

LECTURE 7: Reaching Agreements

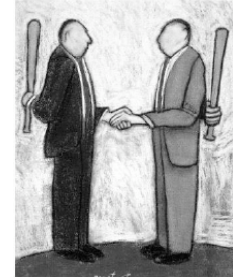
An Introduction to MultiAgent Systems
<http://www.csc.liv.ac.uk/~mjw/pubs/imas>

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Negotiation

- "The process of several agents searching for an agreement" e.g. about price.

➔ Reaching consensus

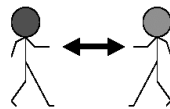


"Rules of Encounter" by
 Rosenheim and Zlotskin, 1994

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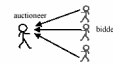
Negotiation

- May involve:
 - Exchange of information
 - Relaxation of initial goals
 - Mutual concession



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Recap - Auctions



- An Auction takes place between an auctioneer and a collection of bidders.
- In most settings, the auctioneer desires to maximise the price; bidders desire to minimise the price.
- Types of Auctions:
 - English auction
 - Dutch auction
 - First-price sealed bids
 - Vickrey (Second-price sealed bids)
- Useful for allocating goods. But too simple for many other settings.



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Negotiation Example 1



Consider two companies A and B decide to form an alliance to develop a software product for the shipbuilding industry. Company A has the shipbuilding market and knowledge in that domain. Company B is a software company that specialises in CAD systems and CAE. They negotiate to agree upon the financial assets, the skills and technology contributed by each company, how much of the new product each company will own and who will market the product and provide first-line support for the product.



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Rules of Encounter

- Research by Rosenschein & Zlotkin
- Public rules (*protocols*) by which agents come to agreements
- Agents
 - Are not centrally designed
 - Will not act benevolently unless it is in their interest to do so
 - Do not have a notion of global utility

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Mechanisms, Protocols, and Strategies

- Negotiation is governed by a particular *mechanism*, or *protocol*
- The mechanism defines the “rules of encounter” between agents
- *Mechanism design* is designing mechanisms so that they have certain desirable properties
- Given a particular protocol, how can a particular *strategy* be designed that individual agents can use?

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Mechanism Design

- Desirable properties of mechanisms:
 - *Convergence/guaranteed success*
 - *Maximizing social welfare*
 - *Pareto efficiency*
 - *Individual rationality*
 - *Stability*
 - *Simplicity*
 - *Distribution*

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Mechanism Research

- Social engineering for communities of machines
 - The creation of interaction environments that foster certain kinds of social behavior

Telephone example
Global benefit from good protocol
(Vickrey)

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Broad Working Assumption

- Designers (from different companies, countries, etc.) come together to agree on *standards* for how their automated agents will interact (in a given domain)
- Discuss various possibilities and their tradeoffs, and agree on protocols, strategies, and social laws to be implemented in their machines

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Attributes of Standards

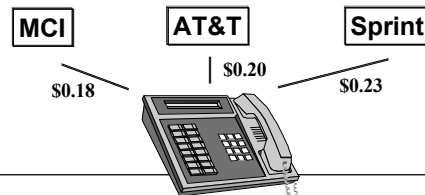
- ✓ *Efficient*: Pareto Optimal
- ✓ *Stable*: No incentive to deviate
- ✓ *Simple*: Low computational and communication cost
- ✓ *Distributed*: No central decision-maker
- ✓ *Symmetric*: Agents play equivalent roles

Designing protocols for specific classes of domains that satisfy some or all of these attributes

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Phone Call Competition Example

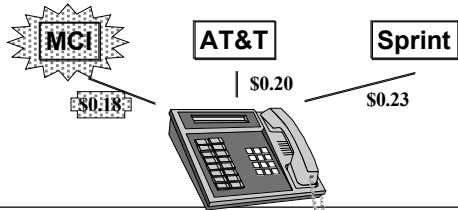
- Customer wishes to place long-distance call
- Carriers simultaneously bid, sending proposed prices
- Phone automatically chooses the carrier (dynamically)



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Best Bid Wins

- Phone chooses carrier with lowest bid
- Carrier gets amount that it bid



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Attributes of the Mechanism

- ✓ *Distributed*
- ✓ *Symmetric*
- ✗ *Stable*
- ✗ *Simple*
- ✗ *Efficient*

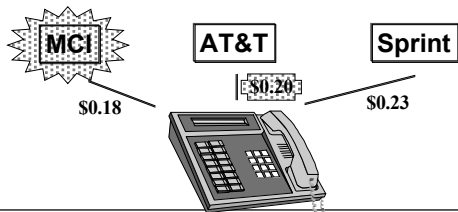
Carriers have an incentive to invest effort in strategic behavior



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Best Bid Wins, Gets Second Price (Vickrey Auction)

- Phone chooses carrier with lowest bid
- Carrier gets amount of second-best price



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Attributes of the Vickrey Mechanism

- ✓ *Distributed*
- ✓ *Symmetric*
- ✓ *Stable*
- ✓ *Simple*
- ✓ *Efficient*

Carriers have no incentive to invest effort in strategic behavior



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Reaching Agreements

- How do agents *reaching agreements* when they are self interested?
- In an extreme case (zero sum encounter) no agreement is possible — but in most scenarios, there is potential for *mutually beneficial agreement* on matters of common interest
- The capabilities of *negotiation* and *argumentation* are central to the ability of an agent to reach such agreements

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Heterogeneous, Self-motivated Agents

The systems:

- are not centrally designed
- do not have a notion of global utility
- are dynamic (e.g., new types of agents)
- will not act “benevolently” unless it is in their interest to do so

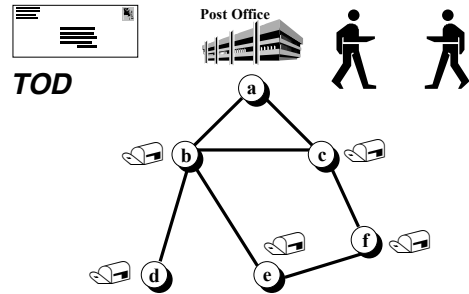
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Domain Theory

- Task Oriented Domains
 - Agents have tasks to achieve
 - Task redistribution
- State Oriented Domains
 - Goals specify acceptable final states
 - Side effects
 - Joint plan and schedules
- Worth Oriented Domains
 - Function rating states' acceptability
 - Joint plan, schedules, and goal relaxation

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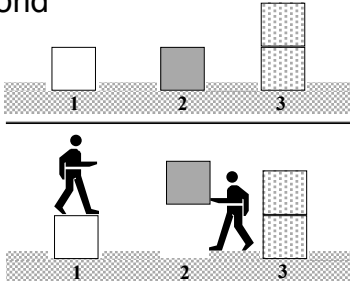
Postmen Domain - Task Oriented



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State Oriented Domain Blocks World

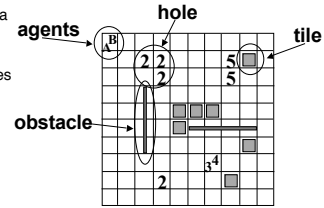
- Agent goals stated in terms of acceptable states of the world
- Agent actions may interfere or help with other agents
- Negotiate joint-plans and schedules



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Worth-oriented Domain The Multi-Agent Tileworld

- Each agent assigns a worth to each potential state
- Joint plans, schedules and goal relaxation



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Negotiation in Task-Oriented Domains

Imagine you have 3 children, each of whom needs to be delivered to 3 different schools each morning. Your neighbour has 4 children who also need to be taken to school. Delivery of each child is a task. Assume that one of your children and one of your neighbour's children both go to the same school. It obviously makes sense for both children to be taken together and only you or your neighbour needs to make the trip.

--- Rules of Encounter, Rosenschein and Zlotkin, 1994

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TODs Defined

- A TOD is a triple

$$\langle T, Ag, c \rangle$$

where

- T is the (finite) set of all possible tasks
- $Ag = \{1, \dots, n\}$ is the set of participating agents
- $c = \wp(T) \rightarrow |^*$ defines the cost of executing each subset of tasks
- ∨ An *encounter* is a collection of tasks

$$\langle T_1, \dots, T_n \rangle$$
 where $T_i \subseteq T$ for each $i \in Ag$

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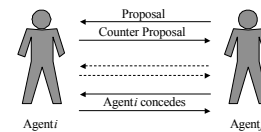
Negotiation

- Auctions are *only* concerned with the allocation of goods: richer techniques for reaching agreements are required
- *Negotiation* is the process of reaching agreements on matters of common interest
- Any negotiation setting will have four components:
 - A negotiation set: possible proposals that agents can make
 - A protocol - defines the legal proposal that an agent can make
 - Strategies, one for each agent, which are private
 - A rule that determines when a deal has been struck and what the agreement deal is

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Negotiation Process 1

- Negotiation usually proceeds in a series of rounds (encounters), with every agent making a proposal (deal) at every round
- Communication during negotiation:



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The Negotiation Set

- The set of deals over which agents negotiate are those that are:
 - individual rational
 - pareto efficient

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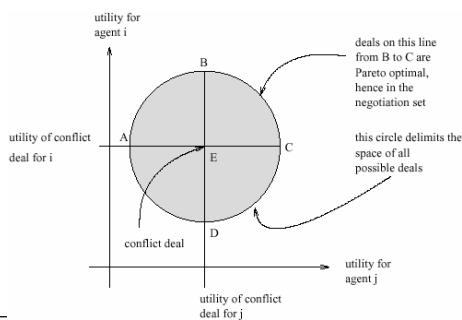
Deals in TaskODs

- Given encounter $\langle T_1, T_2 \rangle$, a *deal* is an allocation of the tasks $T_1 \cup T_2$ to the agents 1 and 2
- The *cost* to i of deal $\delta = \langle D_1, D_2 \rangle$ is $c(D_i)$, and will be denoted $cost_i(\delta)$
- The *utility* of deal δ to agent i is:

$$utility_i(\delta) = c(T_i) - cost_i(\delta)$$
- The conflict deal, Θ , is the deal $\langle T_1, T_2 \rangle$ consisting of the tasks originally allocated. Note that $utility_i(\Theta) = 0$ for all $i \in Ag$
- Deal δ is *individual rational* if it weakly dominates the conflict deal

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The Negotiation Set Illustrated



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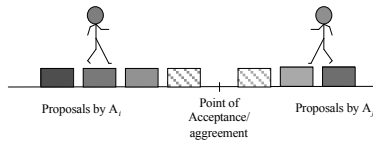
Negotiation Protocols

- Agents use a product-maximizing negotiation protocol (as in Nash bargaining theory)
- It should be a symmetric PMM (product maximizing mechanism)
- Examples: 1-step protocol, monotonic concession protocol...

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Negotiation Process 2

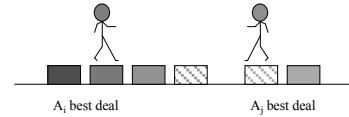
- Another way of looking at the negotiation process is:



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The Monotonic Concession Protocol (MCP) 1

- Negotiation proceeds in rounds
- On round 1, agents simultaneously propose a deal from the negotiation set.
- Agreement is reached if one agent finds that the deal proposed by the other agent is at least as good or better than its proposal.



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The Monotonic Concession Protocol 2

- If no agreement is reached, then negotiation proceeds to another round of simultaneous proposals.
- In round $u+1$, no agent is allowed to make a proposal that is less preferred by the other agent than the deal proposed at time u .
- If neither agent concedes, then negotiation terminates with a conflict deal.

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The Monotonic Concession Protocol 3

- Advantages:
 - Symmetrically distributed (no agent plays a special role)
 - Ensures convergence
 - It will not go on indefinitely
- Disadvantages:
 - Agents can run into conflicts
 - Inefficient – no guarantee that an agreement will be reached quickly

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Key Questions

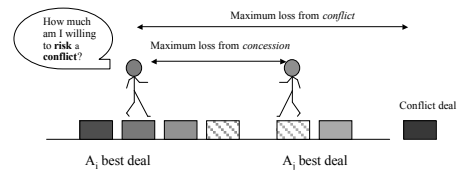
3 key questions to be answered:

- What should an agent's first proposal be?
It's most preferred deal.
- On any given round, who should concede?
The agent least willing to risk conflict.
- If an agent concedes, then *how much* should it concede?
Just enough to change the balance of risk.

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The Risk Factor

One way to think about which agent should concede is to consider how much each has to lose by running into conflict at that point.



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The Zeuthen Strategy

- Uses the risk evaluation strategy
- Suppose you have conceded a lot. Then:
 - Your proposal is now close to conflict deal.
 - You are more willing to risk conflict.
- An agent will be *more willing* to risk conflict if the difference in utility between its current proposal and the conflict deal is *low*.
- Degree of willingness to risk a conflict can be defined as:

$$\text{Risk}_i^j = \frac{\text{utility } i \text{ loses by conceding and accepting } j\text{'s offer}}{\text{utility } i \text{ loses by not conceding and causing conflict}}$$

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Negotiation Strategies Cont

- Zeuthen Strategy –
 - Start – A offers B the minimal offer
 - $\text{Utility}_B(\delta(A,1)) = \min_{\delta \in \text{NS}} \{\text{Utility}_B(\delta)\}$
 - Next - A will make a minimal sufficient concession at step t+1 iff $\text{Risk}(A,t) \leq \text{Risk}(B,t)$
 - If both agents follow the above strategy, they will agree on a deal $\delta^* \in \text{NS}$, such that $\Pi(\delta^*) = \max_{\delta \in \text{NS}} \{\Pi(\delta)\}$

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About MCP and Zeuthen Strategies

- **Advantages:**
 - Simple and reflects the way human negotiations work.
 - Stability – in Nash equilibrium – if one agent is using the strategy, then the other can do no better than using it him/herself.
- **Disadvantages:**
 - Computationally expensive – players need to compute the entire negotiation set.
 - Communication burden – negotiation process may involve several steps.

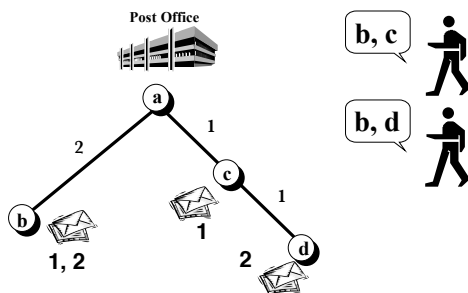
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Nash Equilibrium Again...

- The Zeuthen strategy is in Nash equilibrium: under the assumption that one agent is using the strategy the other can do no better than use it himself...
- This is of particular interest to the designer of automated agents. It does away with any need for secrecy on the part of the programmer. An agent's strategy can be publicly known, and no other agent designer can exploit the information by choosing a different strategy. In fact, it is desirable that the strategy be known, to avoid inadvertent conflicts.

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Not as easy as it seems



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Negotiation Domains: Worth-oriented

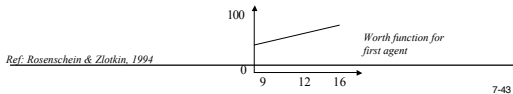
- "Domains where agents assign a worth to each potential state (of the environment), which captures its desirability for the agent", (Rosenschein & Zlotkin, 1994)
 - agent's goal is to bring about the state of the environment with highest value
 - we assume that the collection of agents have available a set of joint plans – a joint plan is executed by several different agents

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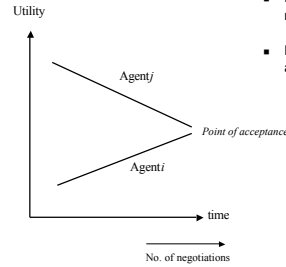
Worth-oriented Domain: Example

2 agents are trying to set up a meeting. The first agent wishes to meet later in the day while the second wishes to meet earlier in the day. Both prefer today to tomorrow. While the first agent assigns highest worth to a meeting at 16:00hrs, s/he also assigns progressively smaller worths to a meeting at 15:00hrs, 14:00hrs....

By showing flexibility and accepting a sub-optimal time, an agent can accept a lower worth which may have other payoffs, (e.g. reduced travel costs).



Utility Graphs 1

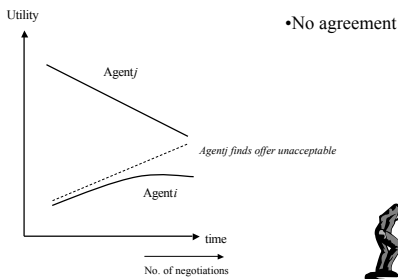


- Each agent concedes in every round of negotiation
- Eventually reach an agreement



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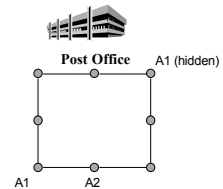
Utility Graphs 2



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Deception-Free Protocols

- Zeuthen strategy requires full knowledge of
 - tasks
 - protocol
 - strategies
 - commitments
- Hidden tasks
- Phantom tasks
- Decoy tasks



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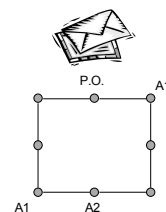
Deception in TODs

- Deception can benefit agents in two ways:
 - Phantom and Decoy tasks*
Pretending that you have been allocated tasks you have not
 - Hidden tasks*
Pretending *not* to have been allocated tasks that you have been
 - Key role of information about opponent's objectives and values
 - Usefulness of mixed (random) strategies

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Postmen

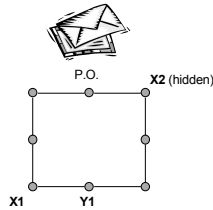
- Postmen start from the PO
- Get letters, deliver them and return to PO
- Agent 1 has 2 letters.
Total path=8
- Agent 2 has one letter: path =8
- No advantage from redistribution -> Flip a coin and one does nothing



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Hidden task

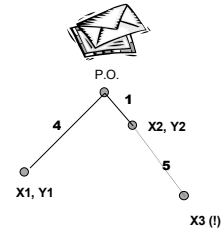
- Agent 1 hides letter X2
 - Its declared path length = 6
 - A2's path length = 8
- A2 can deliver X1 and Y1 with no penalty
- A1 delivers X2 secretly and pays only 2 units



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Decoy task

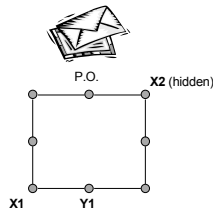
- Both agents have letters to deliver to one place 4 units away and to another 1 unit away.
- Total path = $2 \times (8+2) = 20$
- If one agent delivers X1&Y1 and the other X2&Y2, total path = $8 + 2 = 10$
- They should flip to decide
- But, if A1 pretends to have a letter X3 to be delivered 6 units away, A2 will get to deliver X1,Y1 (cost 8) while A1 gets the cost 2 trip



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Mixed (probabilistic) deal

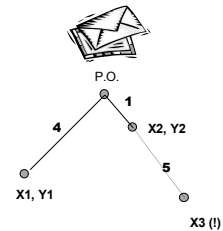
- Public deals:
 - Default (known) cost A1 = 6
 - Default cost A2 = 8
- A1 delivers both $3/7$ times
- A2 delivers both $4/7$ times
- Average cost to A2: $(4 \times 8) / 7 = 32/7 = 4.57$
- Cost to A1: $(3 \times 8 + 4 \times 2) / 7 = 32/7$
- Hiding a task does not benefit A1



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All or Nothing Mixed deal

- A's advertised cost = 20
- B's public (real cost) = 10
- A must do the whole delivery with $p=2/3$ instead of $1/2$
 - Average cost = 6.7 instead of 5
- Worse, if he can't fake a letter to X3 (decoy) then B will be aware of the deception and A could be fined



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Related Work

- Similar analysis made of State Oriented Domains, where situation is more complicated
- Coalitions (more than two agents, Kraus, Shechory)
- Mechanism design (Sandholm, Nisan, Tennenholtz, Ephrati, Kraus)
- Other models of negotiation (Kraus, Sycara, Durfee, Lesser, Gasser, Gmytrasiewicz)
- Consensus mechanisms, voting techniques, economic models (Wellman, Ephrati)

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Conclusions

- By appropriately adjusting the *rules of encounter* by which agents must interact, we can influence the private strategies that designers build into their machines
- The interaction mechanism should ensure the *efficiency* of multi-agent systems

Rules of Encounter

Efficiency

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Argumentation

- Argumentation is the process of attempting to convince others of something
- Gilbert (1994) identified 4 modes of argument:
 1. *Logical mode*
"If you accept that *A* and that *A* implies *B*, then you must accept that *B*"
 2. *Emotional mode*
"How would you feel if it happened to you?"
 3. *Visceral mode*
"Cretin!"
 4. *Kisceral mode*
"This is against Christian teaching!"

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