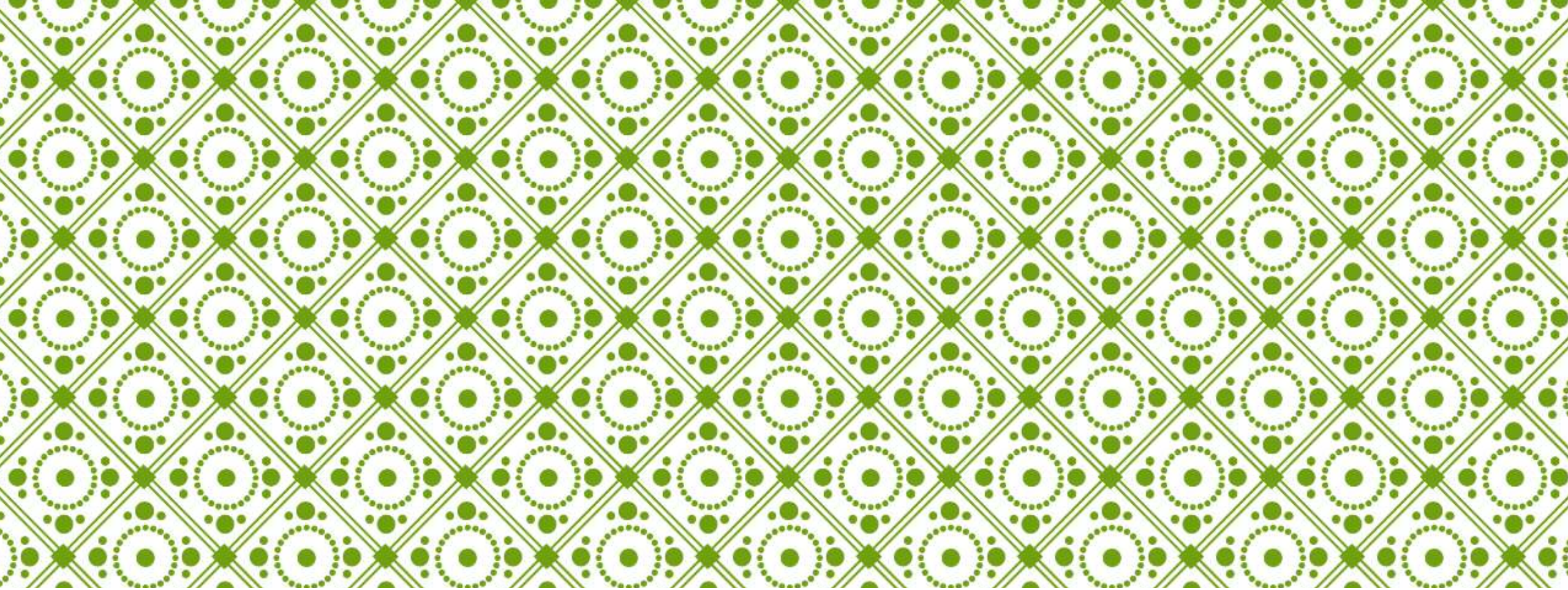

AGENT BASED SIMULATION

EXPLORING THOUGHT EXPERIMENTS

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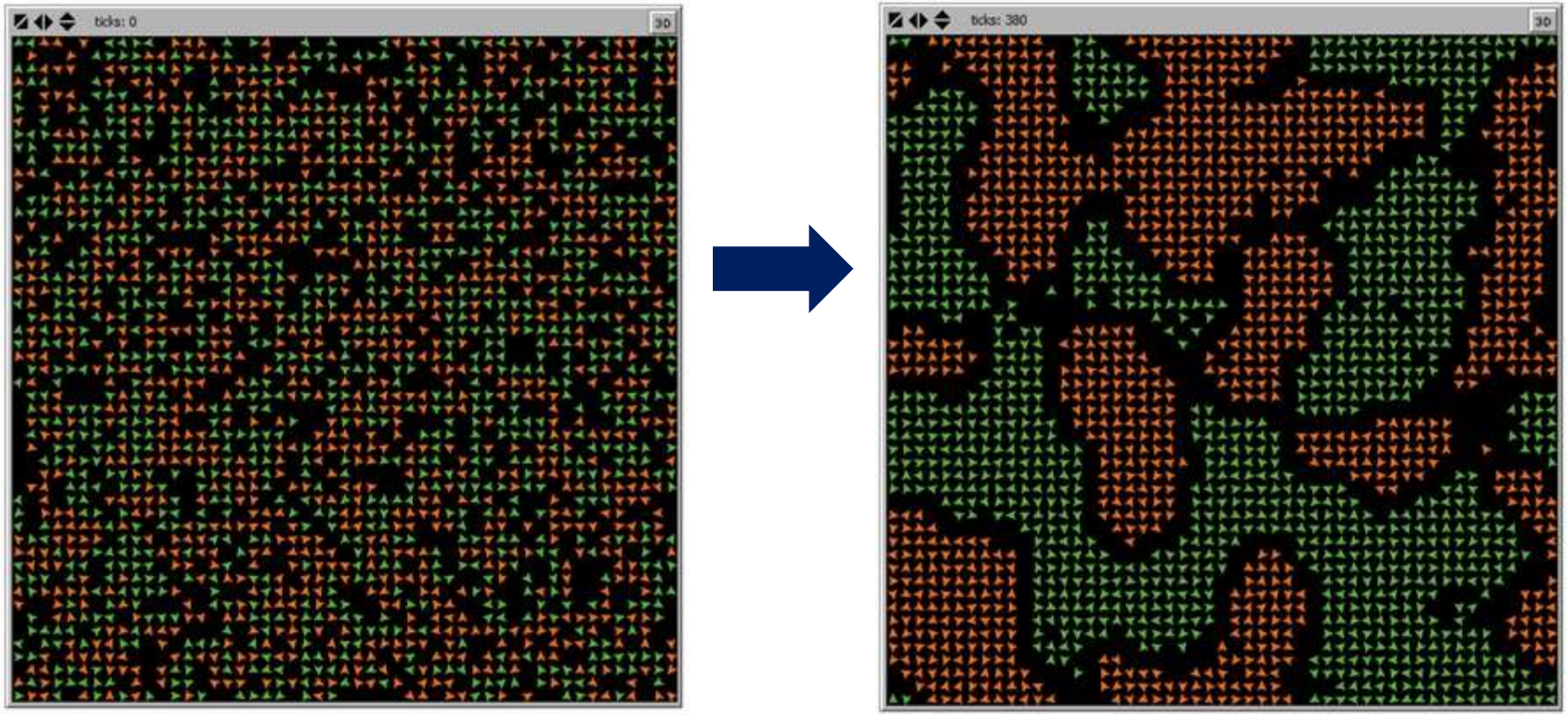
Why do ghettos form?

- Urban areas are rarely well mixed demography wise (ethnicity, race, religion, language, profession, …)
- Many are ghettos where one grouping dominates
- But why do ghettos form even in seemingly cosmopolitan societies?
- Thomas Schelling hypothesized that people like to have a moderate %age T of neighbours to be like them
- He wondered what would happen a family who found that the %age around them was less than T decided to move to another location where this condition would be satisfied.

Little India, Singapore

Chinatown, Kolkata

Segregation model



- Each agent here acts selfishly, acts locally – she likes it she stays, if not she moves
- At a global level, ghettos form

Segregation rule(s)

One simple rule

For each agent in population {

If the %age of neighbours who are like them is < T%

Then move

}

Simple rules can lead to complex emergent behaviour

Schelling won the Nobel Prize for Economics in 2005

To appreciate the value of simulation as a research methodology, it pays to think of it as a new way of conducting scientific research. Simulation as a way of doing science can be contrasted with the two standard methods of induction and deduction.

…..

Simulation is a third way of doing science. Like deduction, it starts with a set of explicit assumptions. But unlike deduction, it does not prove theorems. Instead, a simulation generates data that can be analyzed inductively. Unlike typical induction, however, the simulated data comes from a rigorously specified set of rules rather than direct measurement of the real world.

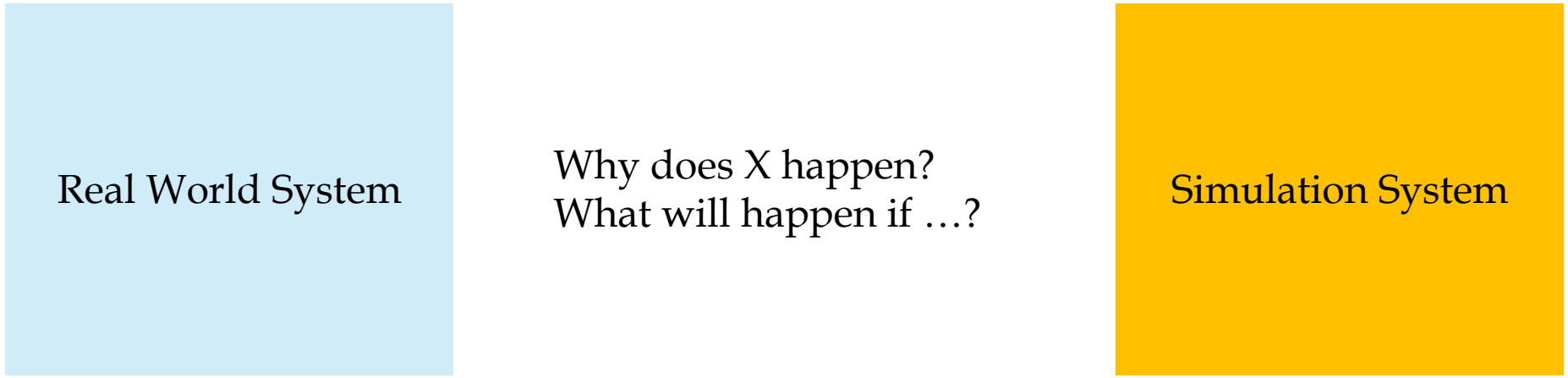
…..

Simulation is a way of doing thought experiments

Robert Axelrod

Axelrod being awarded the National Science Medal by Barrack Obama

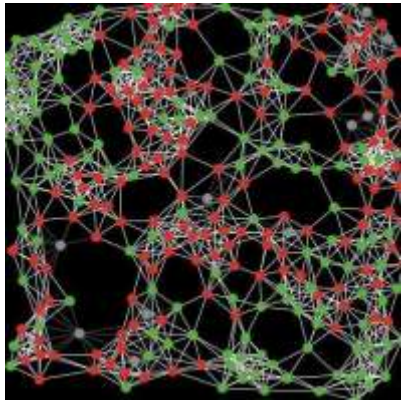
Simulation

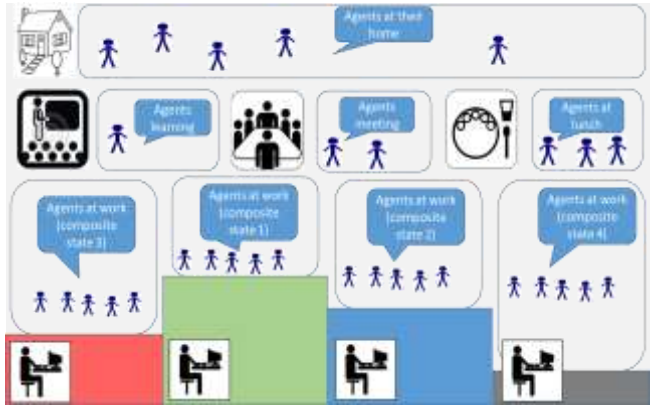


A simulation system is built primarily to either understand the workings of a complex system whose dynamics and state can be measured or observed only in limited ways or to do thought experiments about a hypothetical system which either does not exist or indeed cannot

Agent based simulation

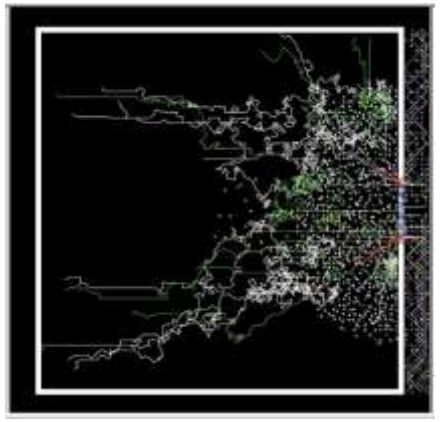
- People's behaviour is complex and difficult to know the implications of individual action at the level of a population
- ABS provides a realistic virtual theatres to generate micro dynamics leading to macro outcomes
- Filled with 'realistic' correlates of people called Agents
- Examples of agents
  - Employees , Customers, Investors, Car drivers, Manager, Borrowers,
- Agents have behaviour
  - can learn, evolve, reason,…
  - can make friends, purchase a product, pass on information to another agent,
- Can be used to understand as-is system, or hypothetical worlds
- Goals of simulation are usually macro level metrics
  - Attrition, Productivity, Footfalls, Loan defaults, Traffic choke points, SLA, ….





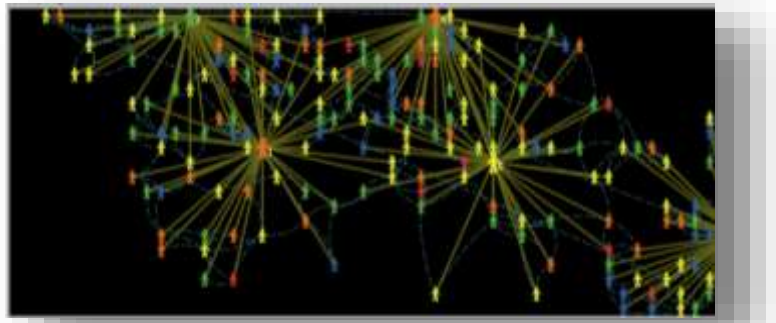
Agent based simulation – Properties of agents

- Agents have autonomy: capacity to take decisions, do actions without being ‘controlled’ by a central authority
- Agents have ‘human like’ behaviour: they can shop, drink, open an account, …
- Agents communicate with other agents and the world: they can ‘talk’ to other agents, they can listen to A and not listen to B, they can modulate their communication depending upon who is being communicated to
- Agents can learn / evolve / copy: their behaviour can change over time based on their ‘experiences’ and interactions with other agents. An agent who sees another agent use a certain strategy may mimic that behaviour
- Agents act locally leading to emergent behaviour at a macro level. A car-driver-agent may double park in order to pick up groceries, leading to a traffic jam at the level of several junctions.



Components of an agent world

- The World
  - Form, topology: a room, an office, a road network,
  - Physical / virtual: can be a correlate of a physical system or a virtual network of networks
  - Behaviour: the things that happen in the world. Traffic lights driven by a schedule, a fire may break out, the shop may open at 10:00 AM
- Agents:
  - Type: Usually more than one type of agent in every simulation. Shopper / Shopper-friend / Salesman, Prey – predator, …
  - Behaviour for each type of entity
- And outside the fish tank
  - The outcomes of interest: Footfalls in stores, mean time to destination, ..



Sample things agents in agent based worlds can do

Since ABS are programmable environments, agents could of course be made to do anything but here are a few of the things agents do in their virtual worlds

- Perceive the world
  - Status at one's location: If agent is on a food tile then collect food
  - Observe in one's neighbourhood: If X% of neighbours are not like you then move
  - Search in one's neighbourhood<X>: Look for a cab in field of vision upto a depth of <X>
- Decide what to do
  - Agent Y is violating a norm, decide if agent is to be punished
  - Workload has increased, decide if coding-agents should be asked to work for more hours or if coding-agents on the bench should be used
- Communicate
  - Send agent-23 a message
  - Ask agent-42 for information on status
- Do / execute
  - Take left at the intersection
  - Code for 2 hours at a certain individual productivity
  - Buy 1 unit of milk at retail store

Differences between Multi-agents and ABS

- Multi-agents are focused on being intermediaries who will do things / take decisions with some measure of intelligence, individual, social, economic …
- Agents in ABS particularly where agents are humans are generally focused not on *tasks*, this is a side effect but on how their behaviour in doing tasks is impacted by various factors
- Multi-agents are Elves in a Potter universe, doing things which no Witch, Wizard or even Muggle wants to do or can do well
- Agents in ABS are virtual rats in experiments

Differences between Discrete Event Simulation and ABS

- The process is at the heart of DES, the entities are mere fodder to the process
- Entities get 'processed' by various servers in a kind of Auschwitzian way
- Entities in DES have no behaviour
- Leave alone autonomy, learning, evolution etc
- Generally used for classical capacity planning exercises such as
  - How many counters need to be open at the bank so queue length < 10
  - How many additional high end servers does the ecommerce vendor need to deal with the Black Friday demand surge?
- The two, DES and ABS are in fact complementary and increasingly used in hybrid systems
  - E.g: How many counters at the bank where the people waiting in queue actually behave like persons, they may jump lines, quit, even make a scene ☺

Crowd behaviour in an emergency

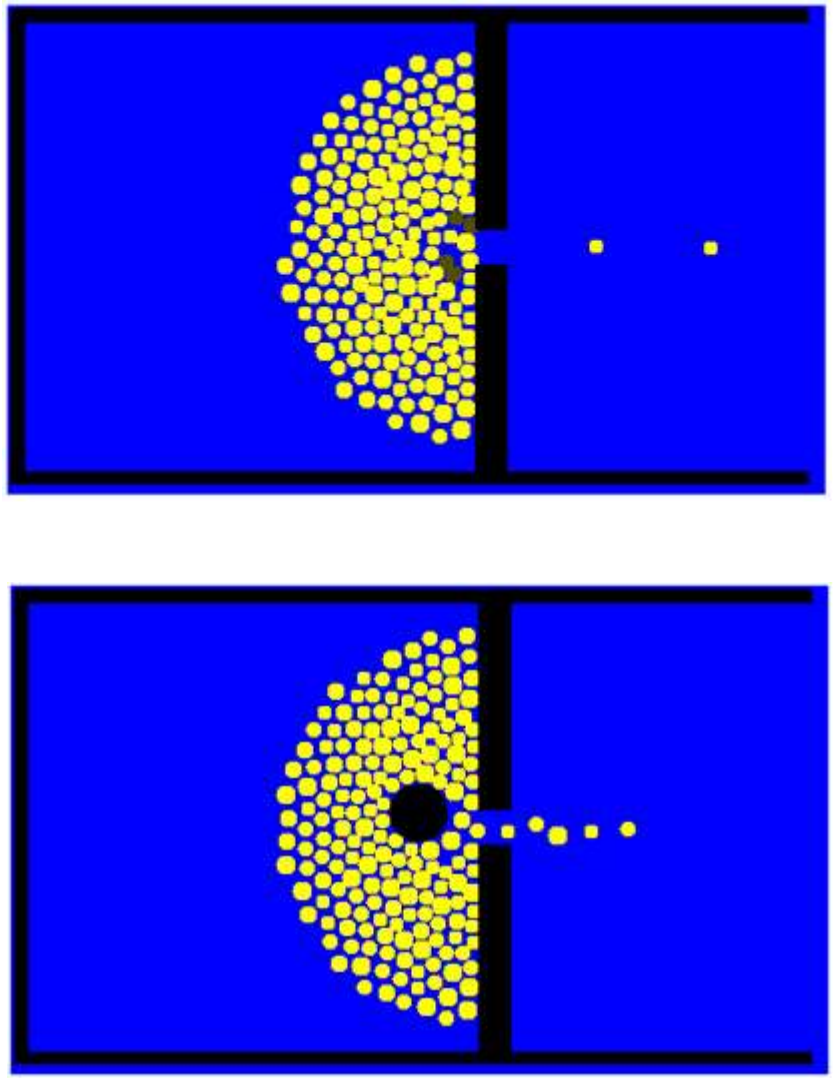
- Kiss Club, Santa Maria, Brazil
- 20 meters x 32 meters space
- Single exit – just 3 meters wide
- At other end stage
- 1300 people were crammed inside
- Performers did pyrotechnics, place caught fire
- Smoke added to the panic
- False exit – people tried to get out through bathroom
- Panic led to stampede, exit area got blocked
- Over 200 people died

Inside the Club, Just before fire

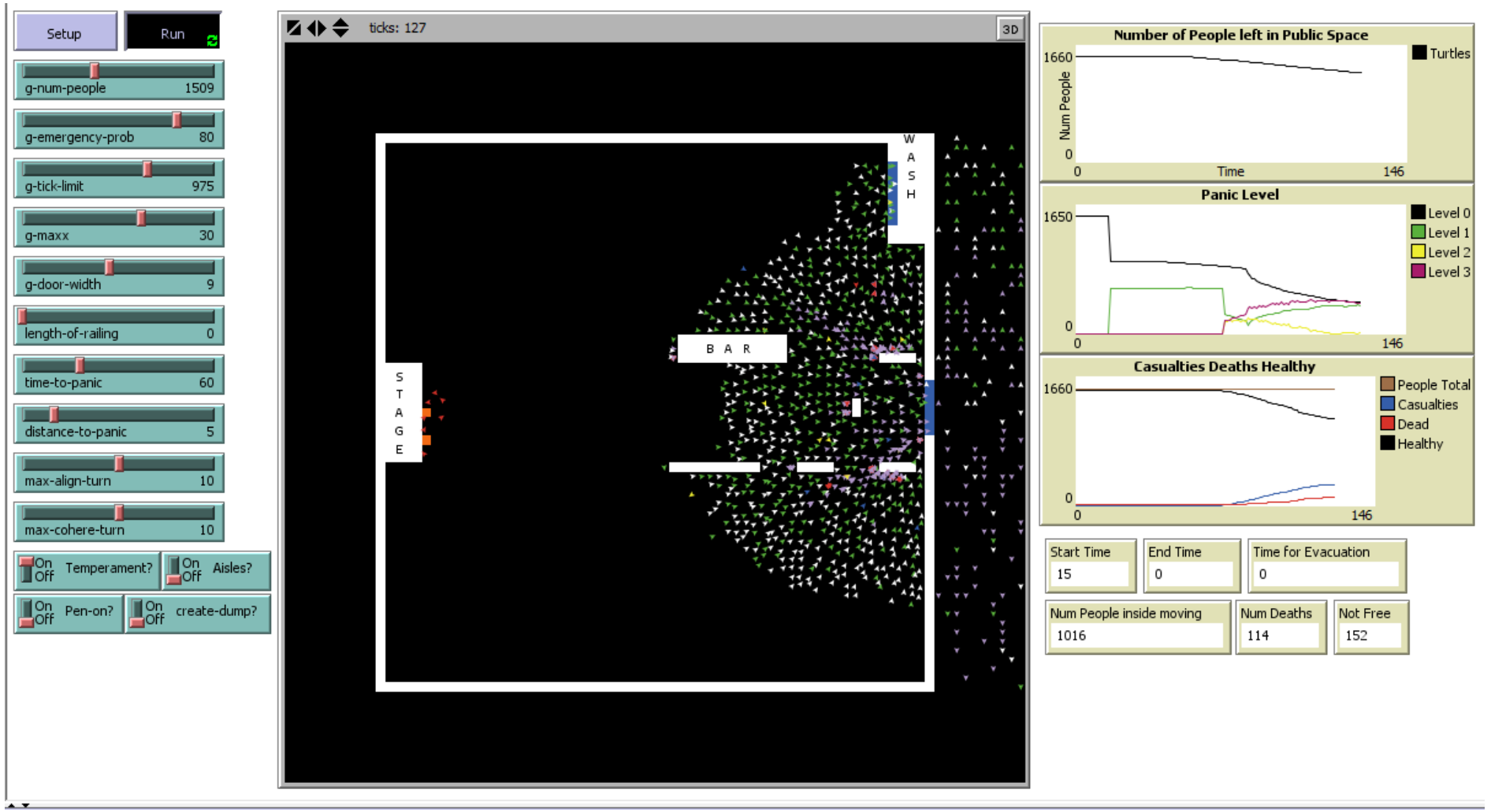
Narrow Entrance

Models of crowd behaviour

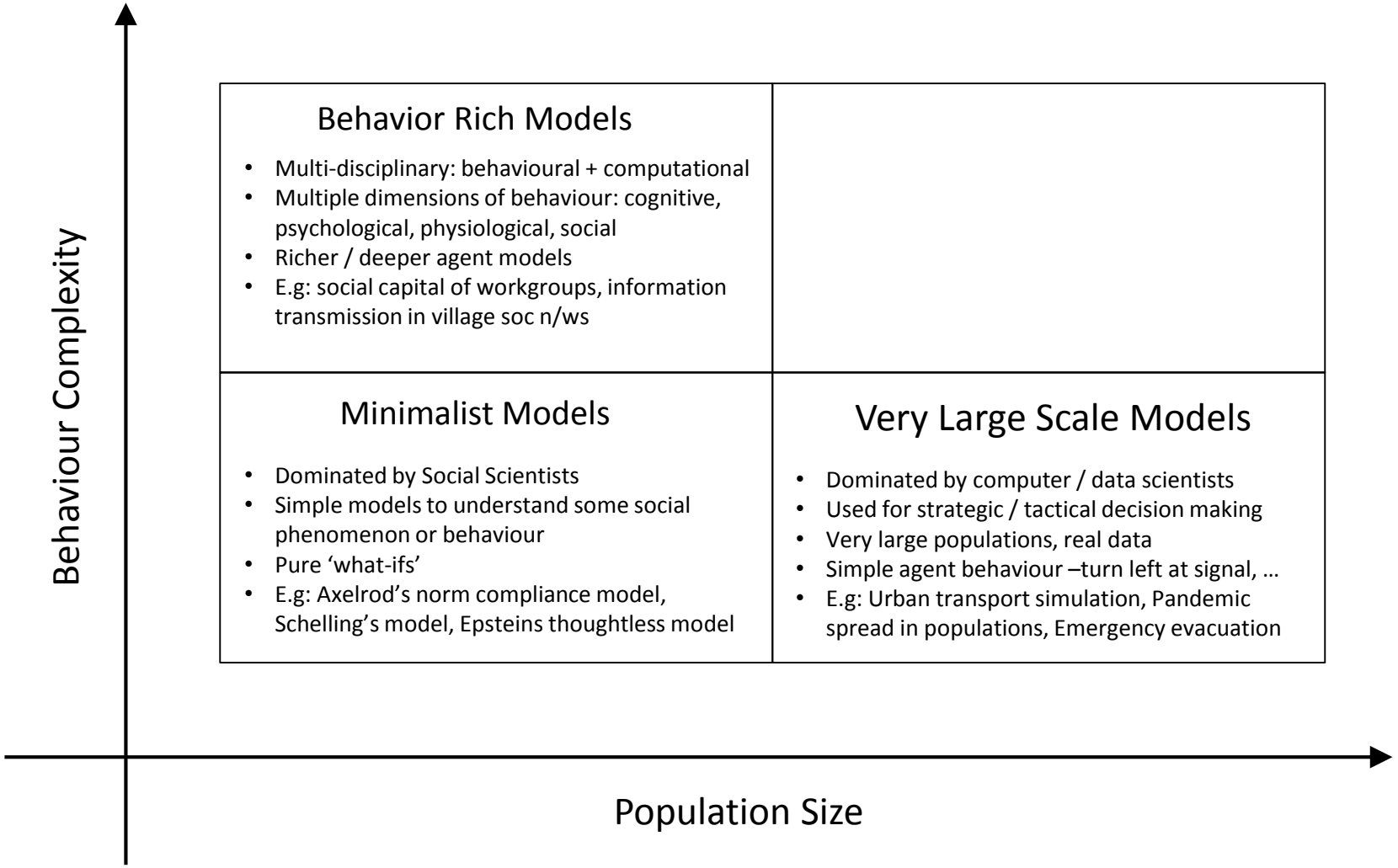
- Well studied problem
- Two approaches
- Individual as physical particle in a flow (Helbing, Burstedde and others)
  - Very little individual initiative
  - Individuals have no 'behaviour'
  - Counter intuitive but correct result on pillar
- Individual as decision making entity
  - Individual has initiative
  - Individual has behaviour
  - Affected by group
  - More suitable for emergency situations
  - See next slide for an 'emotional' model



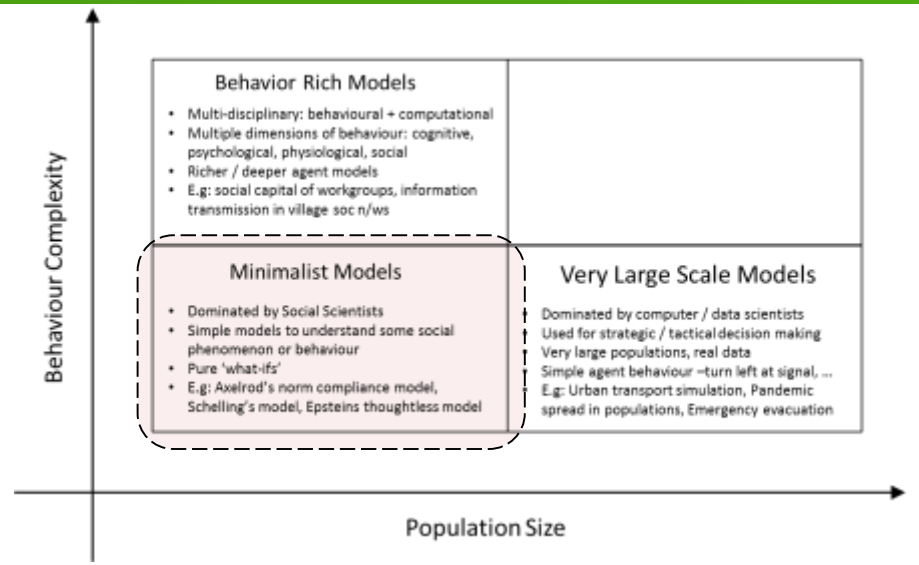
ABS simulation model – levels of fear and levels of behaviour



Types of Agent Based Systems



Minimalist Systems



Axelrod: The establishment of norms using an evolutionary approach

Norms

- Norms definitions:
  - –"The rules that a group uses for appropriate and inappropriate values, beliefs, attitudes and behaviours. These rules may be explicit or implicit. Failure to follow the rules can result in severe punishments, including exclusion from the group."
  - –or
  - –"The policies, rules, explicitly stated or unwritten codes of conduct that has been agreed upon or been imposed on a society or community."

Establishment of norms

- A norm is a social contract
- That may be agreed upon by a community or set by authority
- Examples:
  - Exchange of pleasantries when two people pass one another or meet
  - Keep to your lane while driving
  - Don’t queue jump
  - ….
- Once established, a norm may have great staying power (for ex: gender roles)
- But how do norms get established in the first place?
- A norm requires that a set of people do things in a certain way, even if it carries a cost
- Always a temptation to violate the norm and be ‘free’
- If a sufficient number of people violate the norm, it can quickly collapse

Axelrod's evolutionary approach

- Axelrod's hypotheses on how norms exist:

  "A norm exists in a given social setting to the extent that individuals usually act in a certain way and are often punished when seen not to be acting in this way."

- The Norms Game -
- To cooperate? (comply with the norm) or defect? (violate the norm)
- A pool of players who are visible to each other (note that this principle can be played with – see Mahmoud et al)
- A player who cooperates may get a small positive payoff
- A player who defects gets a larger payoff (which is why the player defected to begin with)
- But if the defection is seen by others, they punish the defector and in turn attract a small cost
- Each player has a strategy in terms of what is called Boldness (tendency to defect) and Vengefulness (to punish others)
- A strategy that works for a player will tend to be used again
- A player may copy or mimic the strategy of another player who seems to be doing well
- Effective strategies will tend to survive in the population

The Axelrod Model - 1

- Population of N agents
- Each agent has two variables Boldness and Vengefulness – [0, 7] interval
- Higher the boldness, higher the likelihood of norm violation
- Higher the vengefulness, higher the likelihood of punishing others for a violation
- Each run, each agent decides to comply or violate (based upon her Boldness score)
- Each act of norm compliance or violation attracts rewards and penalties from others
- A player's defection 'hurts' others some of whom (based upon Vengefulness) then punish the defector
- Each punishment attracts an enforcement cost
- At the end of a run, each agent would have a score
- Higher scoring agents would have more offspring in the next generation
- Either 2 offspring (if score > mean + standard deviation) or 1 offspring (>= mean)
- i.e. can be interpreted that other agents would copy strategies of successful agents

The Axelrod Model - 2

Payoff for violation or conformity

Hurt due others violation

Punishment due violation

Enforcement cost for punishing

$$S_i = A_i + \left(H \times \sum_{\substack{j=1 \\ J \neq i}}^{N} B_j\right) + \left(P \times D_i \times \sum_{\substack{j=1 \\ j \neq i}}^{N} C_{ji}\right) + \left(E \times \sum_{\substack{j=1 \\ j \neq i}}^{N} F_{ij}\right)$$

Table 1. Example of Payoffs in the Norms Game Attained by a Player With Boldness Equal to 2/7 and Vengefulness Equal to 4/7

Event	Payoff per Event	Number of Events	Payoff
Defection	$T = 3$	1	3
Punishment	$P = -9$	1	-9
Hurt by others	$H = -1$	36	-36
Enforcement cost	$E = -2$	9	-18
Score			-60

Where

$$A_i = \begin{Bmatrix} R \text{ if agent } i \text{ has violated the norm} \\ K \text{ if agent } i \text{ has not violated the norm} \end{Bmatrix}$$

$$B_j = \begin{Bmatrix} 1 \text{ if agent } j \text{ has violated the norm} \\ 0 \text{ if agent } j \text{ has not violated the norm} \end{Bmatrix}$$

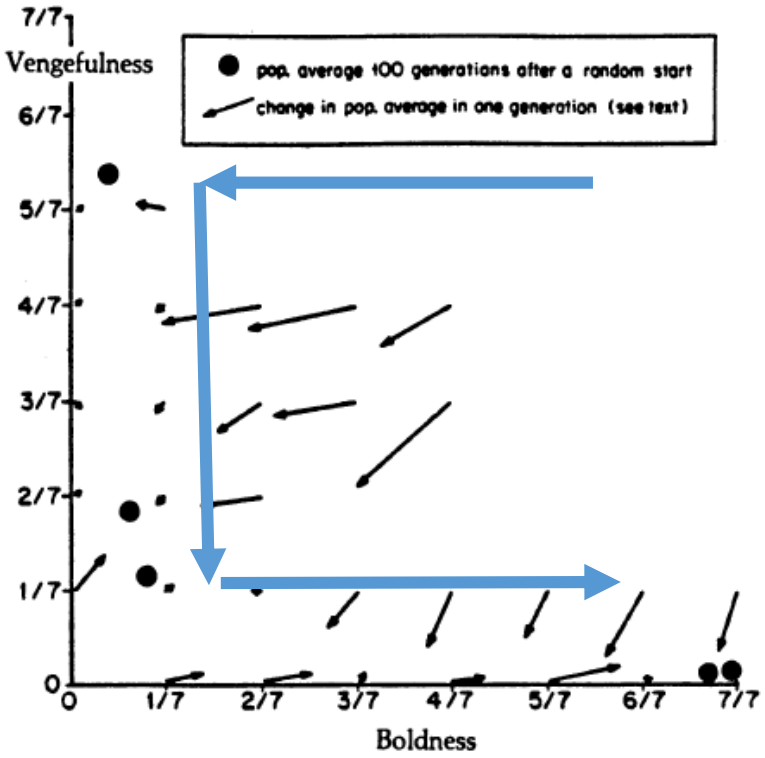
$$D_i = \begin{Bmatrix} 1 \text{ if agent } i \text{ had violated the norm} \\ 0 \text{ if agent } i \text{ had not violated the norm} \end{Bmatrix}$$

$$C_{ji} = \begin{Bmatrix} 1 \text{ if agent } j \text{ saw } i \text{ violating norm and punished} \\ 0 \text{ otherwise} \end{Bmatrix}$$

$$F_{ij} = \begin{Bmatrix} 1 \text{ if agent } i \text{ saw } j \text{ violating the norm and punished} \\ 0 \text{ otherwise} \end{Bmatrix}$$

The Axelrod Model - 3

- Model showed interesting dynamics
- First population moved to a state of low boldness
- Because heavy punishment for defection led to a low risk appetite
- Then population moved to a state of low vengefulness
- Because vengefulness carries enforcement cost
- So agents who had high V had lower scores than those who didn't
- Which then led to a population with high boldness and low vengefulness
- In other words total norm collapse



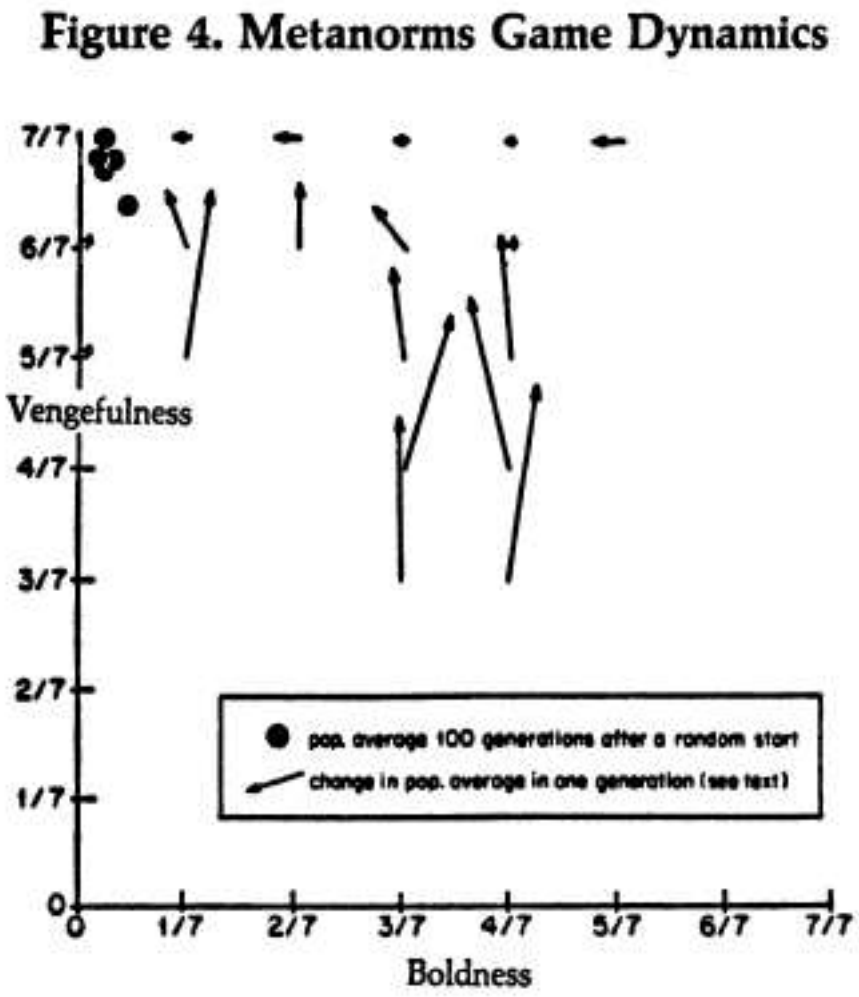
The Axelrod Model – The Metanorm

Sanctions against Iran

Washington waged a lonely battle throughout the 1980s and 1990s to muster cooperation from even its closest allies to little avail….

In 1995, the United States Congress passed the Iran–Libya Sanctions Act (ILSA). Under ILSA, all foreign companies that provide investments over $20 million for the development of petroleum resources in Iran will have imposed against them two out of seven possible penalties by the U.S.:

- In other words, do not just punish the defectors
- Also punish those who do not punish the defectors
- Axelrod called this a Metanorm
- Metanorm: A norm or policy about norms
- With the Metanorm, the population moves to norm establishment, never collapse



Extensions and evaluations around the Axelrod Model

- Numerous extensions / evaluations around the Axelrod model
- Epstein – Norms and having to think about Norms
- Galan and Izquierdo – Re-evaluation and extension
  - If number of generations >> 100 (say 1000000) then results different from Axelrod
  - Norm collapse follows norm establishment (norm collapse - 75%)
  - Use of Maynard and Price's Evolutionary Stable State (ESS) model
- Mahmoud et al – Playing with visibility
- Savarimuthu – Hybrid model
  - Combines Evolutionary model with Cognitive model
  - Individual norm model and group norm model
- We have explored norms within organizations
  - Walk the talk and corrective action metanorms (SummerSim 14)
  - Norm establishment in Hierarchical, flat, hybrid orgs (SpringSim 15)
  - ESS with single dimension (Prima 15)

Axelrod: Culture spread in populations

How do ideas / culture spread in a population?

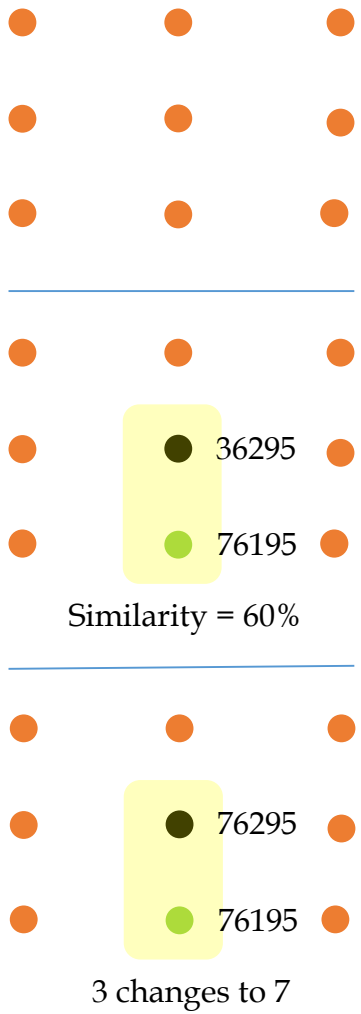
- Culture – a set of values that may be socially influenced
- How do ideas / culture / values spread and what stops them from conquering all?
- Fundamental principle of human communication " transfer of ideas happens most often among people…. Who are similar in certain attributes such as beliefs, education, social status, etc" (Rogers 83, Homans 50)
- Or the likelihood that an idea will spread from one person to another depends on features they already have in common
- Similarity leads to interaction which leads to more similarity
- Also called Social Influence Model
- What are the implications of this?

Principles behind the Axelrod model

- Agent based model
- No coordinating entity or central authority
- Adaptive rather than rational agents

The Model

- A world consisting of a grid of N x N agents
- Cultural values modelled as M 'features', each with R 'traits'
  - For ex: Feature: Sports preference, Traits: Soccer, Tennis, Cricket, …
- Each agent carries all M features and with a specific trait for each feature
  - For ex: Agent 205, {Italian,…,Tennis…., Spaghetti, ….}
- As it is a grid, each agent (except those at edges) have 4 neighbours
- At each 'tick', an agent S is randomly chosen, and a neighbor of S, say T is randomly chosen
- A biased coin toss based on existing cultural similarity between S and T (common features / M)
- If 'heads' then S adopts the trait from one of the non-matching features of T
- Process continues until no more changes possible (neighbours identical or no shared traits)

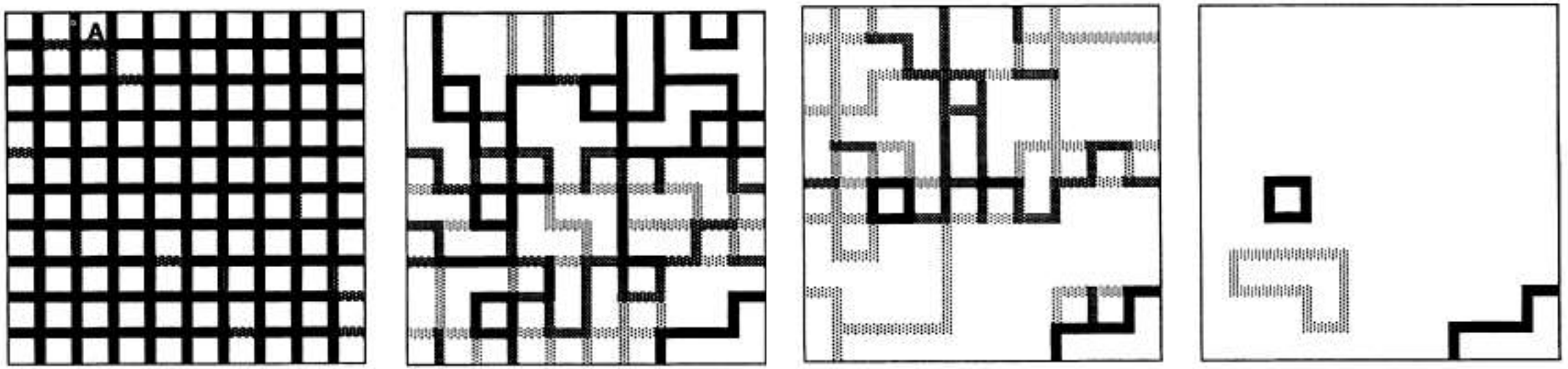


Sample starting point for M=5 and R=10

74741	87254	82330	17993	22978	82762	87476	26757	99313	32009
01948	09234	67730	89130	34210	85403	69411	81677	06789	24042
49447	46012	42628	86636	27405	39747	97450	71833	07192	87426
22781	85541	51585	84468	18122	60094	71819	51912	32095	11318
09581	89800	72031	19856	08071	97744	42533	33723	24659	03847
56352	34490	48416	55455	88600	78295	69896	96775	86714	02932
46238	38032	34235	45602	39891	84866	38456	78008	27136	50153
88136	21593	77404	17043	39238	81454	29464	74576	41924	43987
35682	19232	80173	81447	22884	58260	53436	13623	05729	43378
57816	55285	66329	30462	36729	13341	43986	45578	64585	47330

NOTE: The underlined site and the site to its south share traits for two of the five cultural features, making a cultural similarity of 40%.

A full run



(a) At start (b) After 20,000 events (c) After 40,000 events (d) After 80,000 events

- Region: A set of contiguous sites whose cultural similarity is 100%
- Black – boundary region with similarity < 20%, grey – 20-80%, white – 100%
- After 80,000 iterations, there are 4 regions, since two regions are boundary grey, finally may be only 3 regions

Observations based on these runs

- Initially neighbors have little in common
- So slow to absorb neighbor values
- Over time cultural features shared over wider and wider areas
- Coagulating into a few regions which are fully homogeneous
- Bordered by areas which have no cultural affinity with this region
- It thus does not become one white space but with pockets of other cultures
- Usually 1 dominant culture or 2 cultures with black boundaries
- Thus even though it is a process of local cultural assimilation, it leads to polarization at a global level

Experiments 1

- Varying M and R
  - As number of traits or R increases, the number of stable regions increases
  - As number of features or M increases, interestingly number of stable regions decreases
  - Because with higher M, higher chance of having at least 1 shared trait on 1 feature
- Range of influence
  - From 4 neighbours to 8 and 12
  - As expected, increasing range led to more social influence and fewer stable regions
  - 3.4 for 4, 2.5 for 8 and 1.5 for 12

Average Number of Stable Regions

	Traits per Feature		
Number of Cultural Features	*5*	*10*	*15*
5	1.0	3.2	20.0
10	1.0	1.0	1.4
15	1.0	1.0	1.2

Experiments 2

- Size of territory
  - 2x2, …, 100x100
  - Number of stable regions increases until it peaks for around 12x12, it then declines and then returns to around 2 for 100x100
  - This is interesting and counterintuitive
  - It turns out that in terms of very small regions, there is not enough space for many regions
  - In moderate sized territories, there is not enough room for many regions but not not enough for contests to dissolve boundaries
  - While in large territories, there is enough room for many regions and sufficient too for negotiations leading to dissolved boundaries.`

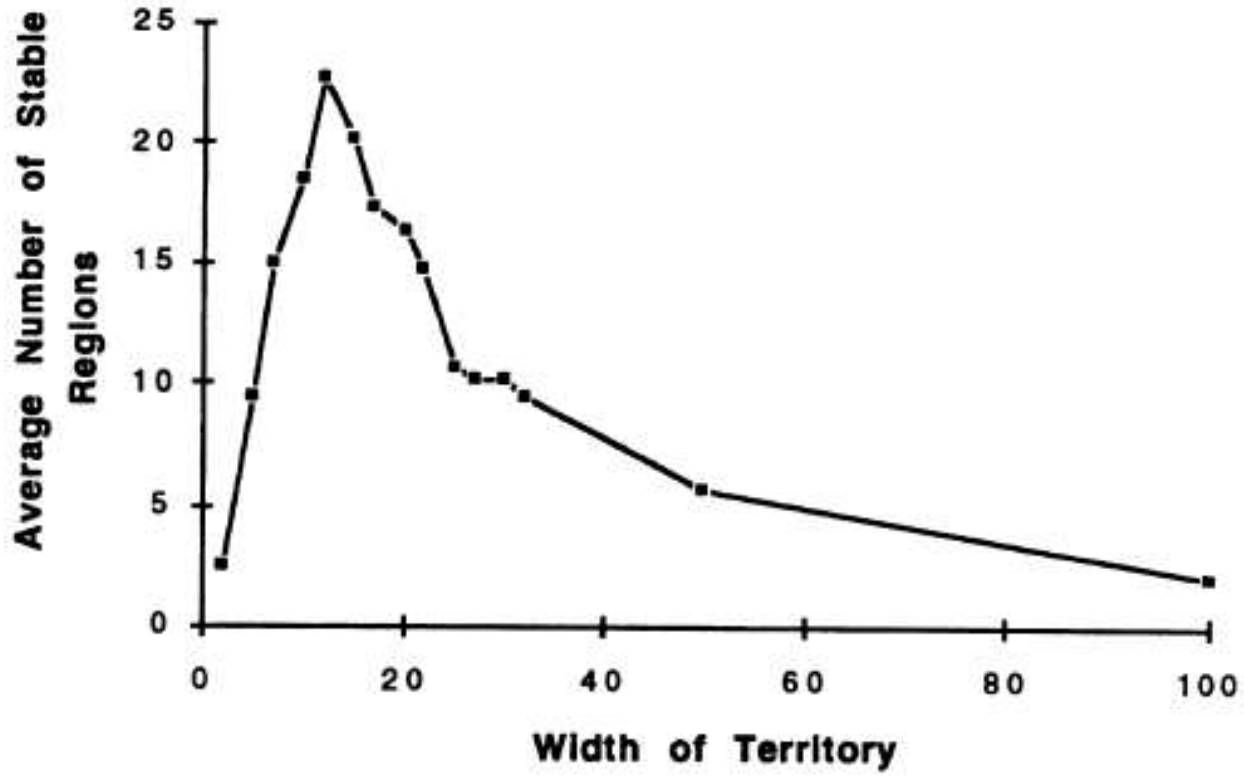
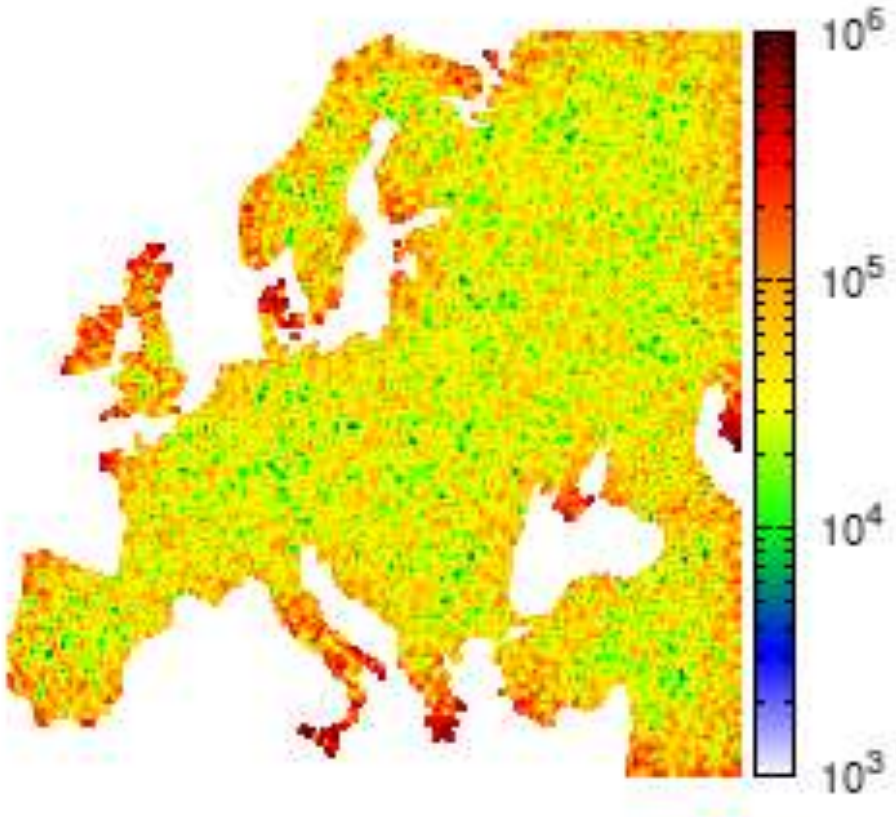


Figure 2: Average Number of Stable Regions
NOTE: The parameters for these runs are five cultural features, 15 traits per feature, and four neighbors for interior sites. Each territory size was replicated 40 times, except the territories with 50 × 50 sites and 100 × 100 sites territories, which were replicated 10 times.

Use of the model

- Has had a significant effect on understanding cultural assimilation in societies
- Has been extended by several workers
- Some of which have not been minimalist models but working on real data
- For example: Dybiec et al, 2012 to study culture spreading in ancient Europe using the notion of cultural centers
- Here figure on right is a frequency histogram presenting fraction of time when each point was a cultural centre
- Builds upon the notion of cultural drift which was briefly discussed in the Axelrod model

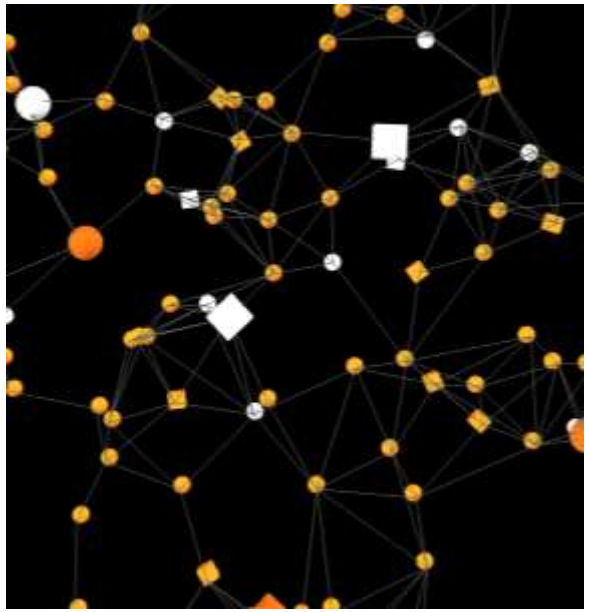


A simple extension: Culture custodian model

- How does one introduce a new idea?
- Initially no of people who believe in the new idea will be less than people who don't
- If we go by the bare boned Axelrod model discussed in the previous slides
- The new idea will get swamped by the old one as most revert to old idea
- However if we have an entity called a Culture Custodian
- A Culture Custodian is a champion, an evangelist of an idea
- A Culture Custodian is someone who will convert her neighbours to her idea
- But who will herself never get converted to some other idea.
- Then what could happen?

Agent Model

- A population with 2 characteristics or traits
- Each trait in turn can have 2 values
- Traits are Colour and Shape
  - Colour can be Orange or White
  - Shape can be Circle or Square
- Population live in a network of relationships
  - Work organization, friends, peer group, alumni, …



- If two neighbors have the same value in one trait and differ in another
- Then one of them converts to the same value as the other in the differing trait
- However if one is a Culture Custodian, conversion is only one way

Experiments

1. Given a population where one value in each of the two characteristics is low in the population then what would happen after N time intervals

2. Given the same population where one value in each of the two characteristics is low in the population but one of these values has a culture custodian what would happen after N time intervals

Results - 1

The results were very interesting

1. Without culture custodians, the dominant values in the traits nearly swamp the other. Since Orange and Circles were the dominant values in the Colour and Shape traits, they slowly shut out the other 2 values (White and Square). See Figure A

2. With culture custodians, if the custodian is evangelizing the less dominant trait values, slowly the less dominant trait value becomes the dominant trait value. See Figure B.

3. Another interesting observation also demonstrated by Axelrod is that even lesser trait values never entirely vanish from the population but remain in pockets.

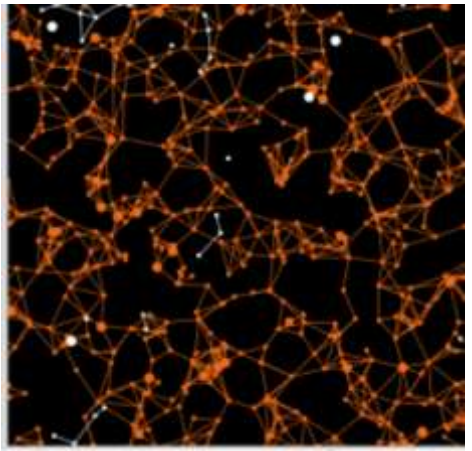


Figure A

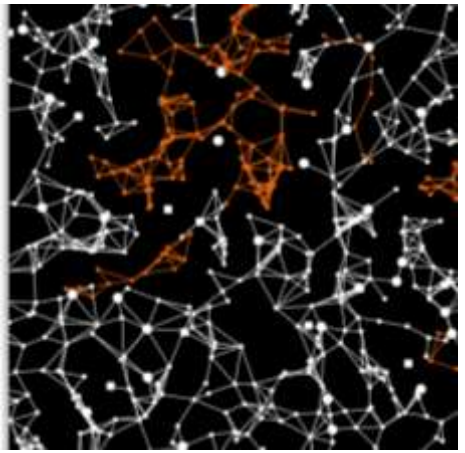
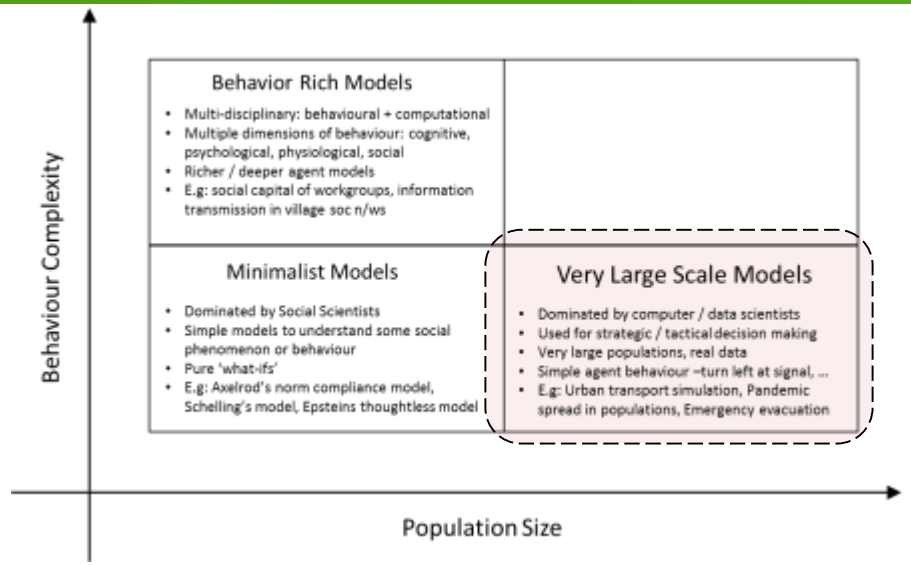


Figure B

In summary: Minimalist models

- Usually not tied down by data or validation
- Explore impact of an idea, a hypotheses on a virtual population
- Usually driven by domain theories and ideas
- If conceived with care, can have a profound impact on our understanding of the mechanics of a social system or phenomena or implications of a certain behaviour
- Representation of the world usually simple: grid, a network, a physical space to be navigated
- World behaviour expressed as a set of events, constraints
- Representation of the agent also simple: as a set of descriptors – type, state, …
- Agent behaviour expressed using simple behaviour rules:
  - if our_type_in_neighbourhood < threshold then move_randomly_to_new_spot



Very Large Scale Systems for Strategic and Operational Decision Making

Slides courtesy Prof Madhav Marathe, Network Dynamics and Social Simulation Lab, Virginia Tech
From Tutorials on Generating Synthetic Populations at IJCAI 16, AAMAS 16 and AAMAS 17

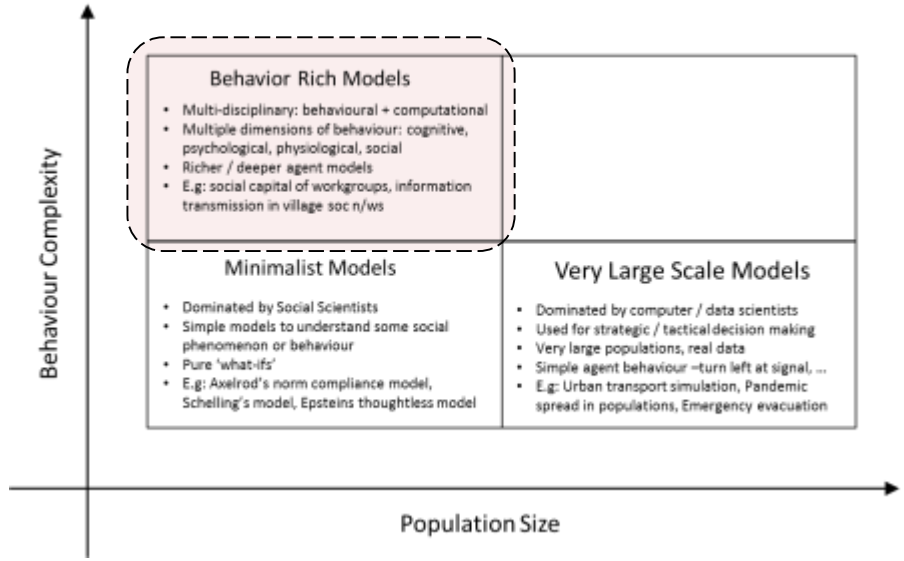
Very Large Scale Real World Agent Based Simulations

- Real world data intensive systems
- Heterogeneous data sources – census, other government departments such as Ministry of Health, Transport
- Demographic data, patterns of use of a resource such as health centers, roads, buses, vaccines sold, …
- Data obtained through a survey of some sample of the population: use a vaccine, rode a bus, turned left at a signal
- A ‘Synthetic Population’ is generated which has the same characteristics as target population
- Used to answer strategic / tactical what-if queries on a real system with artificial population: will commute time reduce if we build this bypass? What bus routes should be closed to prevent disease spread?

The content for the slides in this section Very Large Scale Systems mainly relates to techniques for the creation of synthetic populations, or virtual populations whose characteristics and behaviour approximates that of the real population being modelled. A longer description is given here: http://staff.vbi.vt.edu/swarup/synthetic_population_tutorial/index.php

The slides used during the talk were courtesy Prof Madhav Marathe, Network Dynamics and Social Simulation Lab, Virginia Tech from their tutorials on generating synthetic populations delivered at IJCAI 2016, AAMAS 2016 and AAMAS 2017.

All the slides can be accessed here:
http://staff.vbi.vt.edu/swarup/synthetic_population_tutorial/slides.php



Fine Grained / Deep Models

Need for deep models

- Human behaviour is complex with multiple dimensions at play, physiological, cognitive, psychological, ..
- Each dimension in turn consists of scores of behavioural variables, each of which also have nuanced variations
- Behaviour at any time therefore is a composite
- Which is not captured by simple agent models
- We therefore need to be able to build more complex agents
- Desirable but ….
- Easy to build Baroque models - great fun to play around with ….
- … but almost completely useless
- A big challenge is to be able to justify each element in the model as also the composite model

Work in this space

- Is often secretive such as by various defense labs – many defense establishments have invested heavily here
- For that reason such agents are often called Computer Generated Forces or CGF
- Silverman's group at Upenn on Performance Moderator Functions (PMF)s since 1990s
- The Retsina work at CMU – Sycara and others
- Teamcore work at USC – Tambe and others
- Our work at TCS R&D using behaviour composition over a repository of atomic behaviour relations
  (Ref our work in SummerSim 16, Prima 16, AutumnSim 16, WinterSim 16, WinterSim 17, ModSym 16, ModSym 17)

Simulating organizational behaviour using a grounded approach

Understanding organizations through simulation

Insights from modeling for interventions and new hypotheses

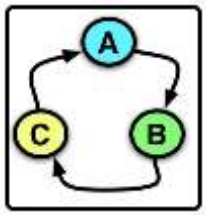
People Problems in Organizations

Behavioral Field Studies and Experiments

Simulations help orgs understand dynamics and implications of study findings

Study Results & Insights

Composing Behavioral Models from past research and study insights



Model testing and evaluation

But first, a short detour into e-Science

e-Science

e-science: "the application of computer technology to the undertaking of modern scientific investigation, including the preparation, experimentation, data collection, results dissemination, and long-term storage and accessibility of all materials generated through the scientific process. These may include data modeling and analysis, electronic/digitized laboratory notebooks, raw and fitted data sets, manuscript production and draft versions, pre-prints, and print and/or electronic publications"

S Bohle, What is e-science and how should it be managed?

Digital - science: "Digital science is about the way research is carried out, disseminated, deployed and transformed by digital tools, networks and media"

European commission, Digital Science in Horizon 2020

Other names with similar meanings: **Open science**, **Science 2.0**, ...

Not just Science but other fields of human endeavor as well

Digital Humanities: An area of scholarly activity at the intersection of computing and the humanities disciplines such as literature, history and philosophy.

Used to either answer existing questions or open up new areas of research through analysis, creation of corpuses, etc.

For example:

Did Shakespeare really write all his works?

Nature of gender bias in 19th century literature

Deciphering the Indus Valley Civilisation script

Women Writers Project: Crowd based effort to create an electronic corpus of writings of pre-Victorian women

e-Science and the Behavioural Sciences

Digitised *sources* of data

Organizational data sources, digital traces of people, smartphones, iOT, social networks, digitized research in OB and HR

Multiple *forms* of data

Structured – Swipe cards
Unstructured – Blogs, tweets
Multi-media – AV records
Sensors – Activity traces

New methods of analysis

NLP
Big data analytics
Machine Learning
Data fusion
Evidence-based Mgmt.

New ways to understand / generate explanations / intervene

Agent based simulation
Abductive reasoning
Serious games

Examples:

- Geo-located activity apps give habits, routines
- Activity plus proximity apps give us offline social interaction patterns
- Event based survey apps can give us self-reports of situations, moods, decisions, impressions
- Social network analysis give us information on information diffusion patterns in years

We can know more about people in an hour than we could earlier in years
We can get data from more people in an hour than we could in years.
But how can we use this data to generate better insights / explain / change behavior?

e-Science and the Behavioural Sciences - 2

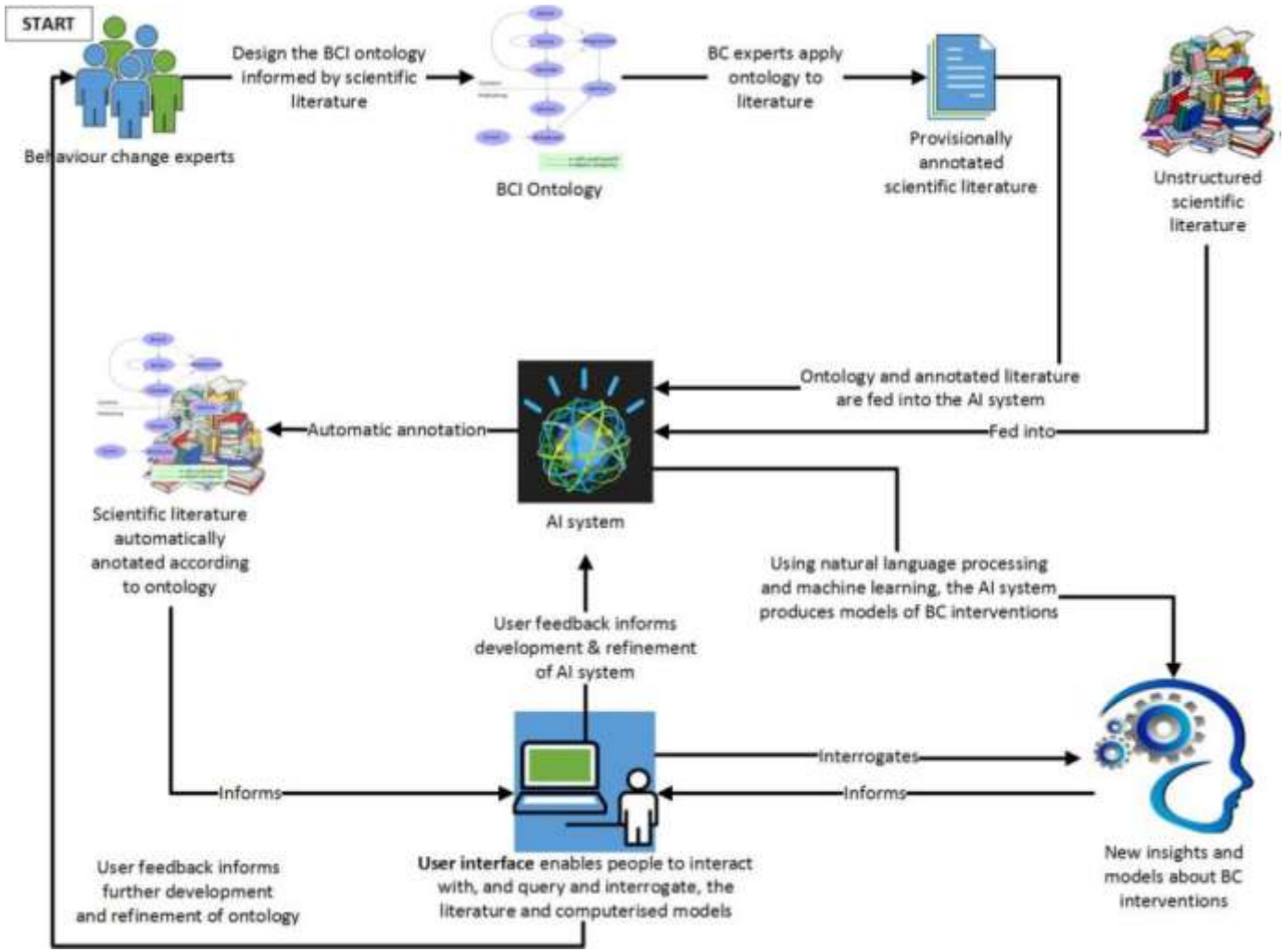
Beginnings being made in various quarters

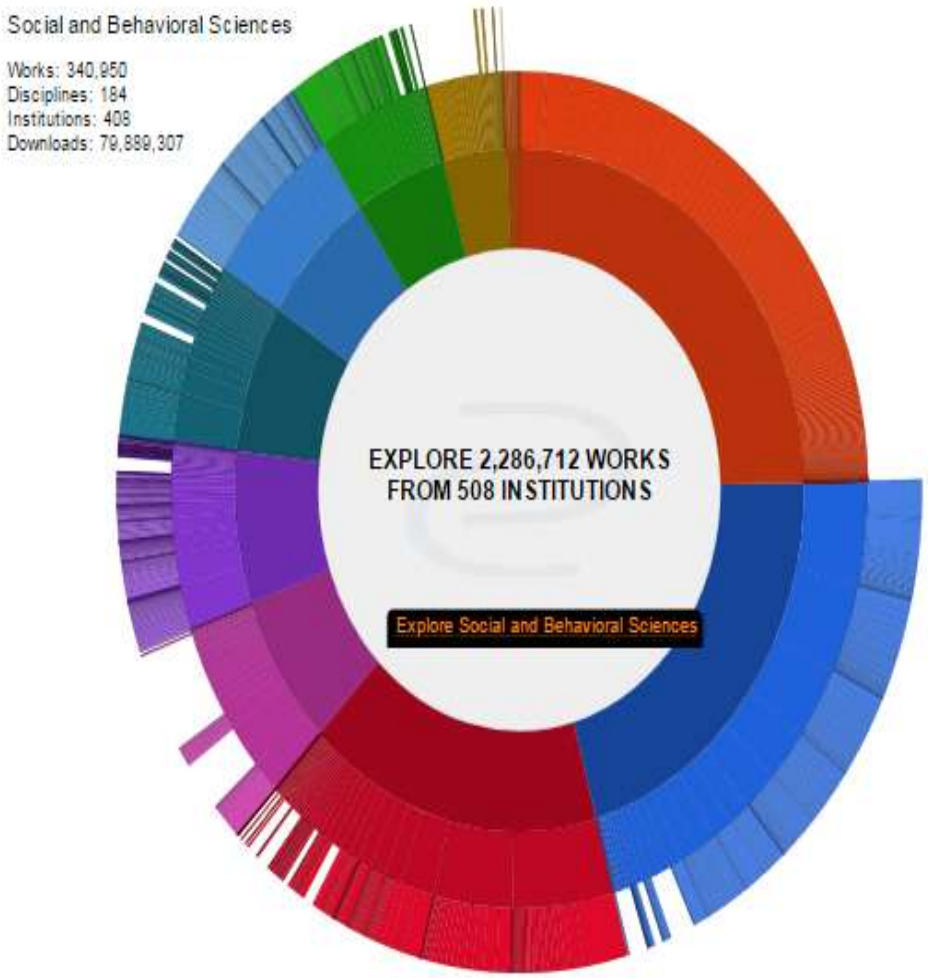
One increasingly popular label: Computational Social Science

Some problems being explored under such umbrellas:

- Online social media analytics – Inferring personality
- How do emails reflect power-distance?
- Repositories: metaBus and the Inter-Nomological Network at UCB
- Resolving the Jingle-Jangle problem in social science literature
- Nature of org non-work-team social networks by mobile proximity detection

Ongoing Worldwide Efforts





Michie et al, International Behavioral Trials Network and UCL

Digital Commons Network

Human Centric Systems – an e-Science effort

The work being done by us in the Human Centric Systems Research effort at TCS R&D is an e-science effort that:

Collects multi-modal behavioural data through sensing, surveys and other sources and means

Mines empirical results from past literature in the behavioural sciences

Uses these to populate a repository of behavioural insights

Which is then used to compose simulate ready models and / or

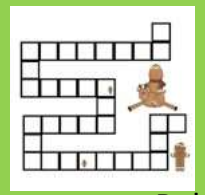
Generating hypotheses through various forms of reasoning

Collection of multi-modal behavioural data

Social networks

Demographics

Secondary data



Behavioural Games

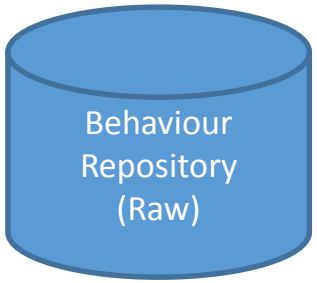
Studies

Plans, Status

Fuse

Mask

Anonymize



Wakeup

Commute

Activity

Work

Lunch

Physiological states

Meeting

Work

Emotional States

Coffee

Commute

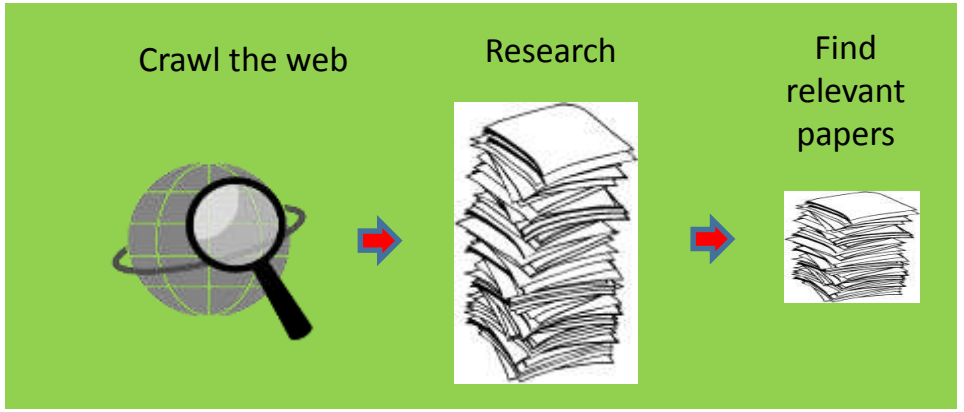
Location

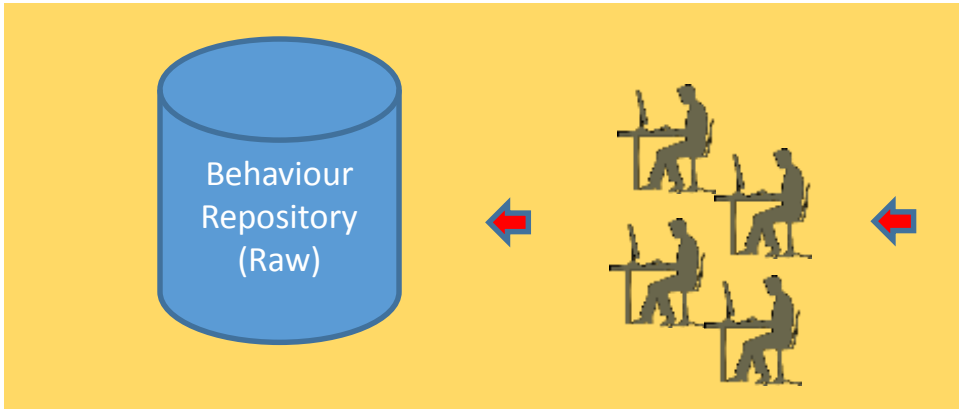
Dinner

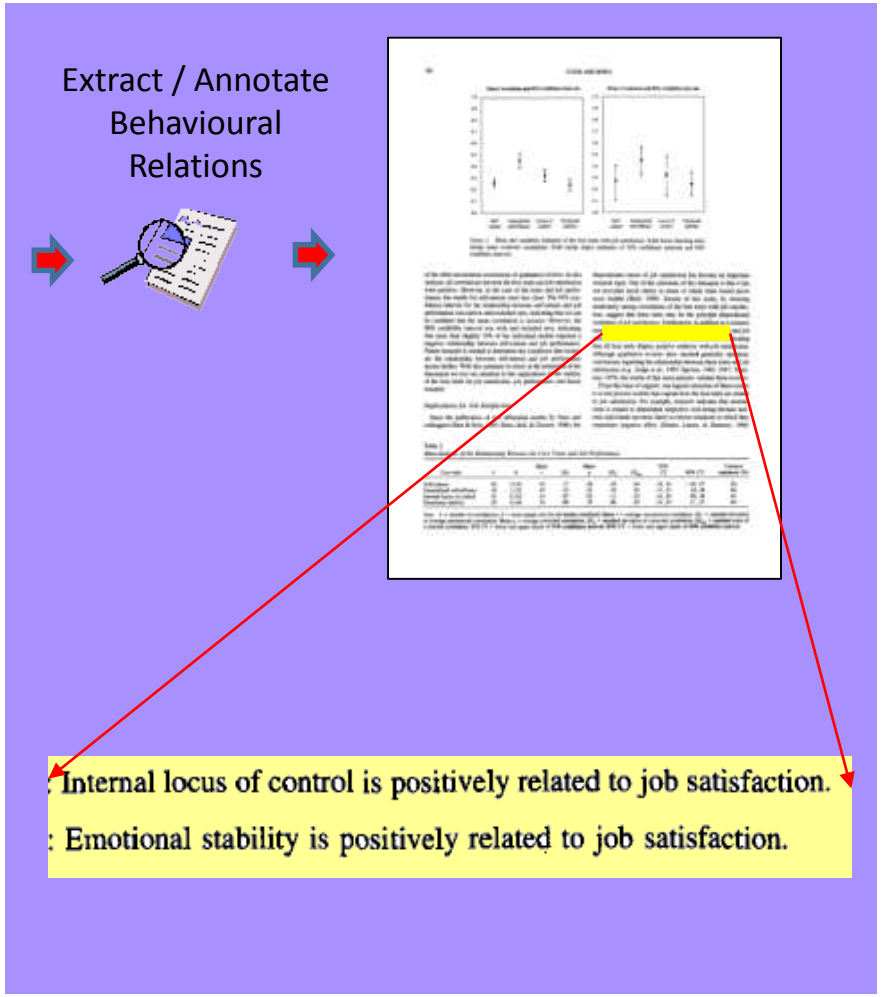
Sleep

Physical States

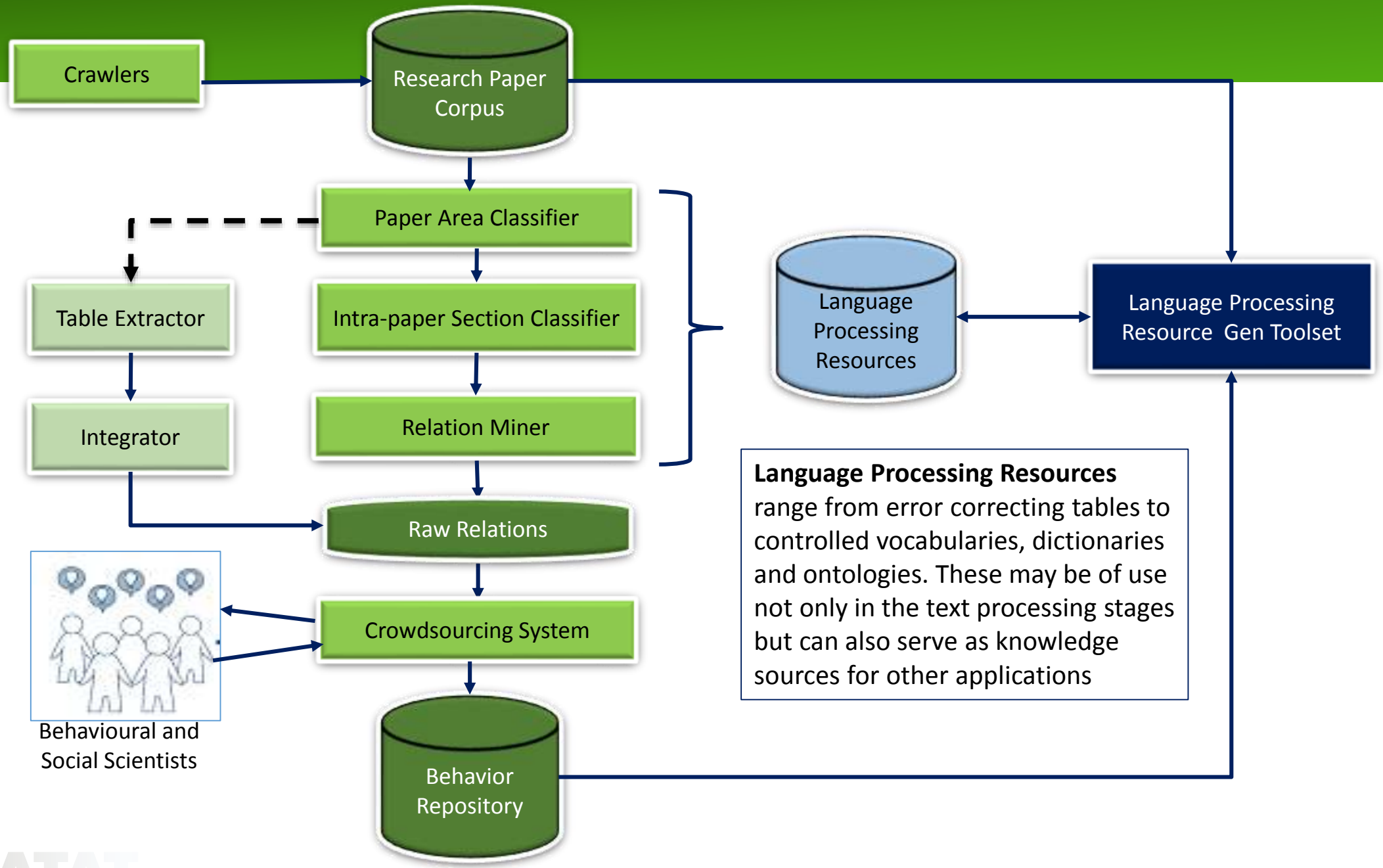
Research Mining





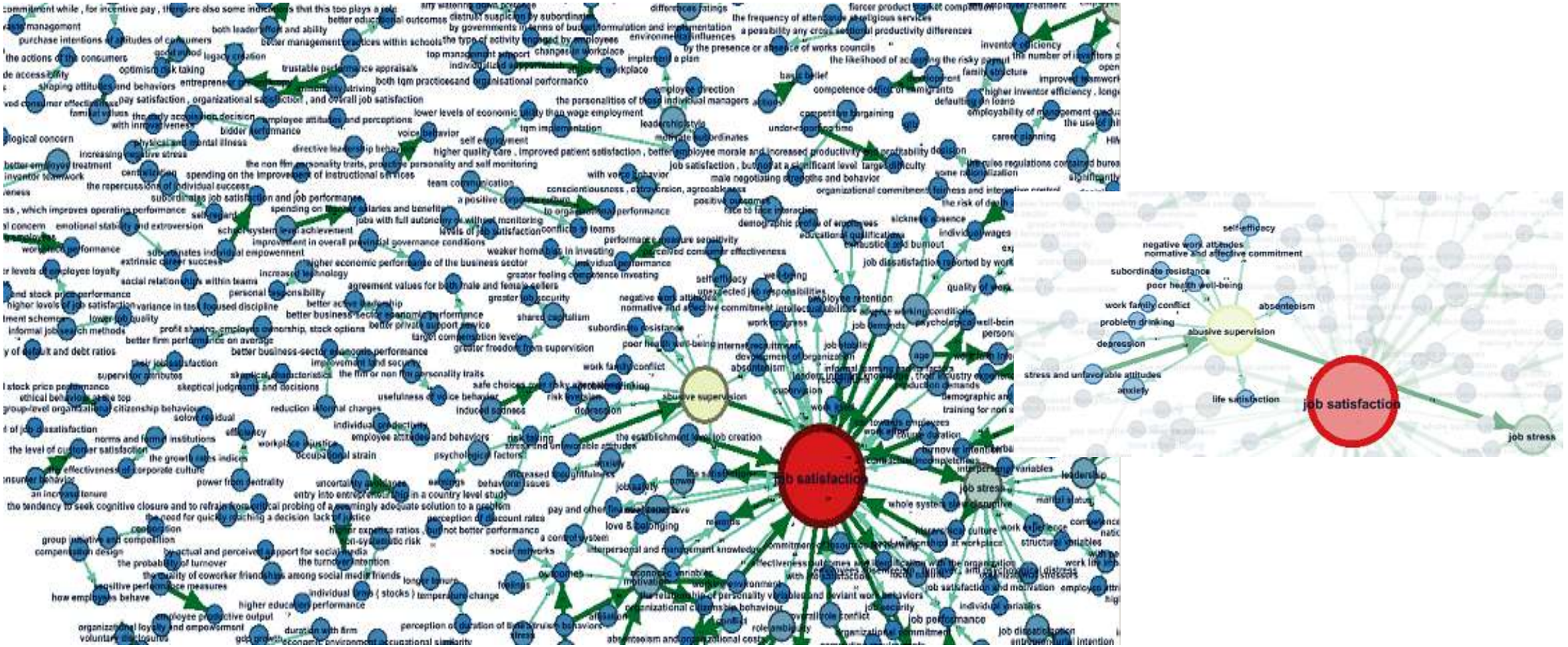


Relation Miner – Framework



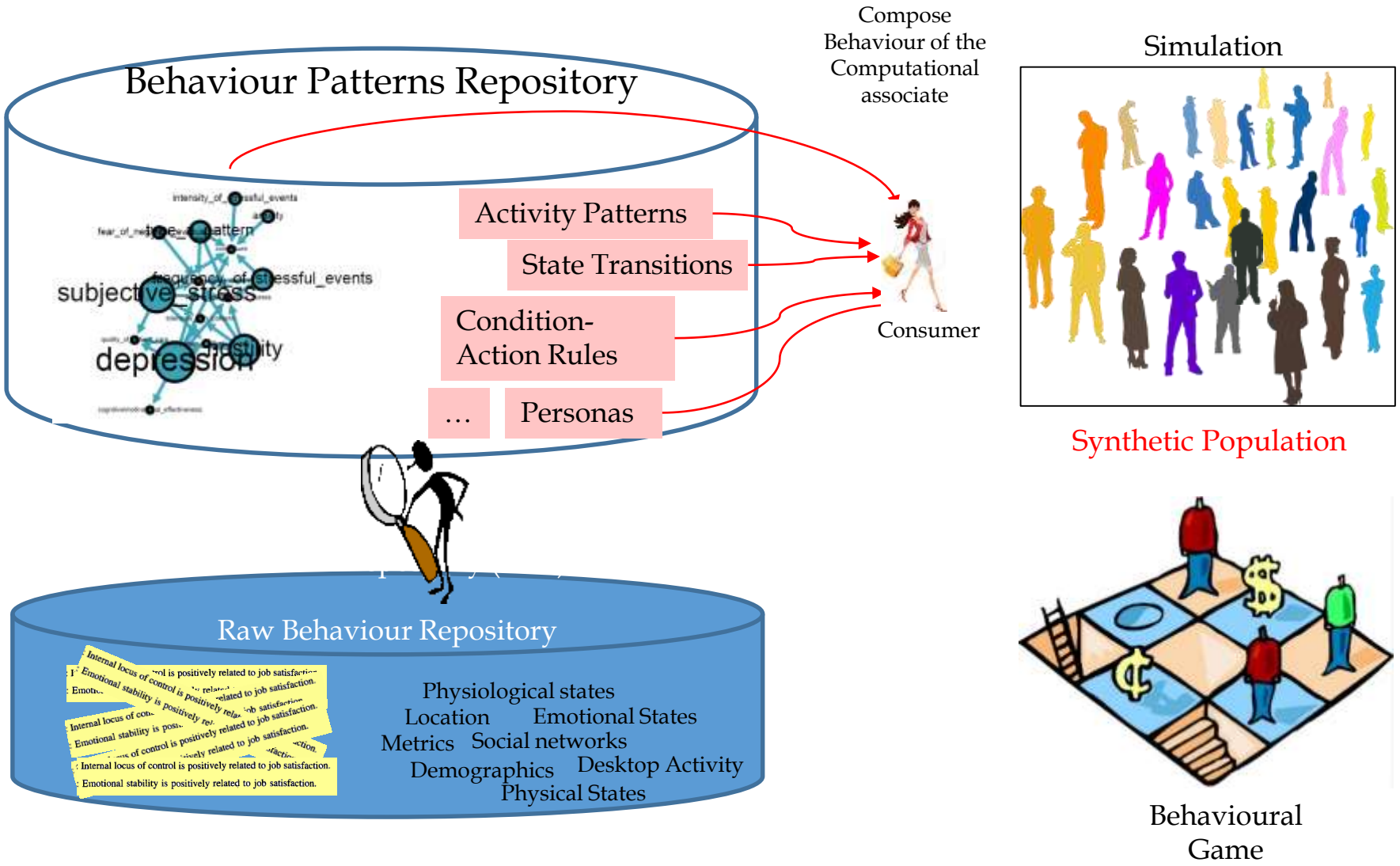
Language Processing Resources range from error correcting tables to controlled vocabularies, dictionaries and ontologies. These may be of use not only in the text processing stages but can also serve as knowledge sources for other applications

Relation Miner – A visualization of the extracted results

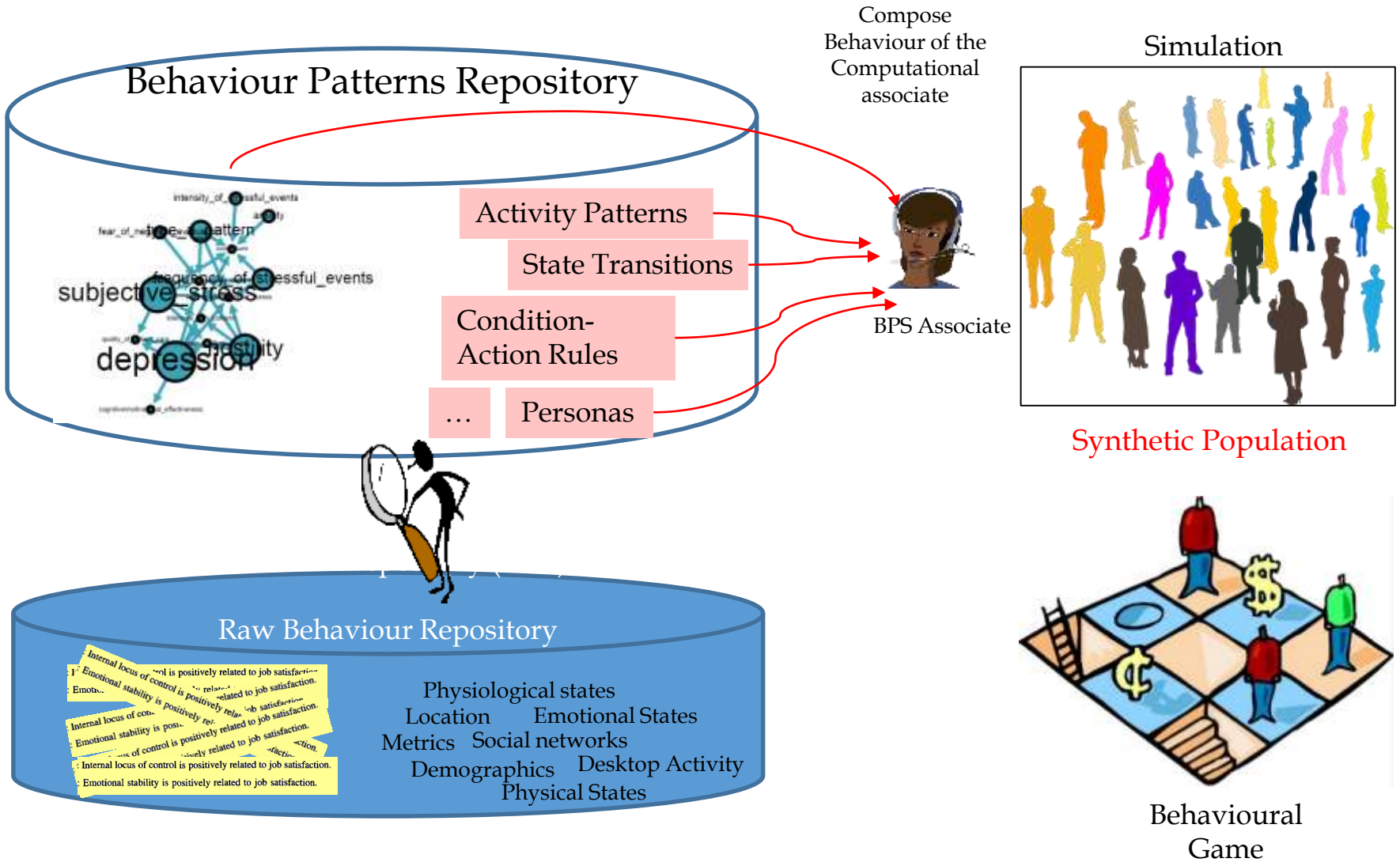


A visualization of some of the extracted relations

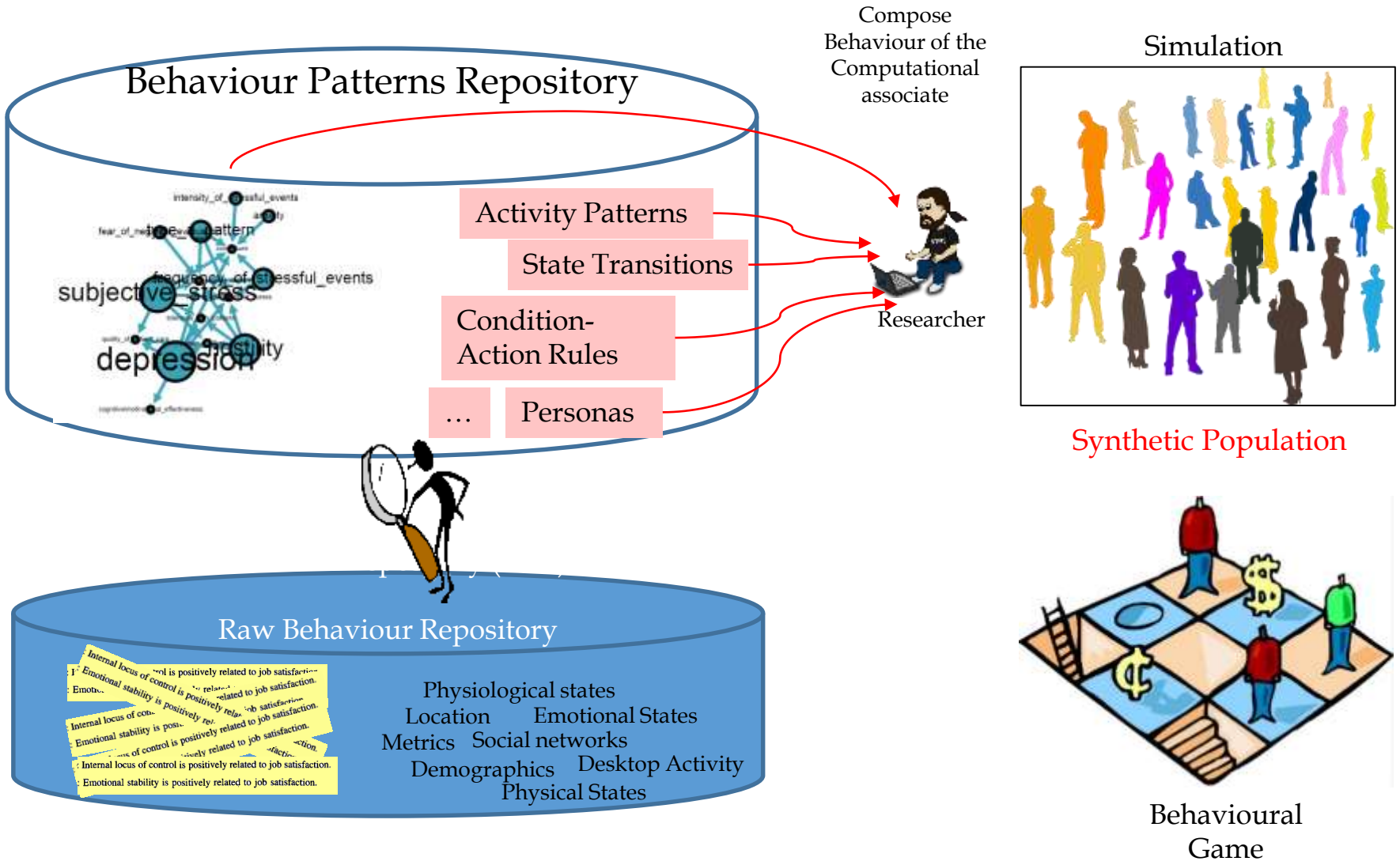
Use Repository to Compose Behaviour Models



Use Repository to Compose Behaviour Models



Use Repository to Compose Behaviour Models



So let us get back to studying organizational behaviour

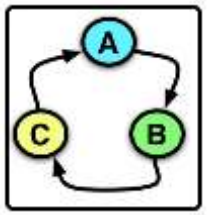
Insights from modeling for interventions and new hypotheses

Research Problems in Organizations

Behavioral Field Studies and Experiments

Study Results & Insights

Composing Behavioral Models from past research and study insights



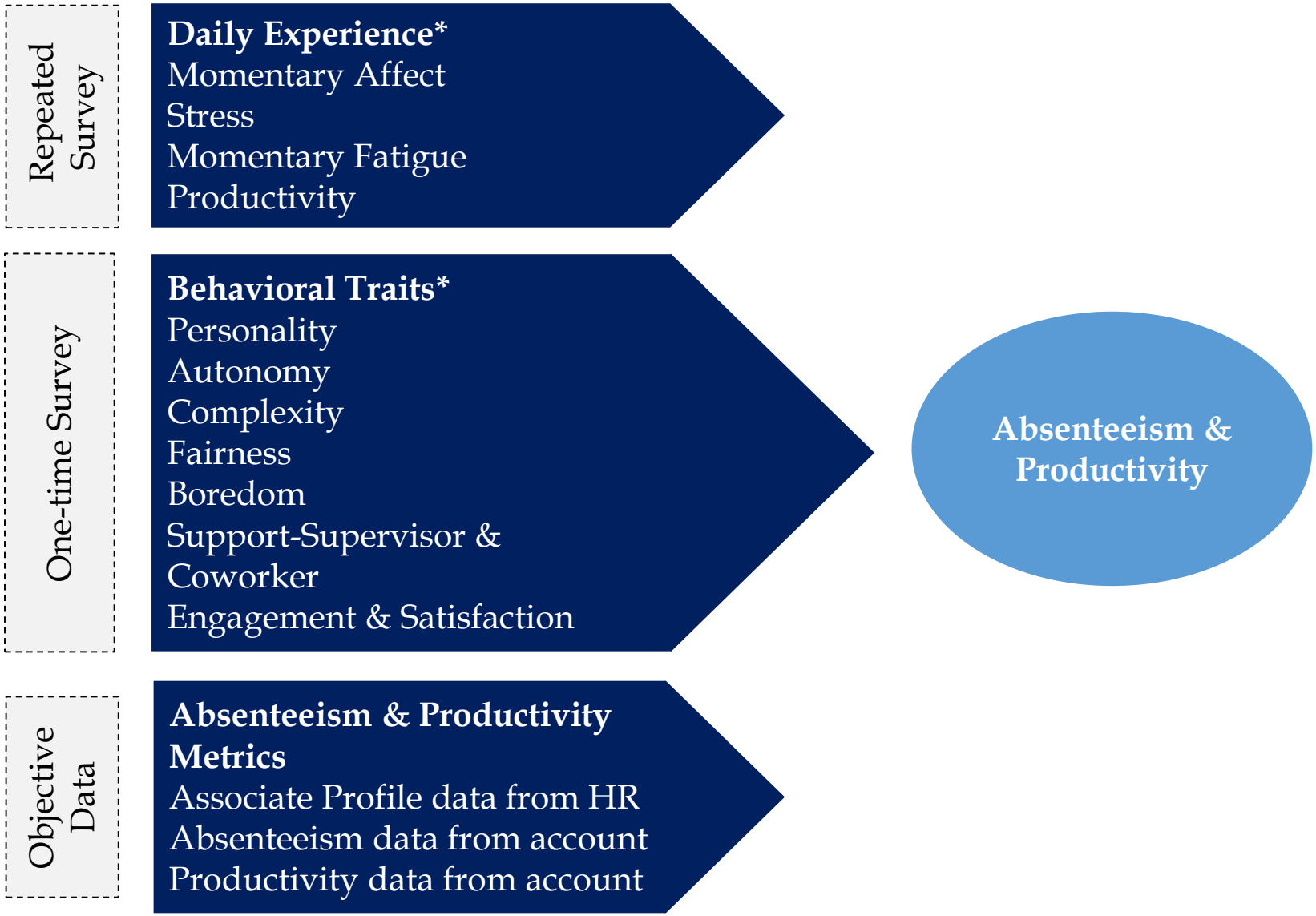
Model testing and evaluation

Case study: Factors impacting productivity & absenteeism and implications

The Problem

A Business Process Services Division wanted to understand the factors that impact productivity and absenteeism in the workplace as well as the implications of these findings

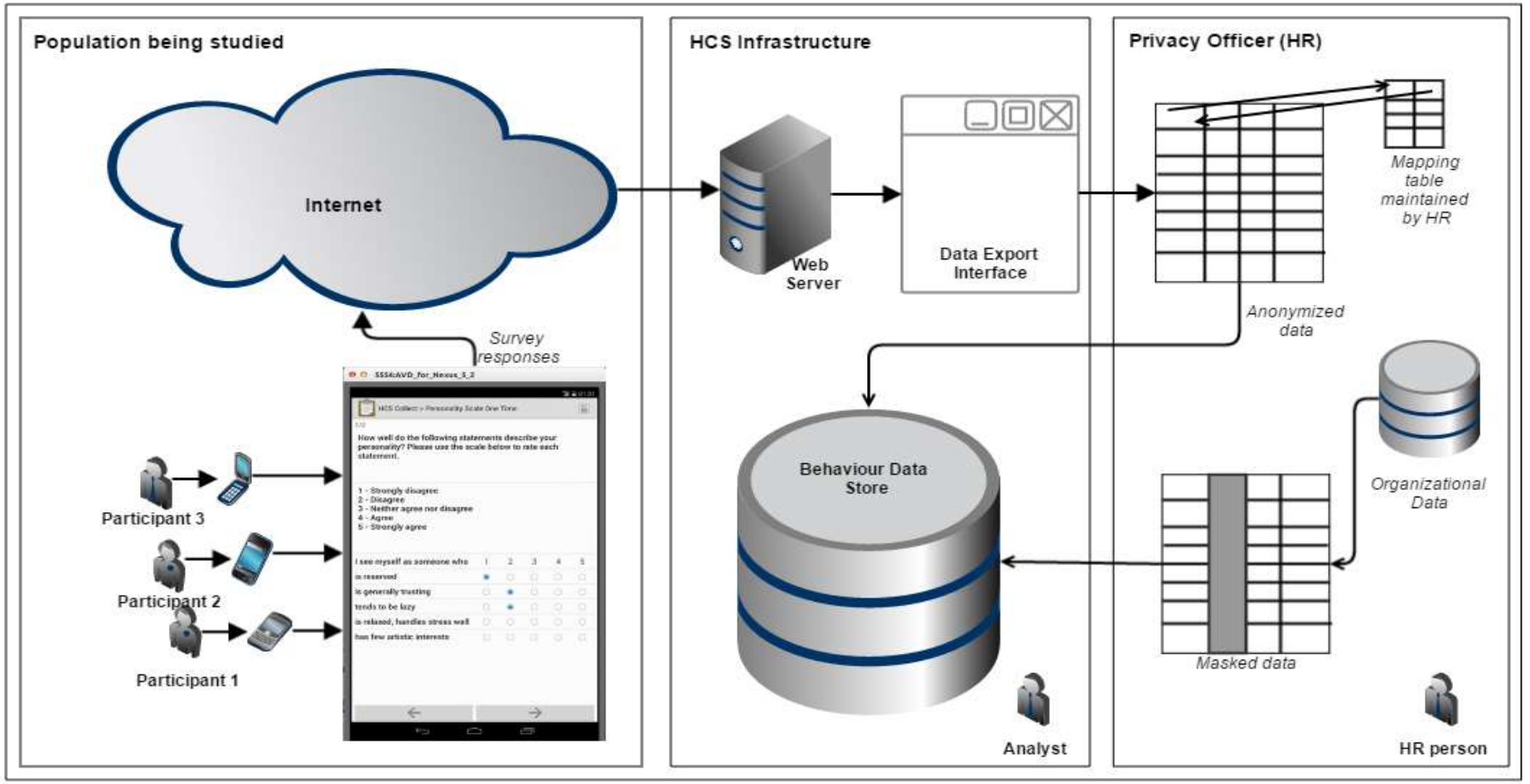
Case Study on Absenteeism and Productivity in Support Services Teams



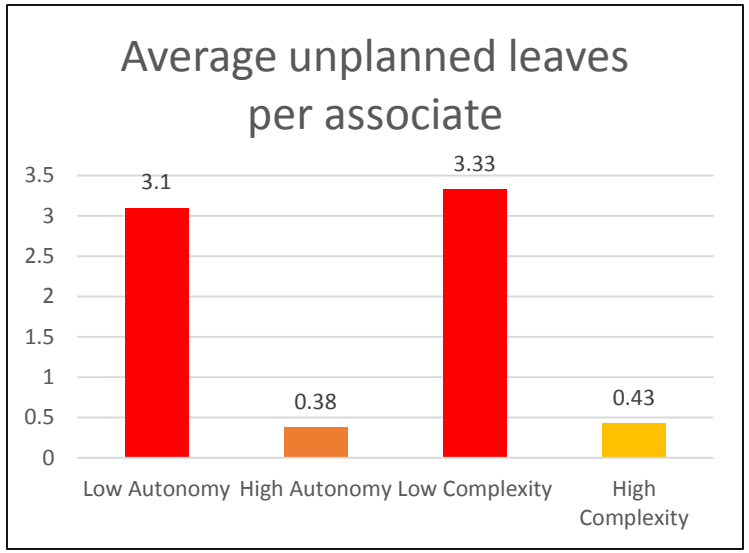
Data collection methods

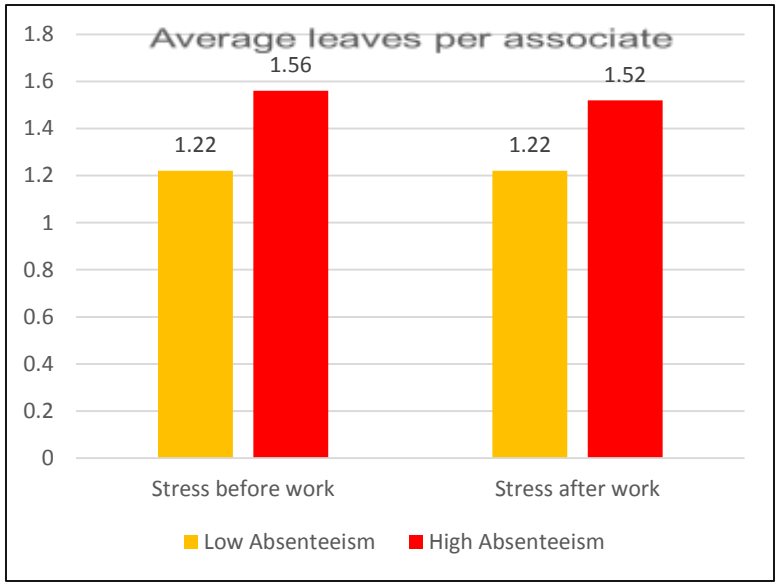
Survey App to get self reports of perceptions, feeling, affect, stress, motivational levels, fatigue

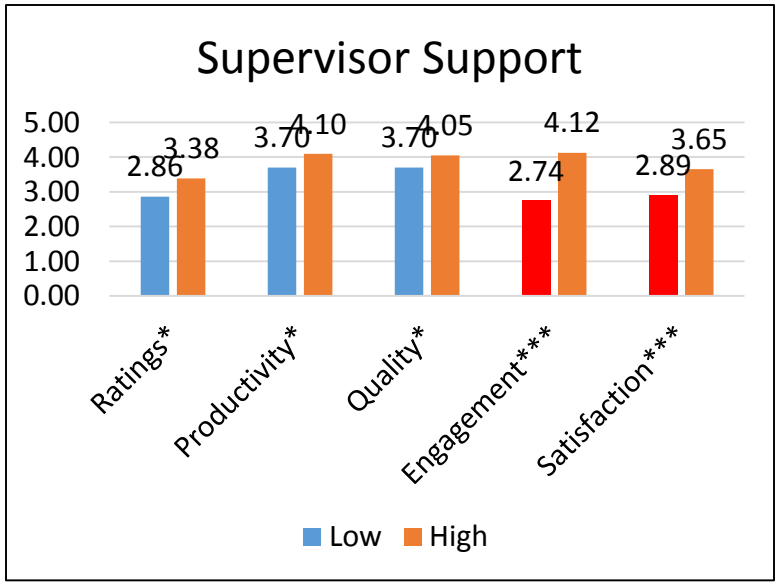
Organizational Data such as demographics, job performance, training records supplied by the HR Officer after masking and anonymizing

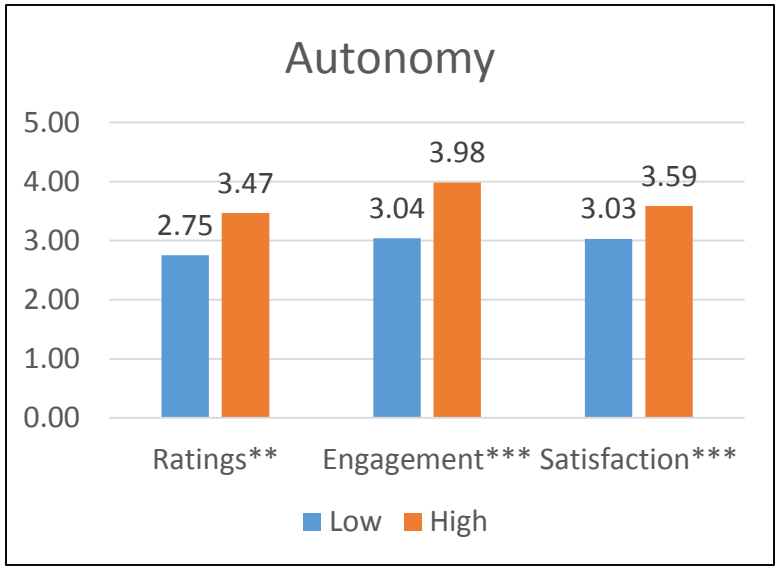


Sample Findings from Study









Field study in a support services organization and some results

1. `Absenteeism – Associates who feel they lack control over their work / whose work is not challenging show high absenteeism
2. Associates who feel they are not getting support from their co-workers and managers feel far less engaged and satisfied with their work. This could signal them having a transactional relationship with their job
3. **Experience of daily stress was found to be significantly correlated with self reported productivity**
4. **A direct positive relationship between stress and absenteeism-people who are more stressed have taken more leave**
5. There is a direct relationship between trainings attended and productivity and quality of work.
6. People who don't feel challenged by their job, demonstrate substantially lower engagement and satisfaction with their job.
7. People who feel they don't have a measure of freedom in their work show far lower engagement and job satisfaction. A perception of a lack of control can be destructive in the long term
8. Engagement and job satisfaction are indicators of the social capital of a team. We are seeing clear indicators of what leads to high / low engagement and job sat
9. We found that had a significant impact on several measures from being engaged to feeling supported at work.
10. Significant and interesting differences between accounts. Account N associates found their work environment highly engaging and invigorating. At the same time these associates found their job to be more stressful on a day to day basis. A fun work environment can thus counteract stresses of the job.
11. **In-depth interviews with account leads also helped us identify relationships between the actual metrics of the number of work hours and fatigue, volume of task arrival and stress as well as work backlog and time pressure**

Field study in a support services organization and some results

To demonstrate the compositional approach we focus on these two findings

1. **Experience of daily stress was found to be significantly correlated with self reported productivity**
2. **A direct positive relationship between stress and absenteeism-people who are more stressed have taken more leave**

We use these findings and others to understand the implications of these in the workplace

Using models to study dynamics of study findings

- **Why Model**: To understand the implications of findings – if stress impacts productivity, what is the implication of this and other findings?
- **Location Realization**: Physical
- **Location Type**: Services Organization Workspace
- **Outcome variables of interest**: Productivity (Turn around time) and Absenteeism
- **Behaviour variables of interest**: Stress, Negative Affect,
- **Number of associates**: 100
- **Maximum work hours in a day:** 8 + 2 hours
- **Task arrival**: Has a usual pattern with a spike after 1 week

We have explored several scenarios:

1. Normal and with spike in work
2. During crisis operations with BCP
3. Impact of using LBA to moderate workload

What is a model?

Model: A model is a sequence and ordering of relations that relate a set of variables to outcome variables of interest.

$V = \{v_1 v_2 \ldots . v_n\}$ are the set of variables

R = $\{r_1 r_2 \ldots . r_m\}$ are the set of relations

Where

$r_j; i$

$= 1, 2, \ldots . , m$ describes a relation between one or more variables in R

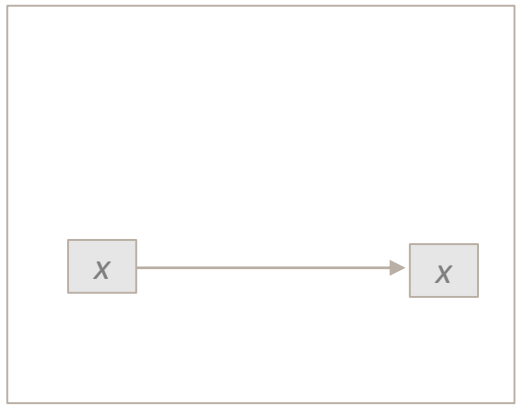
A model m is a linked sequence of relations R_i that link input variable set I $\subseteq V$ with outcome variable set O $\subseteq$ V

Note that there could be multiple models and multiple relations for the set of I and O

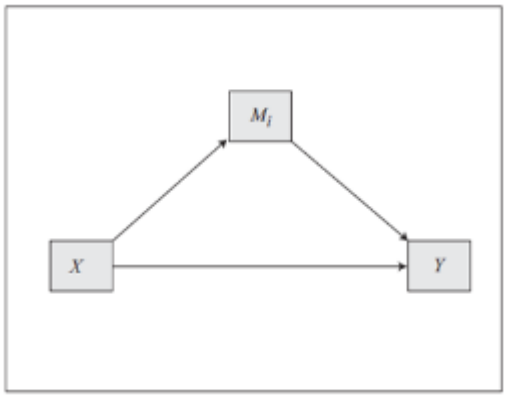
Circular or feedback models are where relations feed back from elements of O to elements of I

Types of relations

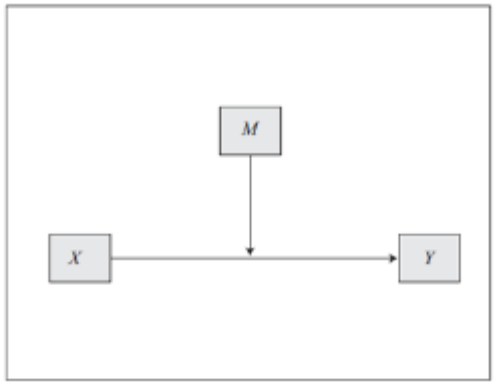
- There are basically 3 types of relationships
- Bivariate relationship: a bivariate relation captures an association between an independent or predictor variable X and a dependent or outcome variable Y
- Mediated relationship: A mediator is a variable (Mi) that explains or accounts for the relation between the independent (predictor) variable (X) and dependent (outcome) Y variable
- Moderated relationship: A moderator is a variable (M) that affects the direction and/or strength of the relation between an independent (predictor) X variable and a dependent (outcome) Y variable.



Bivariate relationship



Mediated relationship



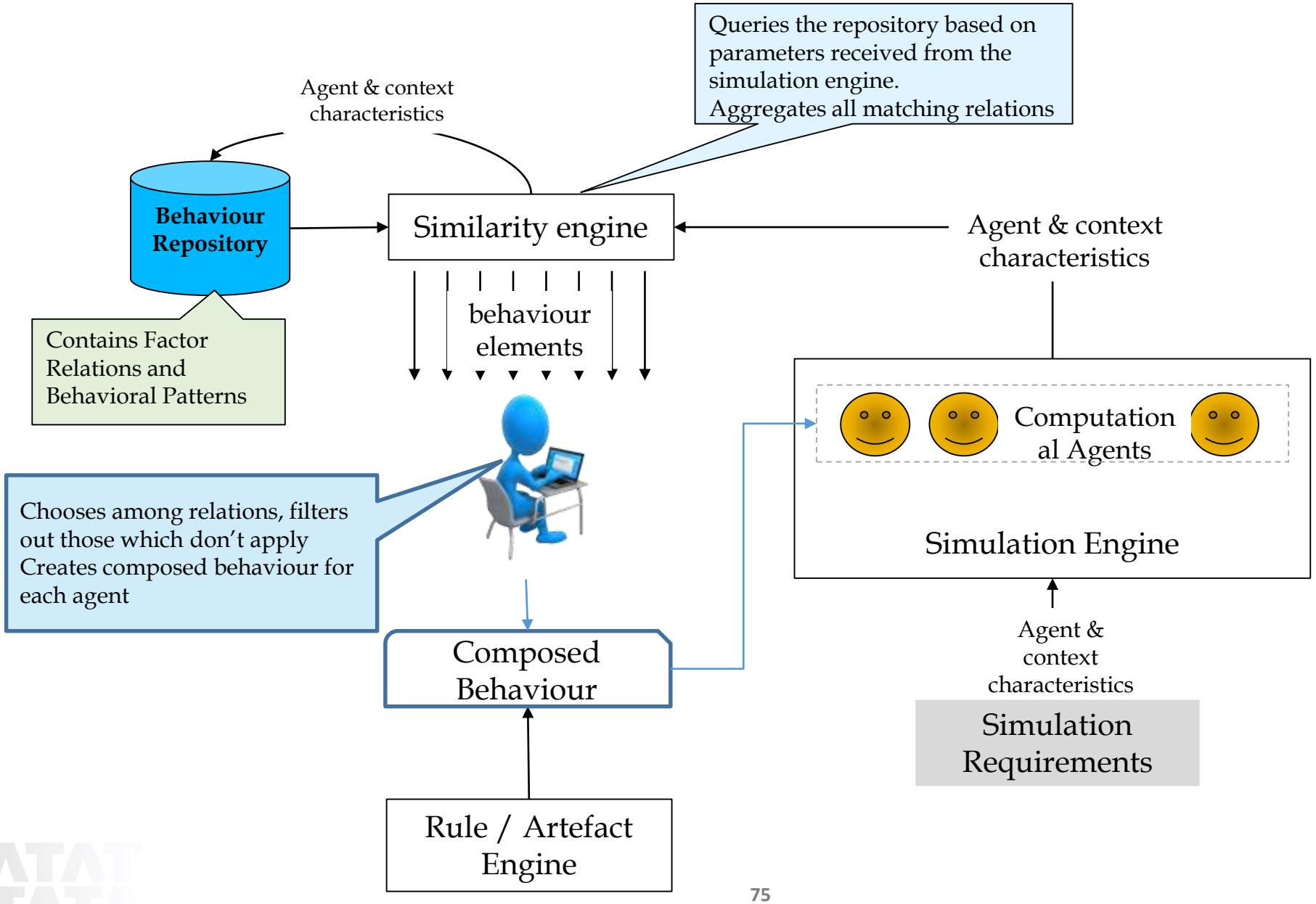
Moderated relationship

At the moment in our work we are focused on composition using bivariate relationships

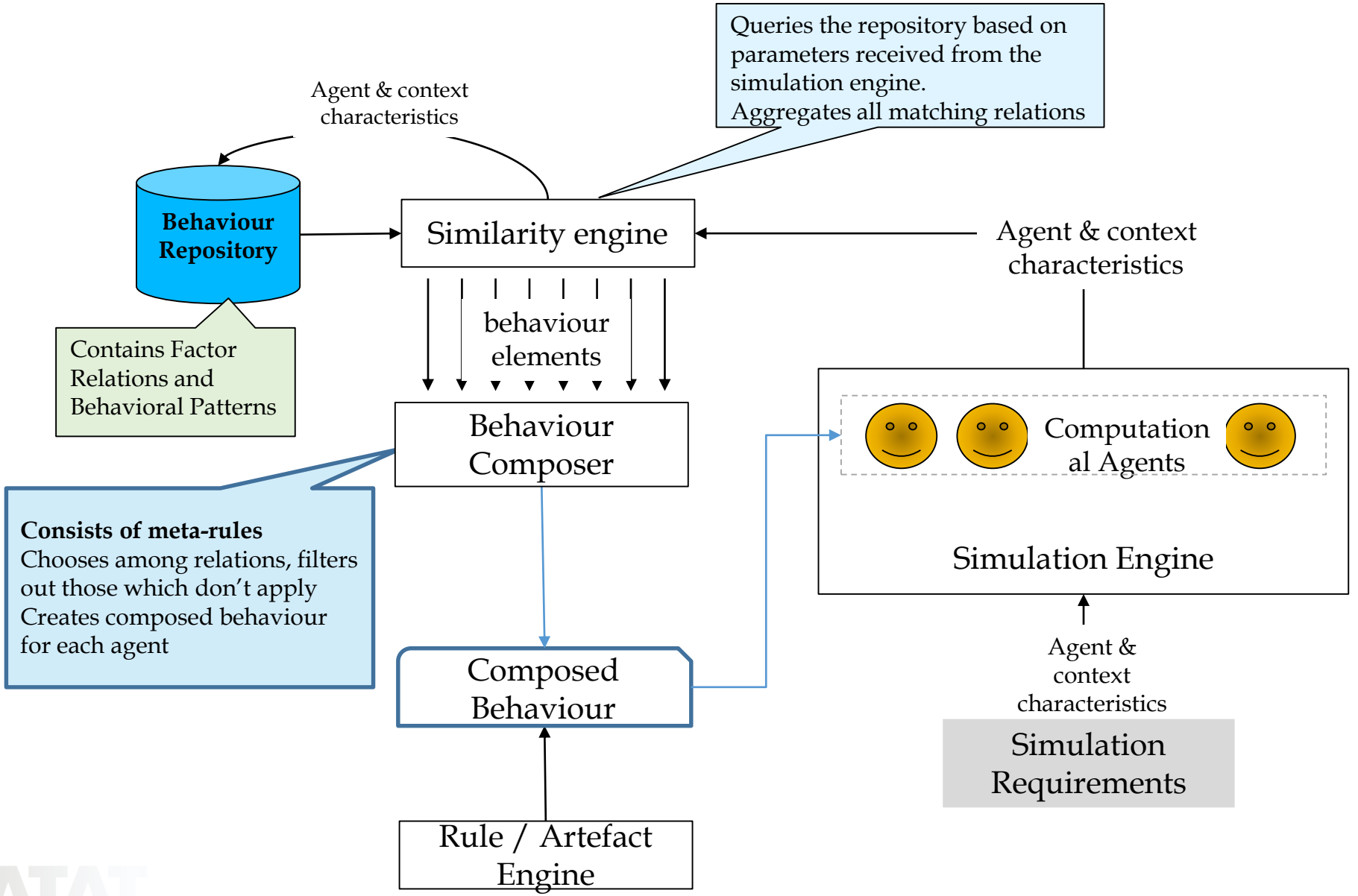
Why do we need composition?

- Studies provide us with some elements of a simulation model
- But we may need more elements to make it more complete
- For example: To understand impact of stress on productivity, we may need to also understand the relationship between workload and negative affect as well as between negative affect and stress
- Given a repository of behavioural relations, *Composition* is the systematic process of selecting and assembling a valid and integrated model from the repository, based on user requirements.
- Behavioural relations are usually Behaviour rules or Regression functions

Simulate System – Human in the loop behaviour composition



Future: Simulate System – Behaviour composition using meta-rules



Challenges in behaviour composition

Behavioral

- Complementary linking variables (individual studies or meta analysis)
- *Jingle-Jangle* problem
- Generalizability of insights (Meta analytic fixed vs random effects model)

Statistical

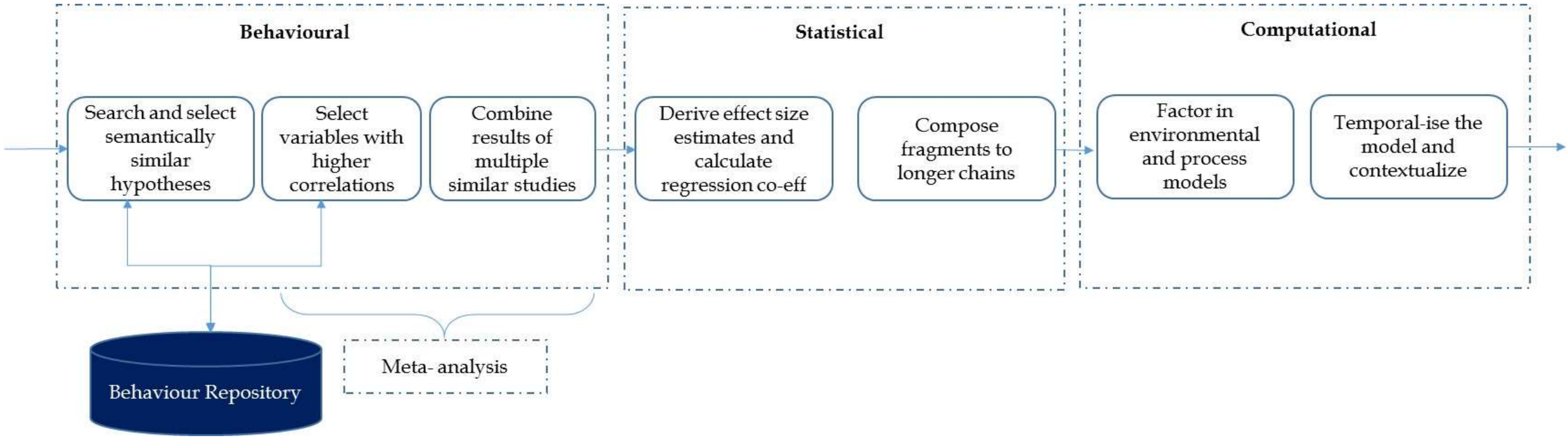
- Strength of behavior variable relation (correlation)
- Composition of behavior fragments (longer chains)

Computationa

- Temporality of variables (fast vs slow variables)
- Computable models (from statistically valid models to simulate ready models)

More details in Duggirala et al, *Evolving a Grounded Approach to Behavioral Composition*, to appear in Winter Simulation Conference 2017

Our approach and guidelines for composition



Behaviour composer (behavioral sciences viewpoint)

Concept 1 - negative affect

choose existing concept

TEXT TAXONOMY

enter text +

exclude exact match

VAR = negative affect

Concept 2 - stress

choose existing concept

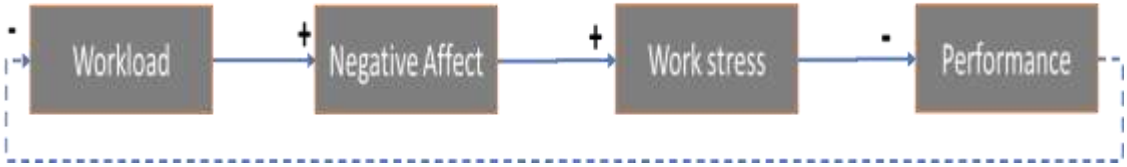
TEXT TAXONOMY

enter text +

exclude exact match

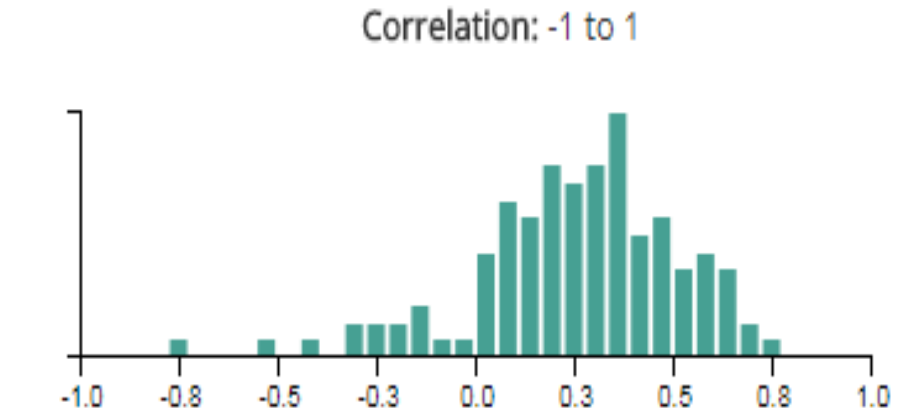
VAR = stress

Select variables of interest



Correlation	Reported Variable 1	Reported Variable 2
0.14	Negative affectivity	Work group stress
0	Negative affectivity	Organizational stress
0.06	Negative affectivity	Job stress
0.2	Trait negative affectivity	Stress at work
0.25	Trait negative affectivity	Daily stressors
0.24	Start of day Negative affect	Stress at work
0.03	Start of day Negative affect	Daily stressors
0.07	End of day Negative affect	Stress at work
0.01	End of day Negative affect	Daily stressors
0.33	Negative affect TI	Stress at work

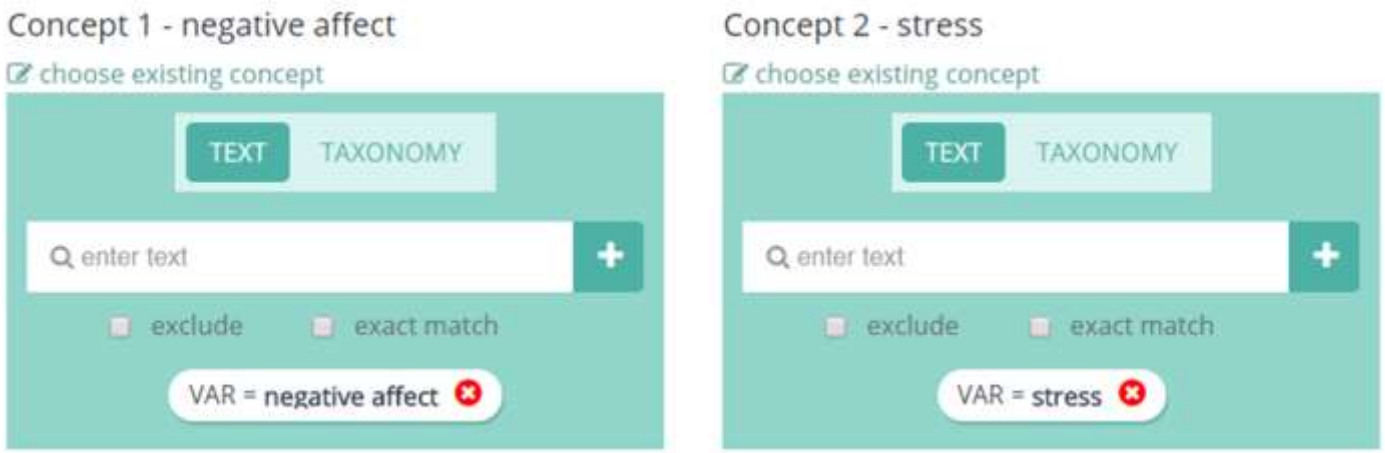
Select similar variables across studies



Select higher correlations

CONSULTANCY SERVICES

Behaviour composer (statistical viewpoint)

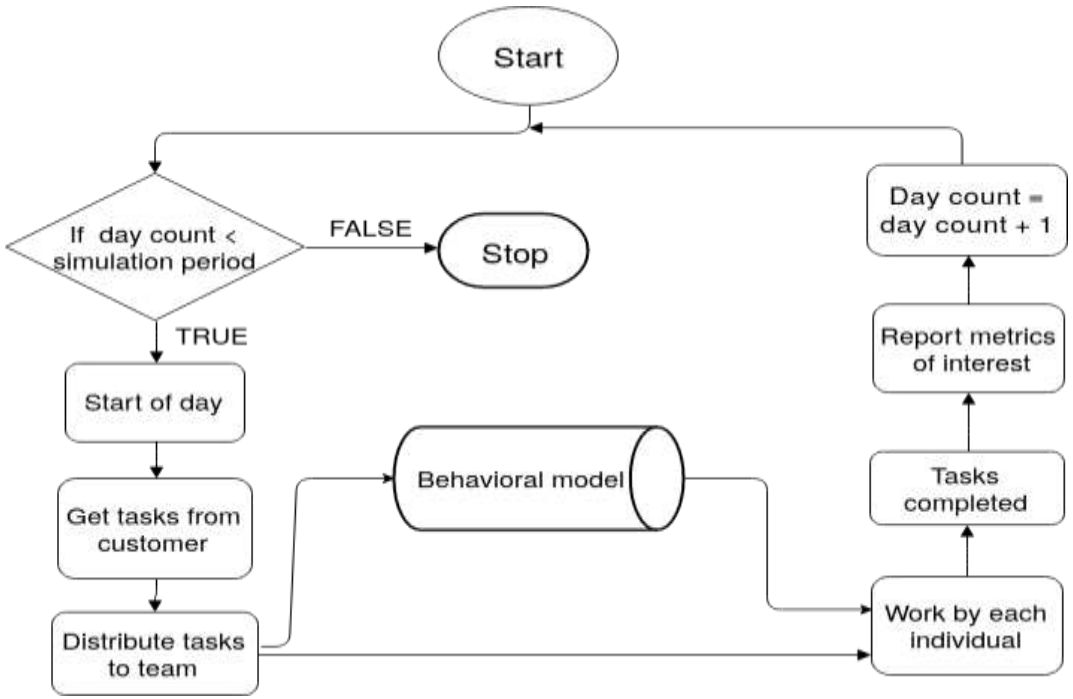


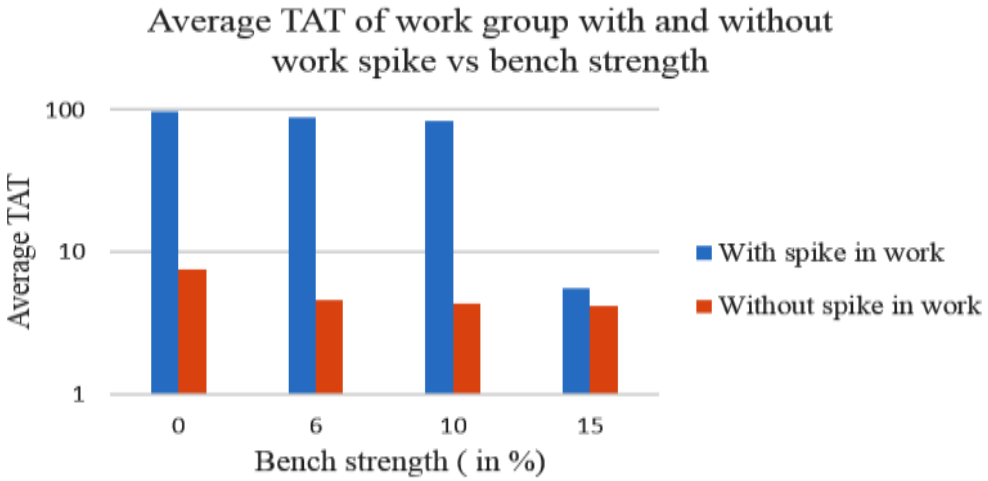
$$\widehat{\beta_1} = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sum(X_i - \bar{X})^2} = \frac{\sum(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)S_x^2} = r_{xy} * \frac{S_y}{S_x}$$

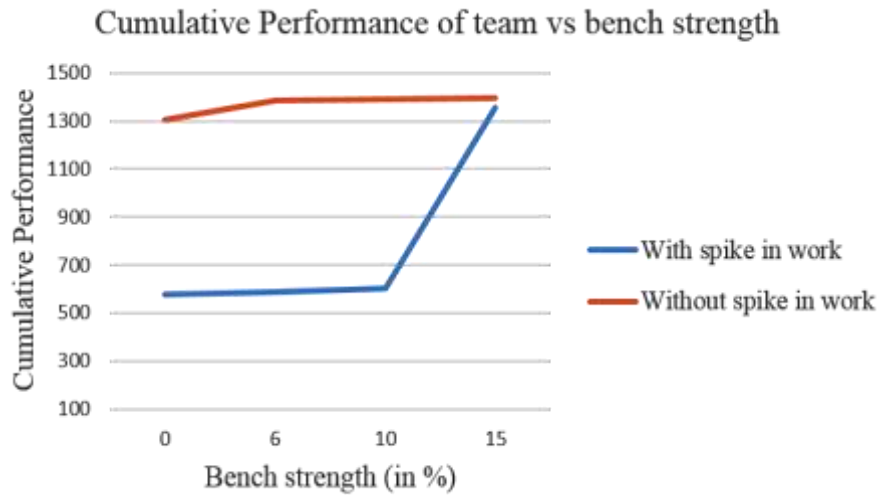
$$\widehat{\beta_0} = \bar{Y} - \widehat{\beta_1}\bar{x} \qquad \widehat{\beta_1} = r_{xy} * \frac{Sy}{Sx}$$

Behavioral variable	Pooled mean	Pooled standard deviation	Form
Workload	3.651	1.581	
Negative Affect	3.128	2.006	Negative Affect = 2.11 + 0.279 * workload
Work stress	2.379	1.421	Work Stress = 1.322 + 0.338 * negative Affect
Job performance	4.30	1.246	Job performance = 9.63 – 0.629 * Work stress

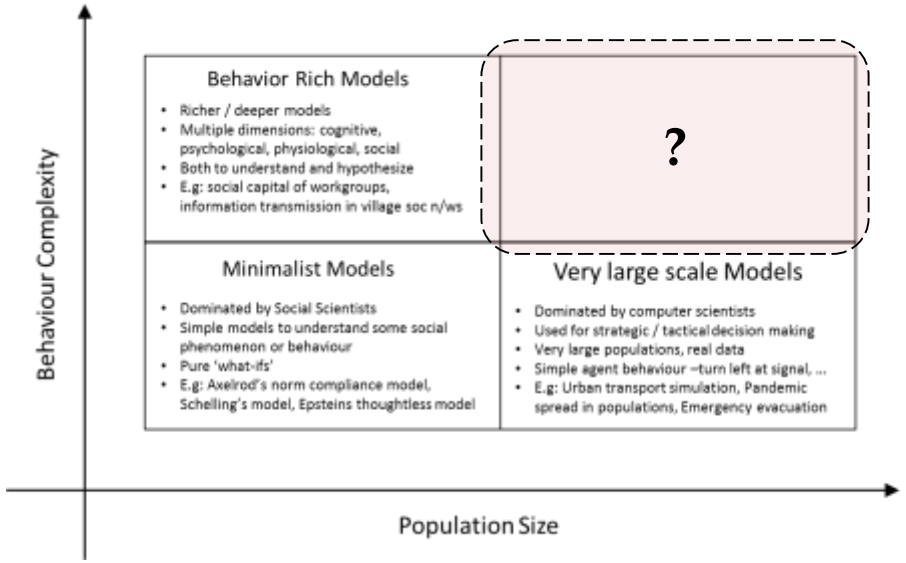
Behaviour composer (computational viewpoint)







Future - Deep Models of Organizations, Societies, Consumers



What we have not covered (and there is a lot)

- BDI (Belief Desires Intention) (Rao, Georgeff 1995)– which provides a planning framework within which agents can act. It provides a mean for the agent to distinguish between selecting a plan and executing it. The planning itself is left to an external agency and would of course depend upon the domain which is being worked on. BDI remains the most used framework for goal based systems where agents have to intelligently plan and satisfy a set of goals

- Platforms
  - NetLogo - https://ccl.northwestern.edu/netlogo/
  - Repast - http://repast.sourceforge.net/repast_3/
  - GAMA - http://gama-platform.org/
  - MASON - http://cs.gmu.edu/~eclab/projects/mason/
  - AnyLogic - https://www.anylogic.com/use-of-simulation/agent-based-modeling/ - Commercial
  - We attach slides of ESL, a simulation platform being developed at TRDDC

- ABS used for non-human centered applications: ABS can of course be used for simulation not just of humans but say mult-agent systems or indeed any set of autonomous entities or hybrid systems of people and programs

- ABS used in social physics systems: Social physics are systems inspired by models in physics to understand behaviour of large scale human systems such as crowds.

ESL: An Actor-Based Platform for Developing Emergent Behaviour of Organisations

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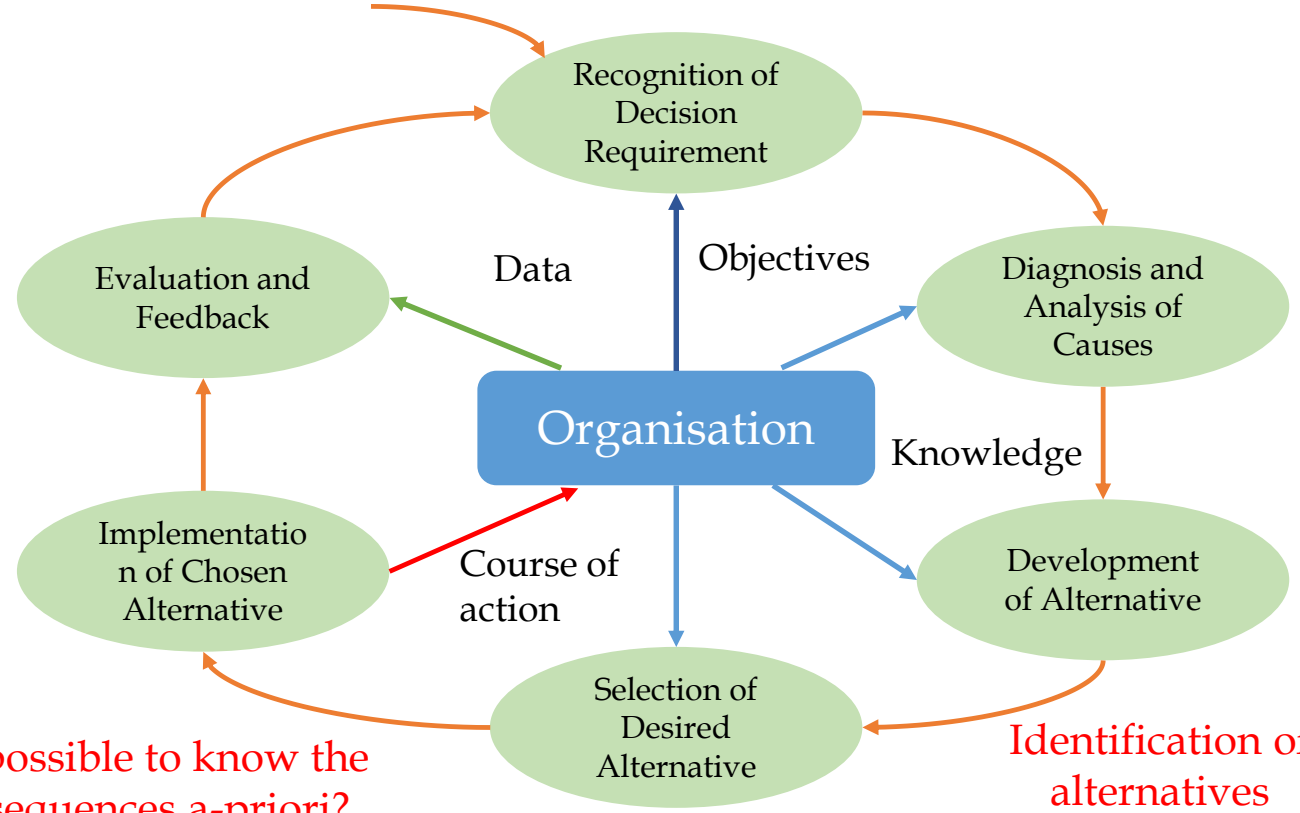
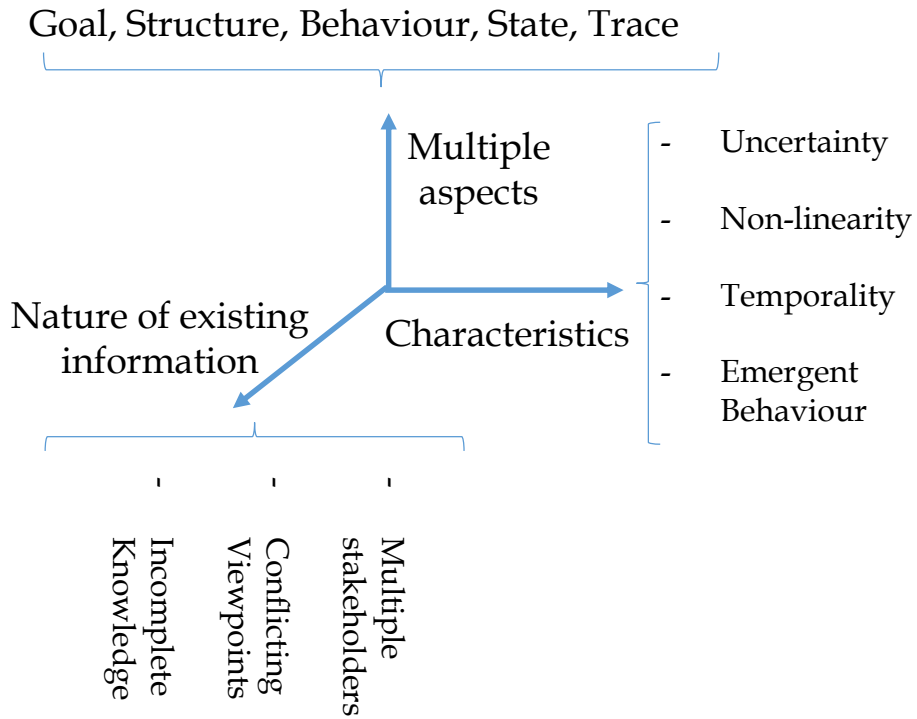
Context: Complex Dynamic Decision Making



Is it possible to know the consequences a-priori? What is the risk factor?

Which alternative is best? Why?

Identification of alternatives



Organisation

Large, complex, dynamic, has multiple aspects, exhibit socio-technical characteristics, subjected to significant uncertainty.

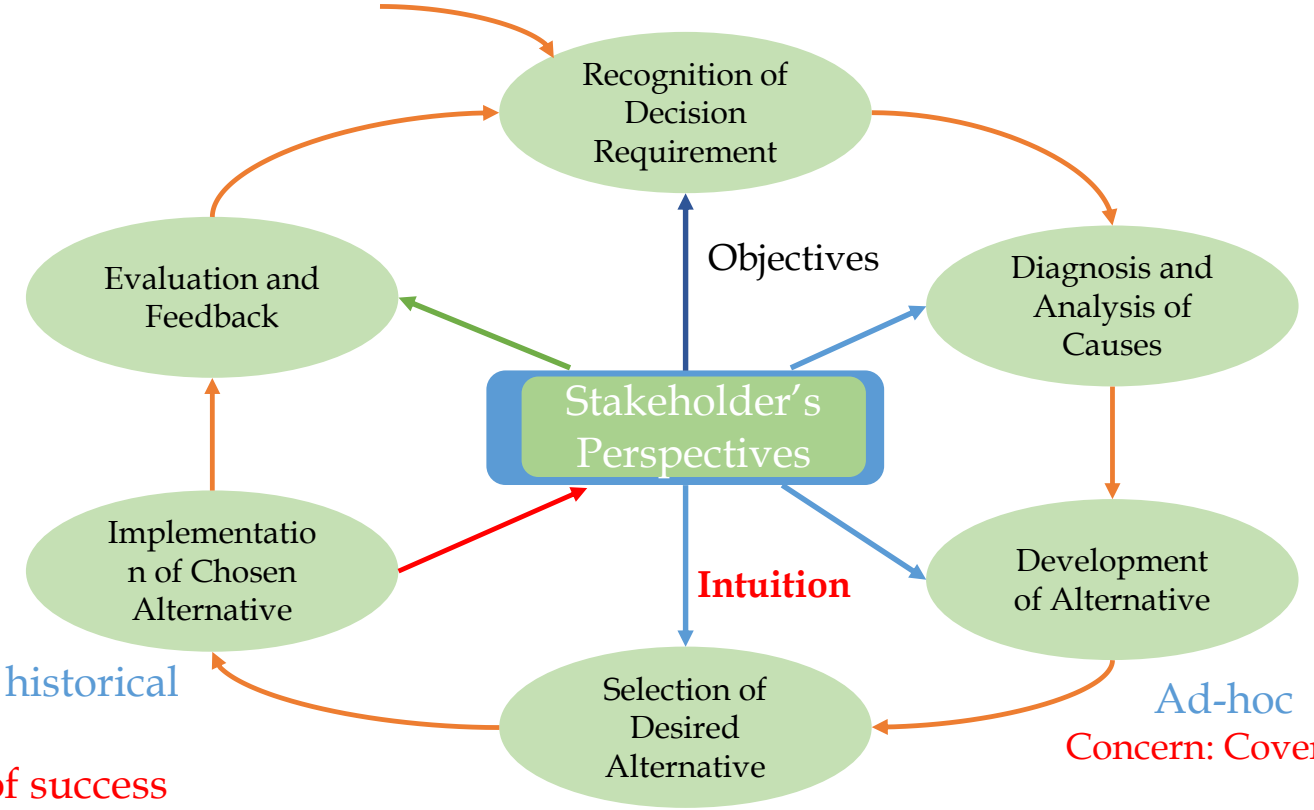
State of the practice

State of the practice

Based on human experts who are aided with spreadsheet and documents

Organisation

Large, complex, dynamic, has multiple aspects, exhibit socio-technical characteristics, subjected to significant uncertainty.



Consequences are estimated based historical occurrences

Concern: high risk, no guarantee of success

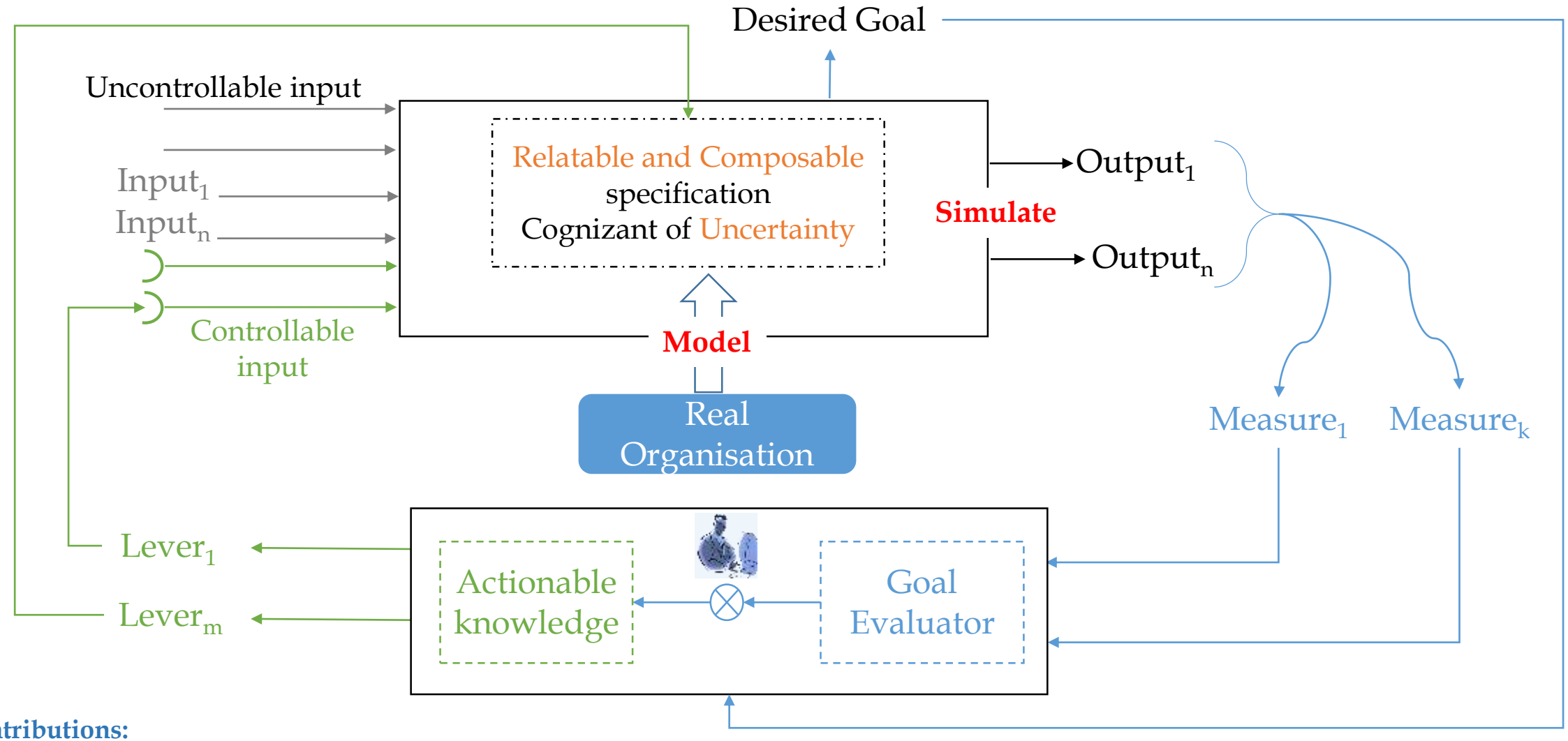
Ad-hoc

Concern: Coverage

Intuition-driven

Concerns: Not precise, biased, based on short-term consequences

Our Approach



Research Contributions:

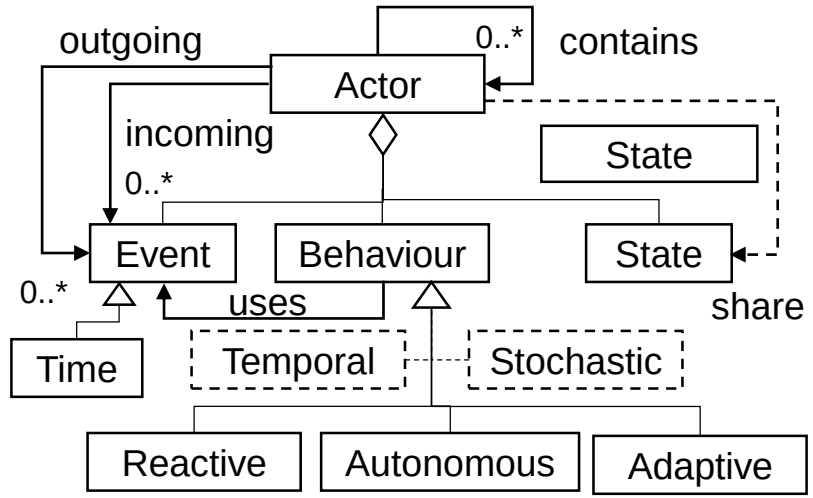
1. **Enterprise Specification Language (ESL)**
2. **Simulation Technology**

Enterprise Specification Language (ESL)

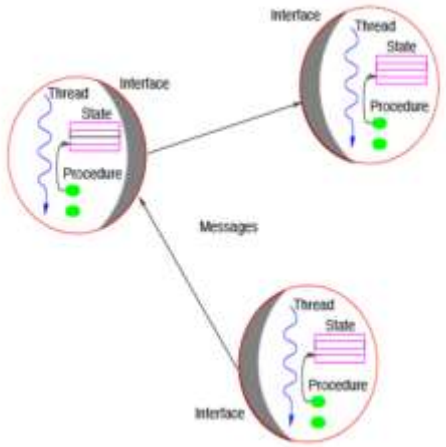
- System is a set of Actors

- Actor
  - Autonomous: Local goals and policies
  - Listens to, processes and raises events
  - Exchanges messages with other actors
  - Modular, Composable and Adaptive
  - supports Uncertainty – known known & known unknown
  - Supports the notion of 'Time'
  - Supports shared variables
  - Supports thread based execution

- Simulation environment
  - Cognizant of emergent behaviour
  - What-if



Language Definition



Execution Semantics

Thanks

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Ravi Mahamuni
Service Design

Ashwanth Thotta
Game Design

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