仿螞蟻群體解題

Ant-inspired Collective Problem Solving

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Ant Colony : A Complex System

蟻群：一個複雜系統礎

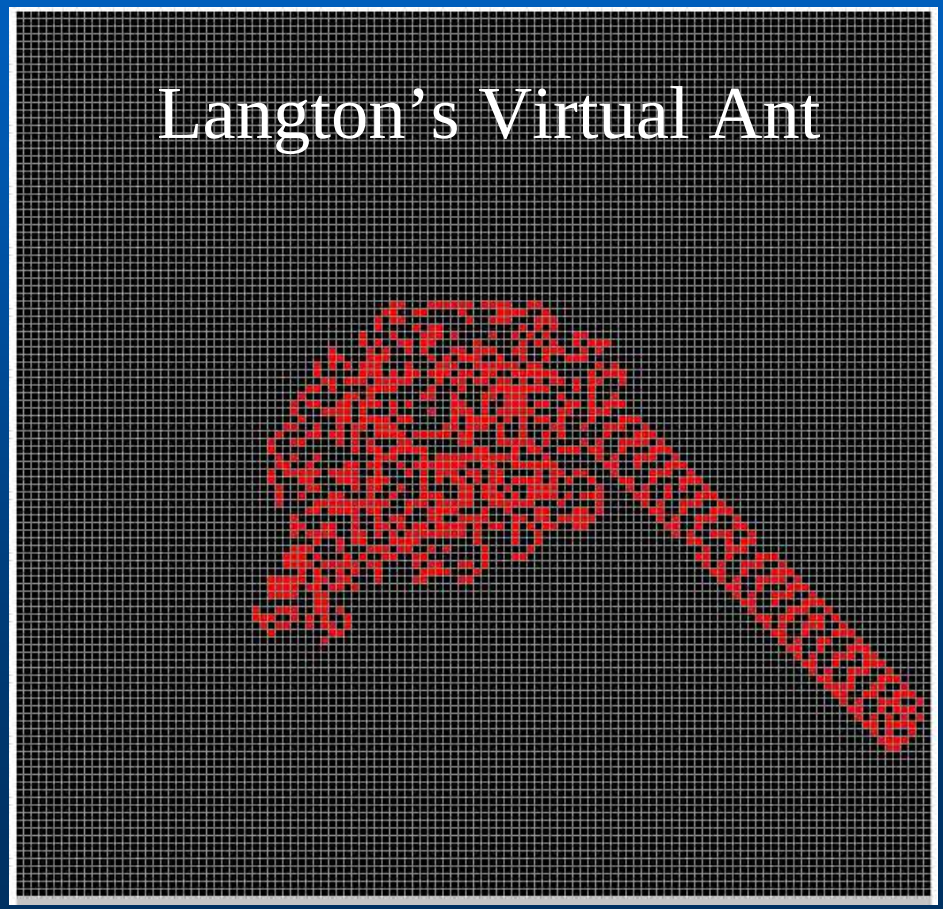
複雜系統的特徵

1. 複雜系統由三個以上的元素所構成
2. 系統的元素彼此交互關聯(inter-dependent)
3. 具有非線性的決定論(deterministic)行為
4. 混沌與非混沌交互作用
5. 合作與競爭交互作用

化約 vs.複雜式系統

	化約式系統	複雜系統
Structure	Designed	Self-organized
Dynamics	Deterministic	Chaotic
Decision	Centric	Distributed
Problem solving	Prior planning; Central control	Emergent

Example of a Simple Dynamic System



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。

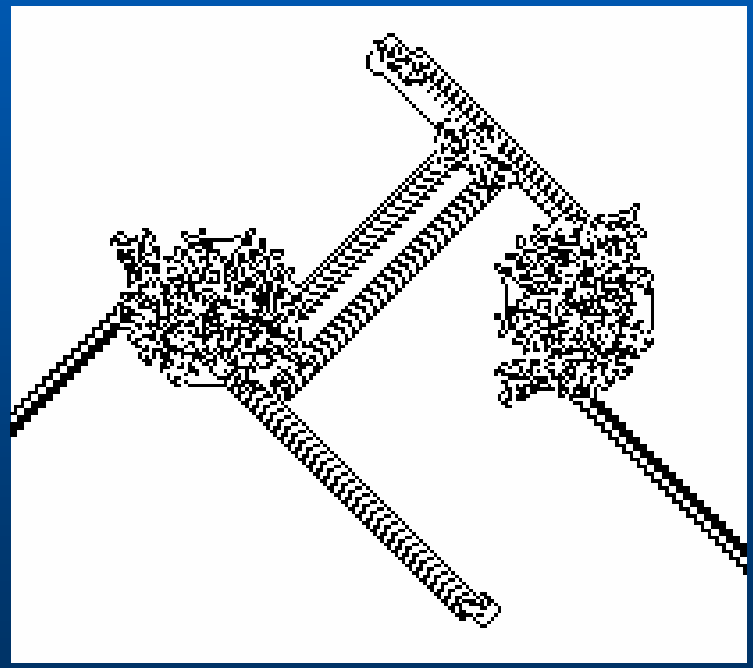
2. 讓螞蟻向前走一步,若遇上白色方格則螞蟻向右轉,並將方格變成黑色;反之, 若遇上黑色方格則螞蟻向左轉,並將方格變成白色。

3. 重複步驟2

Simulation of Langton's Ant

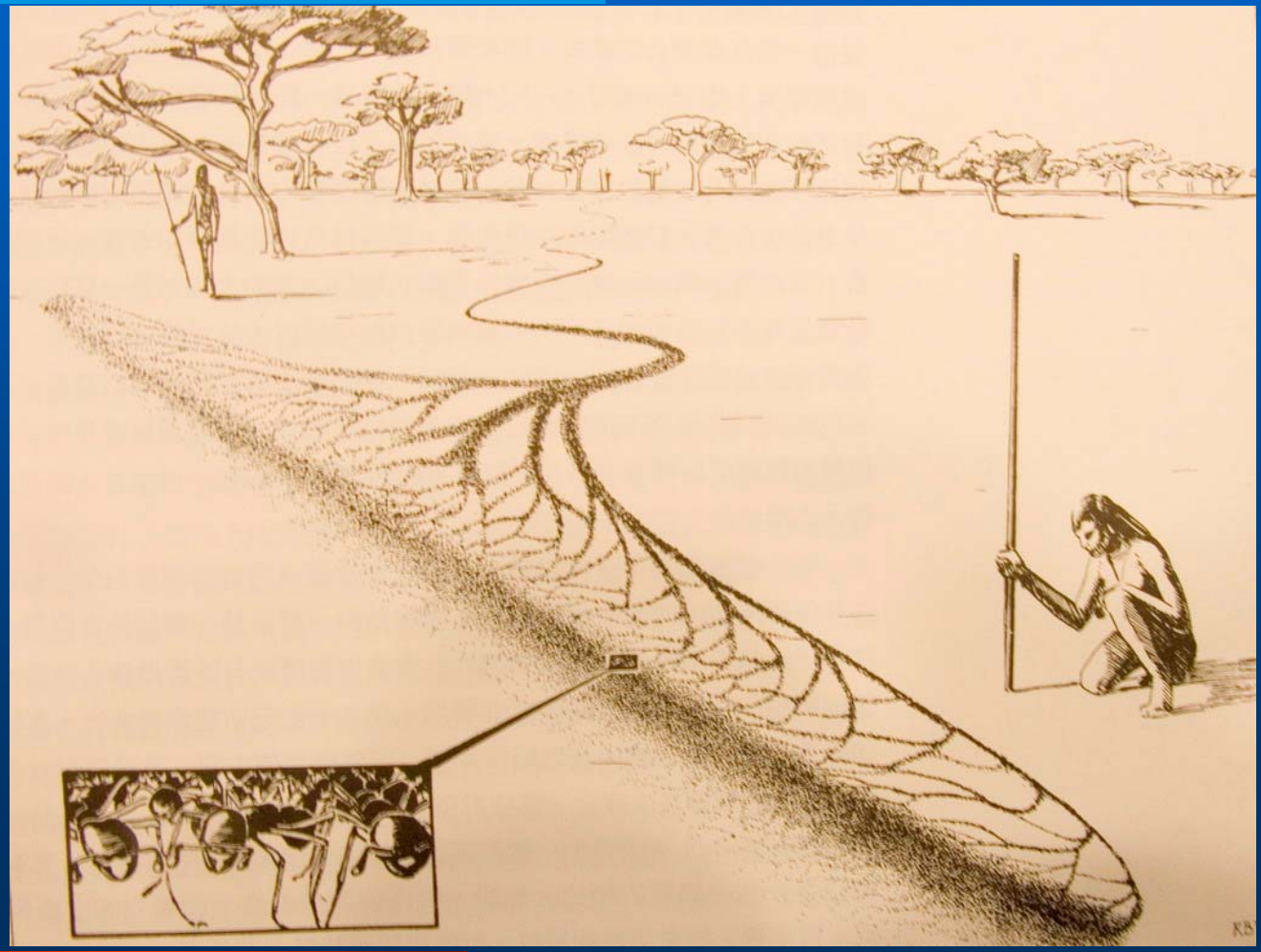
Single Ant

Multiple Ants



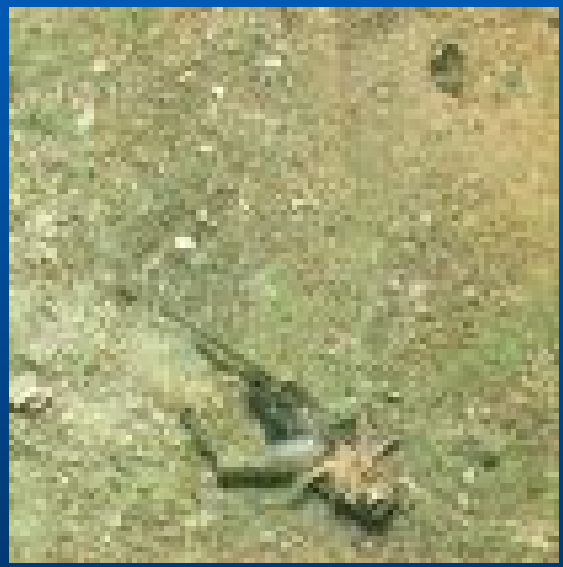
仿螞蟻群體解題行為

螞蟻的超組織模型

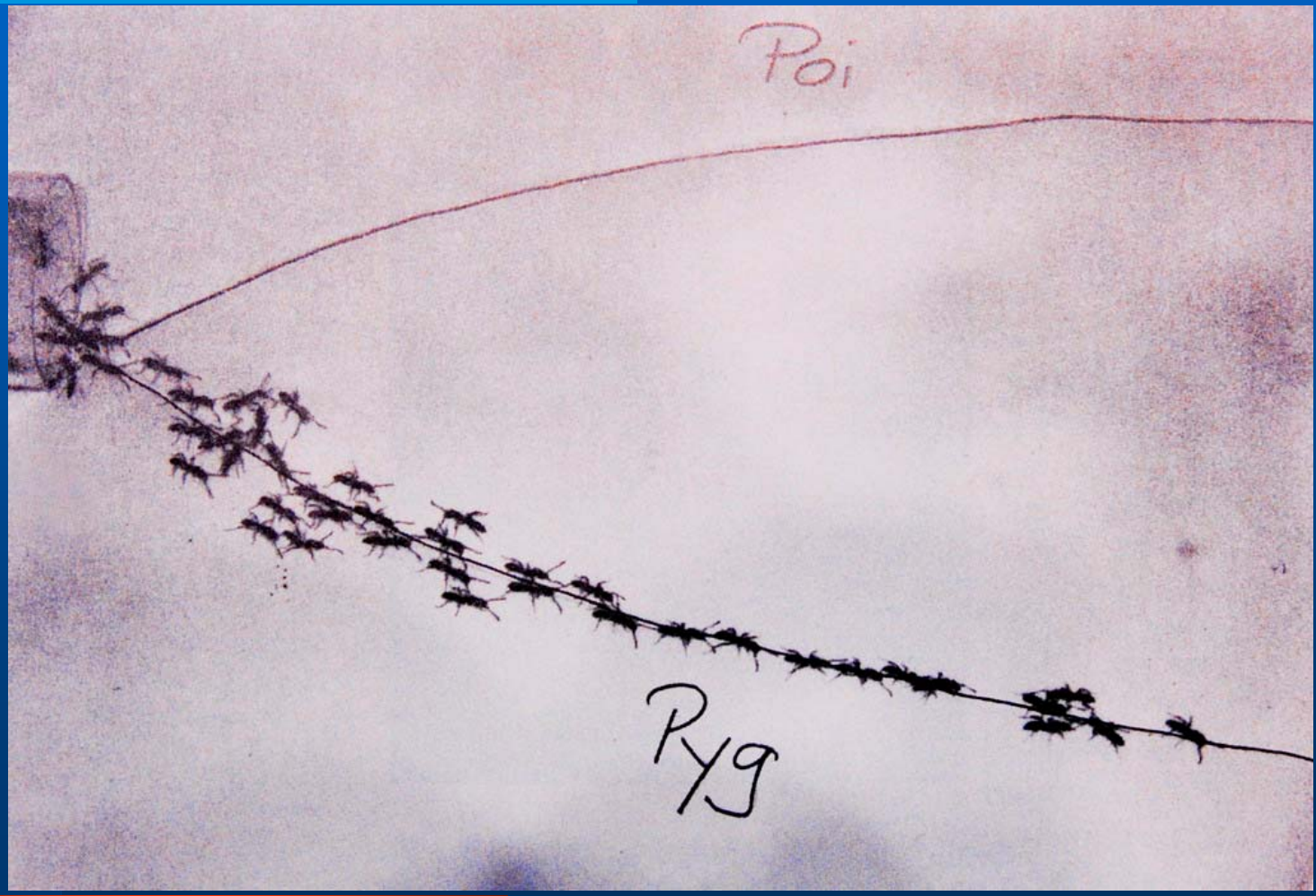


螞蟻搬運食物

螞蟻群體解題

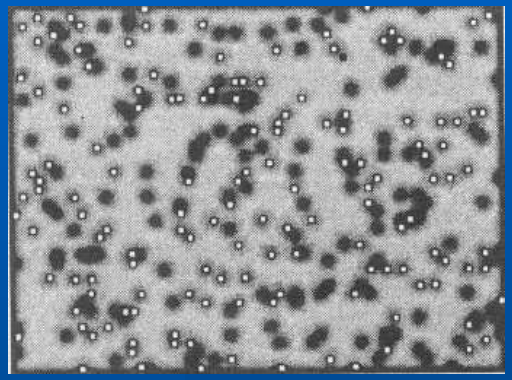


蟻群的溝通和決策

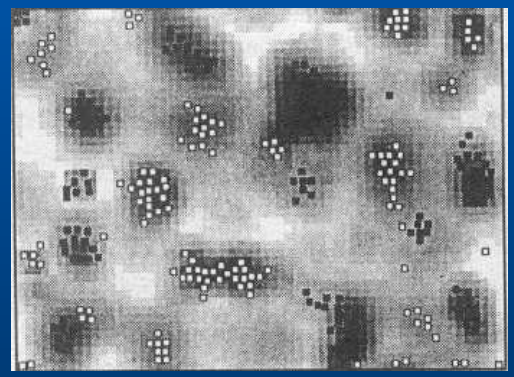


蟻群的分撿行為

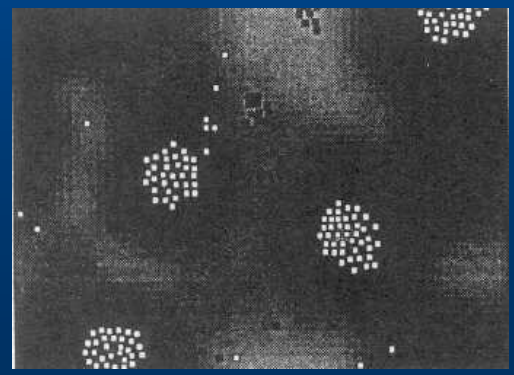
T_1



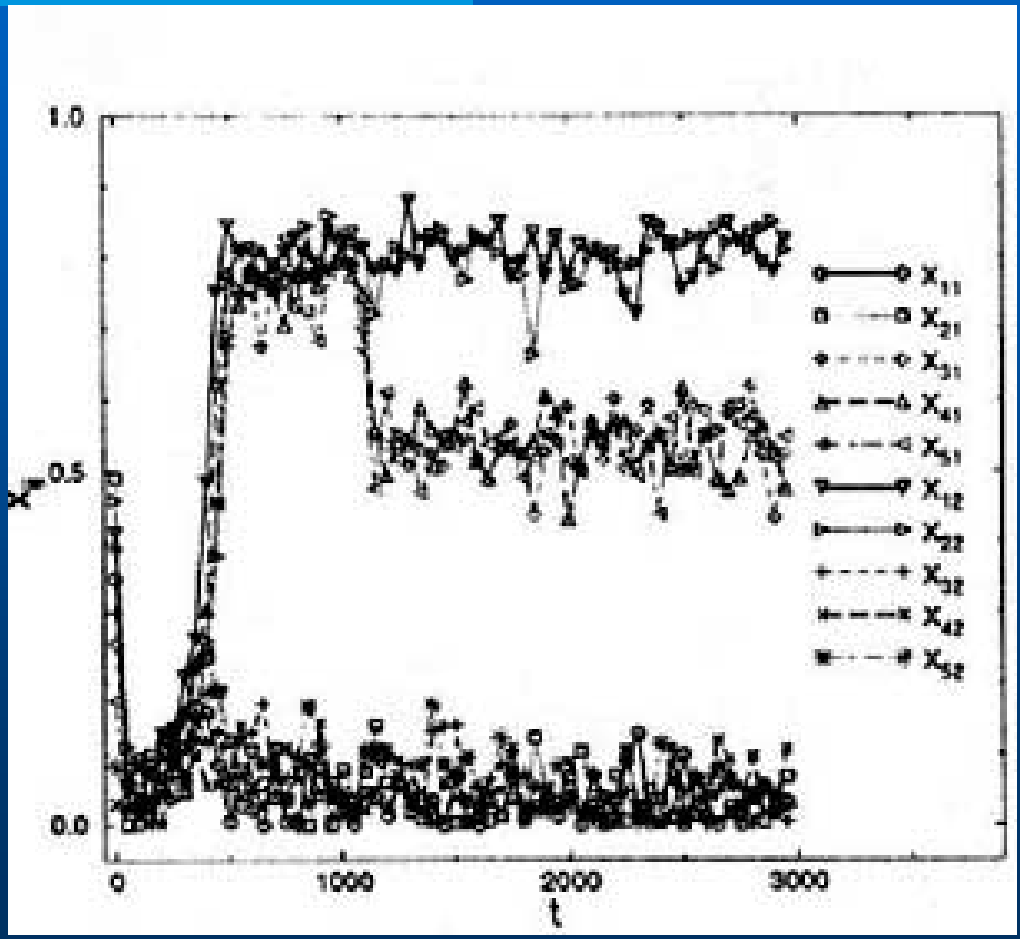
T_2



T_3



蟻群的工作派遣行為

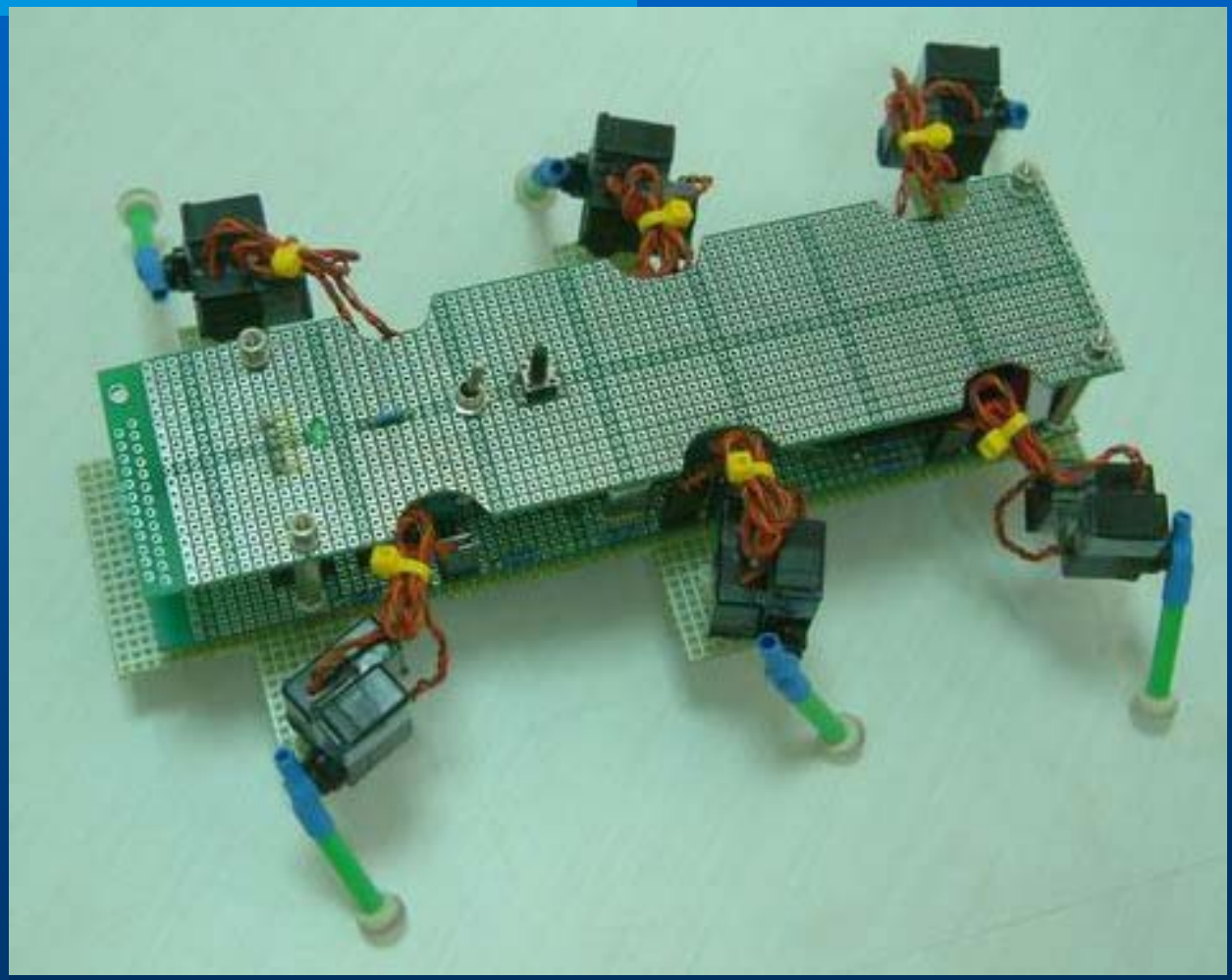


蟻群的築巢行為

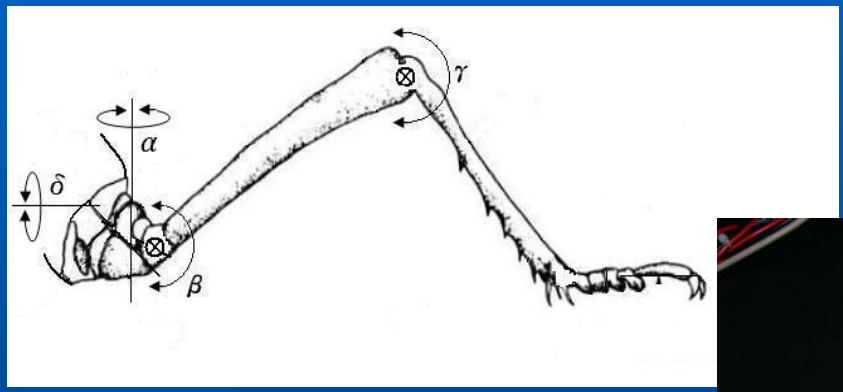
蟻群的搭橋行為

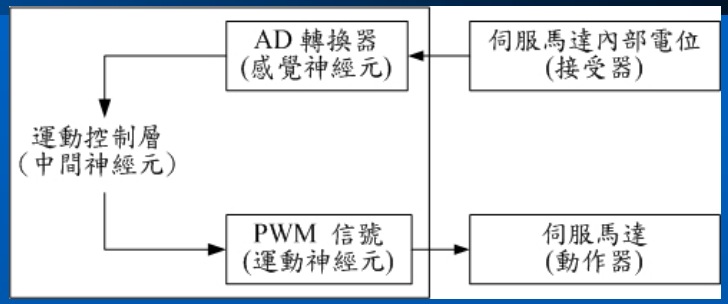
Bridge Building in Ant Colony

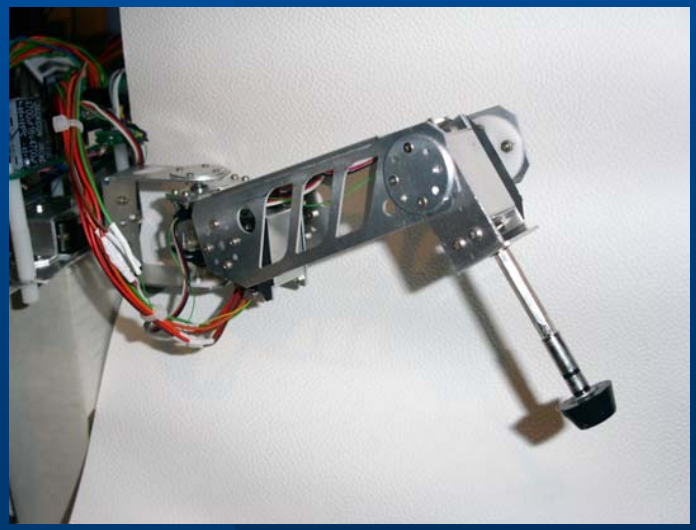
MIAT第一代螞蟻機器人

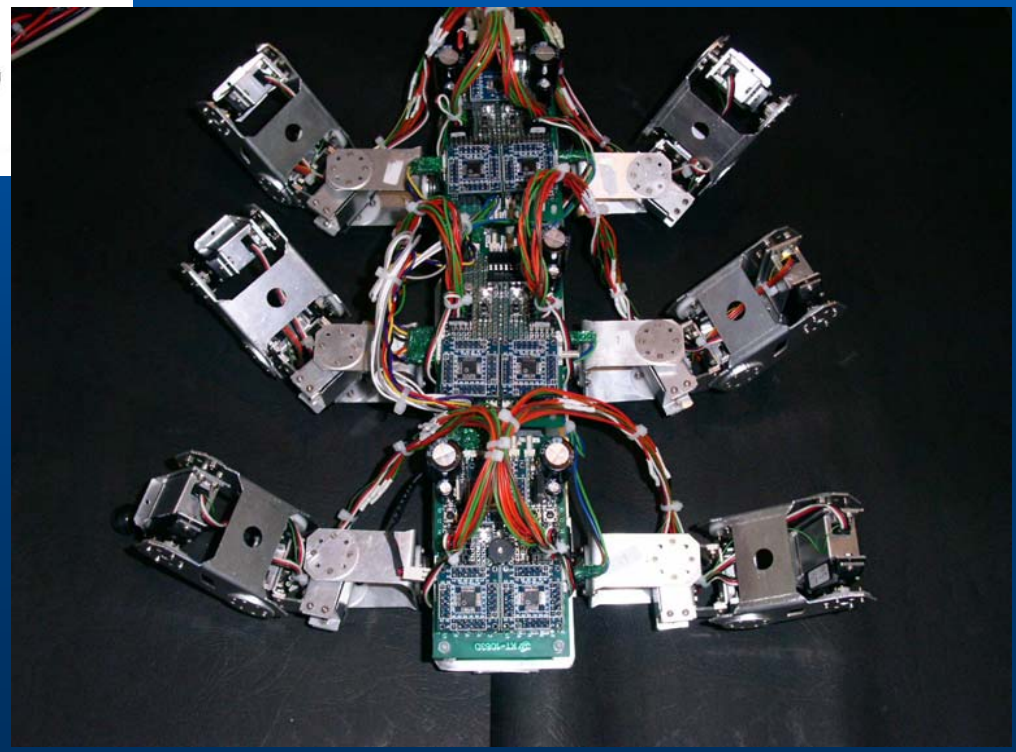


MIAT第二代螞蟻機器人









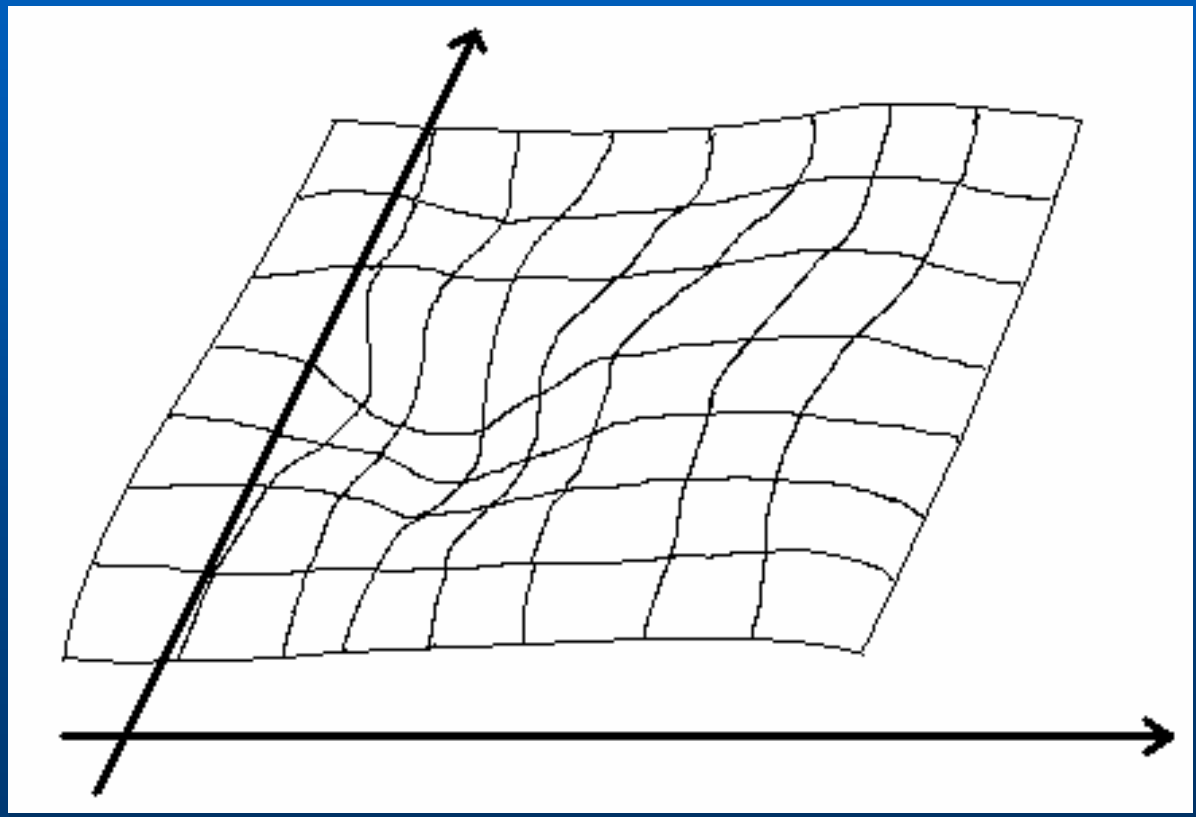
螞蟻的群體解題行為

蟻窩的建造(nest building)
群體覓食行為(foraging)
物件分揀行為(gathering)
蟻群的工作分配(task allocation)
協同搬運(cooperative transportation)
……

螞蟻群體解題

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。

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

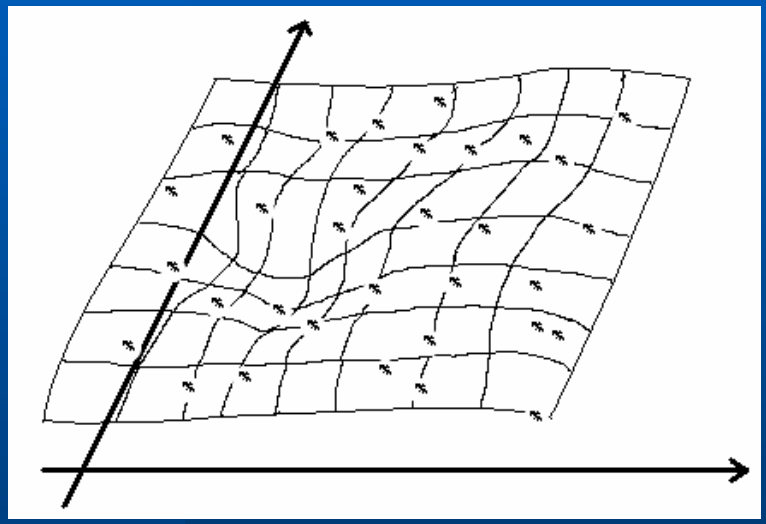
調整搜尋速度：

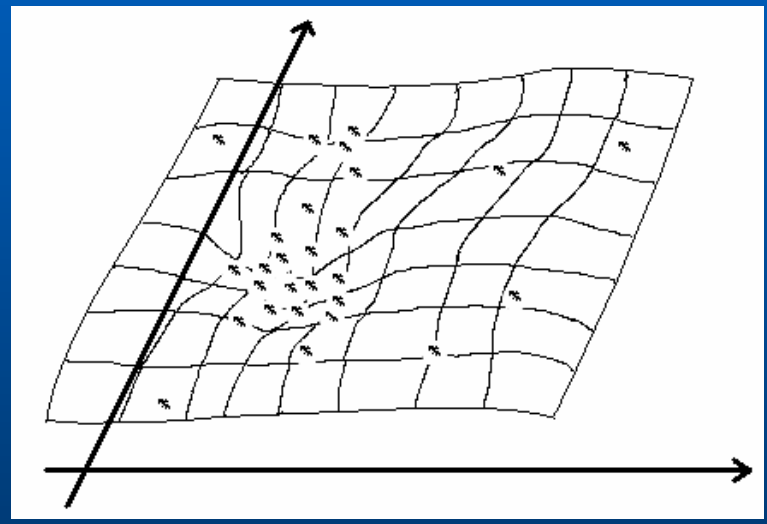
$$v_{j,d}(t) = v_{j,d}(t-1) + \phi_{j,d}^{(1)}(t)(x_{j,d}(t^*) - x_{j,d}(t-1)) + \phi_{j,d}^{(2)}(t)(x_{j,d}(t^{\#}) - x_{j,d}(t-1))$$

新的搜尋位置：

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

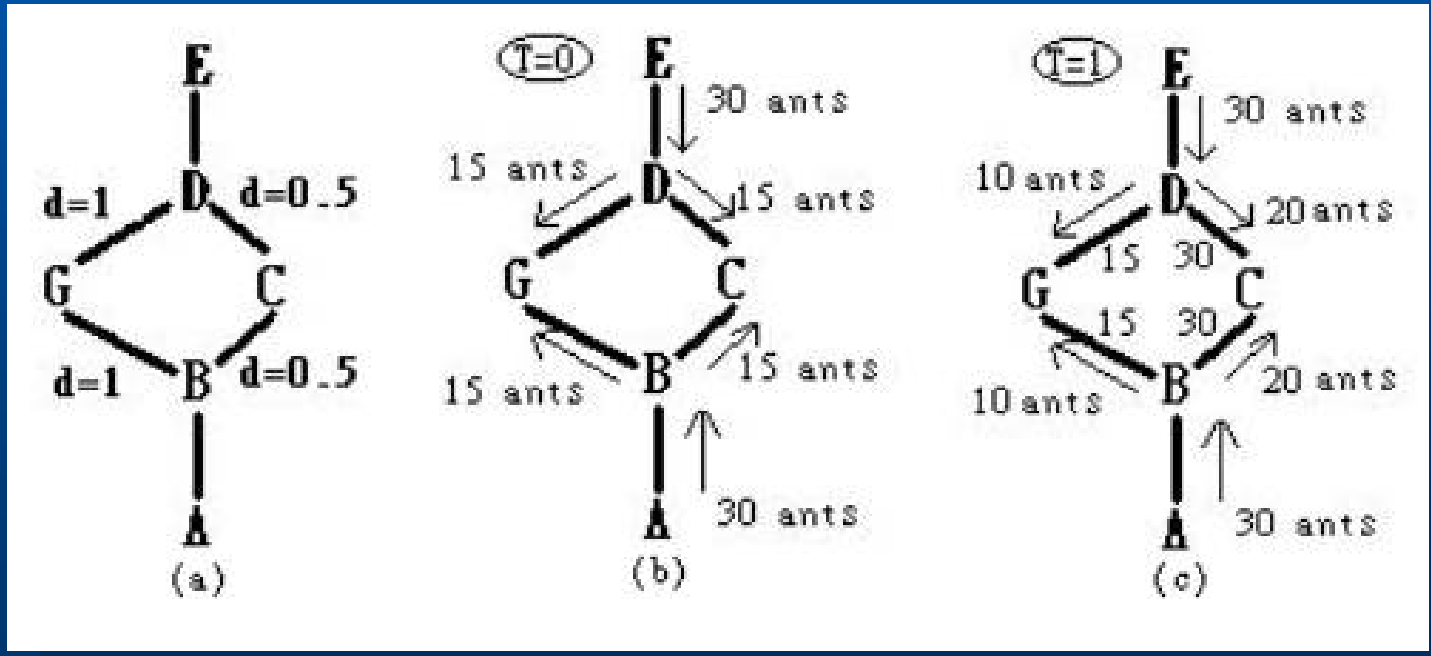
Social Behavior for Optimization



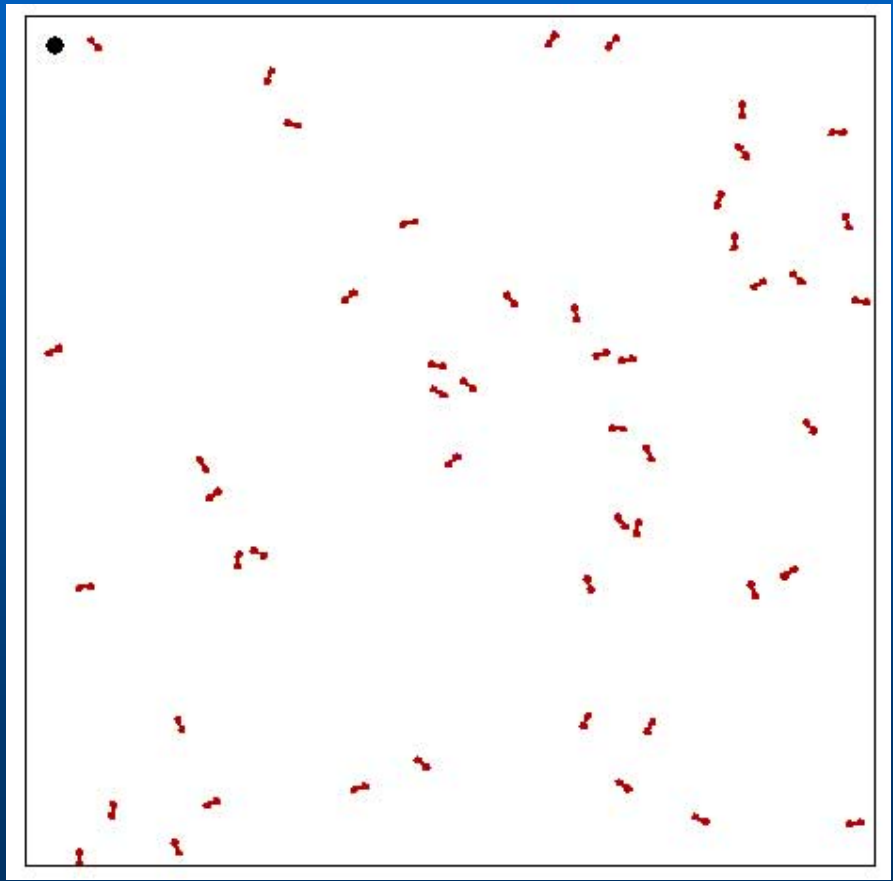


蟻群覓食

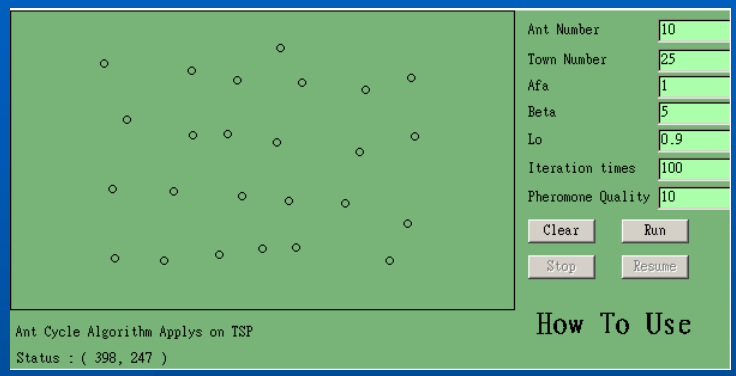
當螞蟻在食物和巢物之間來回行走時，會分泌一種化學物質：費洛蒙(pheromone) 。當巢穴到食物之間有許多路徑可以選擇時，個別螞蟻將傾向於選擇費洛蒙較強的路徑。

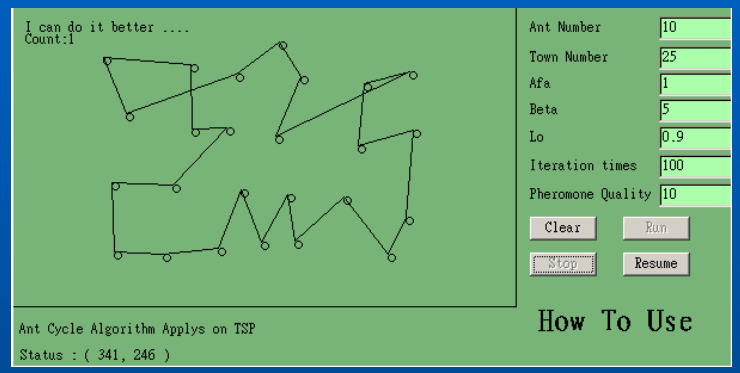


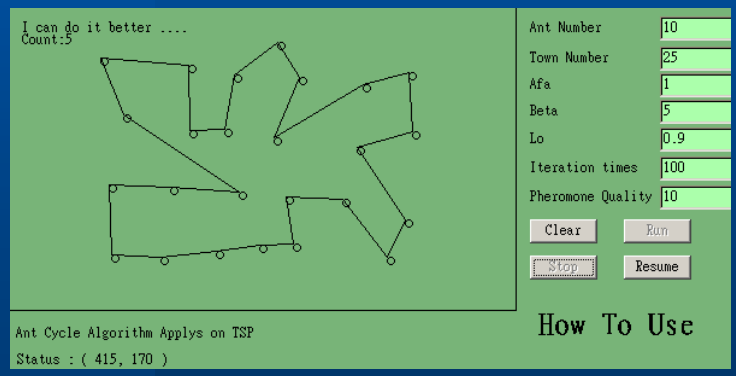
蟻群覓食模擬

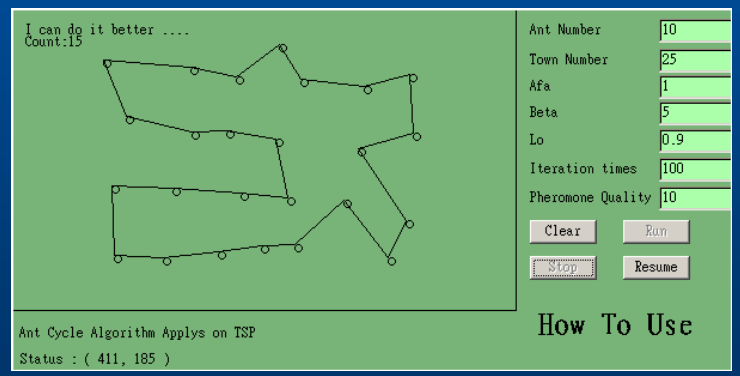


蟻群覓食與TSP最佳化



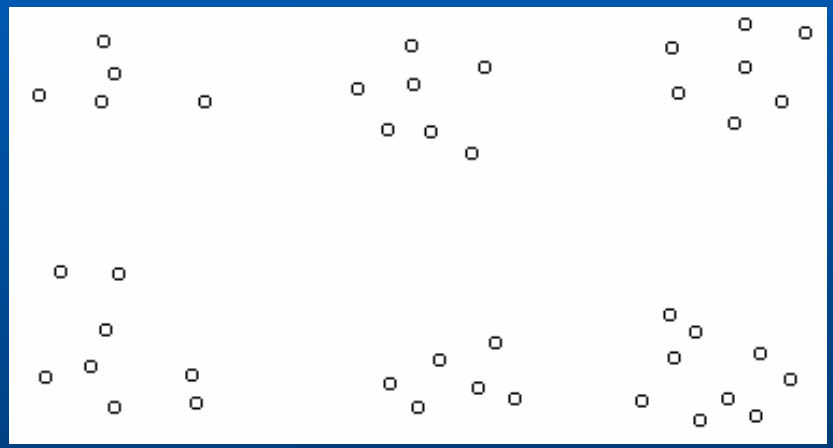


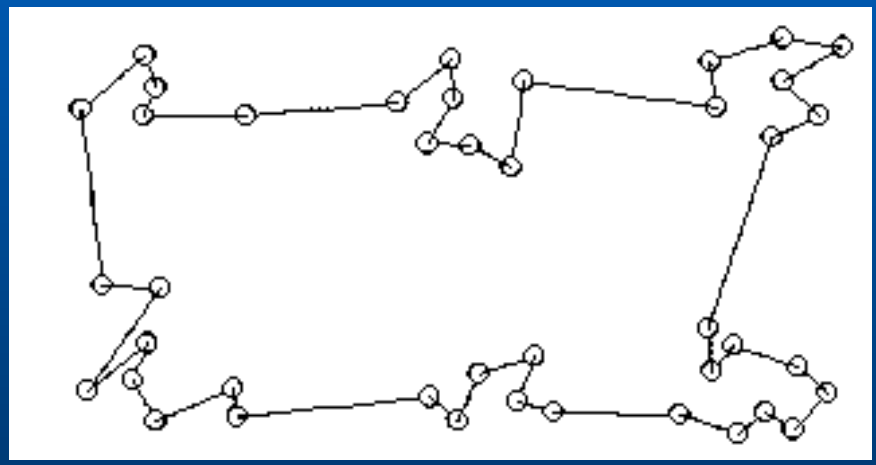




Ant-TSP DEMO

蟻群覓食與TSP最佳化

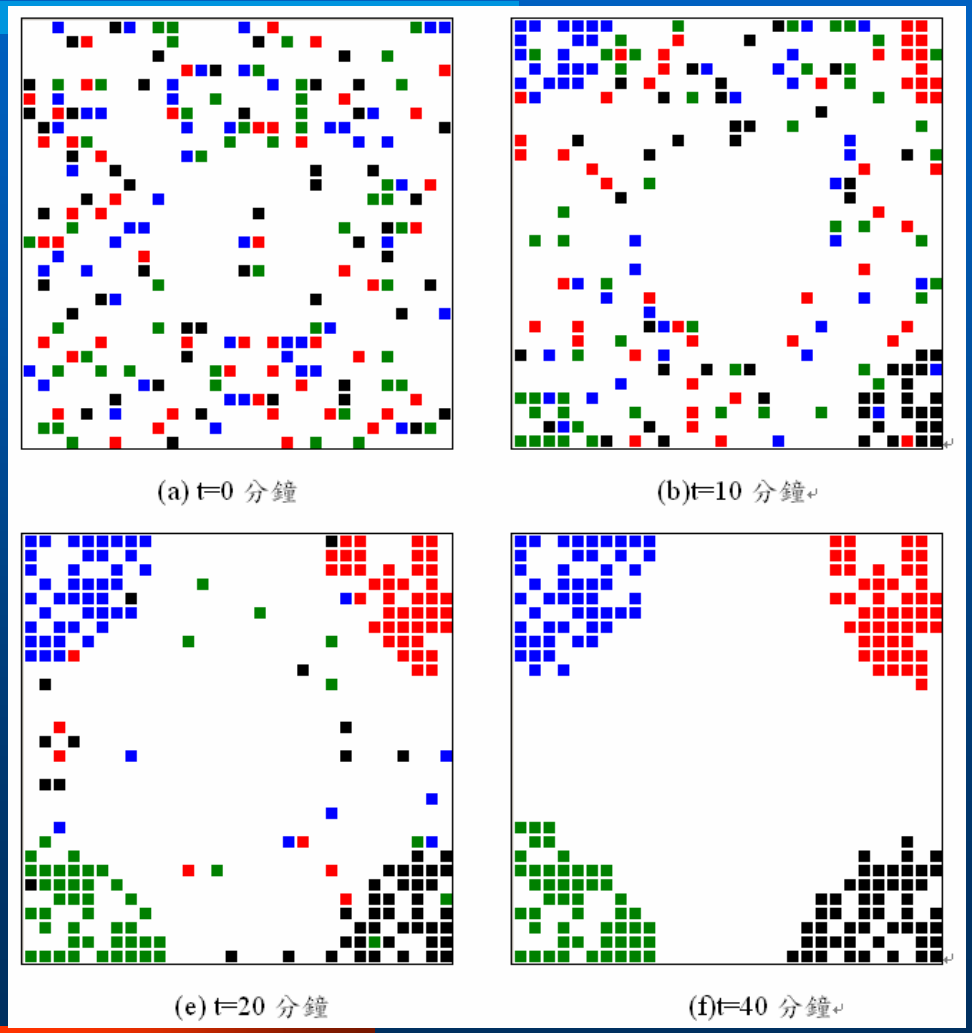




TSP最佳化的性能比較

	10次中的最佳解	平均最佳解	標準差
螞蟻演算法	1115	1120.8	4.5
模擬退火演算法	1126	1135.4	7.4
遺傳演算法	1108	1130.5	12.9

蟻群自組織分揀(Gathering)



(a) t=0 分鐘

(b)t=10 分鐘

(e) t=20 分鐘

(f)t=40 分鐘

螞蟻自組織分揀規則

— 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。

螞蟻自組織分揀規則

—如果在螞蟻所在位置上有一個物體oj，則螞蟻拿起該物資的機率為

$$p(pick\_up) = \left(\frac{k_1}{k_1 + \mathrm{f}(\mathrm{o}_j)} \right)^2$$

—如果螞蟻正攜帶一個物資oj，而所在位置上沒有任何物體，則螞蟻放下oj的機率為，

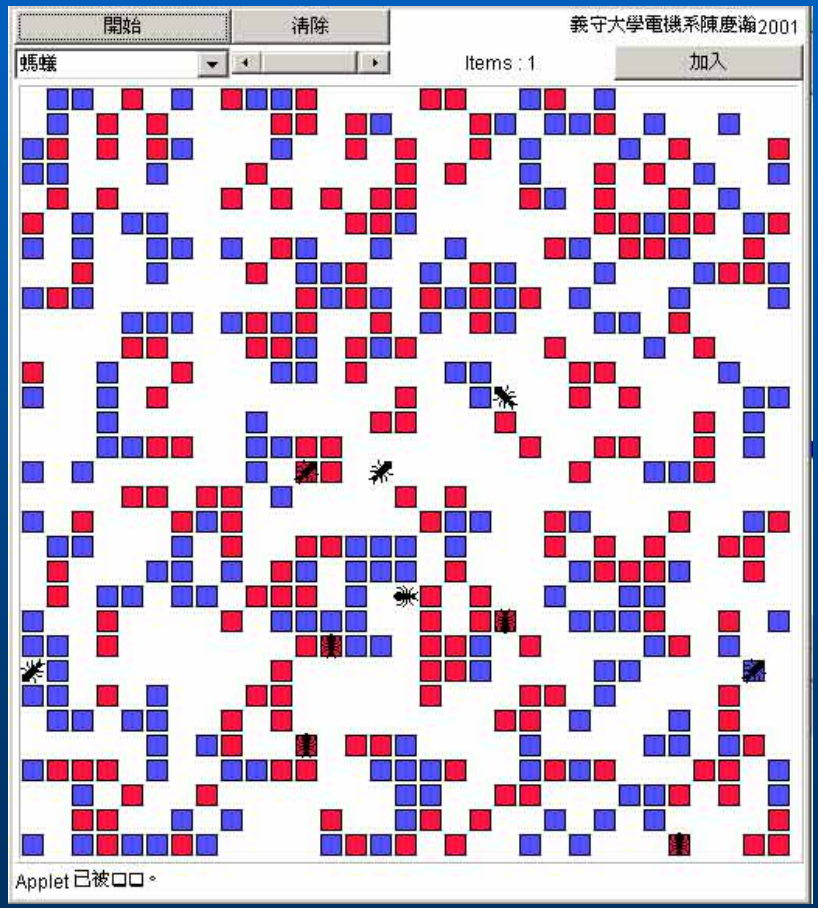
$$p(deposit) = \left(\frac{k_1}{k_1 + \mathrm{f}(\mathrm{o}_j)} \right)^2$$

螞蟻自組織分揀規則

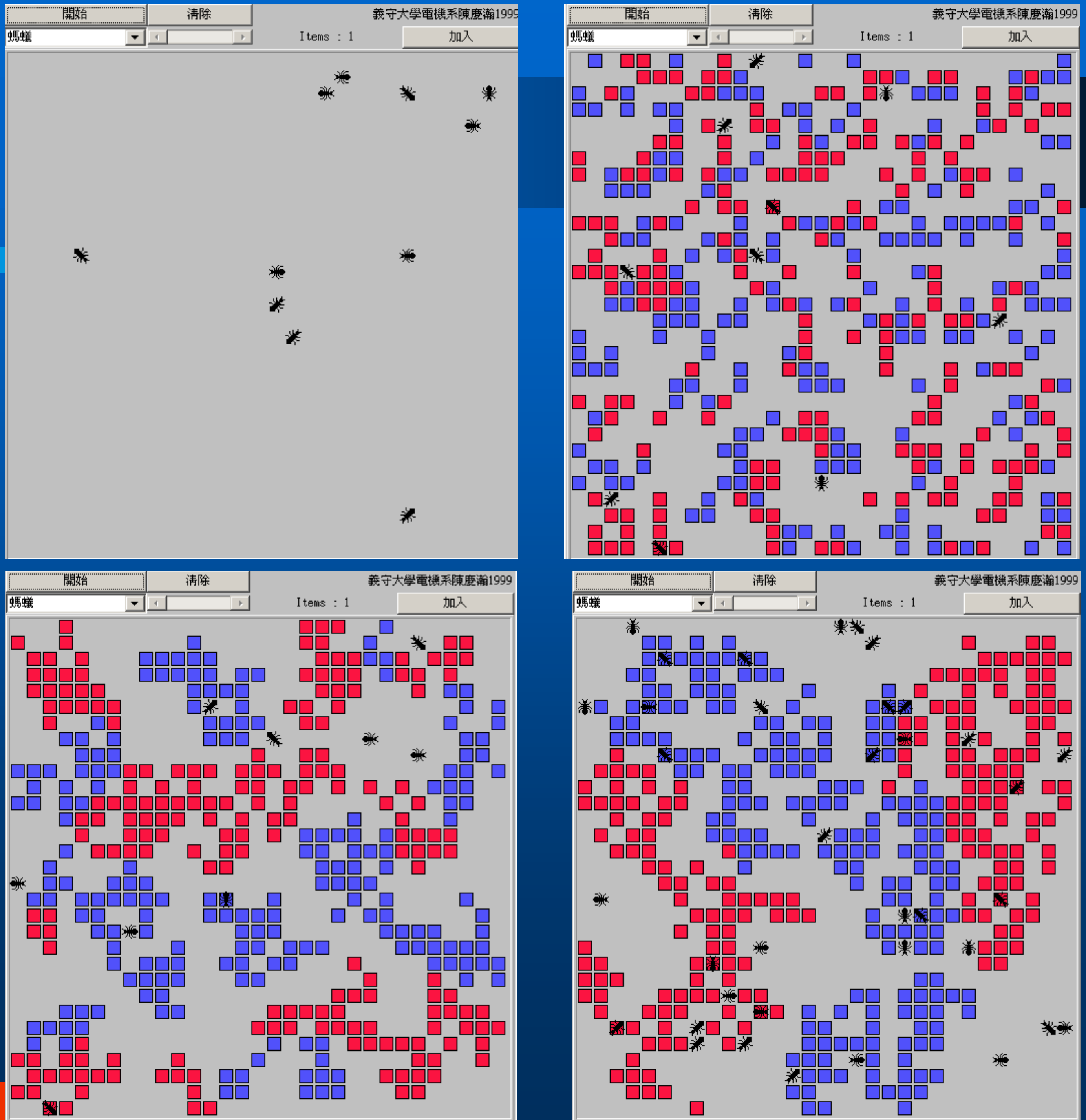
$$f(o_j) = \begin{cases} \frac{1}{s^2} \sum_{o_j \in Neigh(r)} \left[1 - \frac{d(o_j, o_k)}{\alpha} \right], if > 0 \\ 0, otherwise \end{cases}$$

d(oj, ok) 是*oj*與*ok* 的差異度指標

自組織分揀模擬

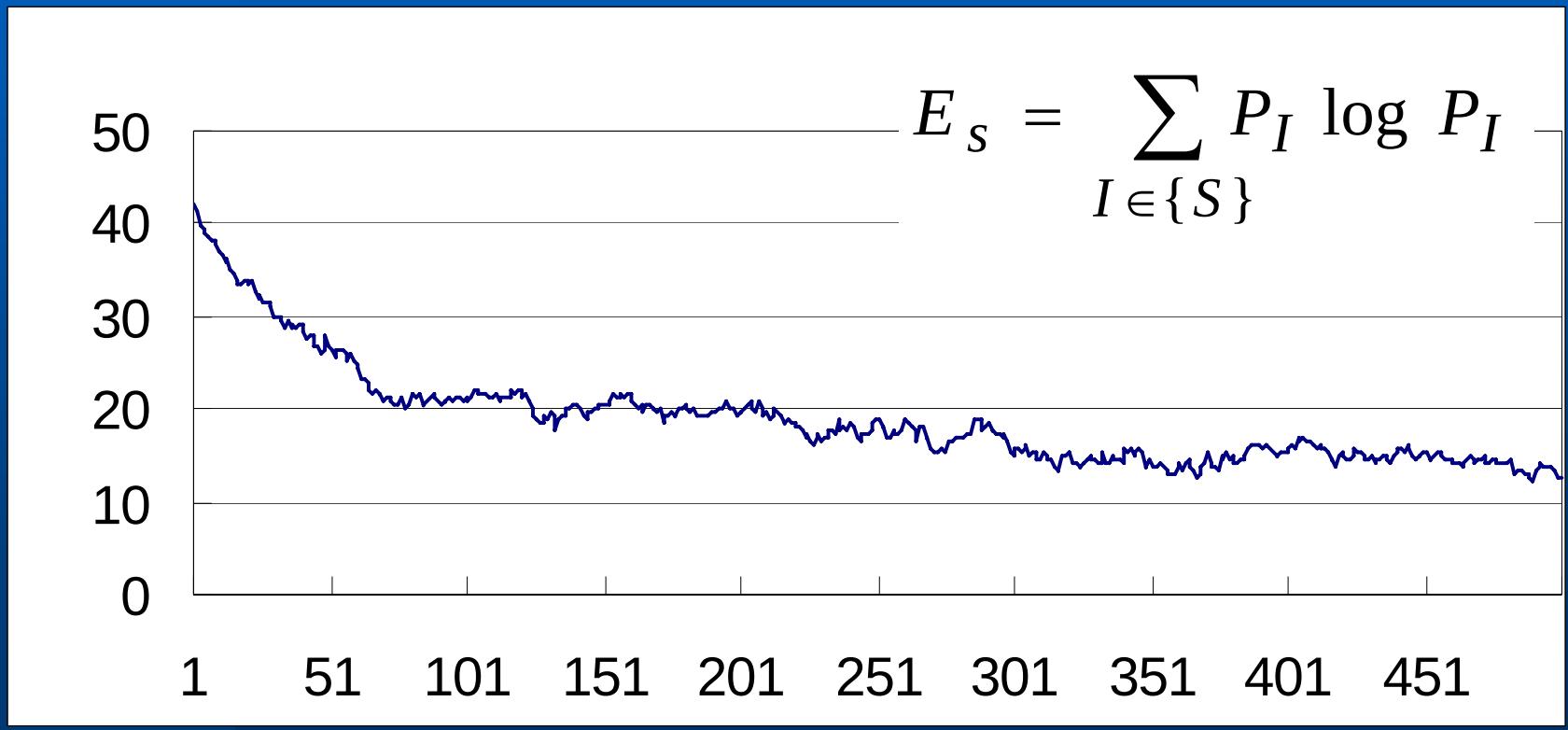


(a) (b)

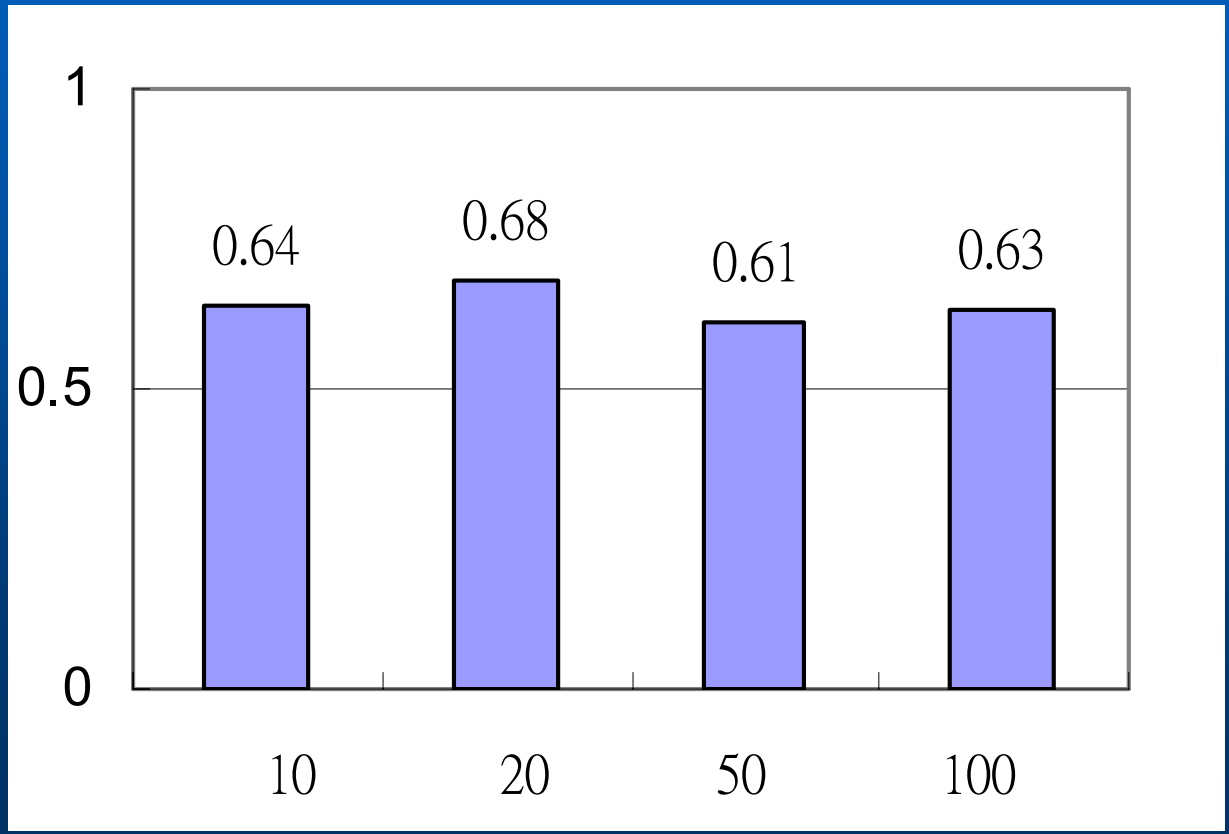


自組織分揀的收斂性

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



螞蟻數量v.s.Performance



螞蟻機率選擇參數

k1	k2	$E_S(100)$	E_S (500)	$E_S(1000)$
0.05	0.10	0.86	0.75	0.72
0.05	0.15	0.75	0.68	0.66
0.05	0.20	0.76	0.67	0.64
0.05	0.30	0.74	0.64	0.64
0.02	0.20	0.81	0.77	0.75
0.04	0.20	0.74	0.66	0.65
0.08	0.20	0.76	0.64	0.59
0.15	0.20	0.75	0.69	0.57

仿螞蟻群體解題的應用

— Optimization

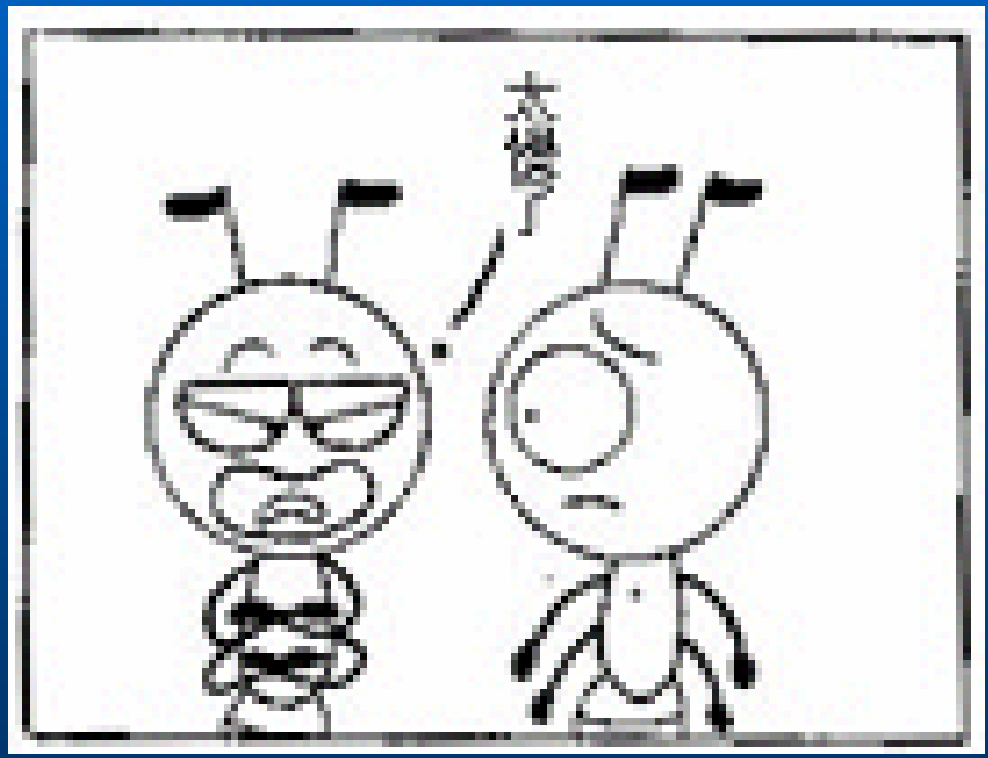
— Data Mining by Clustering

— Adaptive Task Allocation

— Multi-robots System

— Meta-heuristics for New Intelligent System Design

漫畫欣賞1/4



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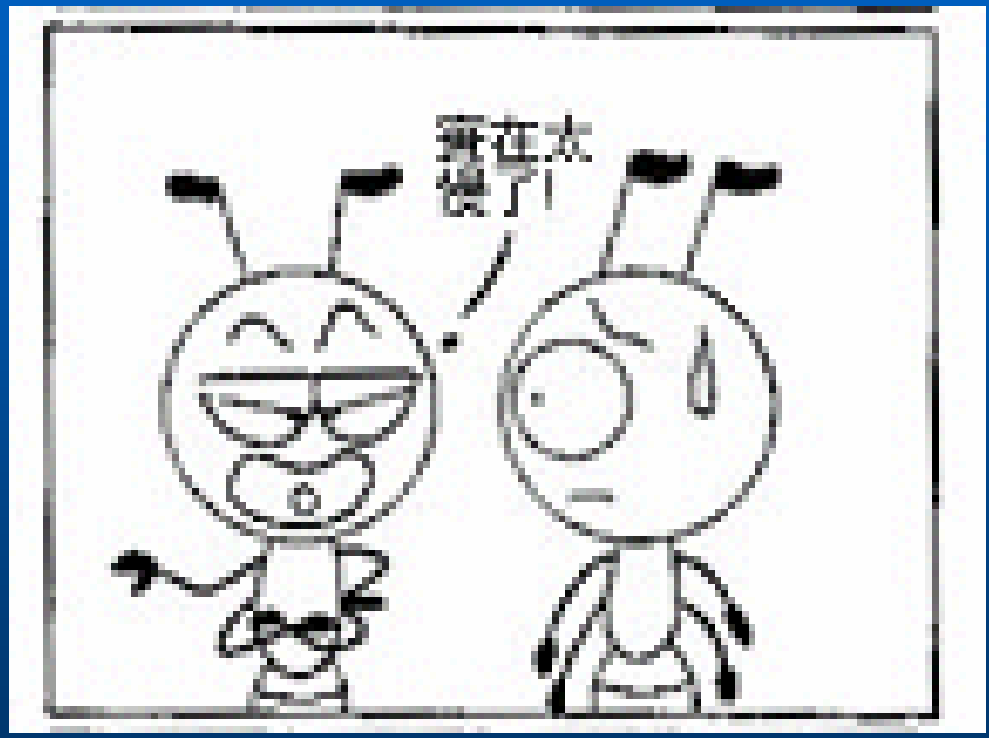
漫畫欣賞2/4



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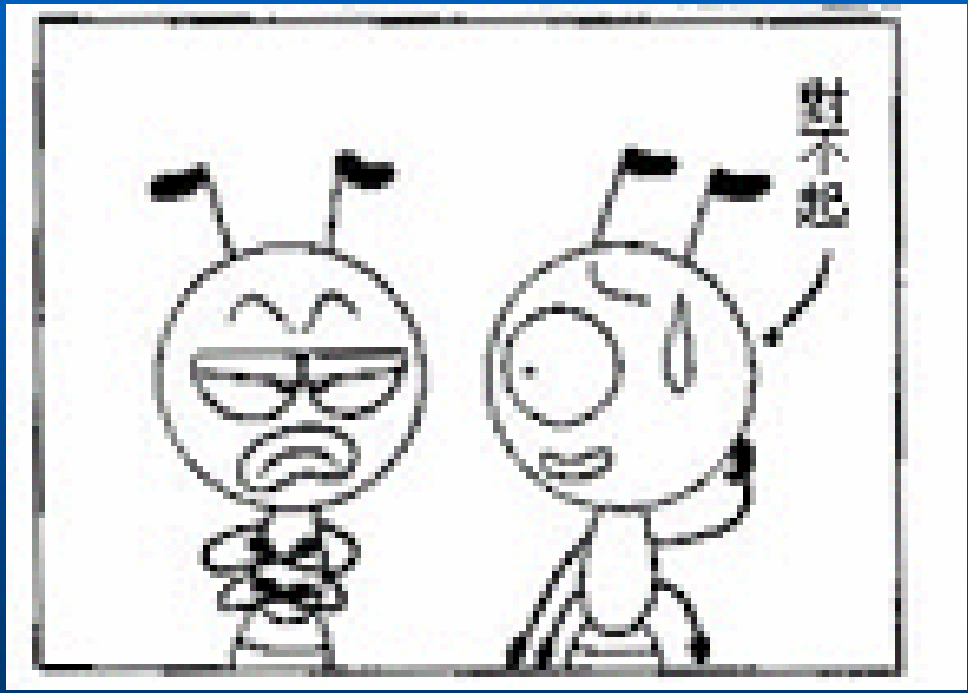

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結語和討論