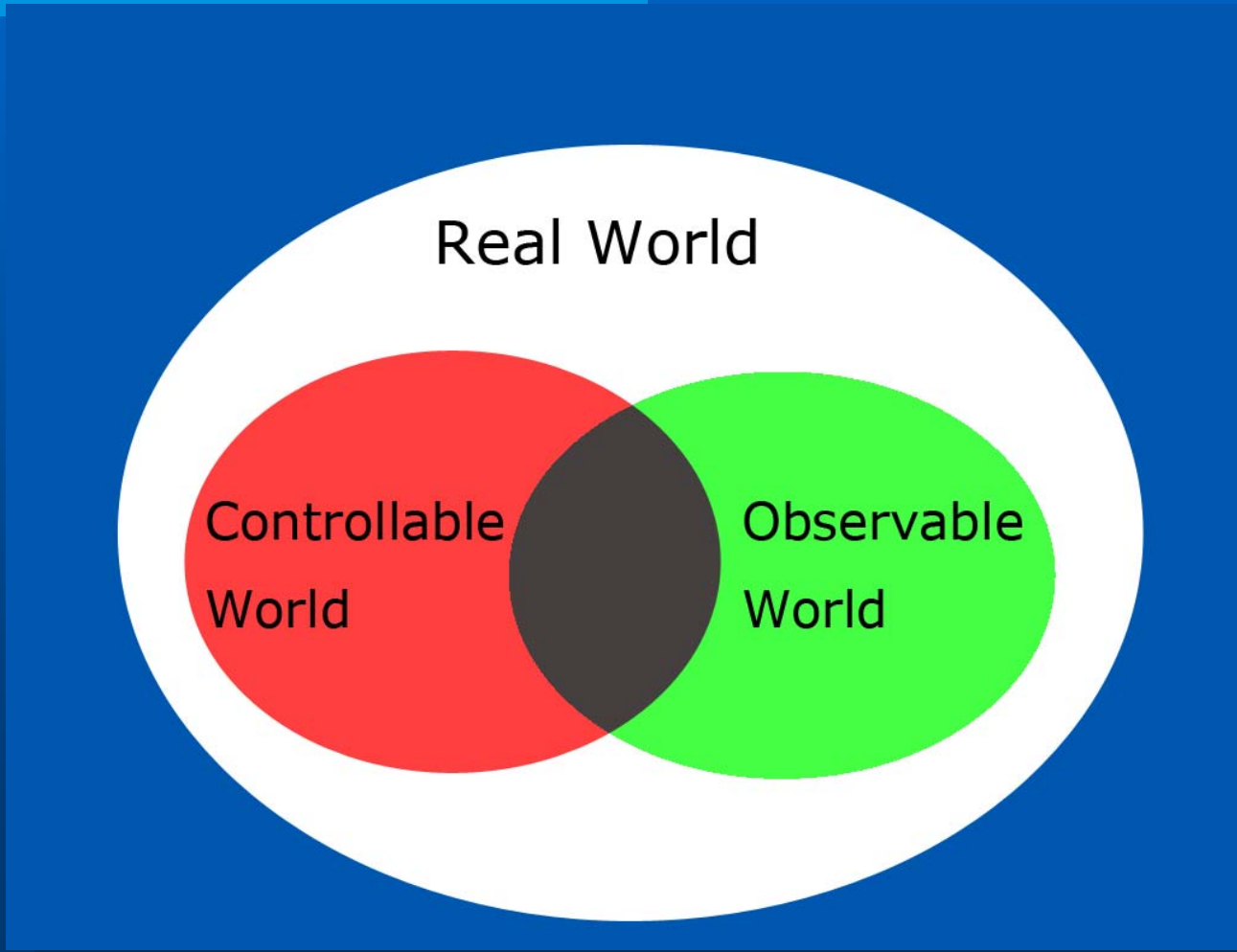
— Multi-robots System

— Meta-heuristics for Intelligent System

(Classification, Recognition, Prediction, Diagnosis…)

群體解題的科學認識論
Scientific Epistemology for Collective Problem Solving

認識論與宇宙觀



理性主義的化約式思考

「把一個困難的問題分解成一些可以解決的較小問題。 先解決那些最簡單、最清楚的問題，一一理解後，再逐步升高層次，探討複雜的事物。」

—笛卡兒

(Descartes, Rene du Perron, 1596-1650)

理性主義的決定論思考

「我們必須將宇宙萬物目前的狀態視為過去狀態的結果，同時也是未來狀態的成因.....沒有甚麼是不能被確定的，未來就如同過去一般將呈現在我們的眼前。」

—拉普拉斯

（Laplace, Pierre-Simon, 1749-1827）

傳統科學認識論觀點的解題

- 解題系統作為一個封閉系統，其結構與運作具有高度內在性、獨立性，而與環境無關。
- 解題系統作為一線性系統，具有可預測性、可控制性及內在的穩定性。

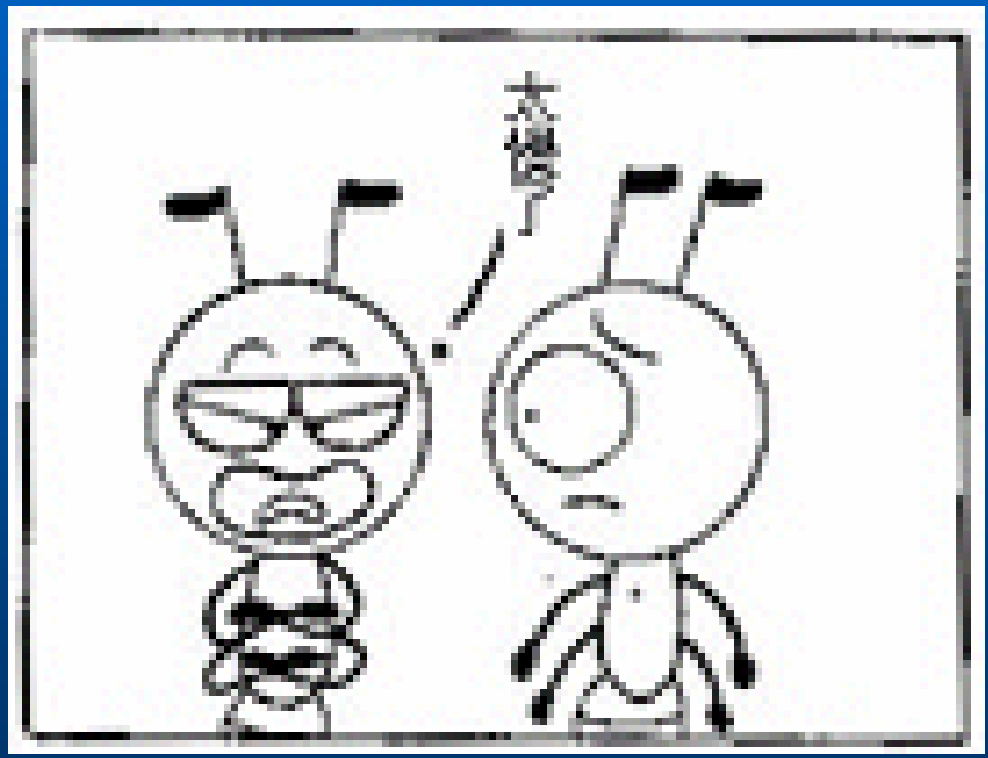
傳統科學認識論的解題困境

- Adaptivity
- Robustness
- Autonomy
- Intelligence

朝向群體解題的科學認識論

- 複雜系統(v.s.化約系統)
- 遠離平衡(v.s.穩定)
- 隨機的決定論(v.s.隨機/決定論)
- 自組織的(v.s.設計的)
- 分散式(v.s.集中式)

漫畫欣賞1/4



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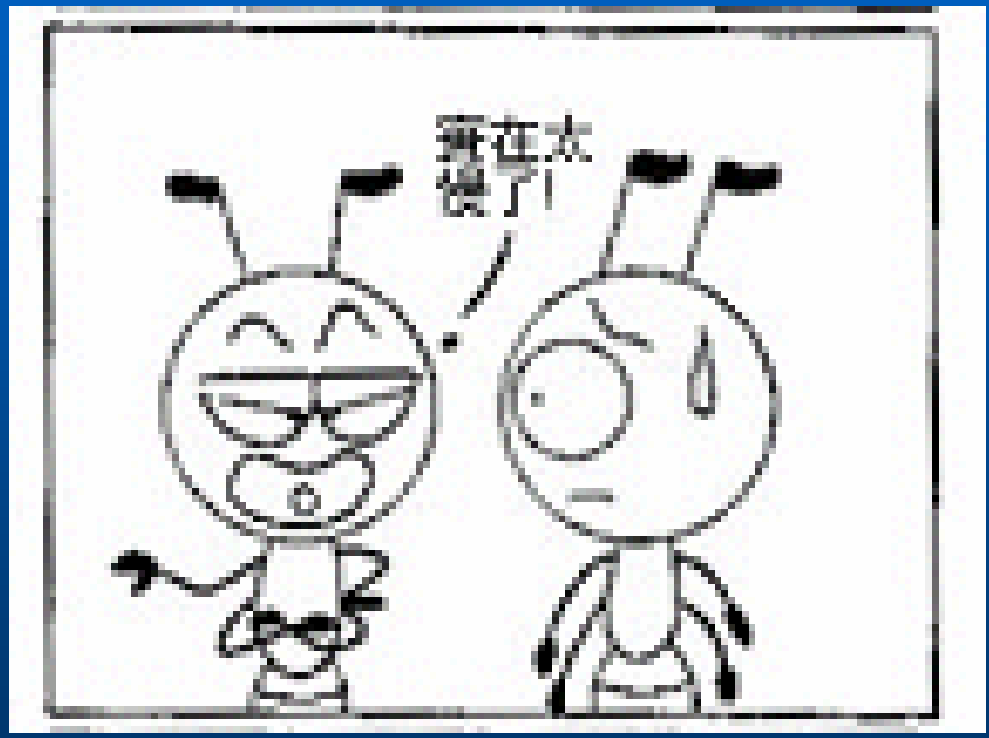

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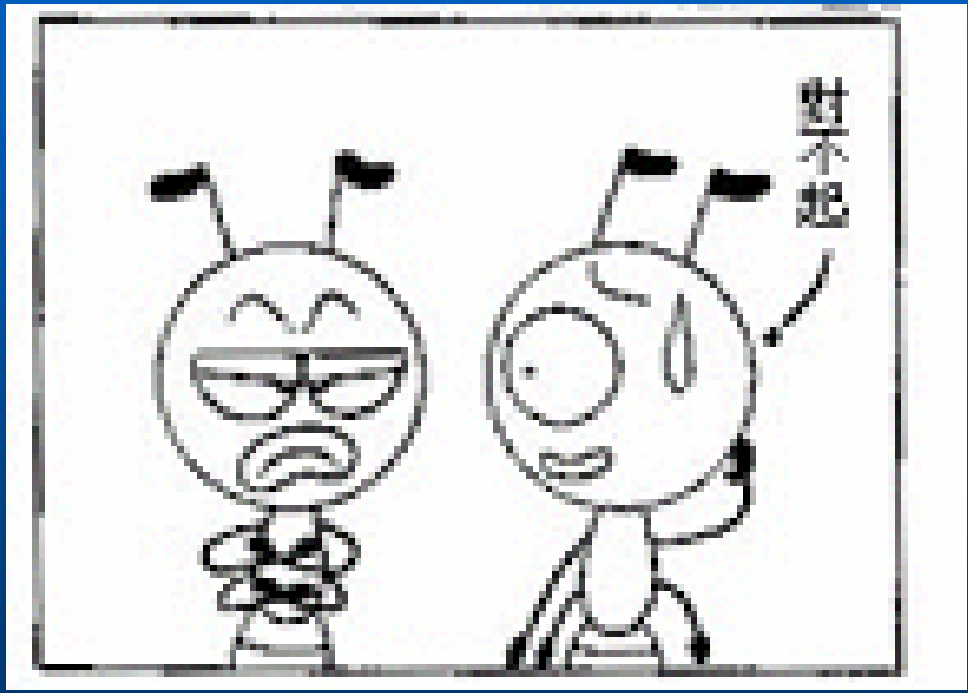

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~FIN~