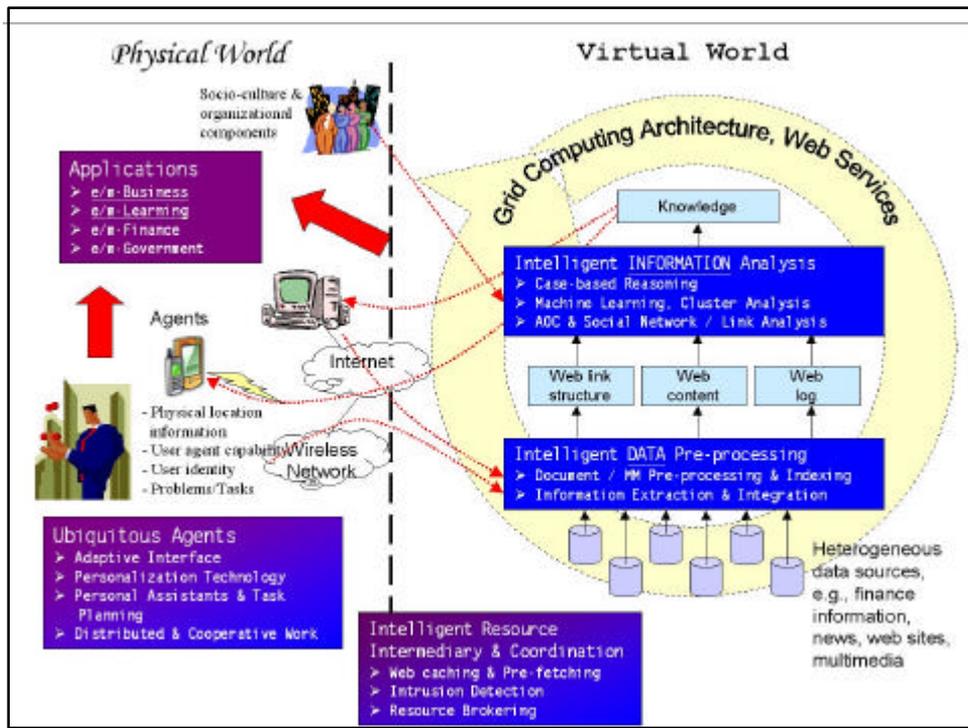


New Challenges in the World Wide Wisdom Web (W4) Research

ISMIS'03 10/30/2003

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World Wide Wisdom Web (W4)

- ◆ To discover the best means and ends
- ◆ To mobilize distributed resources
- ◆ To enrich social interaction
- ◆ To enable users to gain **practical wisdom** of *living, working, and playing*

❖ **Wisdom:** (*Webster Dictionary*, page 1658)

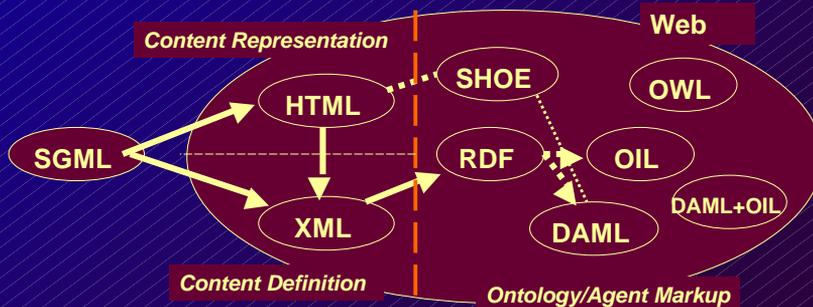
The quality of being wise; knowledge, and the capacity to make due use of it; **knowledge of the best means and the best ends**

W4 Challenge #1

Discovering the Best Means and Ends

Semantics of Web Information

- ◆ **Ontology:** Define meanings and relationships of vocabularies (in terms of classes and properties)
- ◆ **Semantic Web:** Add semantic meanings to Web information based on pre-defined ontology
- ◆ **Benefits:** Enable better human-computer communications as well as software agents access
- ◆ **Example:** DARPA Agent Markup Language (DAML)



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Goal-Directed Reasoning

- ◆ **Classic example:** STRIPS
- ◆ **States:** conjunctions of ground literals
- ◆ **Goals:** conjunctions of literals (containing variables)

$At(Home) \wedge Sell(Supermarket, Banana) \wedge Sell(Supermarket, Milk) \wedge Sell(Hardware Store, Drill)$

$Have(Drill) \wedge Have(Milk) \wedge Have(Banana) \wedge At(Home)$

$At(?x) \wedge Sells(?x, Milk)$

- ◆ **Operator:**

Action: Buy(?x)
Preconditions: $At(?store) \wedge Sell(?store, ?x)$
Effects:
additions: Have(?x)
deletions:

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POP Algorithm

Ordering constraint

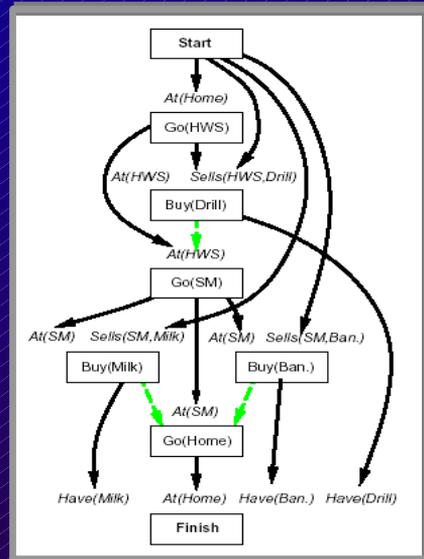
- $S_i < S_j$
- ❖ Step S_i occurs before step S_j

Casual link

- $S_i \xrightarrow{c} S_j$
- ❖ S_i achieves the precondition c of S_j

Open condition

- ❖ Precondition that is not causally linked

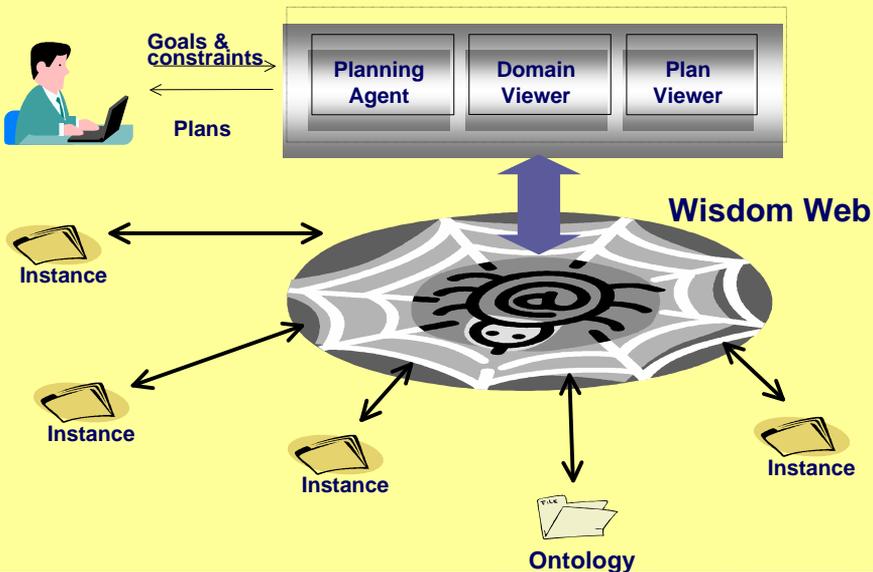


Source: Russell & Norvig

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Case 1: OntoPlan



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Ontology Modeling

```

<!-- Planning domain -->
<rdf:Class rdf:ID="Domain"/>
<daml:ObjectProperty rdf:ID="operators">
  <daml:domain rdf:resource="#Domain"/>
  <daml:range rdf:resource="#Operator"/>
</daml:ObjectProperty>
<daml:ObjectProperty rdf:ID="initial">
  <daml:domain rdf:resource="#Domain"/>
  <daml:range rdf:resource="Logic:Predicate"/>
</daml:ObjectProperty>
<daml:ObjectProperty rdf:ID="goal">
  <daml:domain rdf:resource="#Domain"/>
  <daml:range rdf:resource="Logic:Predicate"/>
</daml:ObjectProperty>

```



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```

<?xml version="1.0"?>
<rdf:RDF
  xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:daml="http://www.daml.org/2001/03/daml+oil#"
  xml:base="http://ntserver.homeip.net/HonorProject/DAML/Logic-onto#">
  <daml:Ontology daml:versionInfo="1.0">
  <daml:comment>An example for logic ontology</daml:comment>
  </daml:Ontology>
  <!-- Term -->
  <rdf:Class rdf:ID="Term"/>
  <!-- Variable -->
  <rdf:Class rdf:ID="Variable">
    <daml:subClassOf rdf:resource="#Term"/>
  </rdf:Class>
  <!-- Constant -->
  <rdf:Class rdf:ID="Constant">
    <daml:subClassOf rdf:resource="#Term"/>
  </rdf:Class>
  <daml:DatatypeProperty rdf:ID="value">
    <daml:domain rdf:resource="#Constant"/>
    <daml:range rdf:resource="http://www.w3.org/2000/10/XMLSchema#string"/>
  </daml:DatatypeProperty>
  <!-- Predicate -->
  <rdf:Class rdf:ID="Predicate">
    <daml:subClassOf rdf:resource="#Term"/>
  </rdf:Class>
  <daml:ObjectProperty rdf:ID="arguments">
    <daml:domain rdf:resource="#Predicate"/>
    <daml:range rdf:resource="#Term"/>
  </daml:ObjectProperty>
  <!-- Common Property -->
  <daml:DatatypeProperty rdf:ID="name">
    <daml:domain rdf:resource="#Variable"/>
    <daml:domain rdf:resource="#Predicate"/>
    <daml:range rdf:resource="http://www.w3.org/2000/10/XMLSchema#string"/>
  </daml:DatatypeProperty>
  </rdf:RDF>

```

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Instance Files

Action: Buy(?x)
Preconditions: At(?store) ^ Sell(?store, ?x)
Effects:
additions: Have(?x)
deletions:

```
<!-- Buy(?x) -->  
<plan:operator>  
  <rdf:comment>Buy the  
<plan:action>  
  <logic:Predicate>  
    <logic:name>  
      <rxsd:string rdf:value="Buy" />  
    </logic:name>  
    <logic:arguments rdf:parseType="daml:collection">  
      <logic:Variable>  
        <logic:name>  
          <rxsd:string rdf:value="?x" />  
        </logic:name>  
      </logic:Variable>  
    </logic:arguments>  
  </logic:Predicate>  
</plan:action>
```

Buy(?x)

```
<!-- Preconditions -->  
<plan:preconditions rdf:parseType="daml:collection">  
  <!-- At(?store) -->  
  <logic:Predicate>  
    <logic:name>  
      <rxsd:string rdf:value="At" />  
    </logic:name>
```

```
<logic:arguments rdf:parseType="daml:collection">  
  <logic:Variable>  
    <logic:name>  
      <rxsd:string rdf:value="?store" />  
    </logic:name>  
  </logic:Variable>  
</logic:arguments>  
</logic:Predicate>
```

At(?store)

```
<!-- Sell(?store, ?x) -->  
<logic:Predicate>  
  <logic:name>  
    <rxsd:string rdf:value="Sell" />  
  </logic:name>  
  <logic:arguments rdf:parseType="daml:collection">  
    <logic:Variable>  
      <logic:name>  
        <rxsd:string rdf:value="?store" />  
      </logic:name>  
    </logic:Variable>  
    <logic:Variable>  
      <logic:name>  
        <rxsd:string rdf:value="?x" />  
      </logic:name>  
    </logic:Variable>  
  </logic:arguments>  
</logic:Predicate>  
</plan:preconditions>
```

Sell(?store, ?x)

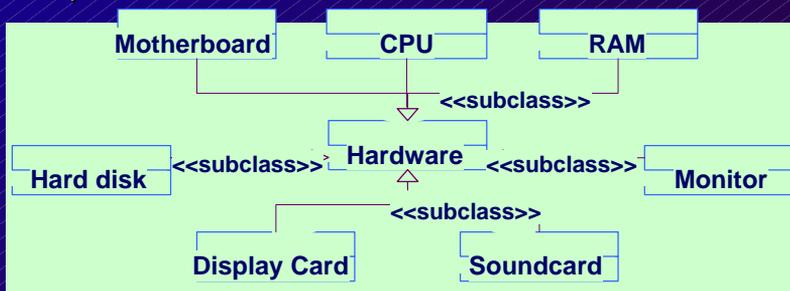
OntoPlan Domain & Plan Viewers

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Case 2: Machine Configuration

- ◆ **A consultation system for machine configurations**
 1. To suggest compatible hardware components (e.g., Socket \leftrightarrow CPU, FSB \leftrightarrow bus speed)
 2. To meet user preference
- ◆ **Hardware Ontology: hardware-onto.daml**
- ◆ **Product information** is located in *distributed* instance files, as well as in local sources



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Assembly Computer - Microsoft Internet Explorer

http://robotics.comp.hku.edu.hk/~jingli/kenoua/Project00013144/

Consultation System

Consultation System for a Computer Store

Links to Systems

Links to Programs

Semantic Web Planning Domain Viewer

Links to SWAP: Knowledge Files

Logic Ontology	logic-onto.html
Planning Ontology	plan-onto.html
Hardware Ontology	hardware-onto.html

Links to SWAP: Instance Files

Planning Information	assembly.html
AMD	AMD.html
ASUSTek	ASUSTek.html
Creative	Creative.html
Gigabyte	Gigabyte.html
Grandfun	Grandfun.html

Computer

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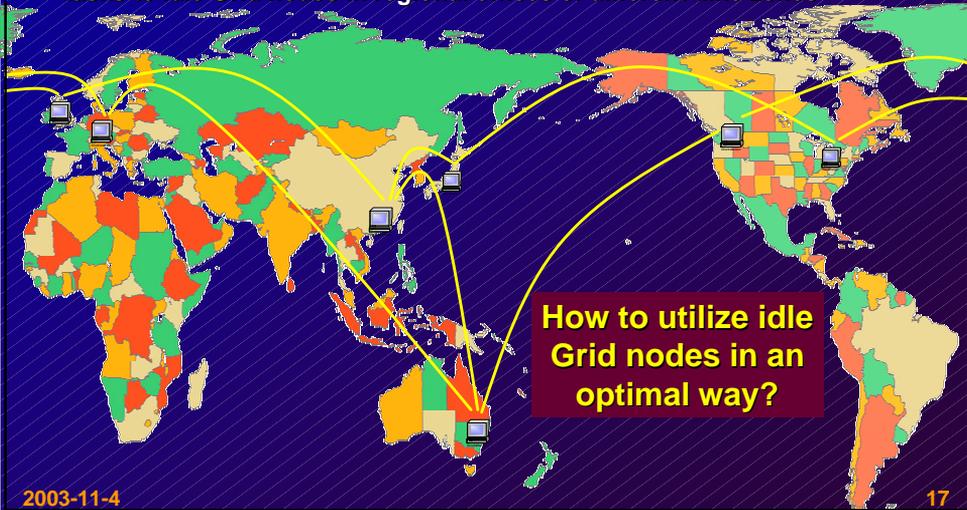
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W4 Challenge #2

Mobilizing Distributed Resources

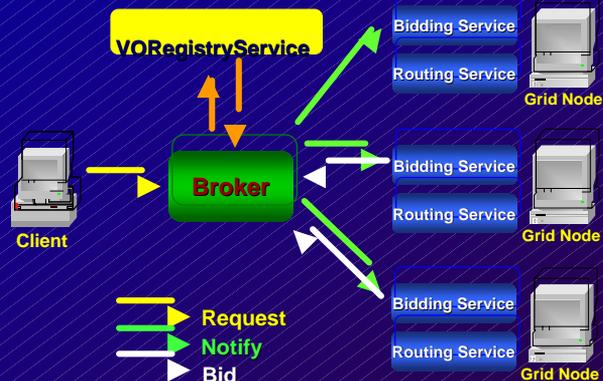
Case 3: Distributed Resource Sharing

- ◆ A courier company receives **thousands of delivery orders** every day
- ◆ **On-demand routing** is needed to determine the best route of a delivery
- ◆ Grid computing offers a resource sharing solution by **distributing routing tasks to idle Grid nodes** in regional offices of different time zones



A Snapshot

- ◆ The broker does not have complete knowledge of nodes capabilities
- ◆ Each agent (node) estimates its own capability based on its memory status, CPU loading, and estimation value
- ◆ All the agents (nodes) share their resources through competition



Messages	
Notify	<broker> <task> <id>
Bid	<node> <id> <value>
Ignore	<node> <id>
Accept	<broker> <id>
Reject	<broker> <id>
Finish	<node> <id>
Reward	<broker> <id> <value>

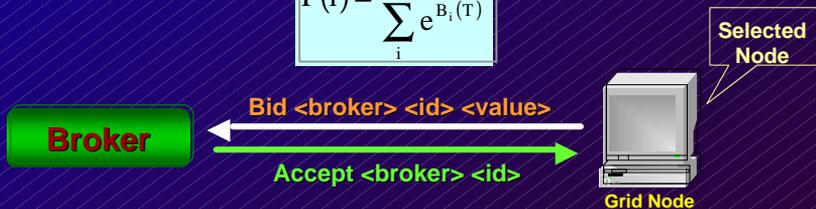
Bidding and Selection

- Grid node i makes an estimation $E_i(T)$ for each task T , and announces bid value $B_i(T)$ to the broker

$$B_i(T) = a \times E_i(T) \quad a \in [0,1]$$

- a is the risk factor determined from the current loading of the node
- The broker selects a node i to execute the task based on the probability:

$$P(i) = \frac{e^{B_i(T)}}{\sum_i e^{B_i(T)}}$$



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Reward and Update

- A reward is sent from the broker after a task is finished
- The node updates the estimation value of an executed task

$$E_i^{t+1}(T) = E_i^t(T) - B_i(T) + R_i$$



- Observation 1:** Services in a Virtual Organization are modeled as an organization of interacting heterogeneous agents



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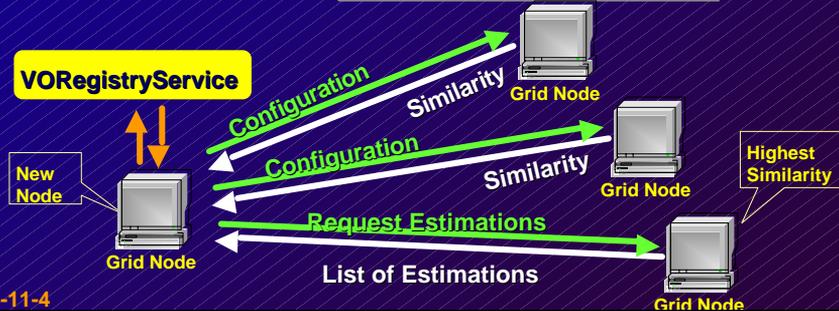
Adding a New Node

- ◆ A node announces its **configuration** to join the Grid (VO)
- ◆ **Similarity** measures of configurations are returned from other nodes (CPU clock speed, memory size, storage size, resources available, etc.)

$$\text{similarity}_1(C_{\text{new}}, C_{\text{old}}) = \sum w_A^j \times \text{similarity}_2(A_{\text{new}}^j - A_{\text{old}}^j)$$

where $\sum_j w_A^j = 1$

C_{new} : configuration of a new node
 C_{old} : configuration of an existing node
 w_A^j : weight of j^{th} attribute
 A_{new}^j : j^{th} attribute of a new node
 A_{old}^j : j^{th} attribute of an existing node



Case 4: Distributed Problem Solving



Given:

- ◆ Different owners set **different policies and constraints** (e.g., resources A and B will not be used at the same time)
- ◆ Policies and constraints are **NOT openly published** (i.e., not centralized)

Question:

- ◆ How to **satisfy all constraints**?

Node and resources	Variable and its domain
Constraints	Clauses
Nodes involved in a constraint	Literals in a clause
Resource scheduling	Satisfiability (SAT)

CNF: $F = \bigwedge_{i=1}^m C_i$ where $C_i = \bigvee_{j=1}^k l_j^i$

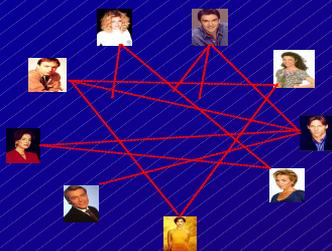
Local Search

(Selman, Levesque, and Mitchell, 1992, etc.)

- ◆ Take the solution space (i.e., the Cartesian product of all variable domains) as a search space, and search it based on a certain rule
 - ❖ Randomly select one position as the start point to search
 - ❖ At each step, move to a neighboring position according to some heuristics

GSAT (1992)	WalkSAT (1994)
GWSAT (1994)	WalkSAT/Tabu (1997)
GWSAT/Tabu (1997)	Novelty (1997)
	R-Novelty (1997)
	Novelty+ (1999)
	R-Novelty+ (1999)
SDF (2001)	
UnitWalk (2002)	

Case 4: Distributed Problem Solving



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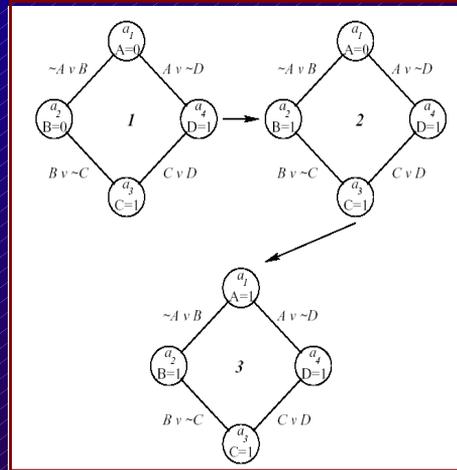
Node and resources	Variable and its domain
Constraints	Clauses
Nodes involved in a constraint	Literals in a clause
Resource scheduling	Satisfiability (SAT)

Centralized methods **cannot be directly applied!**

CNF: $F = \bigwedge_{i=1}^m C_i$ where $C_i = \bigvee_{j=1}^k l_j^i$

Multi-Agent SAT (MASSAT) (with X. Jin)

- ◆ Use multiple computational agents
- ◆ Decompose the search space into several sub-spaces
- ◆ Each agent decides how to locally search a sub-space (i.e., its environment)
- ◆ Through local interactions between agents and their environments, the agents coordinately find a global solution



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Formulation

- ◆ Divide variables into u groups
- ◆ Agent a_i : variable group $v_i = \{v_{i1}, v_{i2}, \dots, v_{ik}\}$
- ◆ Environment e_i of a_i : Cartesian Product of the variable group, $D_i = D_{i1} \times D_{i2} \times \dots \times D_{ik}$
- ◆ Agent's position e_i^j : j^{th} value combination in $D_i = D_{i1} \times D_{i2} \times \dots \times D_{ik}$
- ◆ The position combination of all agents $\{e_1^k, \dots, e_i^j, \dots\}$: a possible solution
- ◆ Basic strategies of agent a_i : $\Phi_i = D_1 \times \dots \times D_i \times \dots \times D_u \rightarrow D_i$
 - ❖ Best-move: $\Phi_i^{-best} = e_i^j$, st, $eval(e_i^j) = \max eval(e_i^k)$ (for $\forall e_i^k \in D_i$)
 - ❖ Better-move: $\Phi_i^{-better} = e_i^j$, st, $eval(e_i^j) > eval(e_i^l)$
 - ❖ Random-move: $\Phi_i^{-random} = e_i^j$, e_i^j is a random position in D_i

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MASSAT Procedure

For $i = 1$ to *MAX-Cycles*
 If all clauses are satisfied Then return T ;

For *distributed agents*

Select one (or more) of three behaviors
 {Best-move, Better-move, or Random-move};

Perform selected behavior(s);

EndFor

If no agent moves Then

Modify the weights of unsatisfied clauses;

End

Update T according to new positions of agents;

EndFor

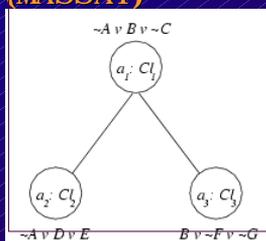
$$W_i^{t+1} = \begin{cases} W_i^t & \text{if } T(C_i^t) = \text{True} \\ W_i^t + \delta & \text{if } T(C_i^t) = \text{False} \end{cases}$$

where W_i^t is the weight of clause C_i at time t .
 δ is a learning rate.

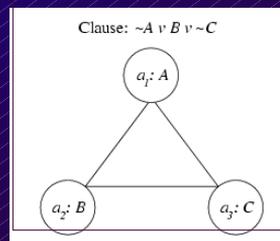
Agent Networks

- ◆ In multi-agent problem solving, an agent network is a virtual graph
 - ❖ nodes are agents
 - ❖ edges are the implicit or explicit relationships among agents
- ◆ The topology of an agent network reflects the connectivity of the network

Variable-Based Representation (MASSAT)



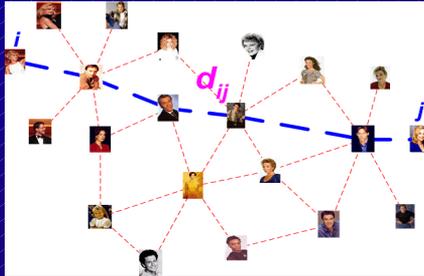
Clause-Based Representation



VS.

Agent Networks

- ◆ How does the topology of an agent network reflect the complexity of solving distributed SAT?
- ◆ Constraint satisfaction in a *small-world* is inefficient (Jin & Liu, 2003)



Classic example:
Small-World
(Milgram, 1967)

1. Highly clustered
2. The shortest path length between any two nodes is small

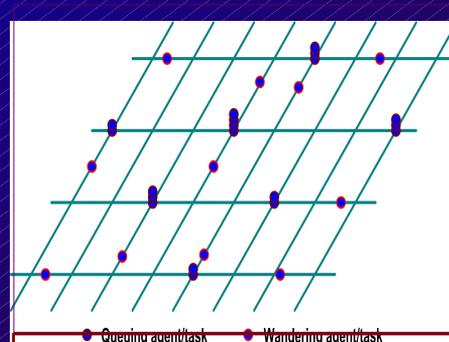
- ◆ **Observation 2:** The agent networks formed in MASSAT do not have *small-world* topologies!

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Case 5: Decentralized Delegation

- ◆ A large number of tasks are to be transferred among nodes
- ◆ Artificial ants in Anthill can disperse piles of objects on Grids (Montresor & Meling, 2002)
- ◆ What is the *macroscopic behavior* having incorporated a time delay between search and transfer?

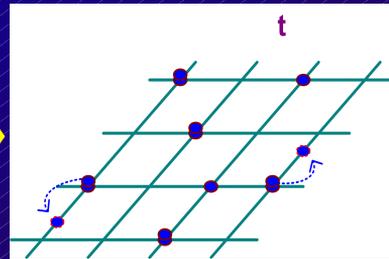
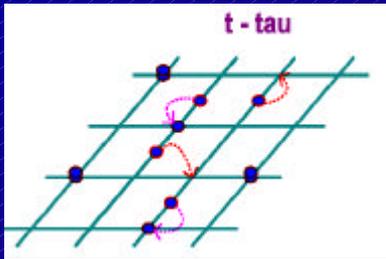


- ◆ Tasks are carried and transferred by **agents**
- ◆ Agent local behavior: *leaving and queuing*

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A Scenario ($m=2$)



$$\frac{dy_1(t)}{dt} = \lambda y(t - \tau) + dy_2(t) - cy(t - \tau)y_1(t)$$

$$\frac{dy_2(t)}{dt} = cy(t - \tau)y_1(t) - dy_2(t)$$

$$y(t) + \sum_{s=1}^2 sy_s(t) = S$$

- the maximum team size is 2
- *lambda*: the rate of wandering agents' meeting an idle node
- *c*: the rate of wandering agents' joining a team of size one
- *d*: the rate of queuing agents' leaving a team of size 2

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A General Model

$$\frac{dy_1(t)}{dt} = \lambda y(t - \tau) + d_2 y_2(t) - c_1 y(t - \tau) y_1(t)$$

$$\frac{dy_s(t)}{dt} = d_{s+1} y_{s+1}(t) + c_{s-1} y(t - \tau) y_{s-1}(t) - d_s y_s(t) - c_s y(t - \tau) y_s(t), \quad (2 \leq s \leq m-1)$$

$$\frac{dy_m(t)}{dt} = c_{m-1} y(t - \tau) y_{m-1}(t) - d_m y_m(t)$$

$$y(t) + \sum_{s=1}^m sy_s(t) = S \quad \text{where } \begin{matrix} \tau > 0, 0 < \lambda < 1, \\ 0 < c_s < 1, 0 < d_s < 1, \\ y_s \geq 0, y \geq 0 \end{matrix}$$

- *M* the maximum team size
- *lambda* the rate of wandering agents' meeting an idle node
- *c_i* the rate at which a wandering agent meets and joins a team of size *i*
- *d_i* the rate at which a queuing agent in a team of size *i* leaves

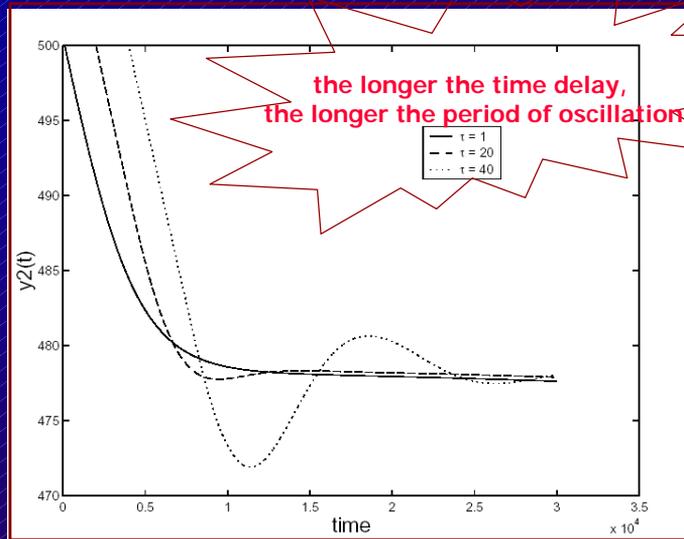
Observation 3:

- ◆ Agent-based load balancing with time delay converges to a steady state
- ◆ The convergence speed decreases as the time delay increases
- ◆ The period of oscillation increases as the time delay increases

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Macroscopic Performance (with Time Delay)



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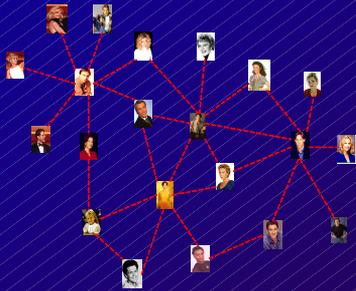
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W4 Challenge #3

Enriching Social Interaction

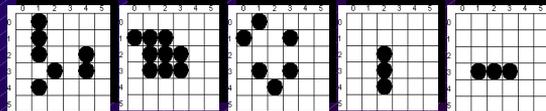
Social Interaction

- **Social Networks:** user groups, or communities of common expertise or practice
- **Social Interaction:** a **self-organizing** pattern of information exchange or experience sharing



Classic example:
Self-Organization in Game of Life
(Conway, 1970)

- ◆ 'Life' rules are applied to an initial population of live cells (i.e., black cells)



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Case 6: RoboNBA Games (with C. H. Ng)

- ◆ Live cells → ◆ **Distributed** player agents
- ◆ 'Life' rule → ◆ Decision/strategy
- ◆ Environment → ◆ Virtual court
- ◆ Patterns → ◆ **NBA-like games**

Basketball competition is a complex behavior

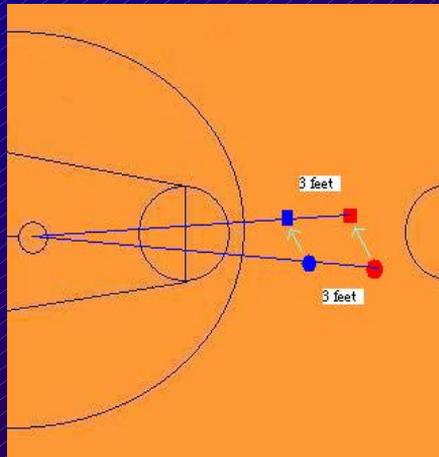
- Team players interact **locally**
- It is difficult to predict a **complete** match

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Example: Moving Action (1 of 8)

- ◆ blue circle – defender's old position
- ◆ red circle – offender's old position
- ◆ blue square – defender's new position
- ◆ red square – offender's new position



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TEAM	MIN	OFF	DEF	REB	STL	3PM	2PM	3PT	2PT	PTS
player 1	6	0	0	0	0	0.00	0	0	0	0
player 2	6	0	0	0	0	0.00	0	0	0	0
player 3	6	0	0	0	0	0.00	0	0	0	0
player 4	6	0	0	0	0	0.00	0	0	0	0
player 5	6	0	0	0	0	0.00	0	0	0	0
player 6	6	0	0	0	0	0.00	0	0	0	0
player 7	6	0	0	0	0	0.00	0	0	0	0
player 8	6	0	0	0	0	0.00	0	0	0	0
player 9	6	0	0	0	0	0.00	0	0	0	0
player 10	6	0	0	0	0	0.00	0	0	0	0
player 11	6	0	0	0	0	0.00	0	0	0	0
player 12	6	0	0	0	0	0.00	0	0	0	0
player 13	6	0	0	0	0	0.00	0	0	0	0
player 14	6	0	0	0	0	0.00	0	0	0	0
player 15	6	0	0	0	0	0.00	0	0	0	0
player 16	6	0	0	0	0	0.00	0	0	0	0
player 17	6	0	0	0	0	0.00	0	0	0	0
player 18	6	0	0	0	0	0.00	0	0	0	0
player 19	6	0	0	0	0	0.00	0	0	0	0
TOTAL	6	0	0	0	0	0.00	0	0	0	0

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RoboNBA Games (30 matches)

◆ Teams used for testing RoboNBA:

Team Name	Rank in NBA	Wins
◆ Dallas Maverick	1st	0.75%
◆ Philadelphia Sixers	10th	0.592%
◆ Washington Wizards	20th	0.461%
◆ Cleveland Cavs	29th	0.197%

TEAMS	Sixers	Wizards	Cavs
Mavericks	22 – 8 (87.0 – 83.7) (107 – 94)	24 – 6 (86.0 – 73.5) (106 – 101)	25 – 5 (82.7 – 72.9) (114 – 93)
Sixers		18 – 12 (78.7 – 76.5) (88 – 80)	24 – 6 (75.4 – 69.0) (116 – 103)
Wizards			14 – 16 (69.3 – 74.3) (93 – 84)

RoboNBA

Real NBA

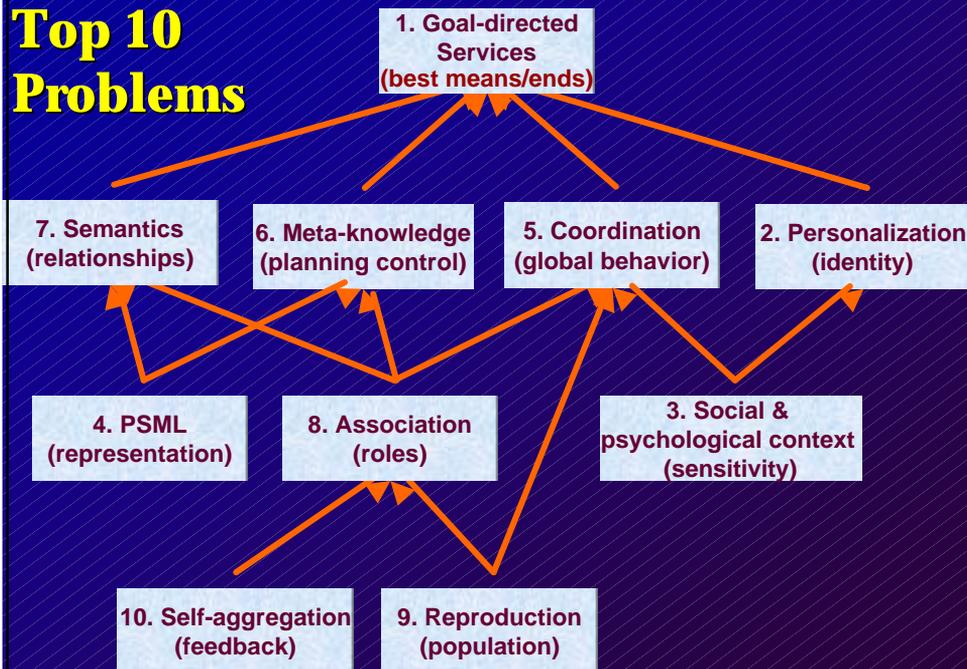
Summary

- ◆ W4 enables humans to gain **practical wisdom** of *living, working, and playing*
 - ❖ **Wisdom:** (Webster Dictionary, page 1658)
The quality of being wise; knowledge, and the capacity to make due use of it; **knowledge of the best ends and the best means**
- ◆ W4 provides
 - ❖ a **medium** for **knowledge and experience sharing**
 - ❖ a **supply** of self-organized resources for driving sustainable **knowledge creation** and **scientific or social development/evolution**

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Top 10 Problems



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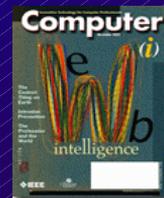
W4: A Goal for *Web Intelligence*

Web Intelligence (WI)

WI explores the fundamental roles as well as practical impacts of

- ❖ **Artificial Intelligence (AI)** (e.g., knowledge representation, planning, knowledge discovery, agents, and social intelligence) and
- ❖ **Advanced Information Technology (IT)** (e.g., wireless networks, ubiquitous devices, social networks, and data/knowledge grids)

on the next generation of Web-empowered systems, environments, and activities



Zhong, N , Liu, J , and Yao, Y Y (eds.) *Web Intelligence*, Springer, 2003



Web Intelligence Consortium

All WIC-related information will be released from the WIC portal

- WIC introduction
- WIC structure
- WIC newsletter
- WICAS journal
- Annual Review
- Books
- White papers
- WIC conferences
- New systems/standards
- WIC research centres
- WIC related companies
- Related resources

WIC Introduction

Web Intelligence (WI) has been recognized as a new direction for scientific research and development to explore the fundamental roles as well as practical impacts of Artificial Intelligence (AI) (e.g., knowledge representation, planning, knowledge discovery and data mining, intelligent agents, and social network intelligence) and advanced Information Technology (IT) (e.g., wireless networks, ubiquitous devices, social networks, and data/knowledge grids) on the next generation of Web-empowered products, systems, services, and activities. It is one of the most important as well as promising IT research fields in the era of Web and agent intelligence.

The Web Intelligence Consortium (WIC) (<http://wi-consortium.org>) is an international, non-profit organization dedicated to advancing world-wide scientific research and industrial development in the field of Web Intelligence (WI). It promotes collaborations among world-wide WI research centers and organizational members, technology showcases at WI related conferences and workshops, WIC official book and journal publications, WIC newsletters, and WIC official releases of new industrial solutions and standards.

The major activities of WIC include:

- **Organizing international and regional Web and agent intelligence related conferences/workshops.**
 - The IEEE/WIC WI-IAT joint conference series (i.e., The IEEE/WIC International Conference

Welcome
Join WIC now!

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 - ❖ **A.M.D. Lab (HKBU)**
 - ❖ **AAMAS/AOC Group (HKBU)**

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The End

Sunrise in Grand Canyon (Liu, 5:23am 8/10/03)