

# 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



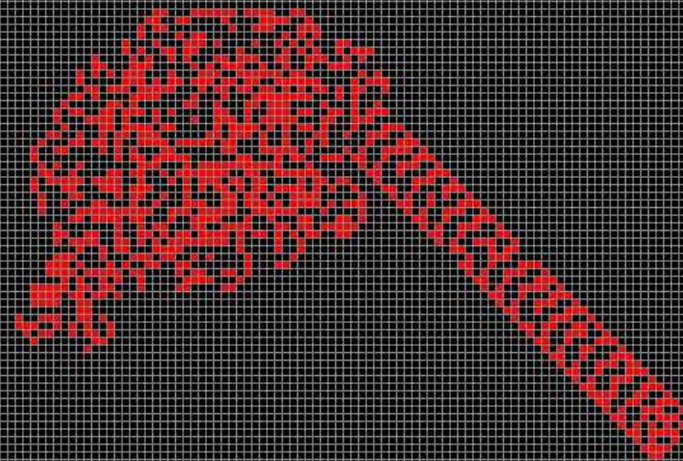
# 化約 vs. 複雜式系統

	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

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

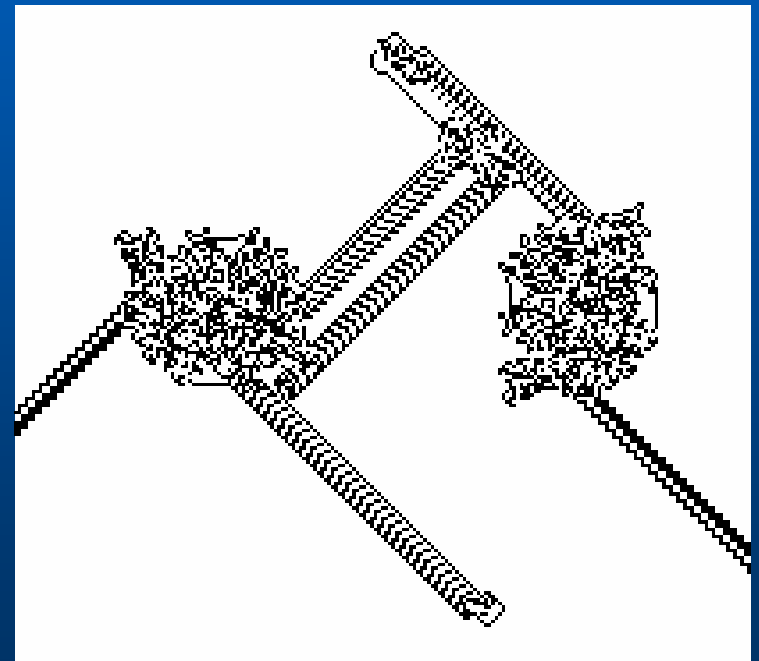


# Simulation of Langton's Ant

Single Ant



Multiple Ants



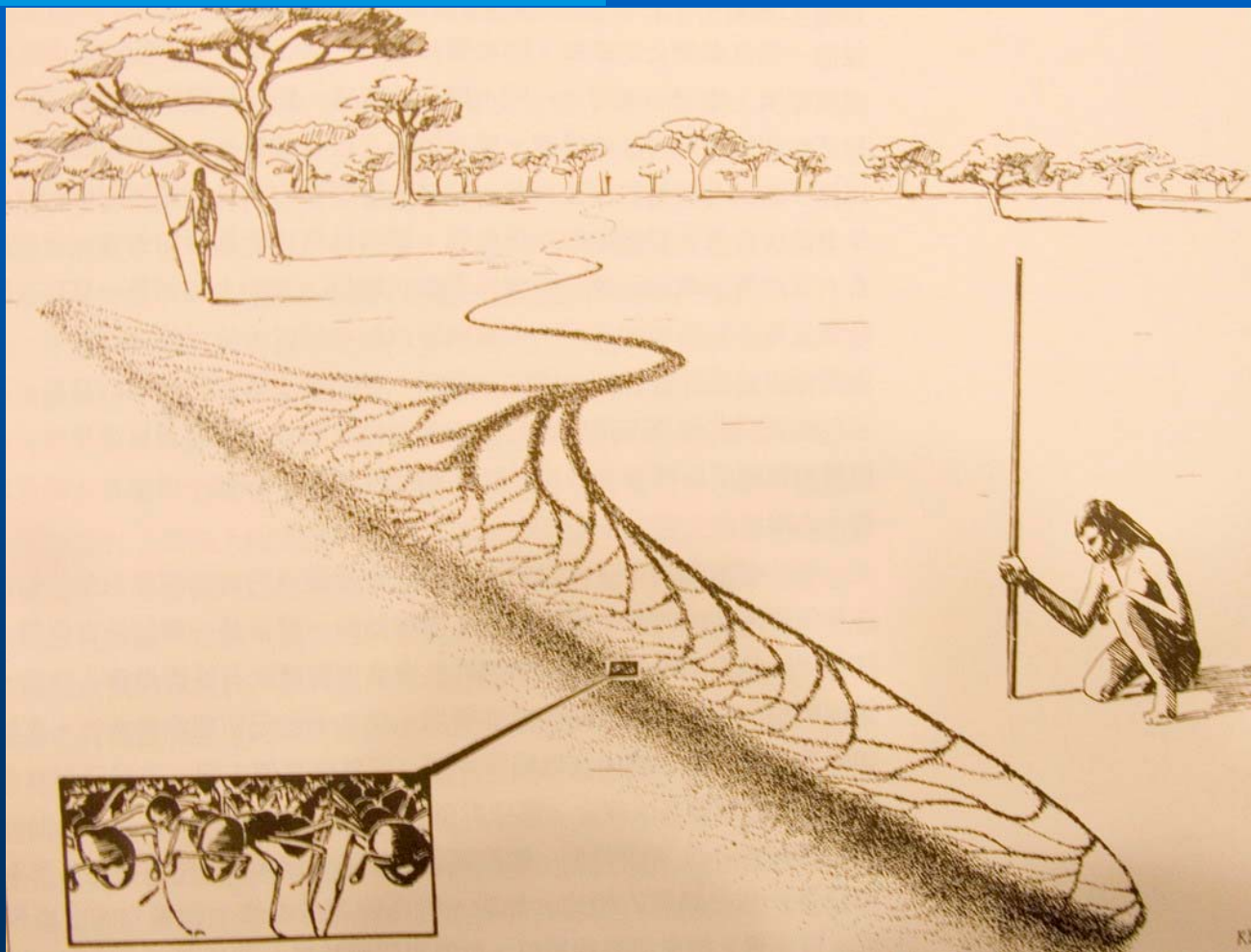


# 仿螞蟻群體解題行為





# 螞蟻的超組織模型



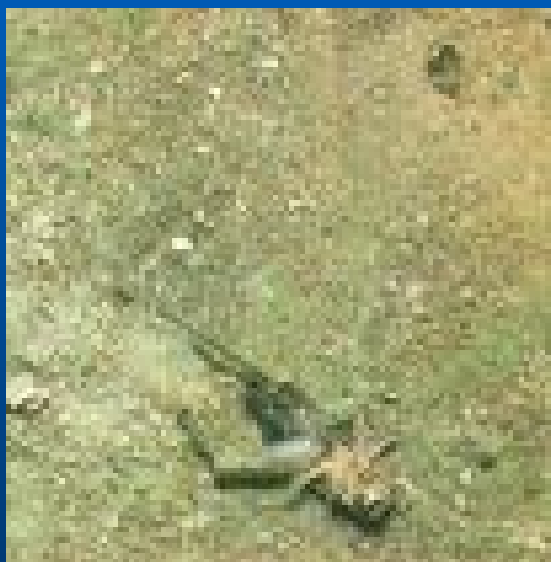


# 螞蟻搬運食物



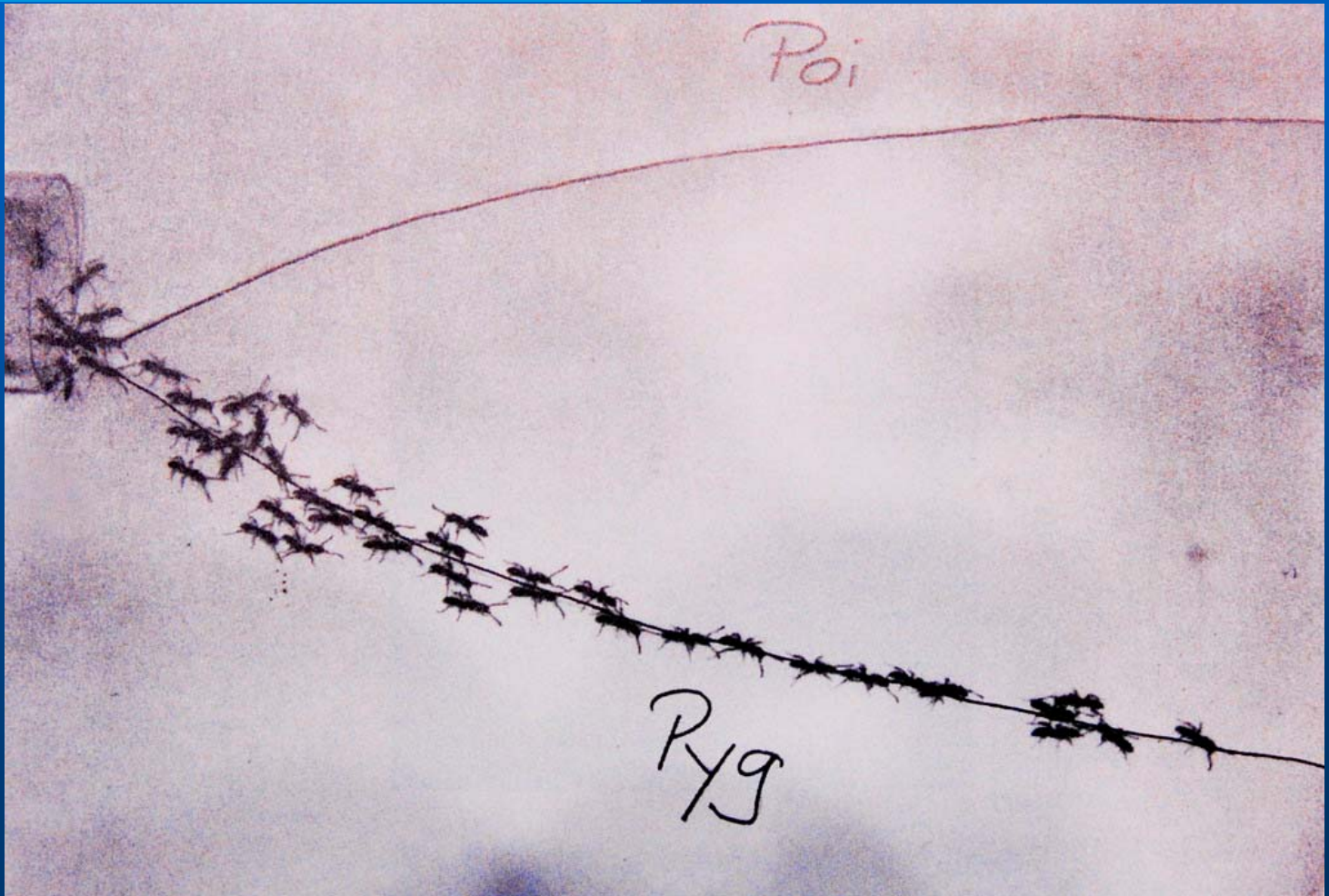


# 螞蟻群體解題





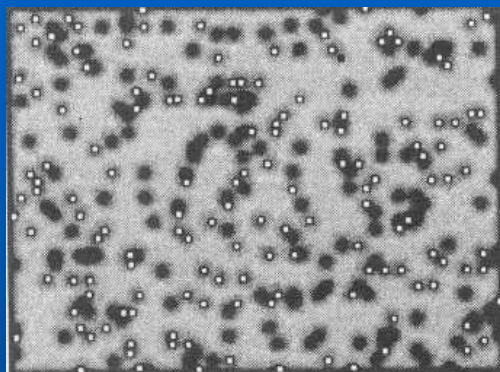
# 蟻群的溝通和決策



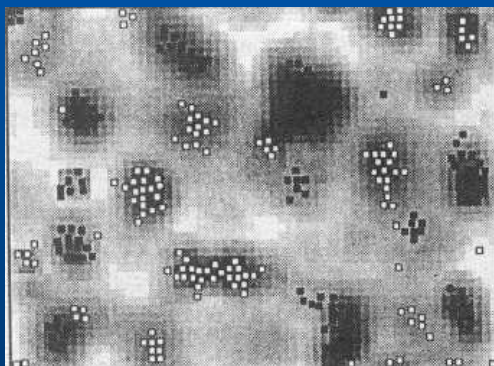


# 蟻群的分檢行為

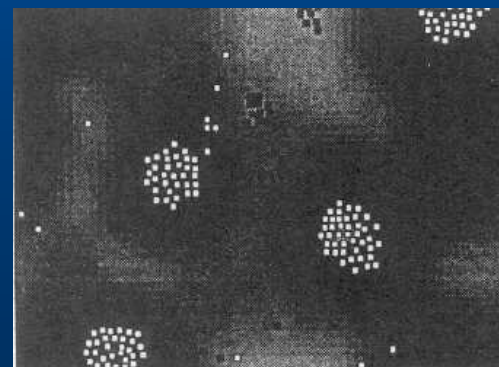
T<sub>1</sub>

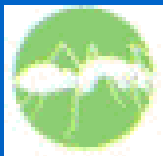


T<sub>2</sub>

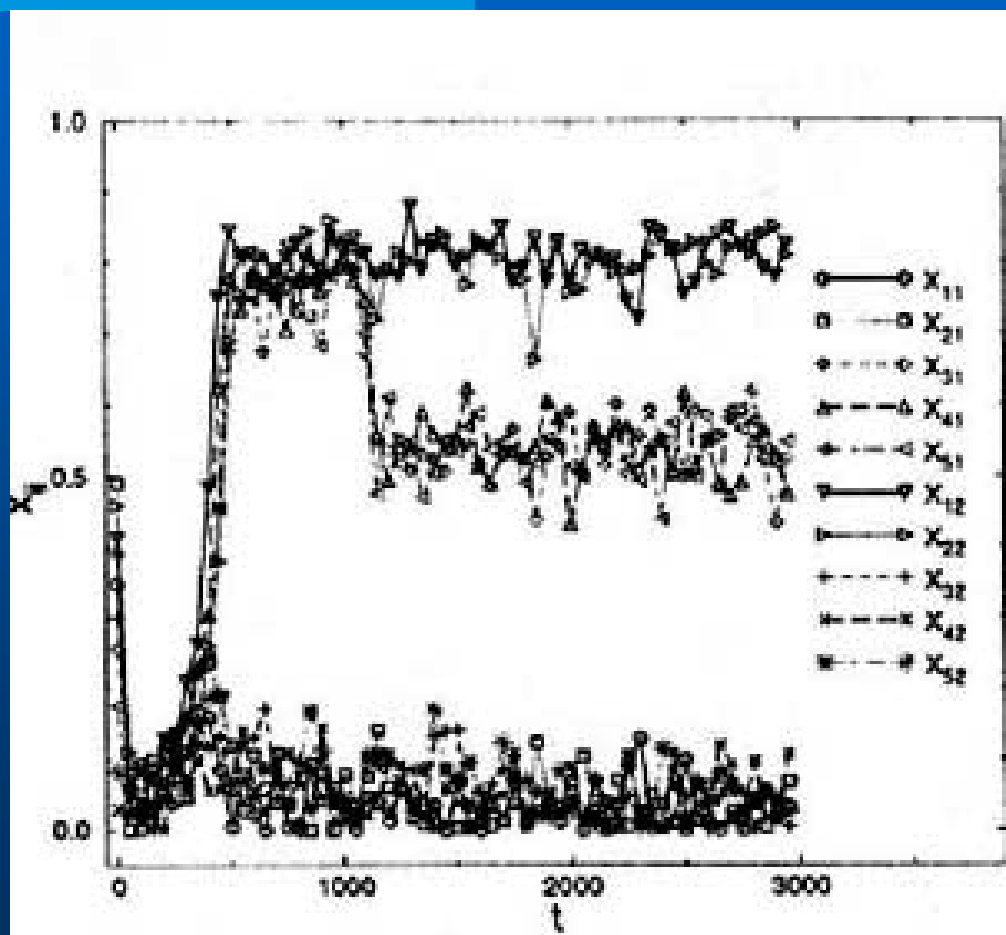


T<sub>3</sub>





# 蟻群的工作派遣行為





# 蟻群的築巢行為





# 蟻群的搭橋行為





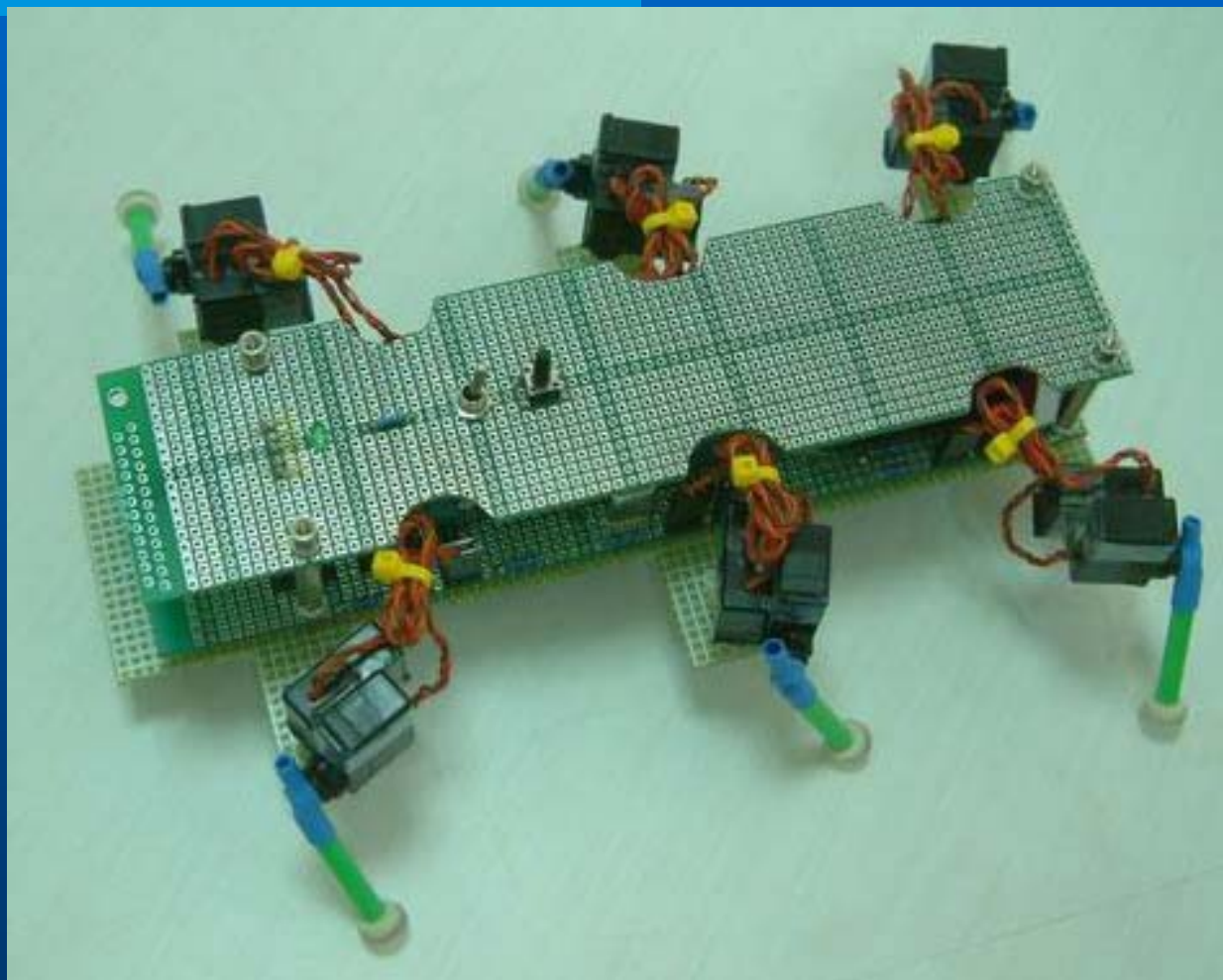


# Bridge Building in Ant Colony



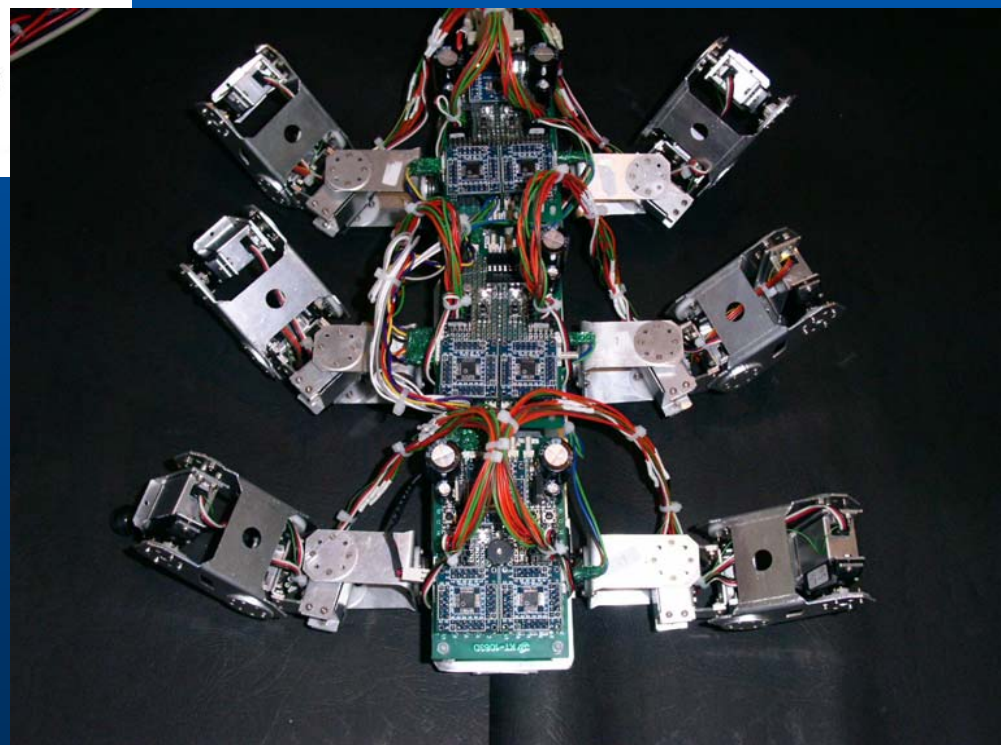
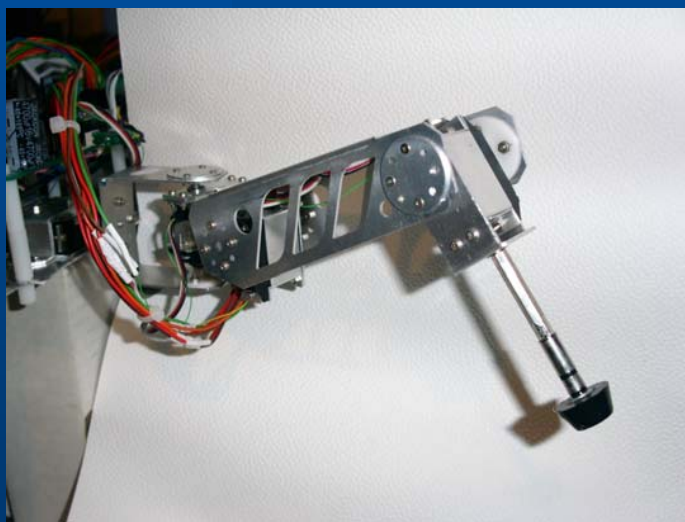
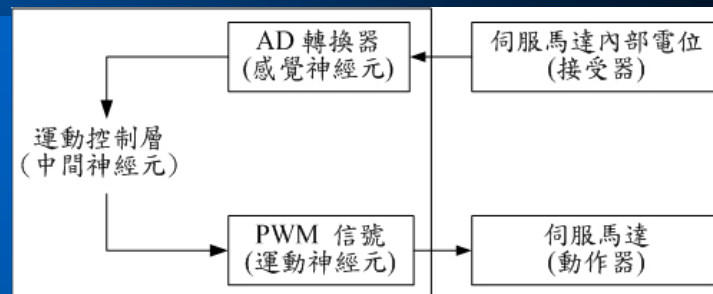
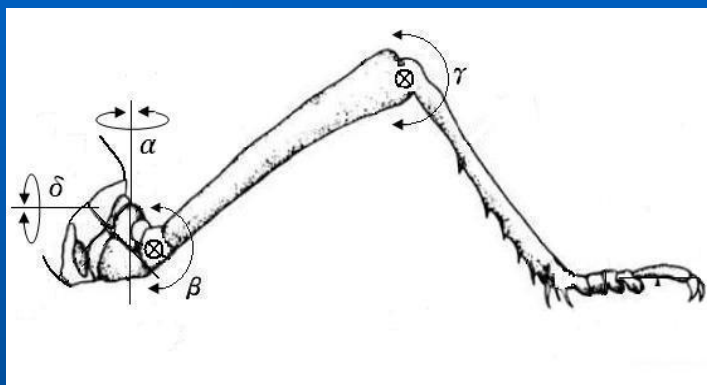


# MIAT第一代螞蟻機器人





# 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)

.....

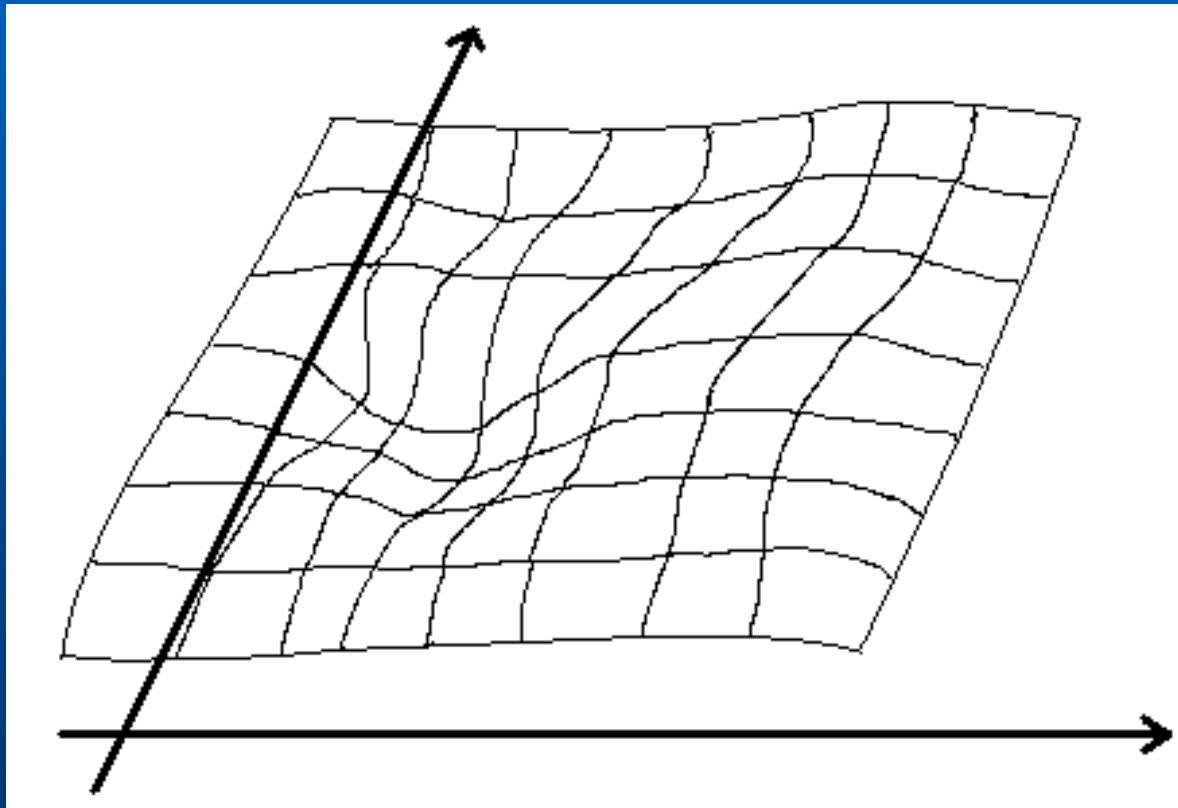


# 螞蟻群體解題

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：

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

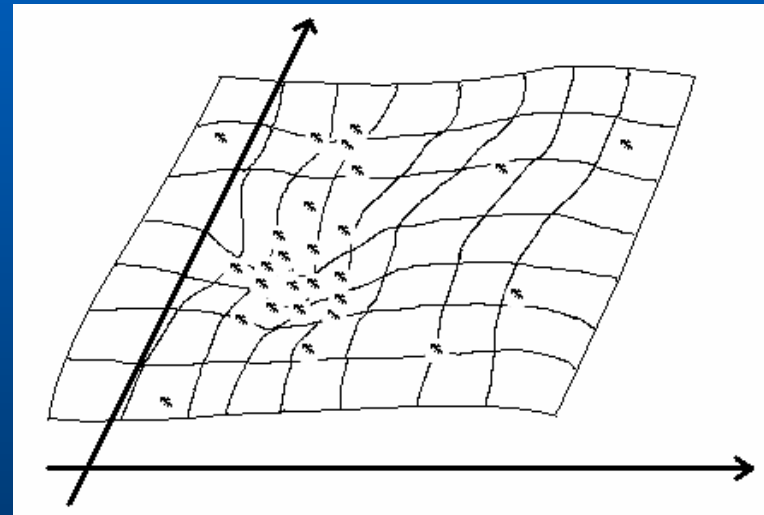
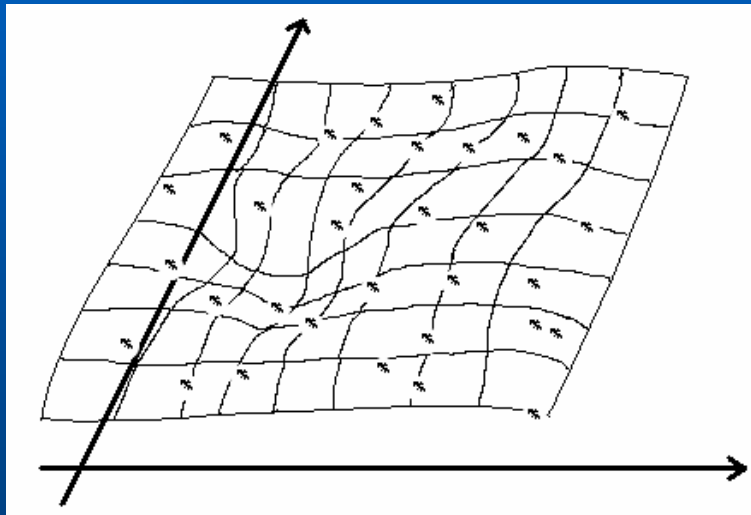
新的搜尋位置：

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





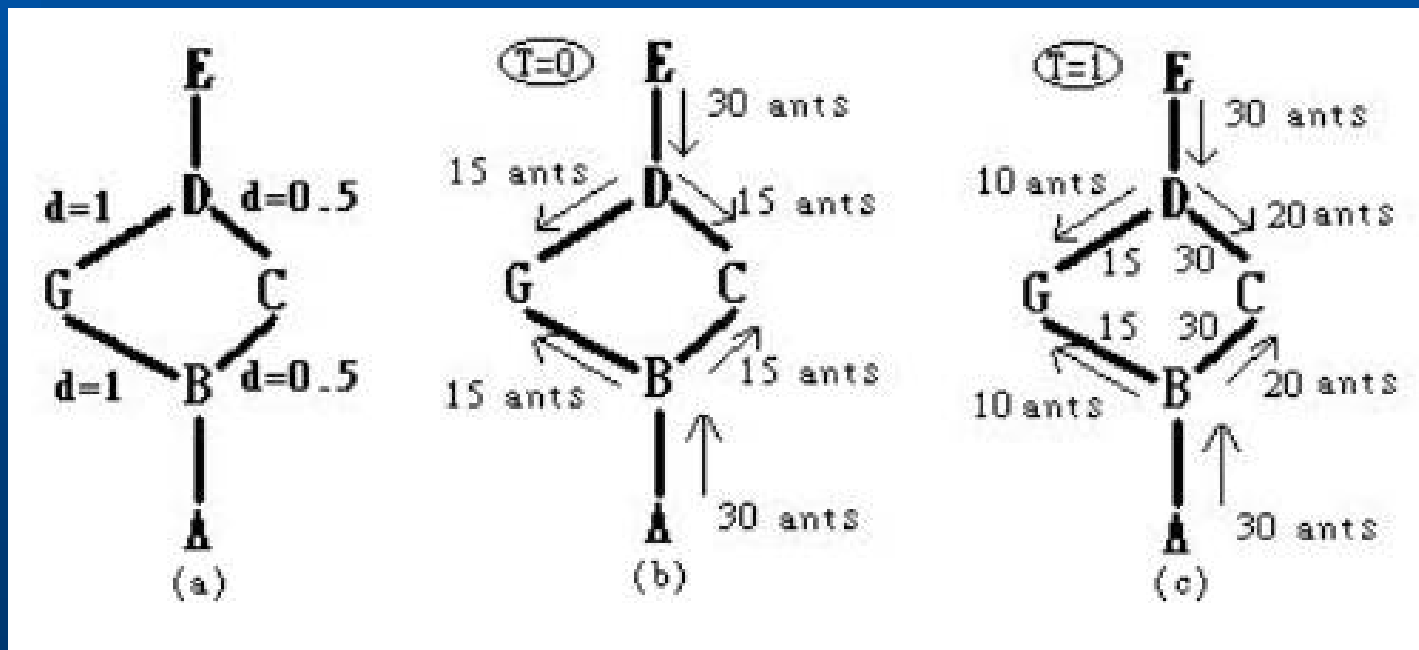
# Social Behavior for Optimization





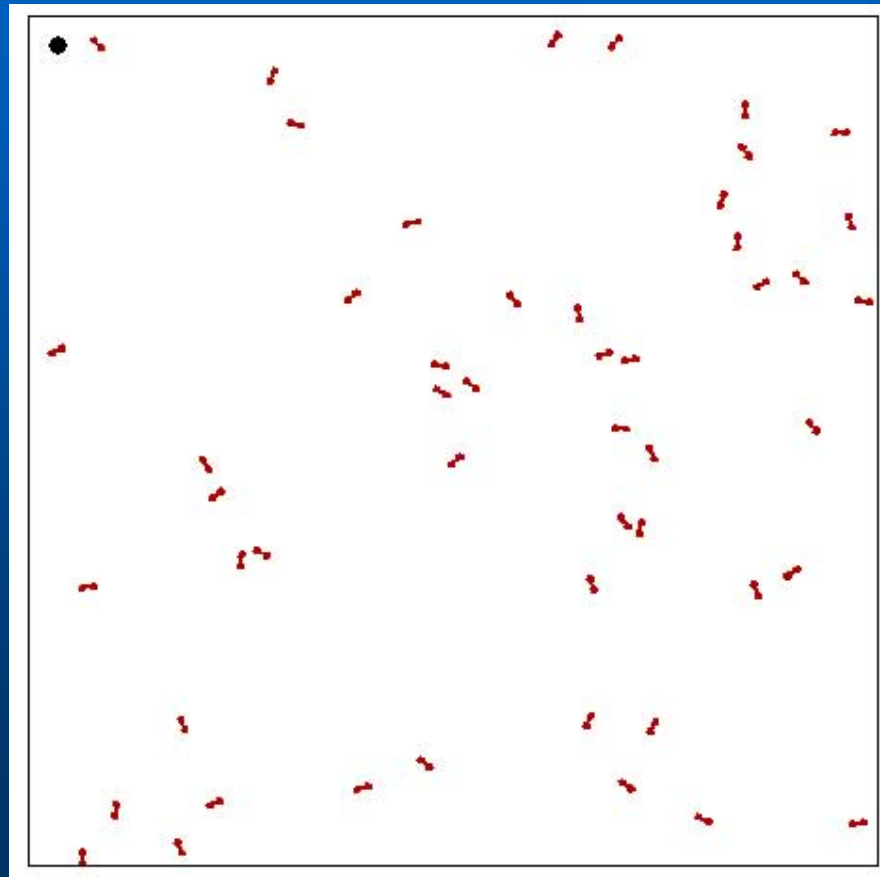
# 蟻群覓食

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。



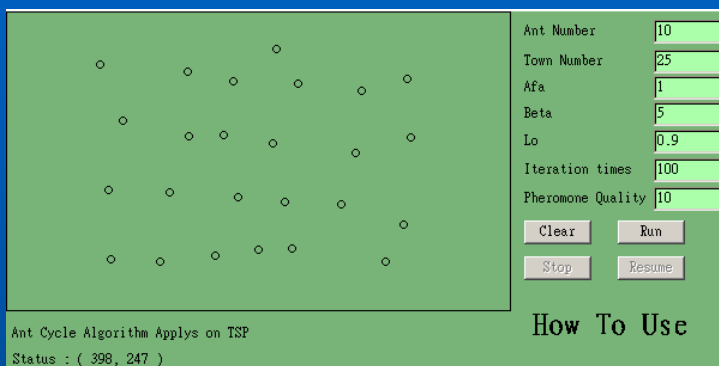


# 蟻群覓食模擬





# 蟻群覓食與TSP最佳化



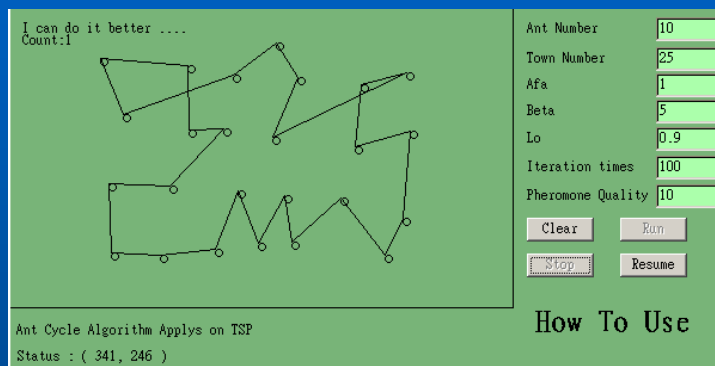
Ant Cycle Algorithm Applies on TSP  
Status : ( 398, 247 )

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

This screenshot shows the initial state of the Ant Cycle Algorithm. The main window displays 25 scattered points representing towns. The control panel on the right contains various parameters and buttons. The status bar at the bottom indicates the current position (398, 247).



I can do it better ....  
Count:1

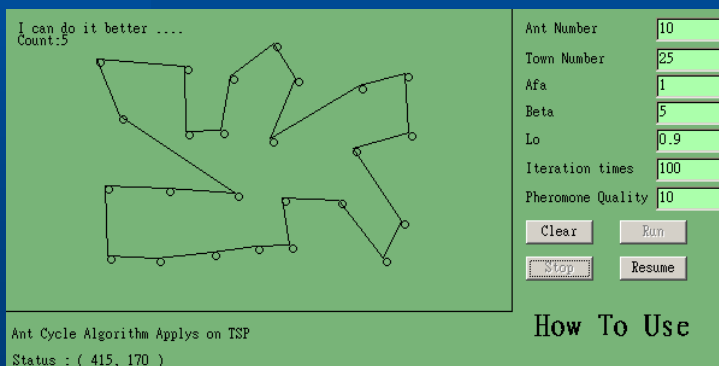
Ant Cycle Algorithm Applies on TSP  
Status : ( 341, 246 )

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

This screenshot shows the first iteration. A single path is drawn connecting some of the towns. The text "I can do it better ...." and "Count:1" appears in the top left. The status bar shows the new position (341, 246).



I can do it better ....  
Count:5

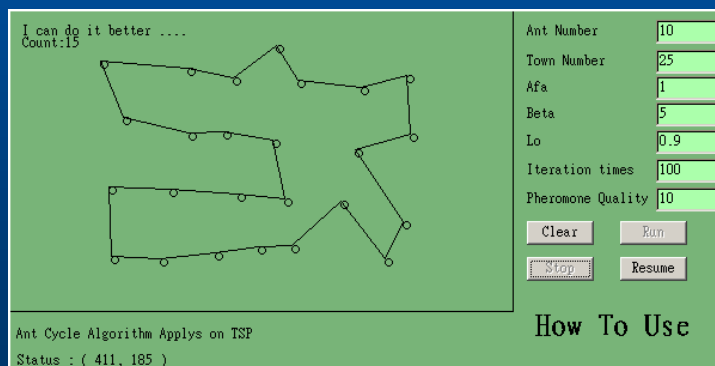
Ant Cycle Algorithm Applies on TSP  
Status : ( 415, 170 )

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

This screenshot shows the fifth iteration. The path has become more complex, visiting more towns. The text "I can do it better ...." and "Count:5" is visible. The status bar shows the position (415, 170).



I can do it better ....  
Count:15

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

How To Use

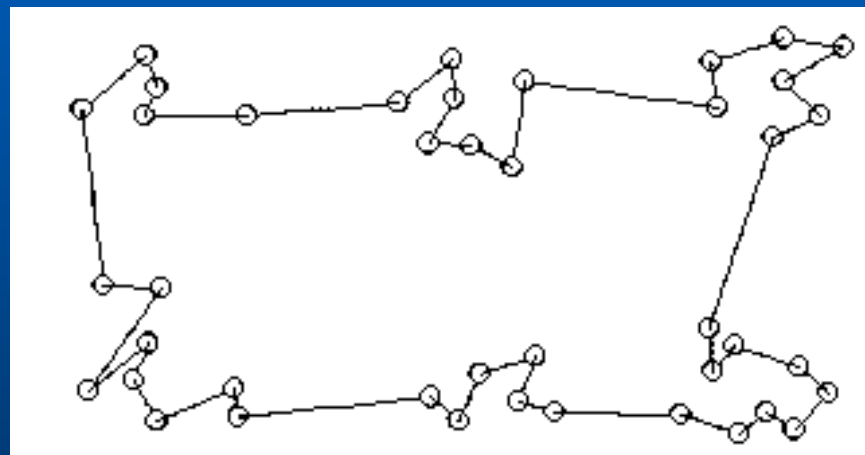
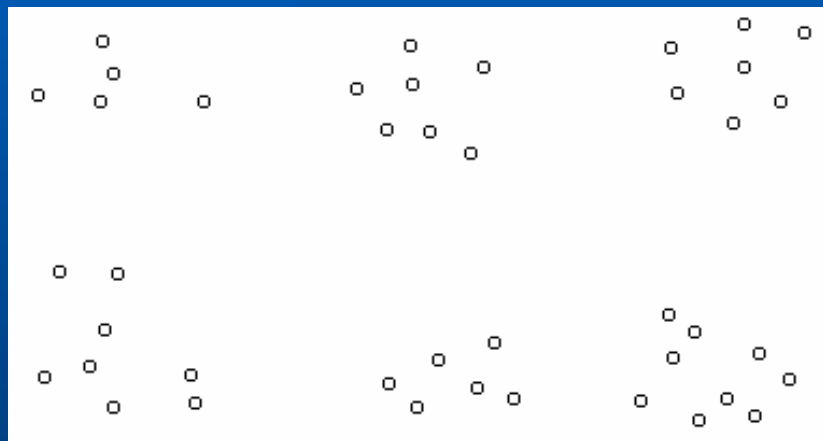
Ant Number: 10  
Town Number: 25  
Afa: 1  
Beta: 5  
Lo: 0.9  
Iteration times: 100  
Pheromone Quality: 10

Clear Run  
Stop Resume

This screenshot shows the fifteenth iteration. The path is further refined. The text "I can do it better ...." and "Count:15" is present. The status bar shows the position (411, 185).

Ant-TSP DEMO

# 蟻群覓食與TSP最佳化



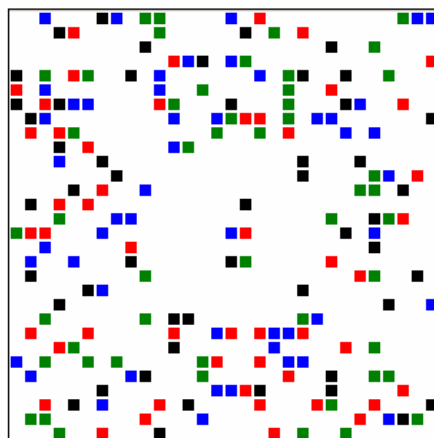


# TSP最佳化的性能比較

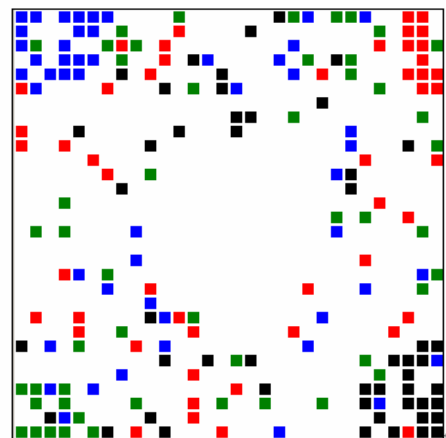
	10次中的最佳解	平均最佳解	標準差
螞蟻演算法	1115	1120.8	4.5
模擬退火演算法	1126	1135.4	7.4
遺傳演算法	1108	1130.5	12.9



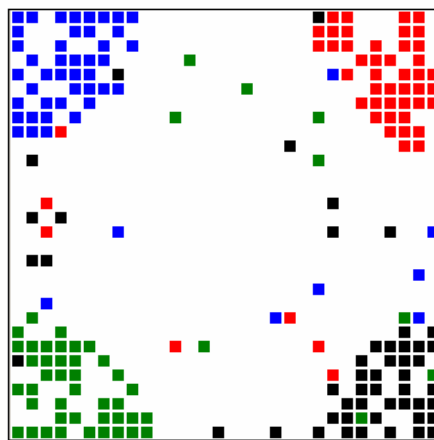
# 蟻群自組織分揀(Gathering)



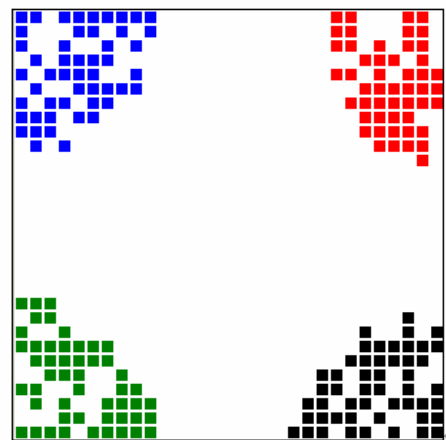
(a) t=0 分鐘



(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 $o_j$ ，則螞蟻拿起該物資的機率為

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

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

$$p(\text{deposit}) = \left( \frac{k_1}{k_1 + f(o_j)} \right)^2$$



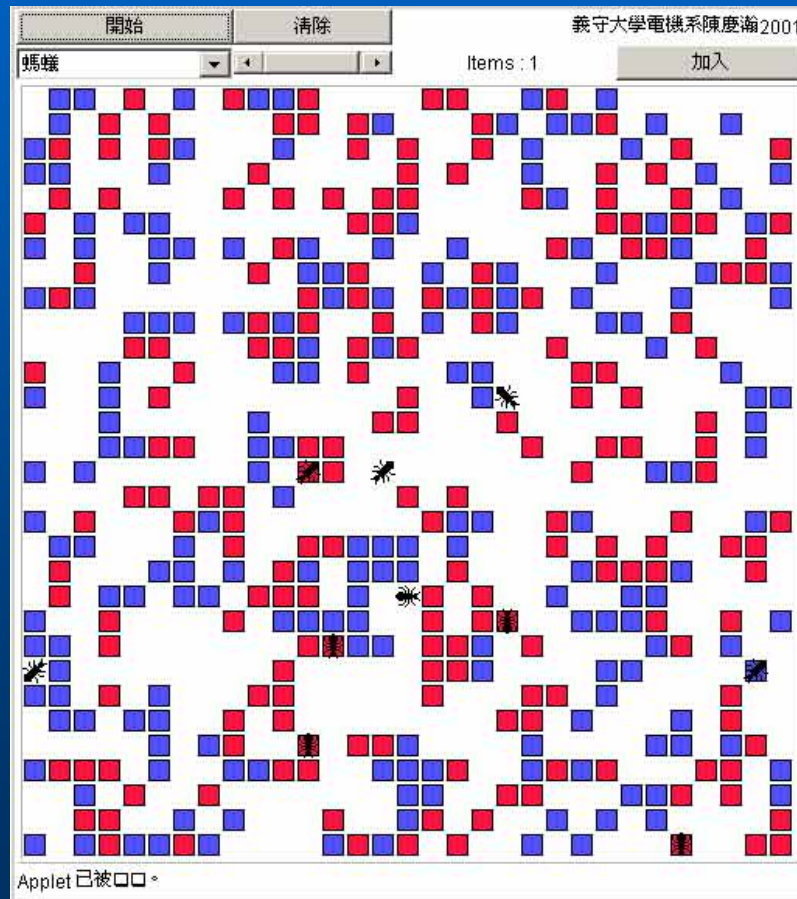
# 螞蟻自組織分揀規則

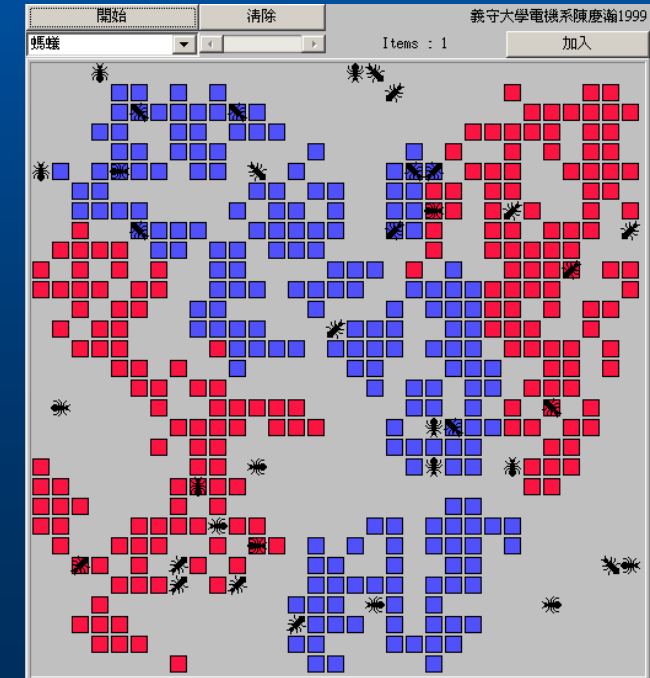
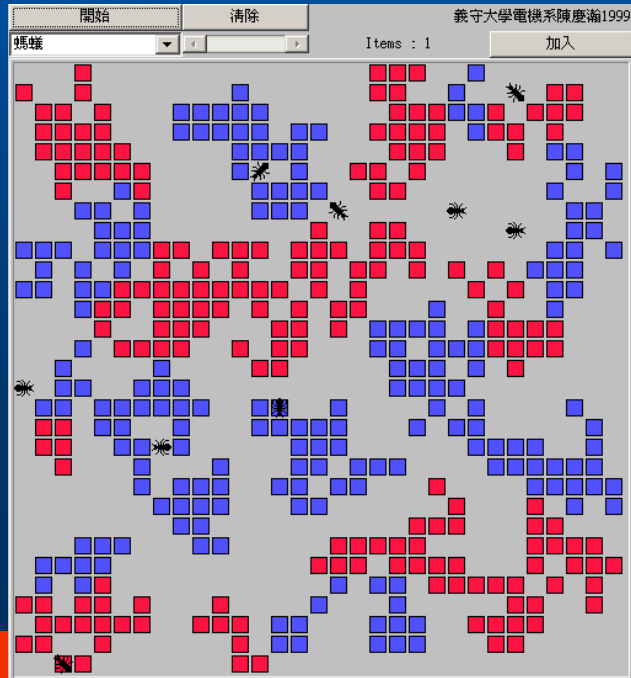
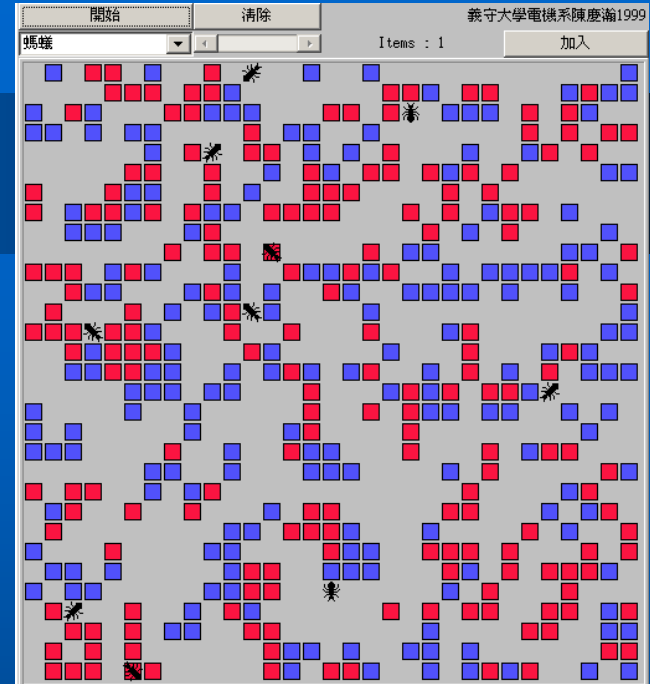
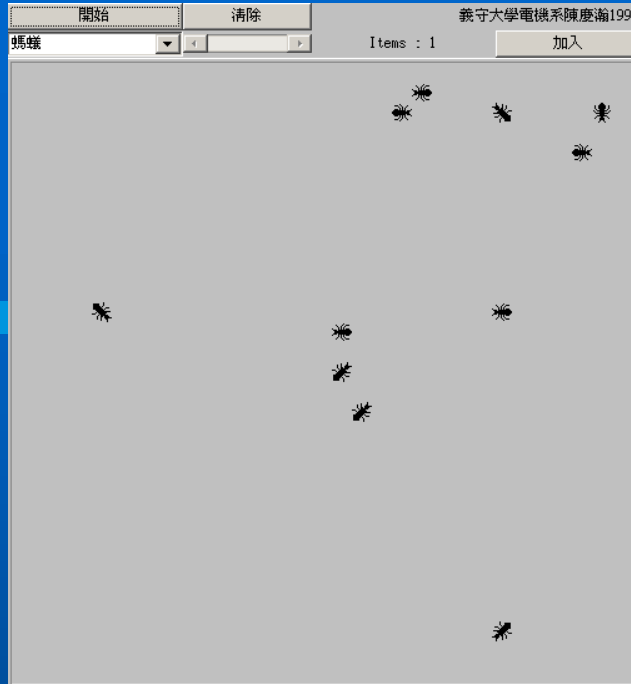
$$f(o_j) = \begin{cases} \frac{1}{s^2} \sum_{o_j \in Neigh(r)} \left[ 1 - \frac{d(o_j, o_k)}{\alpha} \right], & \text{if } > 0 \\ 0, & \text{otherwise} \end{cases}$$

$d(o_j, o_k)$  是  $o_j$  與  $o_k$  的差異度指標



# 自組織分揀模擬



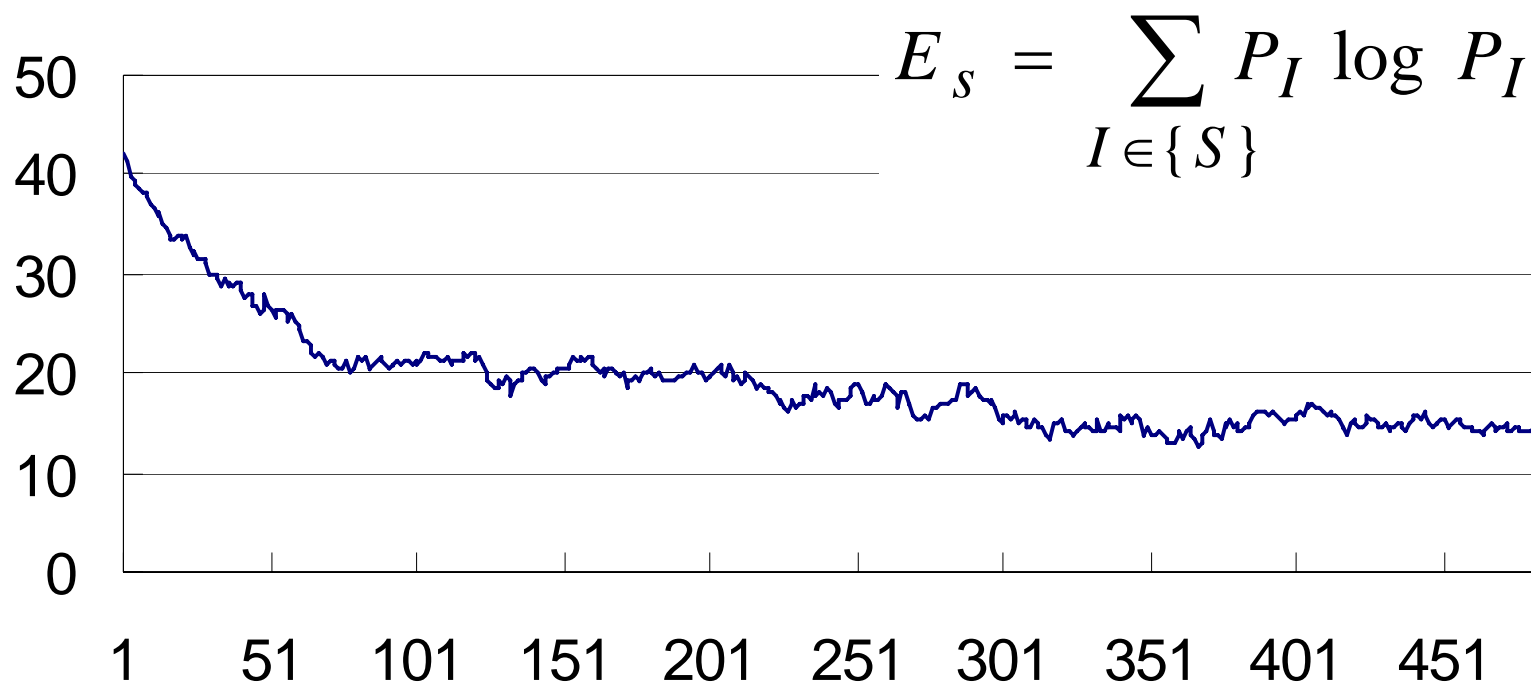


(a)

(b)

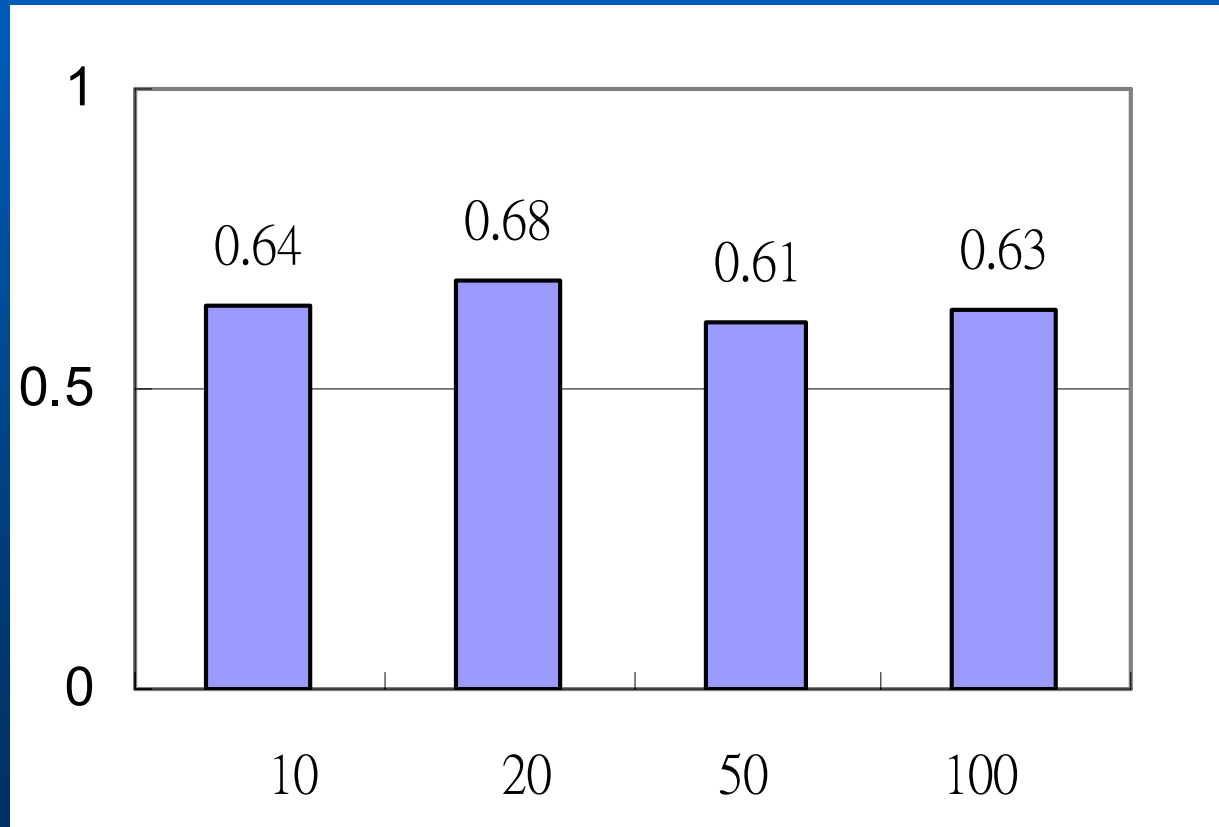


# 自組織分揀的收斂性





# 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



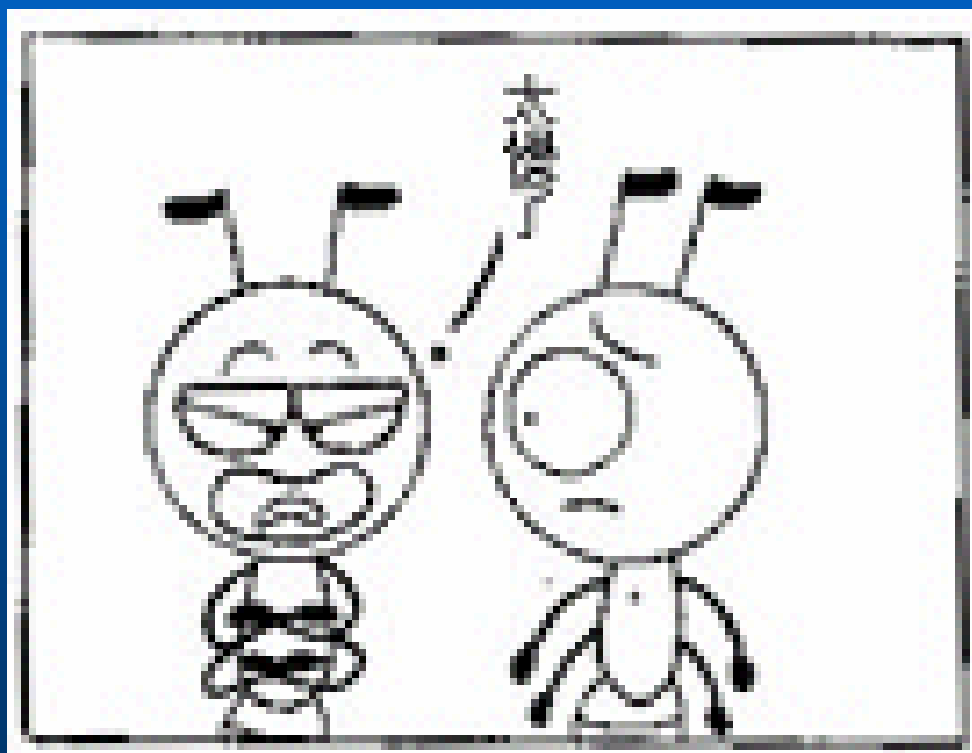
# 仿螞蟻群體解題的應用

- Optimization
- Data Mining by Clustering
- Adaptive Task Allocation
- Multi-robots System
- Meta-heuristics for New Intelligent System Design





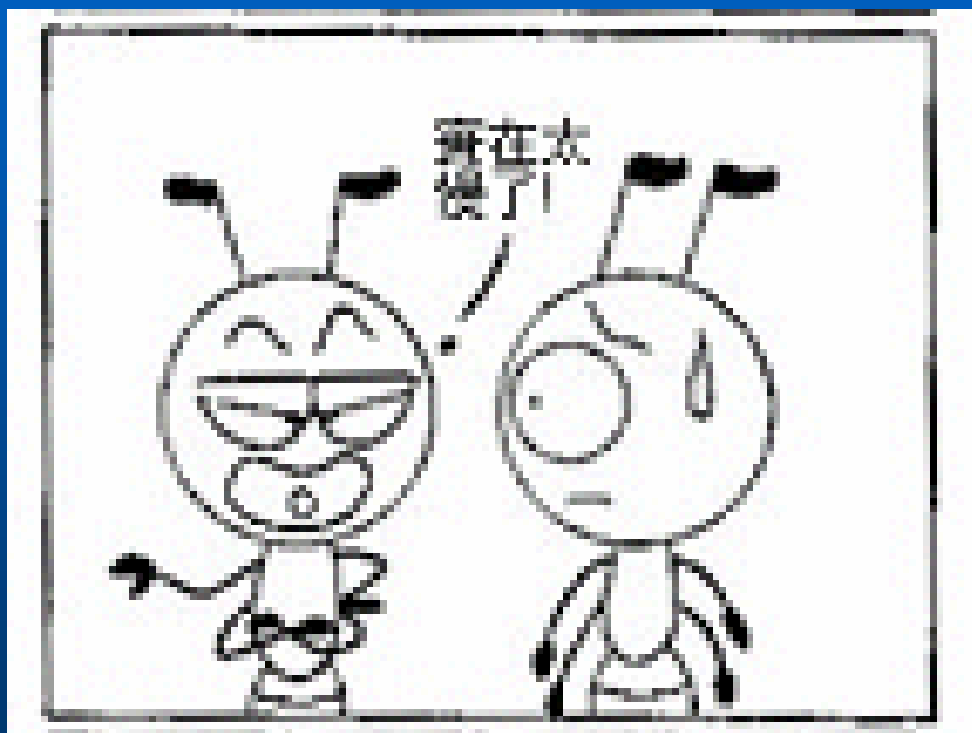
# 漫畫欣賞1/4



摘自[www.mangalan.com.tw](http://www.mangalan.com.tw)



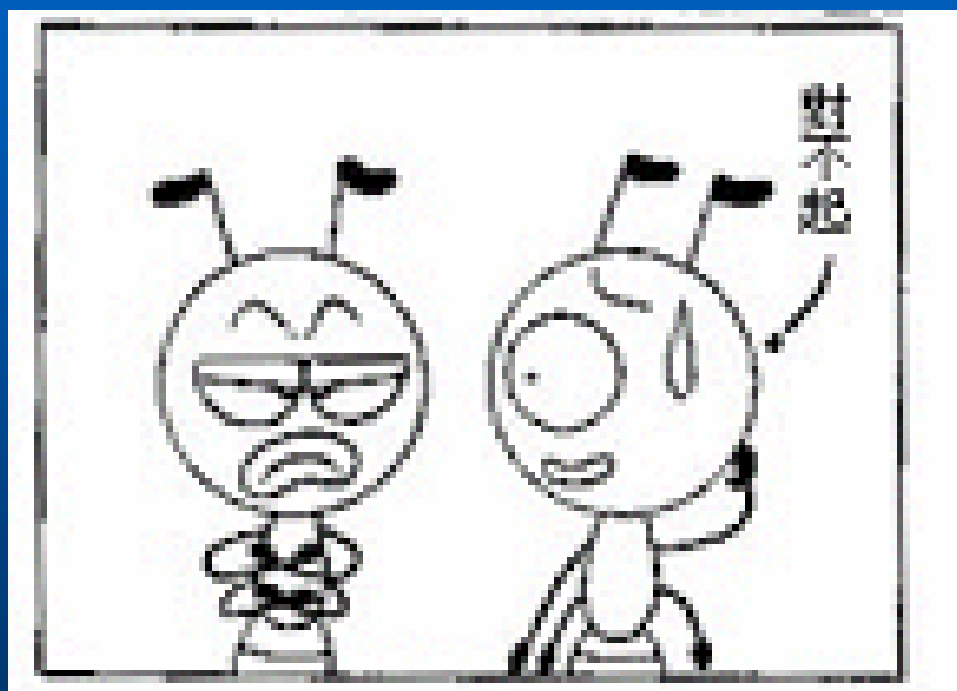
# 漫畫欣賞2/4



摘自 [www.mangalan.com.tw](http://www.mangalan.com.tw)



# 漫畫欣賞3/4



摘自[www.mangalan.com.tw](http://www.mangalan.com.tw)



# 漫畫欣賞4/4



~FIN~



# 結語和討論