

Ants-Inspired Computing : Dynamics of Complex System

仿螞蟻計算：複雜系統的動力學



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Problem solving in Ants swarm

由一群簡單功能的Agents(螞蟻)所形成的群體(蟻群)，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。



Emergent problem solving mechanism

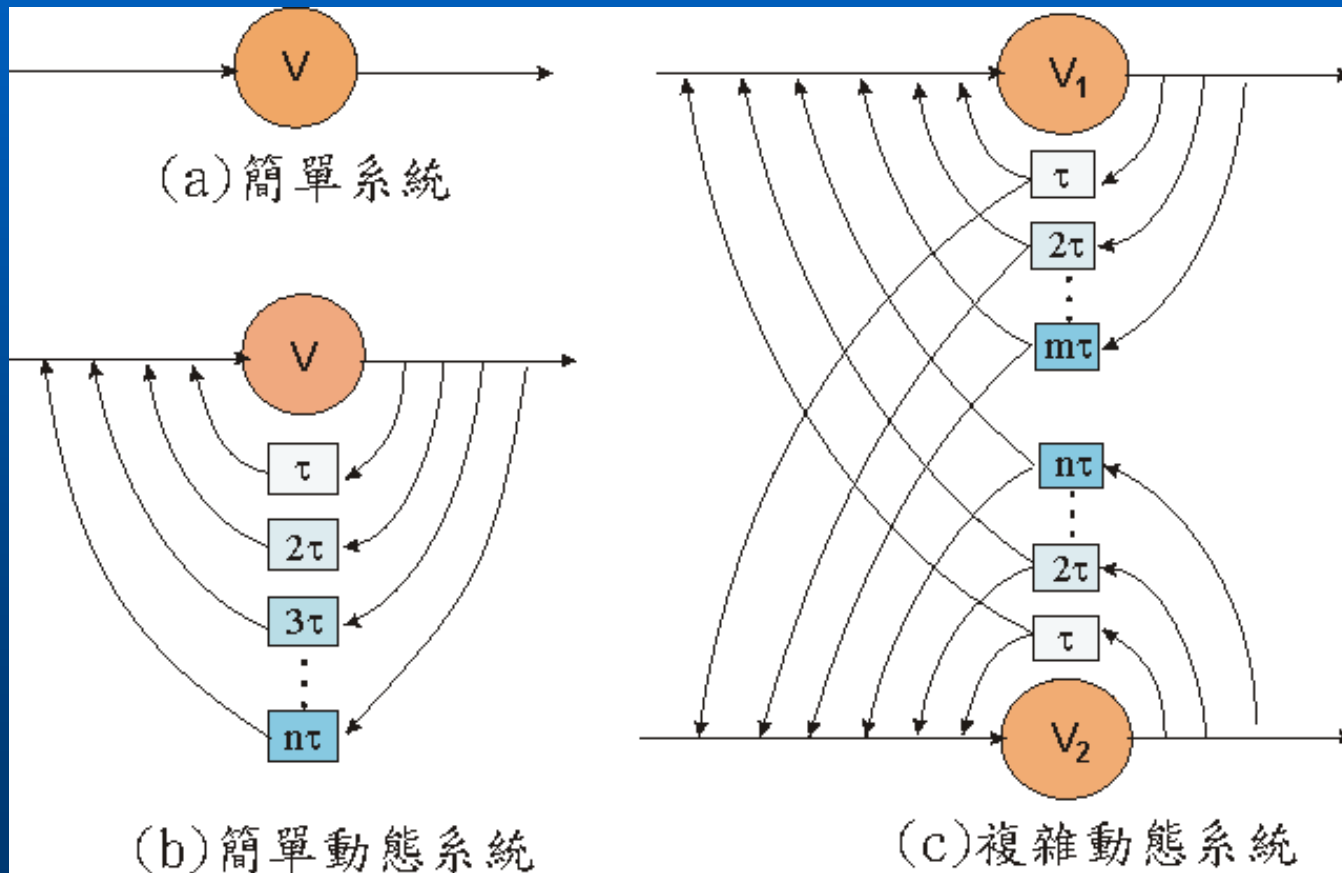
突現式解題機制：

無須預先計畫(**prior planning**)、沒有集中式的監測和控制(**central supervision and control**)的系統行爲。

應用突現式解題機制的計算範式將適用在複雜的、變動的環境中，自主性地、強健地解決一些目標導向(**goal-oriented**)的問題。



Complex, Dynamic System





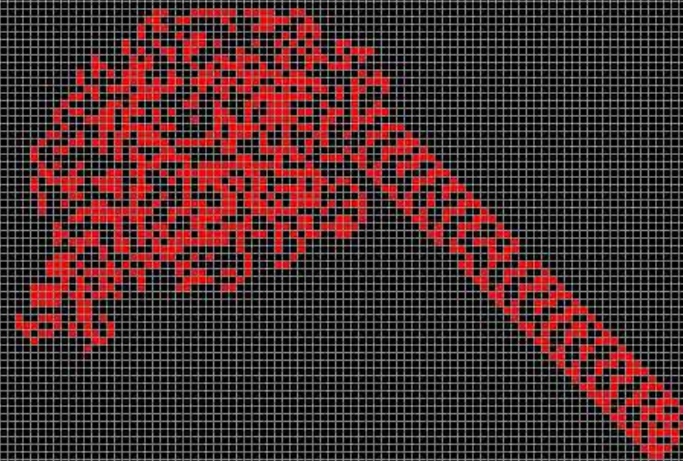
Characteristics of Complex System

1. 系統由三個以上的元素所構成
2. 系統的元素之間會交互作用(interaction)
3. 不可化約(irreductibility)
4. 不可逆(irreversible)
5. 非決定論(non-determinism)



Example of a Simple Dynamic System

Langton's Virtual Ant





Algorithm of Langton's Ant

1. 準備一方格全白棋盤,在中央放一隻螞蟻並隨機設定其面對之方位。
2. 讓螞蟻向前走一步,若遇上白色方格則螞蟻向右轉,並將方格變成黑色;反之,若遇上黑色方格則螞蟻向左轉,並將方格變成白色。
3. 重複步驟2

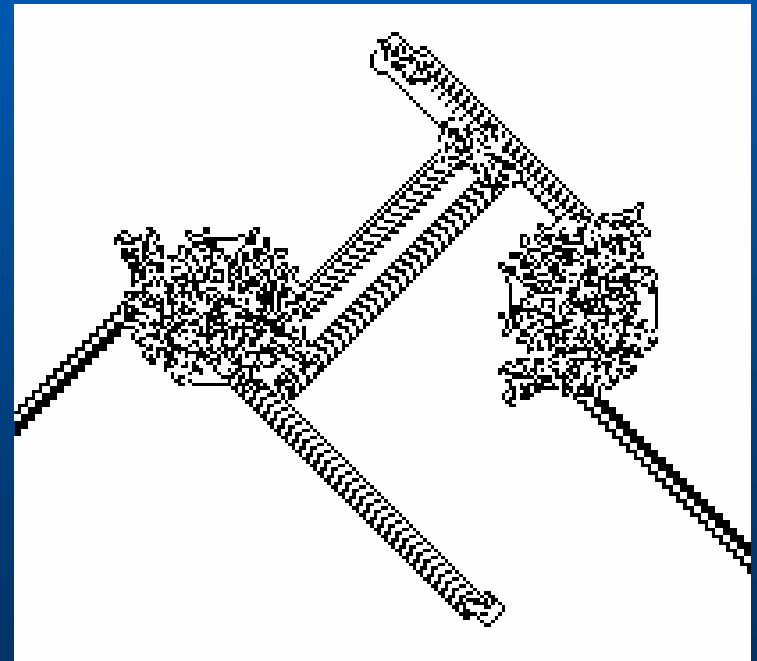


Simulation of Langton's Ant

Single Ant



Multiple Ants





Collective Behavior in Ants swarm

蟻窩的建造(nest building)

群體覓食行爲(foraging)

物件分揀行爲(gathering)

蟻群的工作分配(task allocation)

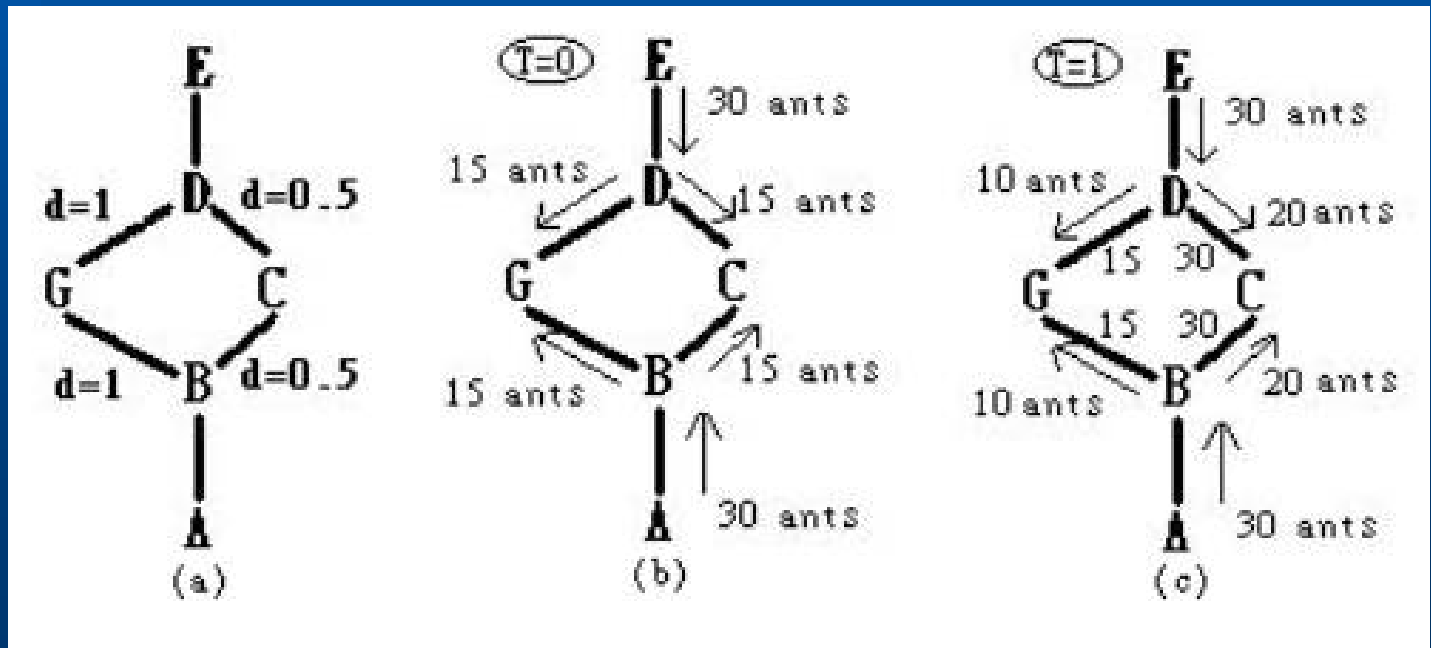
協同搬運(cooperative transportation)

.....



Foraging Behavior in Ants swarm

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。





Characteristics of Ants foraging

Positive Feedback :

快速找到最佳解

Probabilistic Decision Making :

跳出區域性最佳解

Distributed Computing :

Anti-control的平行搜尋策略



Formalization of Ants foraging

費洛蒙更新

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

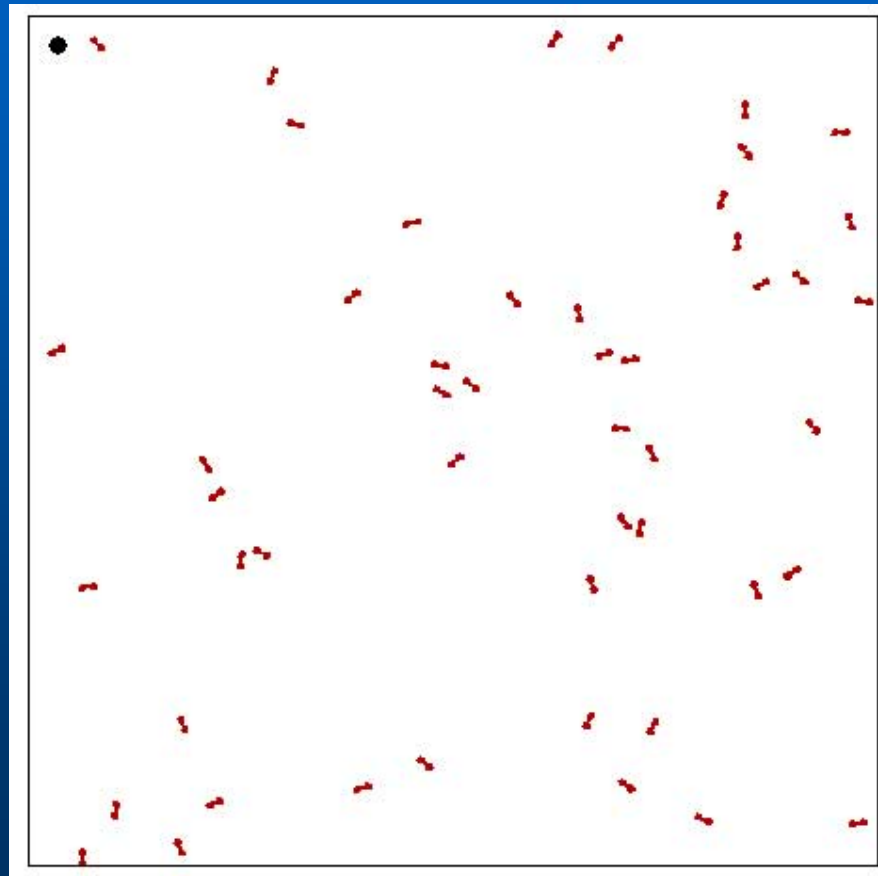
$$\Delta \tau_{ij} = \sum_{k=1}^m \Delta \tau_{ij}^k$$

決策機率

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

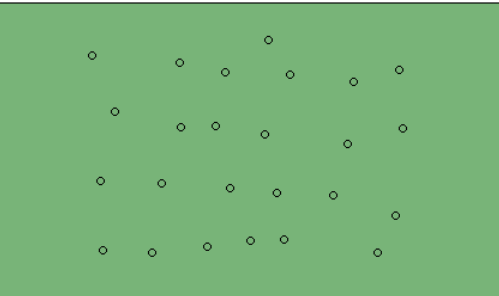


Simulation of Ants foraging





Ants foraging for TSP Optimization



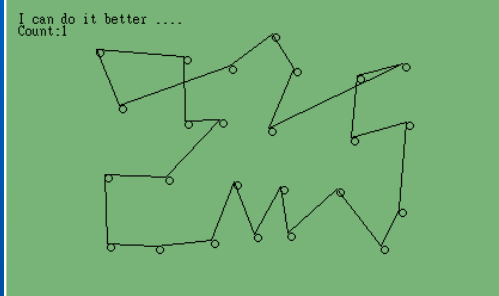
Ant Cycle Algorithm Applies on TSP
Status : (398, 247)

How To Use

Ant Number	10
Town Number	25
Afa	1
Beta	5
Lo	0.9
Iteration times	100
Pheromone Quality	10

Clear Run
Stop Resume

I can do it better
Count:1



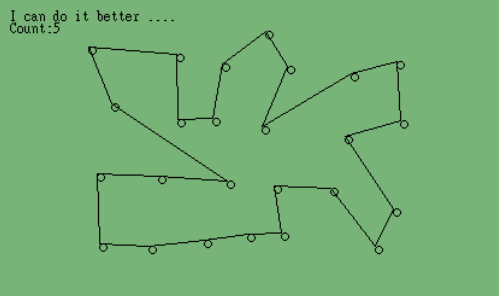
Ant Cycle Algorithm Applies on TSP
Status : (341, 246)

How To Use

Ant Number	10
Town Number	25
Afa	1
Beta	5
Lo	0.9
Iteration times	100
Pheromone Quality	10

Clear Run
Stop Resume

I can do it better
Count:5



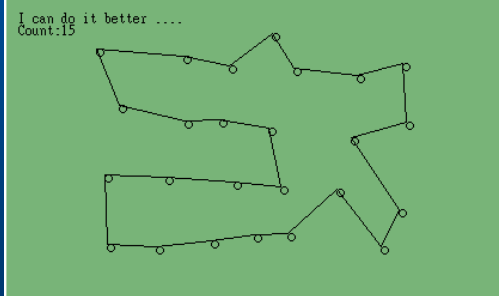
Ant Cycle Algorithm Applies on TSP
Status : (415, 170)

How To Use

Ant Number	10
Town Number	25
Afa	1
Beta	5
Lo	0.9
Iteration times	100
Pheromone Quality	10

Clear Run
Stop Resume

I can do it better
Count:15



Ant Cycle Algorithm Applies on TSP
Status : (411, 185)

How To Use

Ant Number	10
Town Number	25
Afa	1
Beta	5
Lo	0.9
Iteration times	100
Pheromone Quality	10

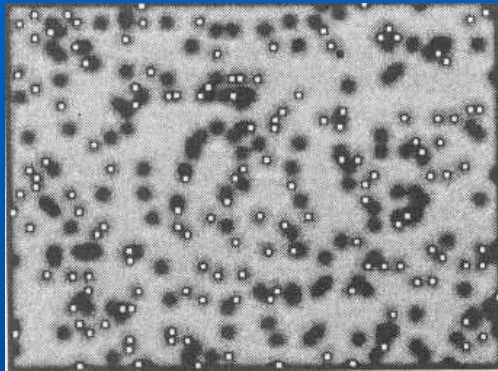
Clear Run
Stop Resume

Ant-TSP DEMO

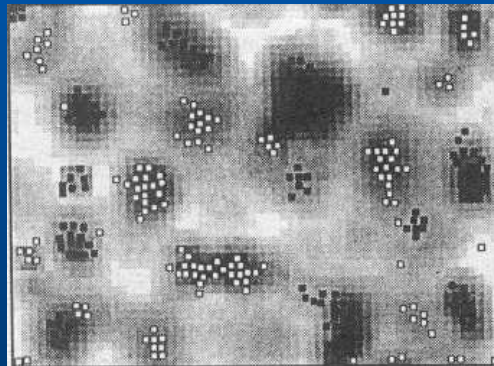


Self-Organizing Gathering(SOG)

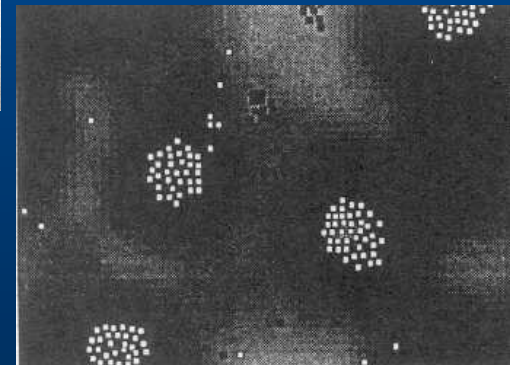
T_1



T_2



T_3





Principe of 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

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

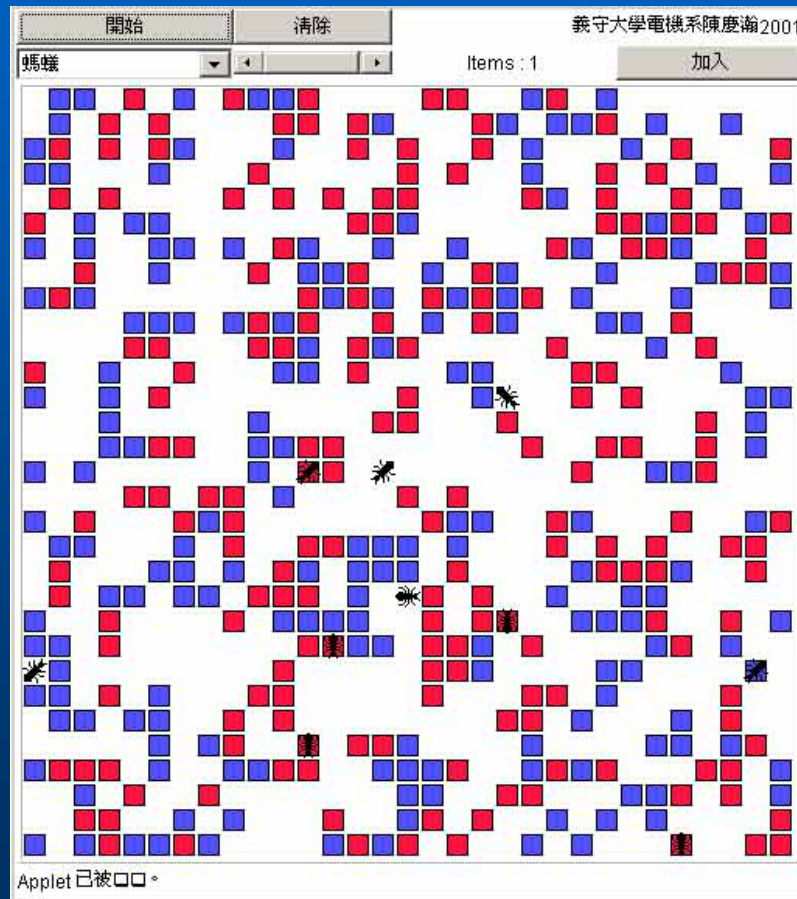
決策

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

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



Simulation of SOG





Spatial Entropy Measurement of SOG

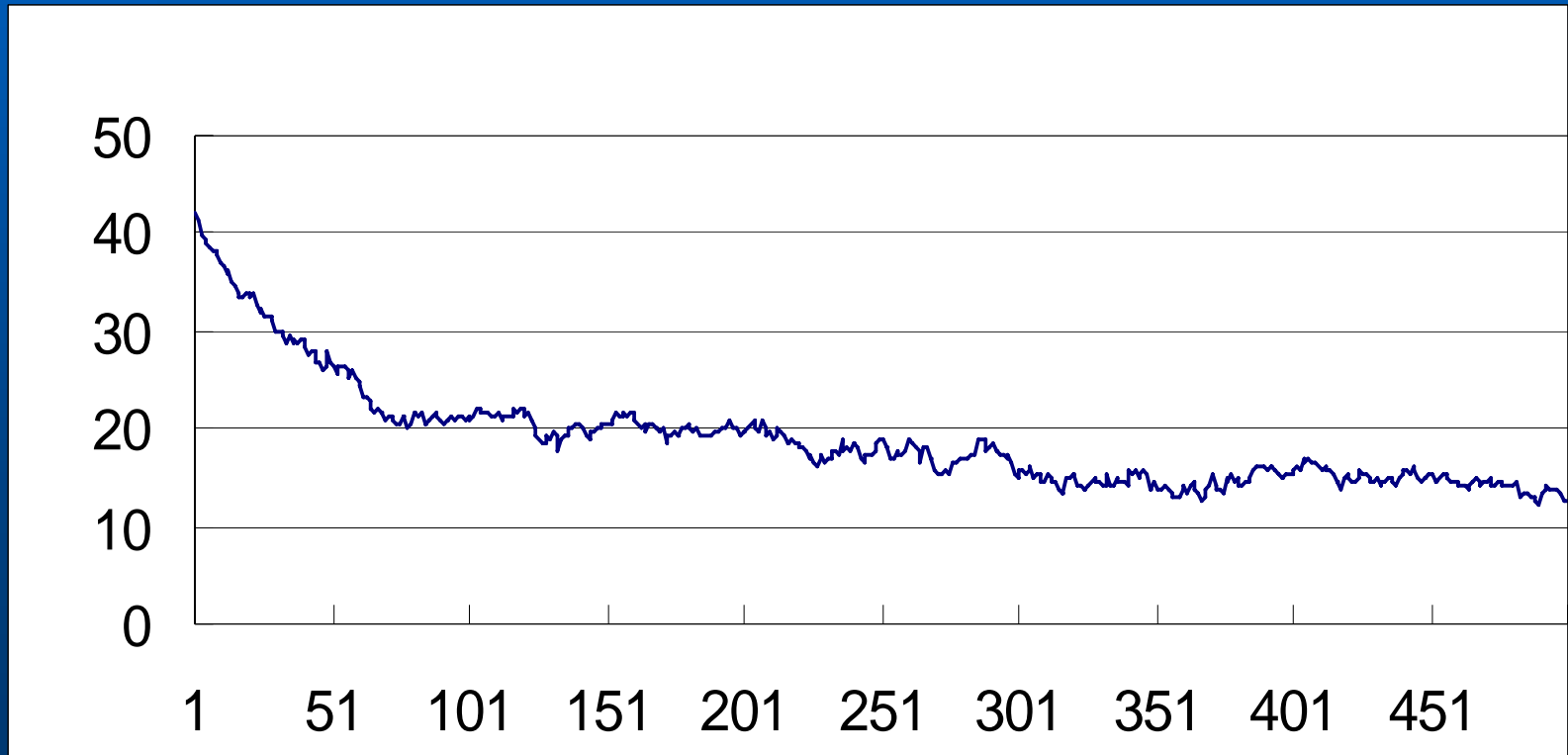
以空間熵度量系統的收斂性

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



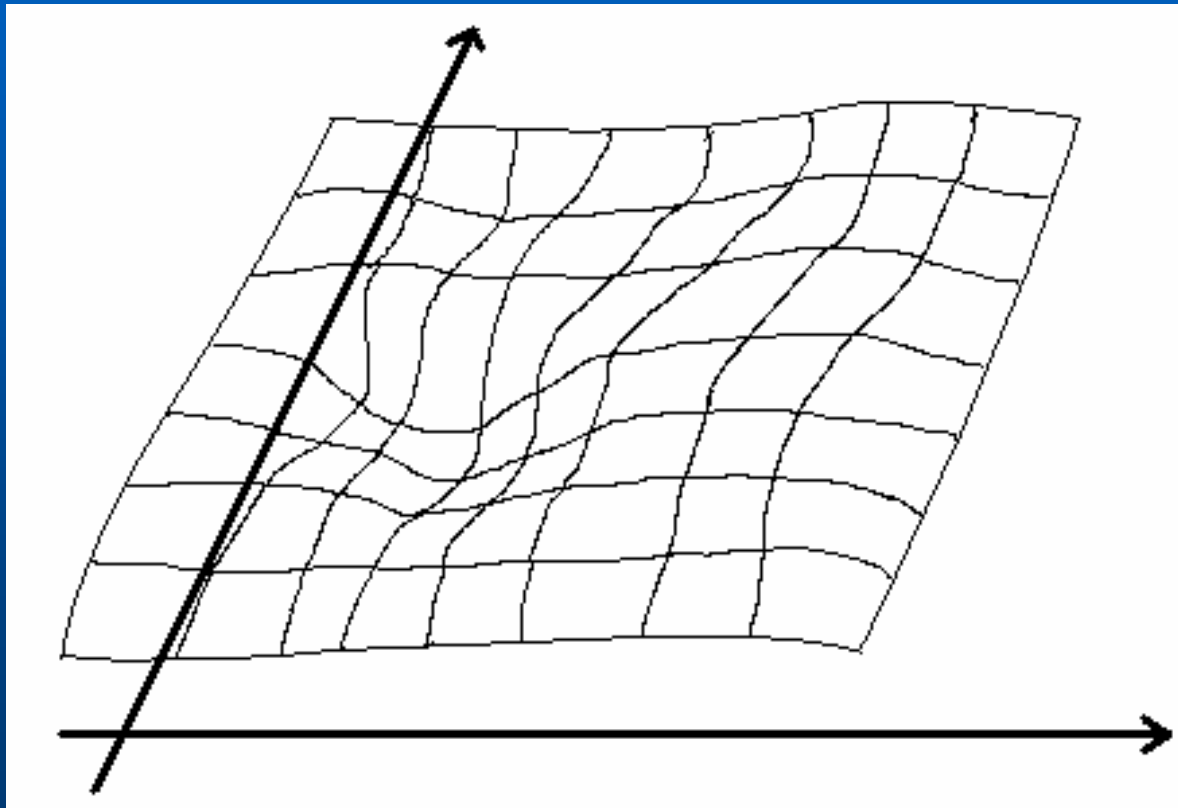
Spatial Entropy Measurement of SOG

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：

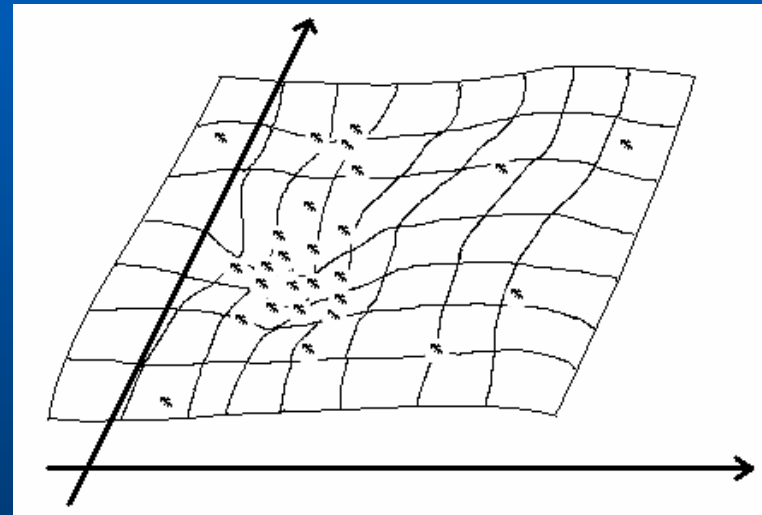
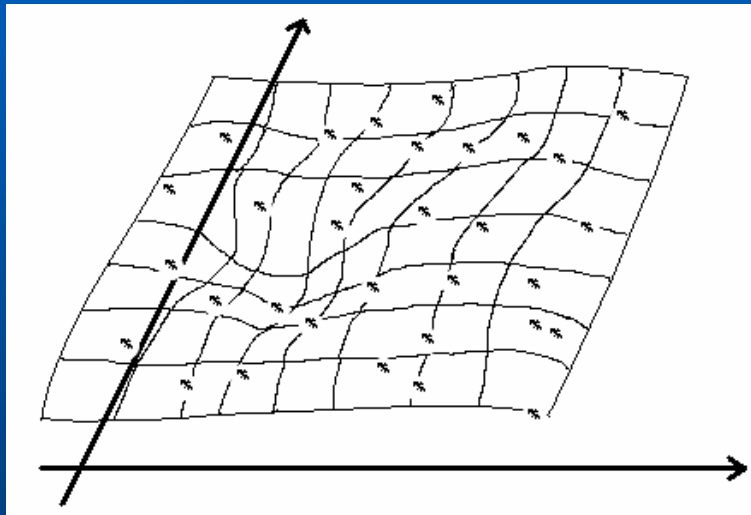
$$v_{j,d}(t) = v_{j,d}(t-1) + \phi_{j,d}^{(1)}(t)(x_{j,d}(t^*) - x_{j,d}(t-1)) \\ + \phi_{j,d}^{(2)}(t)(x_{j,d}(t^\#) - x_{j,d}(t-1))$$

新的搜尋位置：

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



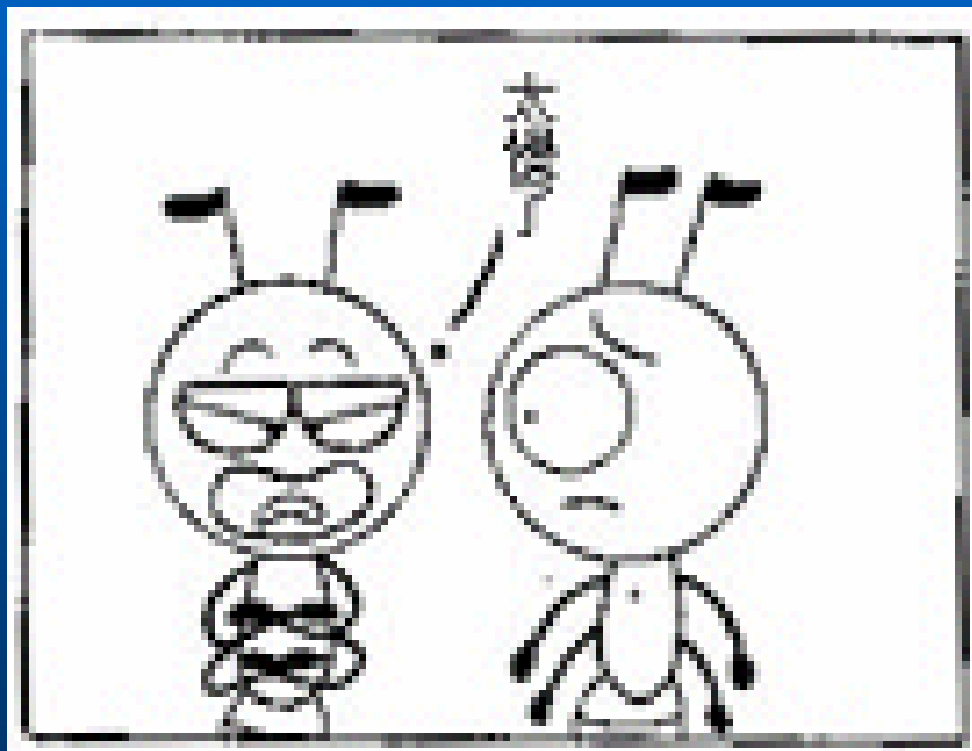
Social Behavior for Optimization



展示程式



漫畫欣賞1/4



摘自www.mangalan.com.tw



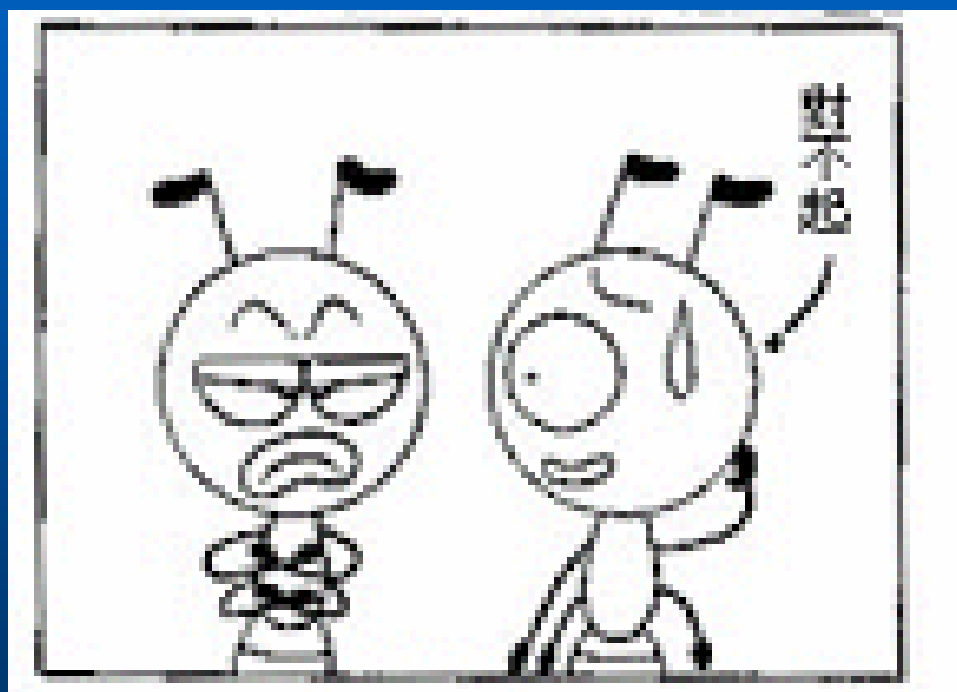
漫畫欣賞2/4



摘自 www.mangalan.com.tw



漫畫欣賞3/4



摘自 www.mangalan.com.tw



漫畫欣賞4/4



~FIN~