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.
- 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)

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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

\[ V_i (\omega_i) = \omega_i \left( H_i + \varepsilon_i + J_{3\beta} \sum_{k \in \hat{\theta}} E[\omega_k] - P \right) \]

Price Social Influence

Idiosyncratic heterogeneity (expectations)

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

Question: which equilibrium would be selected?

Case study II: cognitive hierarchy (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.

  - 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)
Hierarchy of cognitive capacity
from Object-Oriented towards Agent-Oriented Design Patterns*

* I acknowledge J. Ferber for valuable discussions and suggestions. All limitations remain mine.

First attempt: simple Object-Oriented decreased cognitive hierarchy

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

Other proposal: Object-Oriented State managed cognitive hierarchy

ReactiveAgentDU
BehaviouralAgent1DU
BehaviouralAgent2DU
EpistemicAgentDU

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

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 »

« 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: \( X^* = 0.7 \times X^* \)) 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 repeated)

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 \( \varepsilon \) agents choose their strategy at random, with equiprobability: \((1/3)\); (« trembling hand »: mistake, experimentation...)
- The agents’ belief are their average observations on their m last confrontations (where m is their « memory length »)

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

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);

Where is this « level » of organisation?
For which people this level make sense?

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):

\[
P(s_k = +1 | \hat{z}_i) = P(-\varepsilon_i \leq \hat{z}_i)
\]

\[
P(s_i = \pm 1 | \hat{z}_i) = \frac{\exp(\pm \beta \hat{z}_i)}{\exp(\beta \hat{z}_i) + \exp(-\beta \hat{z}_i)}
\]

Any Questions? (please speak slowly !)