ACE & Behavioural Game Theory, Hierarchy of Cognitive Interactive Agents & Design Patterns: What is the connection ?

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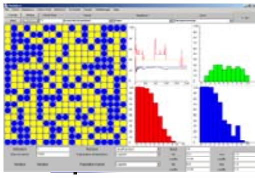
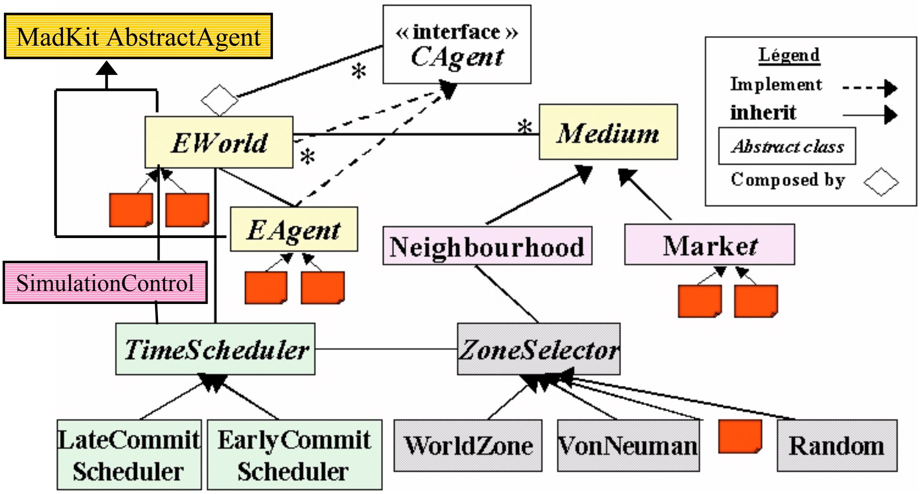
Overview

- Aim : to study by the way of ACE the effect of various degree of *cognitive hierarchy* in *behavioural population games* with *random matching* or *localised social networks*.
  - E dynamics process in complex adaptive systems
- Question 1: What is *Cognitive Hierarchy* and why does it matters for ACE and Behavioural Game Theory ?
- Question 2: How *Design Patterns* and multi-agent approach can help Behavioural Game Theory?
- Case study I: from Statistical Mechanics towards *Cognitive* « Stag hunt » *Coordination Game*
- Case study II: a tentative Two Level coupling models of *Strong Emergence* in a Bargaining Game (future works)



Interlude : Moduleco UML structure



Question 1 : What is *Cognitive Hierarchy* and why does it matters for ACE and Behavioural Game Theory ?

- Behavioural Game Theory (BGT) and Cognitive Economics

➔ BGT « is about what players *actually* do » (*Camerer, 2003*).

➔ BGT expand Analytical Game Theory by adding the possibility of limited capacities, both for *psychological* and *cognitive* reasons.

➔ With social interactions, *learning process* arise both at *individual* and *population* level. The kind of learning depend of the kind of interactions and cognitive hierarchy taking into account.

- Cognitive hierarchy: one couple of words, several meanings
  - Hierarchy in Cognitive Capacity (paper)
  - Hierarchy in iterative « Strategic Thinking » capacity
  - Hierarchy in level of knowledge (i.e. emergence)

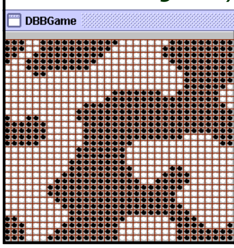
Case study I: from Statistical Mechanics towards Cognitive « Stag hunt » *coordination* game

- From Phan (ABS 2003), Phan, Pajot, Nadal (2003), Nadal *et al.* (2003)…
- Agents interacts and take strategic decisions on a (social) network
- For a given price P, it is possible to have *two equilibrium levels of demand* given agent's expectations, neighbourhood structure, and historic path

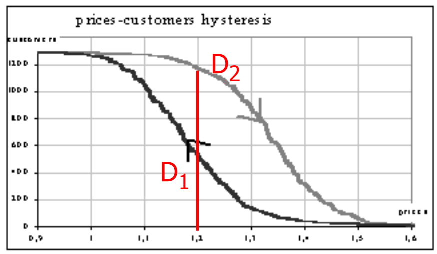
willingness to pay

$$V_i(\omega_i)=\omega_i\left(H_i+\varepsilon_i+J_\vartheta.\sum_{k\in\vartheta}\tilde{E}[\omega_k]-P\right)$$

Idiosyncratic heterogeneity — Social Influence (expectations) — price



Eq. with Moore Neighbourhood, on a *torus,* without noise, reactive agents



Question : which equilibrium would be selected ?

ex. Hierarchy of cognitive capacity (paper)

- Walliser (1998) learning in games
  - In *evolutionary process*, player has a fixed strategy (replication)
  - In *behavioural learning*, player modifies his strategies according to the observed payoff from his past actions (memory, exploration)
  - In *epistemic learning*, « thinking » player updates his beliefs about others' future actions, according to their observed actions.
  - ~~In *eductive process*, player has enough information to perfectly simulate others' behaviour and immediately reaches equilibrium.~~

- Dennett (1996) "Tower of Generate-and-Test".
  - Darwinian creatures: have a rigid phenotype.
  - Skinnerian creatures: have an adaptable phenotype (reinforcement-learning capabilities)
  - Popperian creatures : pre-select actions, given the available information coming from inheritance and/or acquisition.
  - Gregorian creatures enhance their individual performances through the use of "tools". (i.e. language and models)

Under construction !

Design Patterns, ACE and Behavioural Game Theory

Hierarchy of cognitive capacity

from Object-Oriented towards Agent-Oriented Design Patterns*

* I acknowledge J. Ferber for valuable discussions and suggestions All limitations remains mines

EAgent
EAgent Games
ReactiveAgent (programmed)
BehaviouralAgent1 (adaptive by reinforcement on the relation perception-action)
BehaviouralAgent2 (adaptive by simple learning about the behaviour of the others)
EpistemicAgent simulate strategically the behaviour of the others in a model of the world

First attempt : simple Object Oriented decreased cognitive hierarchy

Other proposal: Object Oriented State managed cognitive hierarchy

EAgent Games
EAgentDecisionUnit
ReactiveAgentDU
BehaviouralAgent1DU
BehaviouralAgent2DU
EpistemicAgentDU

Next Step: towards agent-oriented cognitive hierarchy (forthcoming)...

Under construction !

Case study I: from Statistical Mechanics towards Cognitive « Stag hunt » Coordination Game.

A simple example of Cognitive Hierarchy

- Models: the same model may be subject to different interpretation along the « frontiers »

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« agent » (?): Spin d'Ising

agent with *Myopic Best Reply* (strategic; but memory less: *no learning*)

Cumulative Proportional Reinforcement

Behavioural agent (strategic; bounded memory)

Experience Weighted Attraction Model (Camerer, Ho, 1997)

Fictitious Play

Cognitive hierarchy (II): one couple of words, several meanings

Hierarchy in iterative « strategic Thinking » capacity (*Camerer*)

- Question: how deep is the process of *iterative thinking* for anticipating what average opinion expects the average opinion to be (recursively) ?
- Paradigmatic example: from Keynes's analogy between the stock market and a « *beauty contest* » *(2 dimensions : social salience and strategic thinking)*
- Simple numerical example: N players simultaneously choose a number in the interval [0,100] and the winner is those which choose the number closer from 70% of the average opinion.
- In *Analytical Game Theory*, players iterate recursively (or solve: $X^*=0,7.X^*$) the resulting *Nash equilibrium* is zero. This requires that every player believe that others players think recursively, and think that others players do it also (recursively).
- *Experimental Behavioural Games* evidence show that *few people perform more that a couple of step in iterated strategic thinking* (first shot) because *limitation of working memory*
- Results: deep 0 : 50 ; deep 1 : 35 ; deep 2 : 24,5 ; people generally choice between 20-40 (but learn in few steps if the game is repeted)

Case study II (emergence)

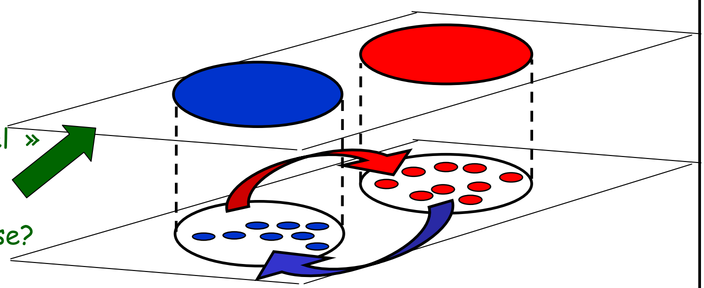
"*The emergence of Classes in a Multi-Agent Bargaining Model*" by Axtell, Epstein, Young (2000)

- « *one-shot* » bilateral game between couples of agents to share a « cake » of value 100; Only proposals with sum: $S \leq 100$ are accepted (bargaining of Nash)
- Problem: how "Classes of behaviour" can emerge spontaneously at the social level from the decentralized interactions ?
  - With a probability $1 - \varepsilon$ agents choose their Best Response, given their beliefs.
  - With a probability ε agents choose their strategy at random, with equi-probability: (1/3) ; (« trembling hand »: mistake, experimentation…)
- The agents' belief are their average observations on their m last confrontations (where *m* is their « *memory length* »)

	H = 70	M = 50	L = 30
H = 70	0,0	0,0	70,30
M = 50	0,0	50,50	50,30
L = 30	30,70	30,50	30,30

Hierarchy in level of knowledge (emergence)

- In: "*The emergence of Classes in a Multi-Agent Bargaining Model*" the emergent phenomenon arise when agents have observable characteristics (tag) that have become *socially salient* (but are fundamentally irrelevant);



Case study II (emergence) : a tentative two level coupling model of cognitive hierarchy with *strong emergence (future works)*

- A multi-level problem, with « observer » and hierarchy.
  - Bonabeau, Dessalles (1997) define emergence as a *decrease in Relative Algorithmic Complexity*. RAC is relative to the description tools available for the observer. Emergence occurs when RAC abruptly drops by a significant amount, *i.e.* the system appears much simpler than anticipated. *Emergence is a multi-level phenomenon, involving « detection »*
  - Muller (2000, 2002), call "*strong emergence*" a situation in which the agents involved in the emerging phenomenon are able to *perceive* it, and to *retroact* on the corresponding process: « *The emergence of Classes.. » of AEY is a weak emergence model*
- Dessalles, Phan (2004) are in attempt to enhance the model of AEY by *adding a second coupled model of costly signalling* ; In this second level model, *endogenous tags are explicitly used by agents to announce their intention to adopt a dominant strategy*. At this level, Agents *get an explicit representation of the interest to be within a dominant class* whenever that class emerges, thus implementing strong emergence.

Conclusion

- Next step : to formalise Agent-Oriented Design Patterns for theses different forms of cognitive hierarchy (with J. Ferber)

Tipping mistakes in the paper (eq. 9 & 10):

$$P\left(s_k = +1 \middle| \hat{z}_i\right) = P\left(-\varepsilon_i \leq \hat{z}_i\right)$$

$$P\left(s_i = \pm 1 \middle| \hat{z}_i\right) = \frac{\exp(\pm\beta.\hat{z}_i)}{\exp(+\beta.\hat{z}_i)+\exp(-\beta.\hat{z}_i)}$$

Any Questions ? (please speak slowly !)