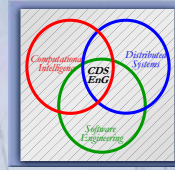*ES595a - Advanced Topics in Software & Systems Design*
Cooperative Distributed Systems Engineering:
Technologies &Applications
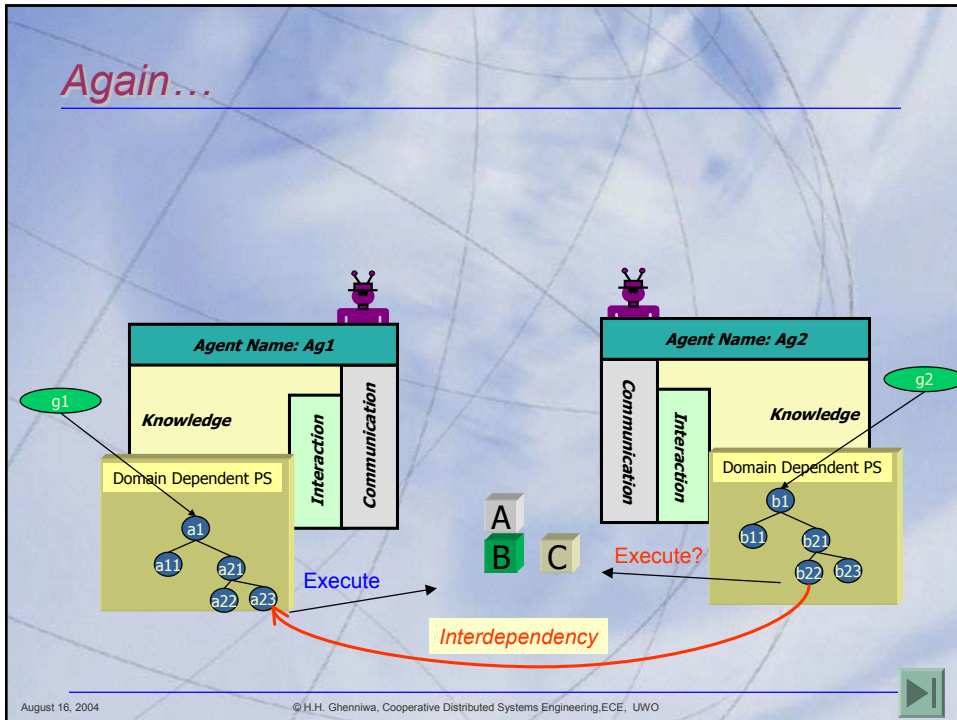
W04: *Agent-Orientation*

Coordination

- How to design a coordination solution

  for different interdependency problems?

- How to model coordination at
  - Reasoning level
  - Action level

Again…

Agent Name: Ag1

Knowledge

Interaction

Communication

Domain Dependent PS

g1

a1
a11 a21
a22 a23

Execute

A
B C

Execute?

Agent Name: Ag2

Communication

Interaction

Knowledge

Domain Dependent PS

g2

b1
b11 b21
b22 b23

Interdependency

The Coordination Mechanism

- A set of
  - decision points for coordinated control
  - interaction devices

  collectively deal with the interdependency problem

  - Main objectives:
    - reduce and resolve the problems associated with interdependency

  - To deal with the dynamic characteristics of the environment
    - *intelligence* and *rationality* are employed
      - *Intelligence* is a set of heuristics related to the nature of the type of interdependency and the application domain
      - *Rationality* is the ability of the agent to analyze
        - *Why*, *when*, *and which* coordination solution is appropriate according to some performance measure

Coordinated Control

Figure 3.1: Alternative Solutions.

Figure 3.2: The payoff matrix representation.
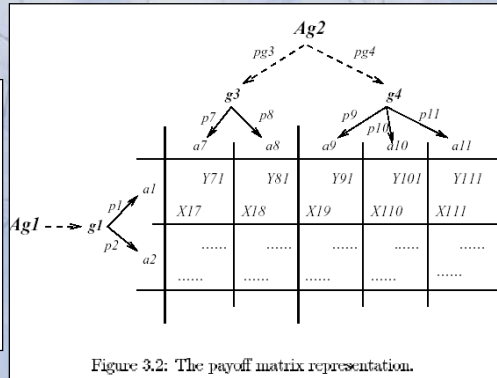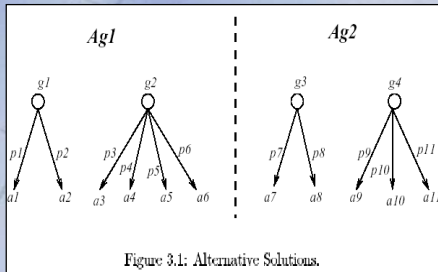
Interaction

- A process during which the agents engage with each other to resolve interdependency problems

  ➤ This interaction may involve different devices, including
    - *Assignment*
    - *Resource-scheduling*
    - *Conflict-resolution*
    - *Synchronization*
    - *Redundancy-avoidance*

Types of Interaction Devices *–Ghenniwa's*

- Assignment Device
  - Capability and the decomposition interdependencies share similar characteristics
    - They are related to goals that cannot be achieved by the agent

  An agent might solicit assistance from other agents

  The assistance can have the form of delegating an appropriate agent to achieve the goal

- Resource Scheduling Device
  - The major problem due to resource interdependency is
    - How to assign an authority for the agent over a resource for a specific interval of time

  A solution to this problem might require the agent to negotiate with the other competing agents
  Negotiation is the process of reaching an agreement

Interaction *–Ghenniwa's*

- Conflict Resolution Device
  - Conflicting interdependency are due to hard incompatibility between the interest of an agent and some other agents (opponents).

  A solution to this problem might require the agent to negotiate with its opponents

- Synchronization Device
  - A problem due to the simultaneous interdependency between agents (colleagues) is
    - determining how to assign a common time frame to achieve the corresponding goals

  A negotiation based synchronization device can be used by the agents to reach an agreement about a common time frame

Interaction *–Ghenniwa's*

- Redundancy Avoidance Device
  - ➢ A problem due to the common interdependency is
    - ▪ to determine how to avoid the efforts of achieving goals that are being, or possibly will be, achieved by some other agents

  To handle these types of problems an agent might participate in selecting one of the agents (partners) including itself to achieve the goal

---

Interaction Device

- The basic characteristics of interaction device

Assignment
Recourse Scheduling
Conflict Resolution
Redundancy Avoidance
Synchronization
Knowledge Update

  - ➢ Problem specifications (PoblemSpec)
  - ➢ Evaluation parameters (EvalPara)
  - ➢ Sub-processes (Spro)

  IntDev < :DeviceType Dev, :PoblemSpec PSpec, :EvalPara EvPar, :Spro Pro >

The Assignment Device

- The basic characteristics
  - ➢ Problem specifications

    > goal, desired-satisfying-time
    >> To deal with goal quality
    >> $G_c = <g, q^*, \delta q>$

  - ➢ Evaluation parameters

    > (goal class, local-schedule of the potential contractors)
    > Focused contracting:
    >> (combination of Modeling and Soliciting approaches)

  - ➢ Sub-processes

    > The decision (selection) process

Negotiation-Based Devices

- Negotiation is the search for an agreement between incompatible desires of different agents

  - ➢ Negotiation can be used to determine the appropriate solution for resource-scheduling; conflict-resolution; synchronization; redundancy-avoidance

    [HG → Why?]

  - ➢ Negotiation strategy depends on the degree of incompatibility
    - ▪ Hard
      - ○ for resource and conflicting interdependencies
    - ▪ Mild
      - ○ for simultaneous interdependency
    - ▪ Soft
      - ○ for common interdependency

Resource-Scheduling Device

- The basic characteristics
  - Problem specifications

    Resource-name, desired-holding-time

  - Evaluation parameters

    Resource-agenda (global-shared; distributed)

  - Sub-processes

    Determine competitors
    Decision Process Negotiation strategy
      e.g., the power of time

Conflict-Resolution Device

- The basic characteristics
  - Problem specifications
    - Goal-name, desired-satisfying-time
  - Evaluation parameters
    - Suspects' desires and commitments
  - Sub-processes
    - Determine opponents
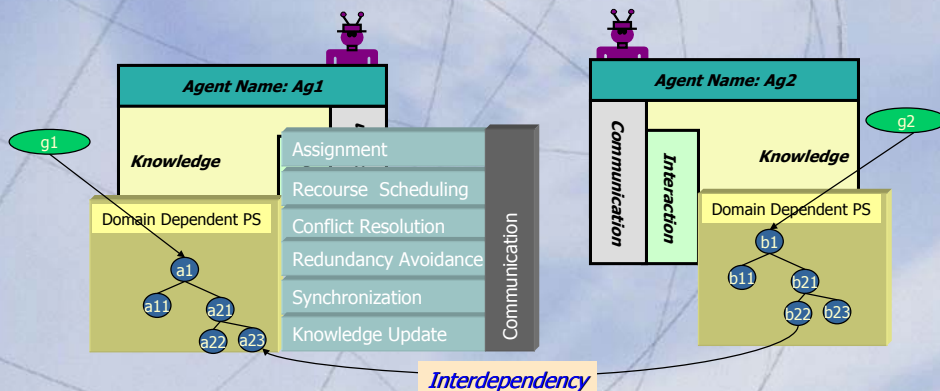   - Decision Process Negotiation strategy
      - e.g., the power of time

Synchronization Device

- The basic characteristics
  - Problem specifications
    - Goal-name, desired-time-frame
  - Evaluation parameters
    - Colleagues' desires and commitments
  - Sub-processes
    - Decision Process, Negotiation strategy:
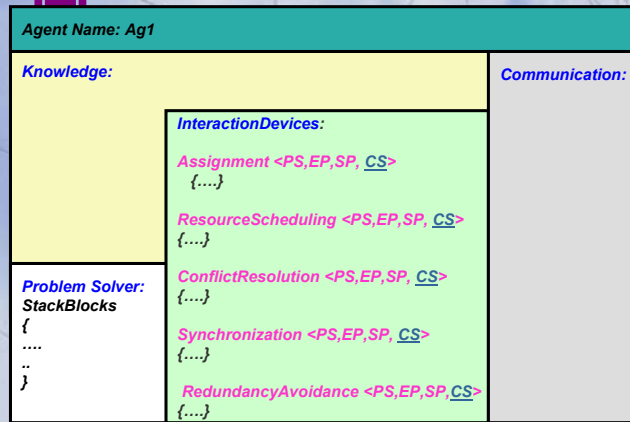   - e.g., the power of time only when it is feasible to generate a counter offer

Agent Conceptual Model
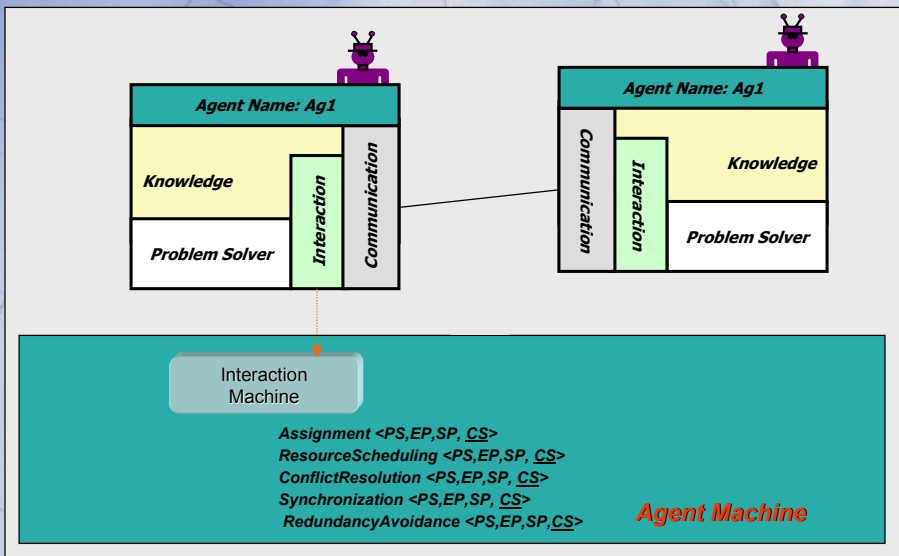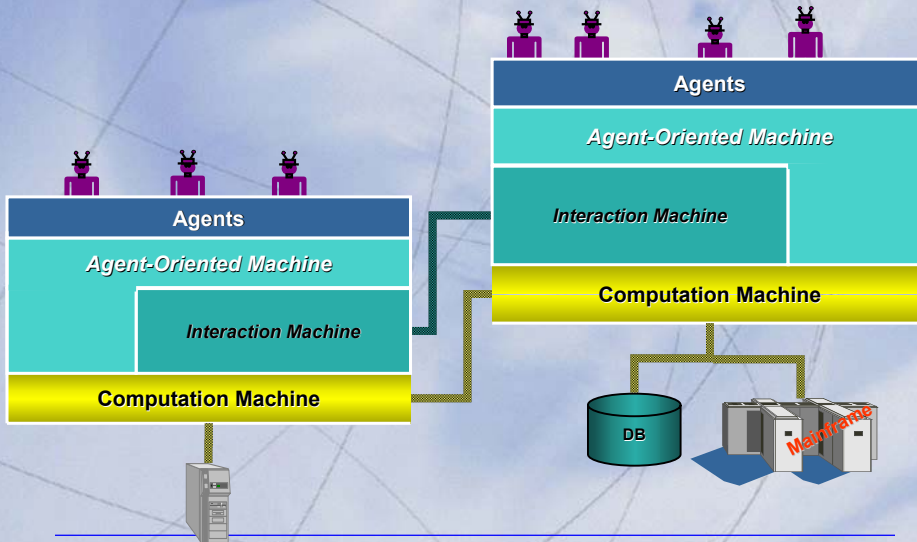### The CIR-Agent –Autonomy & Rationality @ Coordination

The CIR-Agent

OA Paradigm

Agent Name: Ag1

Knowledge:

Communication:

InteractionDevices:

Assignment <PS,EP,SP, CS>
{....}

ResourceScheduling <PS,EP,SP, CS>
{....}

Problem Solver:
StackBlocks
{
....
..
}

ConflictResolution <PS,EP,SP, CS>
{....}

Synchronization <PS,EP,SP, CS>
{....}

RedundancyAvoidance <PS,EP,SP,CS>
{....}

Supporting Levels of Agent Machine

Agent Name: Ag1

Knowledge

Interaction

Communication

Problem Solver

Agent Name: Ag1

Communication

Interaction

Knowledge

Problem Solver

Interaction Machine

Assignment <PS,EP,SP, CS>
ResourceScheduling <PS,EP,SP, CS>
ConflictResolution <PS,EP,SP, CS>
Synchronization <PS,EP,SP, CS>
RedundancyAvoidance <PS,EP,SP,CS>

Agent Machine

Agent-Oriented Machine

Agents

Agent-Oriented Machine

Interaction Machine

Computation Machine

Agents

Agent-Oriented Machine

Interaction Machine

Computation Machine

DB

Mainframe

PS → Block World Domain
Multiple Goals

$g_1 = Above(A,B); g_2 = On(C,B)$

$PS (S_0, g_1 \& g_2, AC) \cong S1$
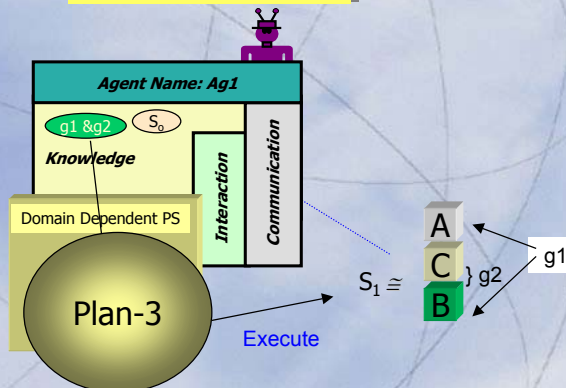
Agent Name: Ag1

g1 &g2 S_o

Knowledge

Interaction

Communication

Domain Dependent PS

Plan-3

$S_1 \cong$

Execute

A

C } g2

B

g1

PS → Multiple Agents

$g_1 = Above(A,B); g_2 = On(C,B)$

$< PS_1(S_0, g_1, AC_1); PS_2(S_0, g_2, AC_2) ; CS(Ag_1, Ag_2, PoblemSpec) > \cong S2$
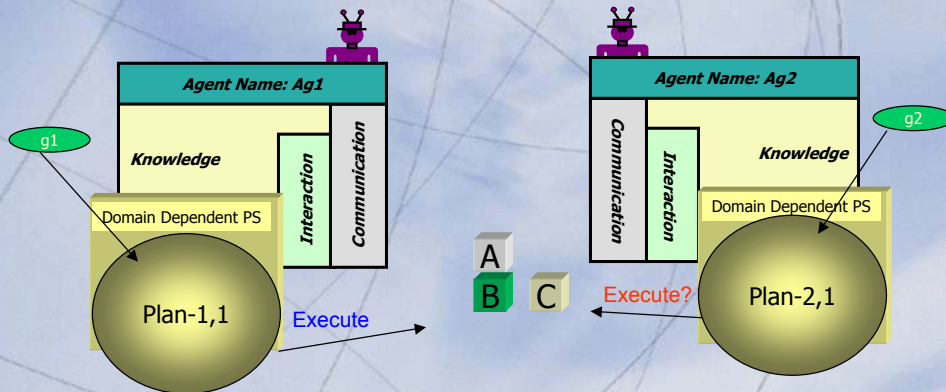
Agent Name: Ag1

Knowledge

Interaction

Communication

Domain Dependent PS

Plan-1,1

Execute

g1

A
B C

Execute?

Agent Name: Ag2

Communication

Interaction

Knowledge

Domain Dependent PS

Plan-2,1

g2

Therefore, …

$S_0 \quad (g_1 \& g_2)$

$< PS_1(S_0, g_1, AC_1); PS_2(S_0, g_2, AC_2) ; CS(Ag_1, Ag_2, PoblemSpec) > \cong S2$

$PS(S_0, g_1 \& g_2 AC) \cong S1$
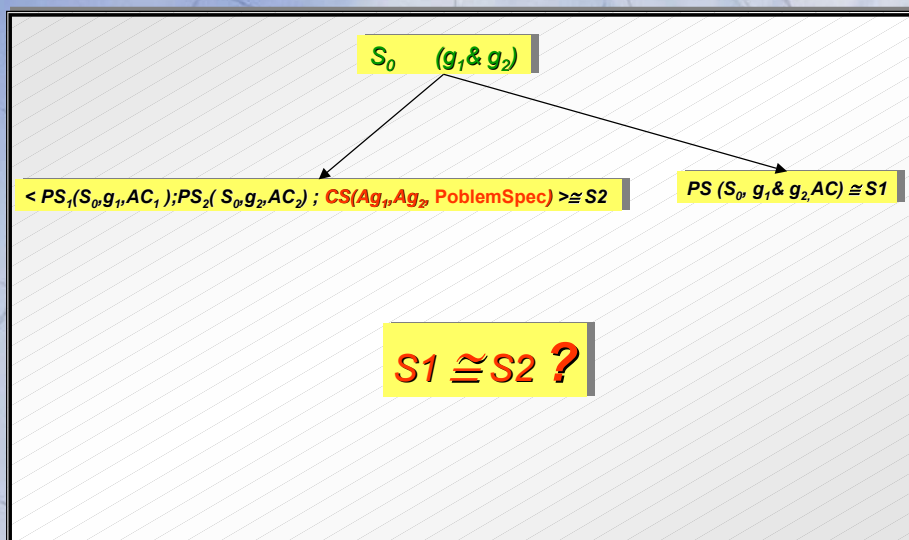
$S1 \cong S2 \ ?$

Agent- Logical (Conceptual) Model

AO Paradigm

		Interaction	Communication	Interdependency	Communication	Interaction	
Agent Name: Ag1							**Agent Name: Ag2**
Knowledge							*Knowledge*
Problem Solver							*Problem Solver*

OO Paradigm

Class Name	Association	Class Name
Attributes (State)		Attributes (State)
Operations (Behavoir)		Operations (Behavoir)
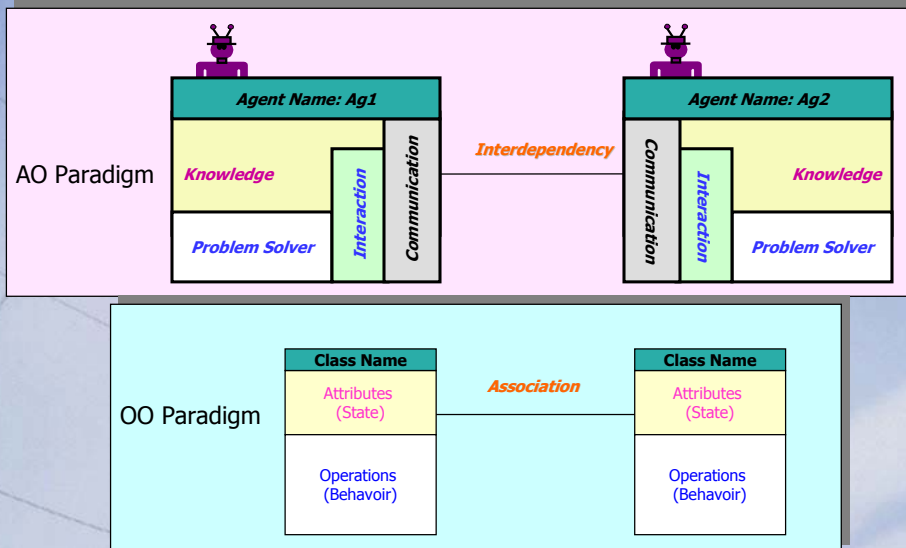
Rationality

- To deal with time-bounded situations

  - rationality is employed at two levels
   - meta-reasoning
    - action-level

Meta-Reasoning Rationality

- The <u>selection of appropriate</u> heuristics for interaction devices

  - The ability of the agent to evaluate the importance of the heuristics –*Which?*
  - The dynamic nature of the performance structure of rationality –*When?*
  - The rational behavior of the agent (e.g. minimizing performance measure) –*Why?*

The Pre-Interaction:

- Reasoning about *"Which"*
  - to identify the <u>type of interdependencies</u> and
  - to determine the <u>agent's belief</u> about <u>their existence</u>

- Reasoning about *"How"*
  - to rationally anticipate the <u>characteristics of the interaction</u> devices

- The decision criterion
  - to select a solution which satisfies some objective function
    - e.g., *minimize* the <u>expected complexity</u>

Reasoning about "Which?"
-Coordinated Control

Figure 3.1: Alternative Solutions.

Figure 3.2: The payoff matrix representation.
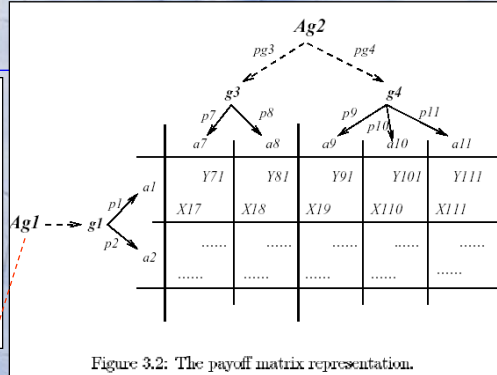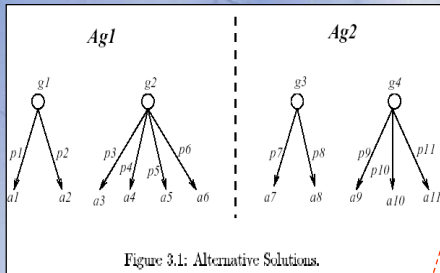
$$\min_{j\in\{1,2\}} c_1^j = pg_3[p_7 X_{j7} + p_8 X_{j8}] + pg_4[p_9 X_{j9} + p_{10}X_{j10} + p_{11}X_{j11}]$$

$$c_1^1 = pg_3[p_7 X_{17} + p_8 X_{18}] + pg_4[p_9 X_{19} + p_{10}X_{110} + p_{11}X_{111}]$$

$$X_{111} = X_{19} = X_{110} = 0 \qquad X_{18} = X_{17} = X_r$$

Which interdependency?

$$c_1^1 = pg_3 p_7 X_r + pg_4 p_{10}X_r = [pg_3 p_7 + pg_4 p_{10}]X_r = p_r^1 X_r$$

Reasoning about "Which?"
-Coordinated Control

- This representation, however, has the following assumptions attached:

  ➤ *Closure*: the state of the world can only be affected through the execution of the agents' actions.

  ➤ *Influence*: during the process of selecting a domain action, each agent is concerned with the influence[1] of the other agents on the world domain rather than on their `mental state' regarding goals[2].

    o [1] This influence is represented in terms of the long term approximation (the agent's mental state) of coordination knowledge.

    o [2] The other agents' mental state regarding their goals is the concern of the interaction devices.

Interaction Device —*Autonomy & Rationality @ Coordination*

- Characteristics of the Assignment Device are determined by:

  - The number of the potential participants

  - The upper time-bound and solution-quality

    - The rationality perspective: *Optimal* vs. *Satisficing* Strategies
      - Bounded-optimality
      - Bounded-duration

Agent Conceptual Model

Agent Name: Ag1

Knowledge

Domain Dependent PS

g1

a1

a11 a21

a22 a23

Reasoning "Which"

Reasoning "How"

Assignment

Recourse Scheduling

Conflict Resolution

Redundancy Avoidance

Synchronization

Knowledge Update

Communication

Interaction

Agent Name: Ag2

Knowledge

Domain Dependent PS

g2

b1

b11 b21

b22 b23

Interdependency