CASE-BASED METHODS AND AGENT-BASED MODELLING:
BRIDGING THE DIVIDE TO HARNESS THEIR RESPECTIVE STRENGTHS

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I want to begin by thanking the CECAN for their support during the course of my research fellowship.

I would also like to thank my two co-authors on this project and paper, Peter Barbrook-Johnson and Corey Schimpf.
OVERVIEW OF ARGUMENT

- In terms of studying social complexity, two of the most dominant methodological camps are case-based methods (CBM) and agent-based modelling (ABM).

- Notwithstanding significant epistemological similarities (i.e., cases and agents are often equivalent), both camps have yet to harness the other’s strengths, which has limited both approaches in terms of studying dynamics.
For example, CBM rarely focuses on the interactions amongst cases or their corresponding emergent behaviour; or how complex configurations might change due to different counterfactual scenarios.

In turn, ABM has yet to use CBM to develop its agents or their rules; let alone use CBM to hypothesize how agents might interact based on different combinations of complex causal configurations.

The purpose of my fellowship (and the papers I am writing with Pete and Corey) was to explore how the links between case-based methods and agent-based modeling could be developed. This results in two key projects:

- Articulating the key ways in which CBM and ABM can be linked.
- And, in turn, developing our R-Studio statistical package, COMPLEX-IT.
ASSERTION 1:

Conventional statistics are significantly limited in their capacity to study social dynamics, let alone complex global-temporal dynamics.

- Part of the problem is the static nature of these methods.
- The other is their focus on aggregates (bell shaped) distributions; rather than different and multiple trends.
- And their failure to study cases and their respective profile — which is the stuff of our globalized, digitally saturated, big data world.
ASSERTION 2:

- The methods of computational modeling and complex system offer useful solutions to these problems.

- Albeit only if one approaches them critically, as not all methods are equally useful for modeling and data mining social complexity -- which is one of the major points of Byrne and Callaghan 2013.

- The two of interest to us here are
  - case-based methods (CBM)
  - agent-based modeling (ABM)
An **agent-based model (ABM)** is a class of **computational models** for simulating the actions and interactions of autonomous agents (both individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole.

It combines elements of **game theory**, **complex systems**, **emergence**, **computational sociology**, **multi-agent systems**, and **evolutionary programming**. **Monte Carlo methods** are used to introduce randomness.

Agent-based modeling is related to, but distinct from, the concept of **multi-agent systems** or **multi-agent simulation** in that the goal of ABM is to search for explanatory insight into the collective behavior of agents obeying simple rules, typically in natural systems, rather than in designing agents or solving specific practical or engineering problems.

Agent-based models are a kind of **microscale model** that simulate the simultaneous operations and interactions of multiple agents in an attempt to re-create and predict the appearance of complex phenomena.
1. QCA is a method that bridges qualitative and quantitative analysis:

Most aspects of QCA require **familiarity with cases**, which in turn demands in-depth knowledge. At the same time, QCA is capable of pinpointing decisive cross-case patterns, the usual domain of quantitative analysis. QCA’s examination of cross-case patterns respects the **diversity** of cases and their **heterogeneity** with regard to their different causally relevant conditions and contexts by comparing cases as configurations.

2. QCA provides powerful tools for the analysis of causal complexity:

With QCA, it is possible to study “**INUS**” conditions—causal conditions that are insufficient but necessary parts of causal recipes which are themselves unnecessary but sufficient. In other words, using QCA it is possible to assess causation that is very complex, involving **different combinations of causal conditions** capable of generating the same outcome. This emphasis contrasts strongly with the “net effects” thinking that dominates conventional quantitative social science. QCA also facilitates a form of counterfactual analysis that is grounded in case-oriented research practices.
ASSERTION 3:

- However, as with all methods, there are several limitations to ABM and CBM.

- Also, while both methods were designed to better model complex causality; and while the concepts of cases and agents are often epistemologically and methodologically equivalent; these two methods have yet to be harnessed by either camp for their respective strengths.

- The time is ripe for exploring these links as mixed-methods computational modeling and complexity methods have become widely popular.
**Assertion 4:**

- **Cases and agents are equivalent in three important ways:**
  - First, they are similar in that they are based on a profile of key factors;
  - Second, they are based on the concept of differences, which link to important and different outcomes;
  - Third, they are linked in time/space to each other through the concept of *agency*:

  By asking what cases do, I am assuming that the case is an agent. This idea is somewhat foreign to some sociological traditions. We don’t generally think of the cases in the General Social Survey as agents with intentions and histories. But it is precisely my intent to begin with the question of what such cases “do” in the Weberian (etc.) sense of social action. What kinds of activities do they undertake? What do they try to accomplish? What kinds of agents are they?

- This is not to say that they are always equivalent.
ASSERTION 5: HOW CBM HELPS ABM

- Narratives and Stories about cases and social life
- Bridges the qualitative-quantitative divide
- Case-Based Holism
- Focused on cases, which can be used to identify agents and their corresponding different complex configurations (profiles of factors). In other words, the focus is on cases, not variables, and therefore keeps ABM oriented toward its overall goal (how variables go together) from the beginning, rather than having to stitch things together later!
- Provide complex causality better than conventional statistics
- Focuses on the link between cases and outcomes!
- Allows for easier rule extraction

Also, one can go from ABM to CBM, using the latter to empirically validate a model.
ASSERTION 6: HOW ABM HELPS CBM

- The importance of counterfactuals (thinking non-observed cases)
- Interactions and inter-(re)actions
  - How cases influence one another
  - How cases respond or change in relation to one another
- The importance of time and trajectory
  - Individual case-base trajectories
  - How cases evolve across time
- Emergent behavior and global-temporal dynamics

Supports future data collection, mainly in terms of thinking about additional factors; but also in terms of potential interactions and other dynamics that have yet to be considered.
COMPLEX-IT
Case-Based Modeling & The SACS Toolkit

A New Approach to Modeling Complex Social Systems

SACS
sociology and complexity science

“According to case-based complexity, cases are complex profiles comprised of a set of inter-dependent variables, which are contextually dependent, nonlinear, dynamic, evolving, self-organizing, emergent, etc. in short, cases have the same characteristics as a complex system. Theoretically speaking, then, cases can be treated and modeled as complex systems...”

BACKGROUND: Building on the case-comparative methods of Charles Ragin and, more recently, the case-based complexity theory of David Byrne, a new set of methodological techniques and arguments have emerged for the study of complex systems, called case-based complexity science and case-based modeling---for more information, click here to see Byrne's 2009, Sage Handbook of Case-Based Method.

CASE-BASED COMPLEXITY SCIENCE: Scholarly activity that seeks to actively integrate case-based methods with complexity science for the purpose of modeling complex systems as cases.

CASE-BASED ENTROPY: An effective way to define and measure the diversity of complexity in a probability distribution is through a specific form of Shannon entropy $H$.

VISIT: http://www.personal.kent.edu/~bcastel3/
Figure 2: Self-Organizing Topographical Map of Eleven Major and Minor Trends

Map A: Top View
- Cases were labelled according to their 6-means cluster membership.
- High Ridge, highly different cases.
- Deep Valley, highly similar cases.

Map B: More detailed view of clusters.
- Healthy
- Unhealthy
- Episodic Depression
- Chronic III
- Poor Health
- Oscillators
- Moderate Depression
- Improving
- Okay

Map C: Shows how each factor is distributed across the matrix – the more red, the higher the value; the more blue, the lower the value.
- Cluster Typology:
  - 1: Low Cholesterol
  - 2: Healthy
  - 3: High Blood Pressure
  - 4: TV Stress Hormone
  - 5: Inflamation syndrome
  - 6: High Blood Sugars
  - 7: Low Stress Hormones
  - 8: High Pro-inflammatory Elements

Factors from 7-Factor Solution, Each Mapped onto U-Matrix (See Table 1 for Factors):
- Blood Pressure
- Metabolic Syndrome
- Cholesterol
- Pro-inflammatory
- Stress Hormones
- Blood Sugar
- Stress Antagonists
Figure 1: Eleven Major and Minor Comorbid Depression/Physical Wellbeing Trends
FIGURE 7:  
Snapshot of SummitSim with a Preference Rating of 3 for all Agents

NOTE: Rich Agents = Squares; Middle Class Agents = Stars; and Poor Agents = Triangles. Cluster A identifies one of the dense clusters of rich agents. Cluster B identifies one of the dense clusters of poor agents; which complexity scientists would call a poverty trap.
COMPLEX-IT

Designed to make the otherwise highly complex tools and techniques of data mining accessible to a wider and less technical audience.

Currently, COMPLEX-IT’s suite includes:

- k-means cluster analysis
- the Kohonen topographical neural net
- a series of data visualization techniques
- case prediction
- a tab for simulating policy scenarios
- a tab for designing an agent-based model

COMPLEX-IT also includes a step-by-step series of questions that, concurrent with the actual process of data analysis, take the user through the model design process – all of which ends with a generated report on the results of one’s study.

VISIT: http://www.personal.kent.edu/~bcastel3/complexit.html