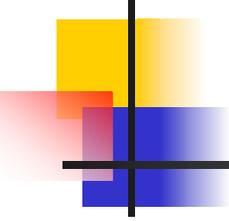# Co-X:Defining what Agents Do Together

Presented by: Tingting Wang

Based on a paper with the same name authored by

H.Van Dyke Parunak, Sven Brueckner, Mitch Fleischer and James Odell, available at: http://www.erim.org/~vparunak/cox.pdf)

Introduction

- Several terms have appeared to characterize agent interactions:
  - Coordination
  - Correlation
  - Competition
  - Contention
  - Cooperation
  - Congruence
- Formal distinctions among these terms are proposed here.
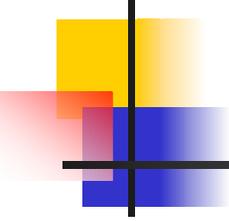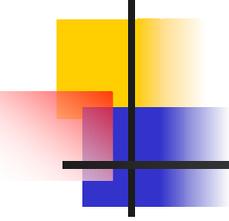
Correlation:Mutual Information

- Correlation: a set of agents with positive joint information

- One measurement: the entropy of the agents' behaviors over time:

$$H(a_i) = -\sum_{j=1}^{n_i} p_{ij} \log_2 p_{ij}$$

p_{ij}:the probability of agent i executes action a_{ij}.
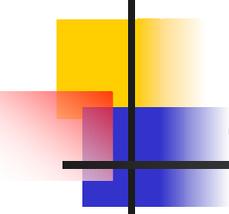
- For systems with 2 agents:

$$H(a_1, a_2) = -\sum_{j=1}^{n_1 * n_2} p_j \log_2 p_j$$

Correlation:Mutual Information(cont.)

- Correlation:
  - $H(a_1,a_2)=H(a_1)+H(a_2)$——individual agents are independent
  - $H(a_1,a_2)<H(a_1)+H(a_2)$——individual agents are dependent, and the difference $I(a_1:a_2)=H(a_1)+H(a_2)-H(a_1,a_2)$ is the correlation.
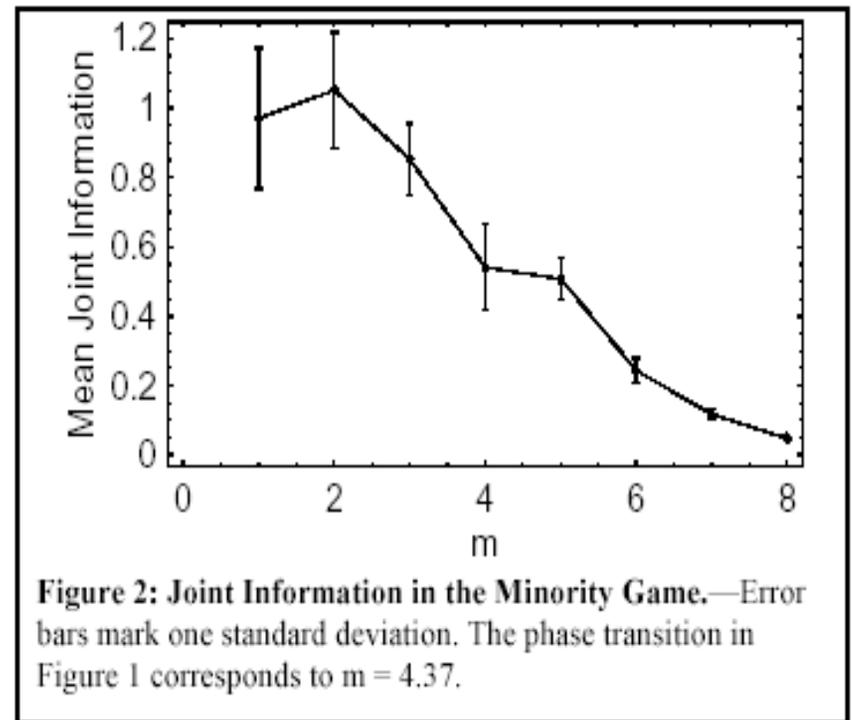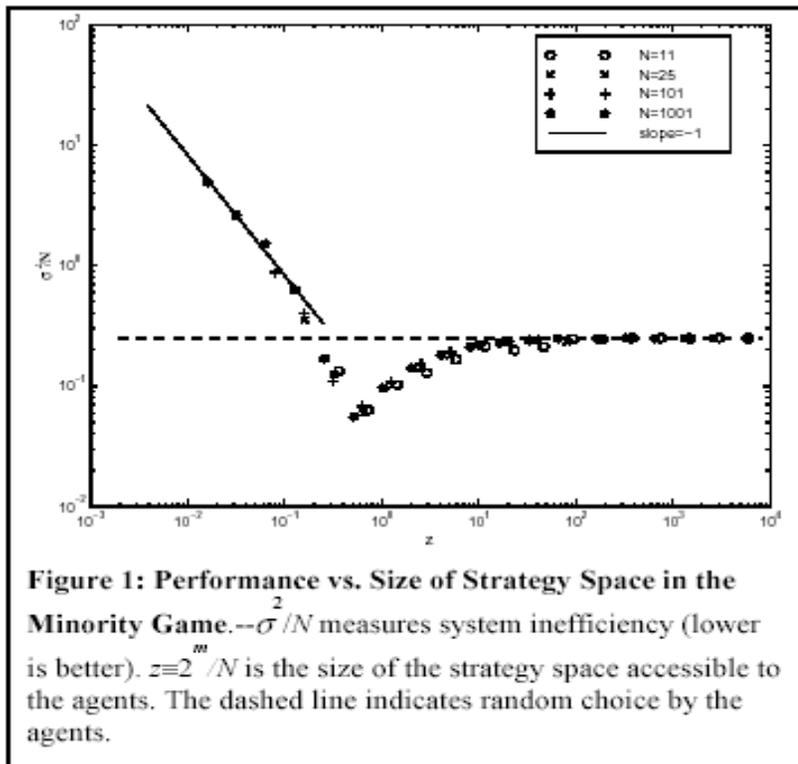- Higher correlation⇔greater joint information

Joint Information

- Suppose: 2 agents, 2 widgets, each agent accesses each widget half of the time to perform its duties, so,

  $p_{1,1}=p_{1,2}=p_{2,1}=p_{2,2}=0.5$

- Each individual agent entropy is:

  $-2*0.5\log_2(0.5)=1$

- At the system level, if no correlation, the entropy is $-4*0.25\log2(0.25)=2$, equal to the sum of the individual agent entropies.

- If correlation exists, agents will not choose one widget at the same time, so only 2 system actions, each with probability 0.5. The system entropy is 1, less than the sum of agent entropies. The joint information is 1.

Correlation in MG

Figure 1: Performance vs. Size of Strategy Space in the Minority Game.--σ^2/N measures system inefficiency (lower is better). $z=2^m/N$ is the size of the strategy space accessible to the agents. The dashed line indicates random choice by the agents.

Figure 2: Joint Information in the Minority Game.—Error bars mark one standard deviation. The phase transition in Figure 1 corresponds to m = 4.37.

- Correlation is highest for low *m*, shows herding behavior.

- High *m* is associated with low correlation, shows random approach.

- A deviation between *m*=4 and *m*=5, phase transition area.
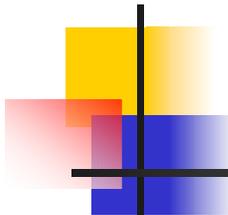
Coordination: communication

- Correlation: statistical non-independence among agents' behaviors

- Coordination: the process involves communication, i.e., information flow between individual agent and its environment

Table 1: Categories of Communication

|		Topology of Inter-Agent Relationships	
		Centralized (between Distinguished and Peer agents)	**Decentralized** (among Peer agents)
Information Flow	**Direct** (messages between agents)	*Construction* (Build-Time) *Command* (Run-time)	*Conversation*
	Indirect (non-message interaction)	*Constraint*	*Stigmergy*[2] (generic) *Competition* (limited resources)
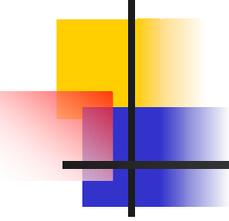
Cooperation & Contention: Intent

- Difference:
  - Correlation: no need of internal structure of the agents
  - coordination: inter-agent organizational issues
  - Cooperation and contention: internal logic of an agent
- To describe cognitive agents, which seek to imitate the representation and process of human cognition.
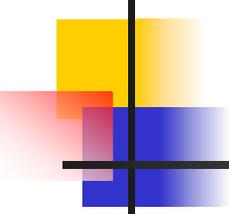
Cooperation & Contention: Intent (cont.)

- To determine cooperation or contention, outside actions are no use, need to observe intent of agents .
  - Cooperation: agents with joint intentions
  - Contention: one agent intend to frustrate the intentions of others.
- Both of them are correlation driven by agents' intent.
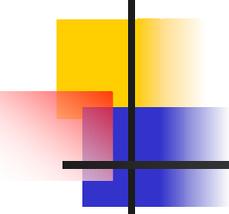
Congruence & coherence: Usefulness

- Difference:
  - Coordination, cooperation, competition: individual agents level
  - Congruence & coherence: system level
- Congruence: to characterize the degree to which agent interactions satisfies system level goals.
- Coherence: the relation among the agents themselves that yields Congruence.
- In MG, the highest level of Correlation occurs for low m, while the system is most Congruent and the agents most Coherent for intermediate levels of m.
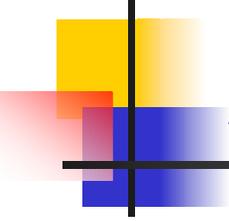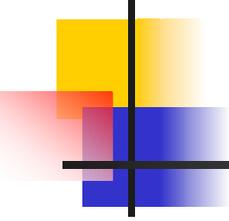
Anticorrelation

- Agents seek to eliminate correlation in some situations:
  - In contention with adversaries who take advantages of our regularities
  - Have similar internal coding with adversaries
  - The mechanism of some systems require an assumption of ergodicity.
- How?

  To make decisions on the basis of random processes(by central controller or by agent itself)

Conclusion

- Correlation: the fundamental characteristic.
- Coordination: Correlation with a focus on the information flow—Conversation, Construction, Command, Constraint, Stigmergy, and Competition.
- Cooperation and contention: Correlation modulated by the intent of individual agents.
  - Cooperation: requires joint intentions
  - Contention: an intention to frustrate the intentions of another
- Congruence: measures the degree of achieving a system-level goal.
- Coherence: the relation among agents that yields Congruence.