The Role of Evidence in Modelling Water, Energy and Social Gatherings

Reflections from the Journey

Dr Kavin Narasimhan

ESRC Policy Fellow – Data Social Scientist (BEIS, UK)

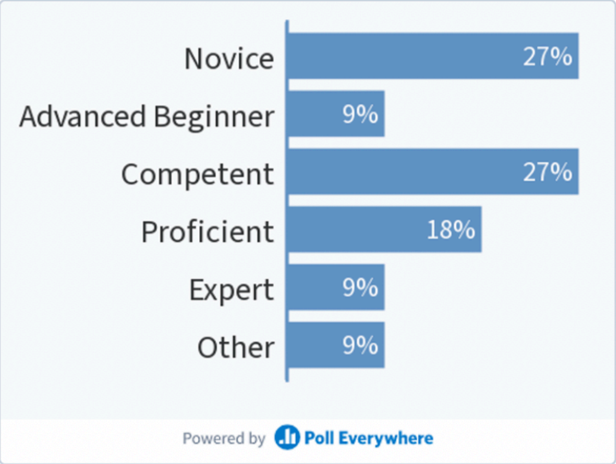
Research Fellow, Centre for Research in Social Simulation, University of Surrey (UK)

Table of Contents

Theory
&
Limited empirical evidence

Please join at PollEv.com/kavinnarasimhan

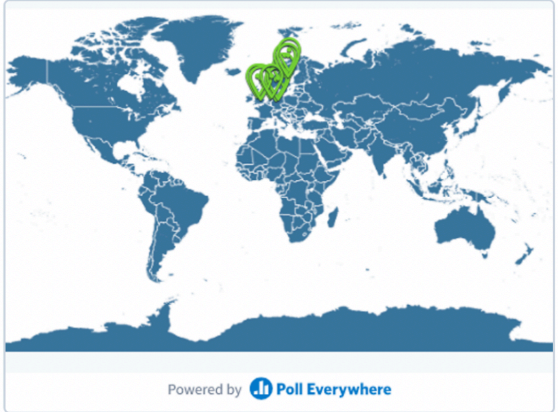
How would you identify your social simulation skills?



Response options	Count	Percentage
Novice	**3**	**27%**
Advanced Beginner	1	9%
Competent	**3**	**27%**
Proficient	2	18%
Expert	1	9%
Other	1	9%

Audience Engagement

Where are you joining us from today?



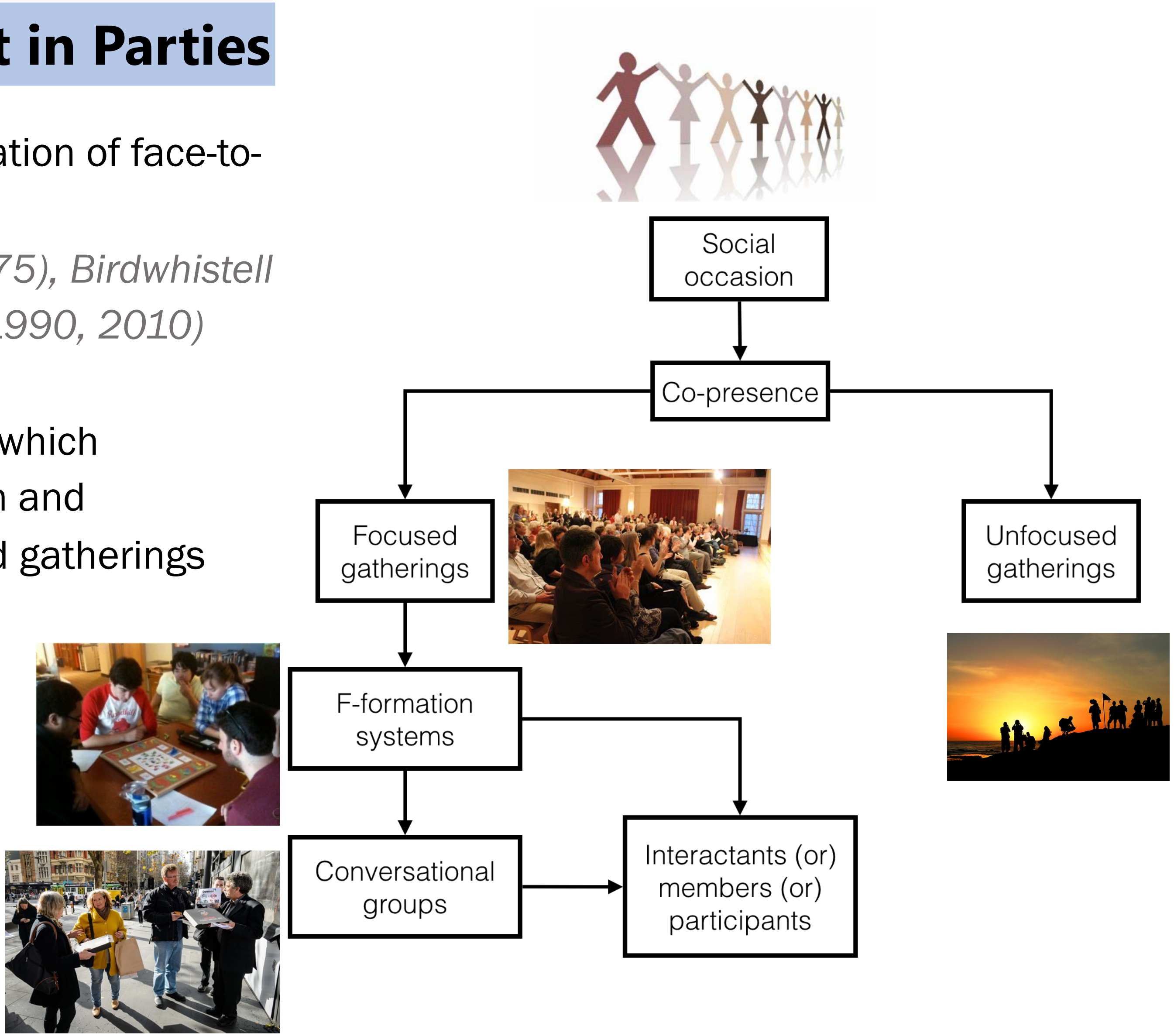
Response options	Count	Percentage
	13	100%

Model of Spatio-temporal movement in Parties

- Huge body of work focusing on the spatial organisation of face-to-face encounters
  Goffman (1961, 1963, 1971), Scheflen (1964, 1975), Birdwhistell (1952, 1970), Hall (1966), Kendon (1973, 1979, 1990, 2010)

- **F-formation system:** Coordination mechanisms by which participants relate their spatial behaviour (position and orientation) with respect to one another in focused gatherings

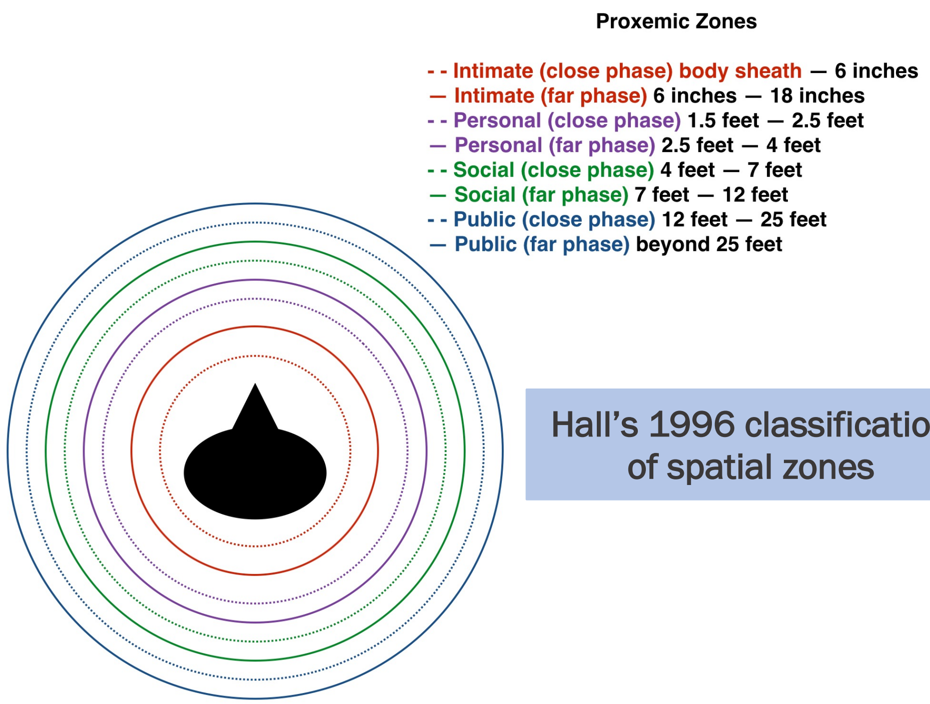
- **F-formations in conversational groups:**
  - Helps to see and hear each other clearly
  - Signals membership of insiders and a social boundary to others/outsiders
  - Establishes a protocol to enter and exit



Theories about space around an individual

Classification of interpersonal distances:

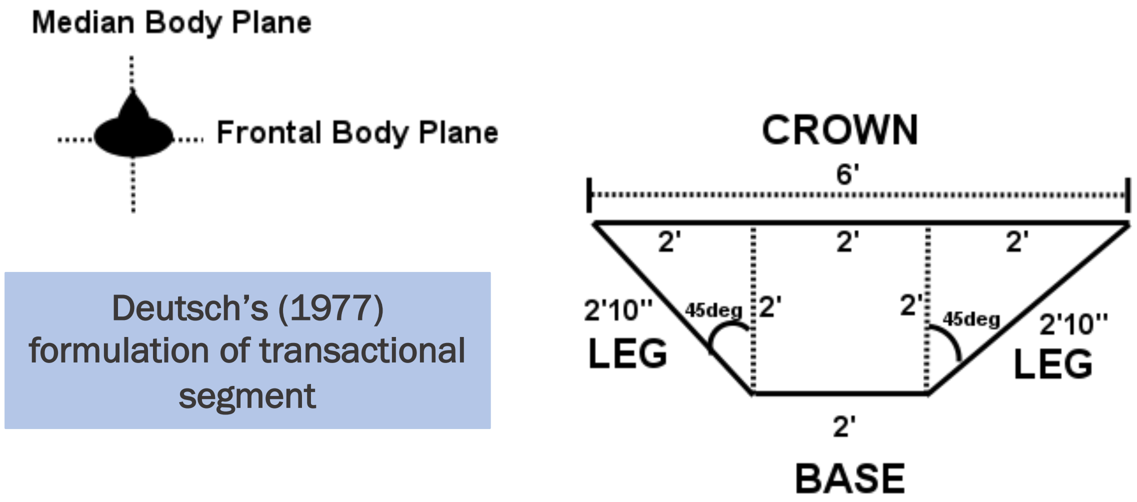
- Intimate distance zone: from skin to 18 inches outwards
- Personal distance zone: 18 inches – 4 feet
- Social distance zone: 4 feet to 12 feet
- Public distance zone: beyond 12 feet



Hall’s 1996 classification of spatial zones

Transactional segment:

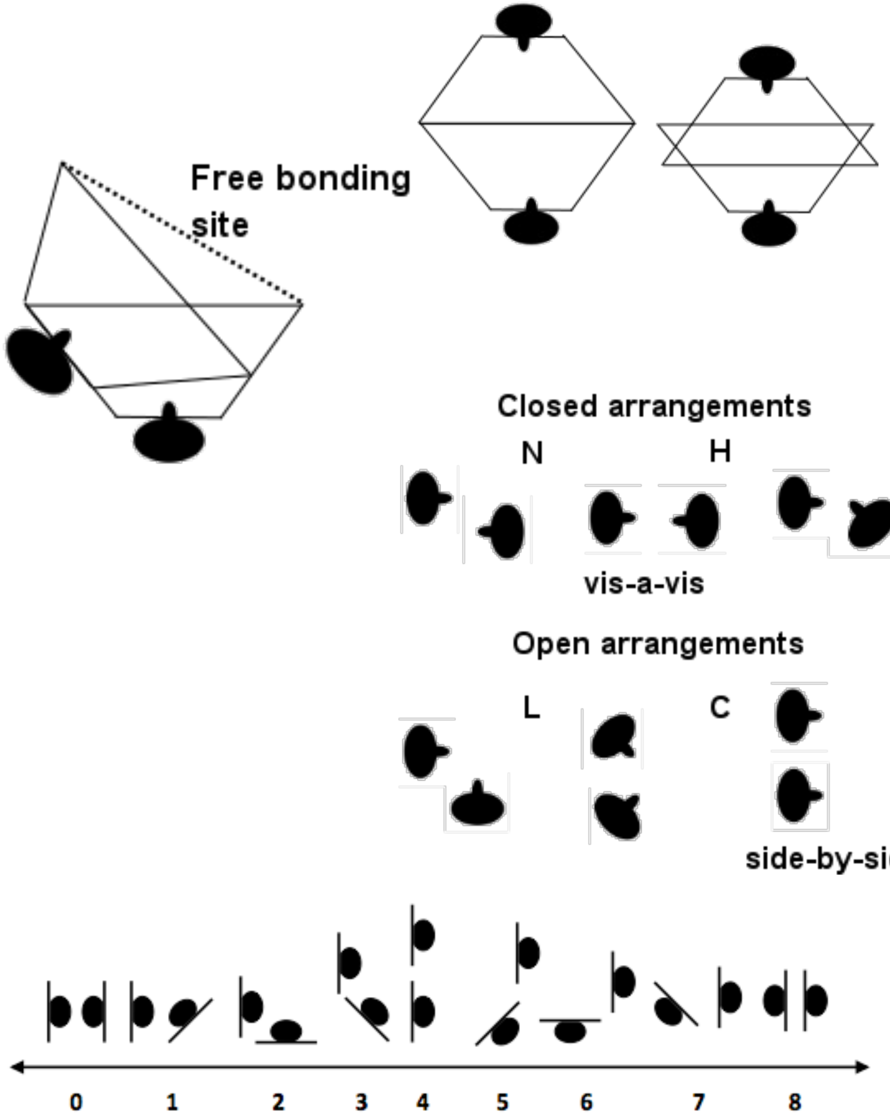
- Trapezoid extending outwards from the body plane
- Legs are approx. 2 feet (half of personal distance)
- Maximum 45º deviation between head & median plane



Deutsch’s (1977) formulation of transactional segment

Theories about space around dyads

Overlapping Transactional Segments

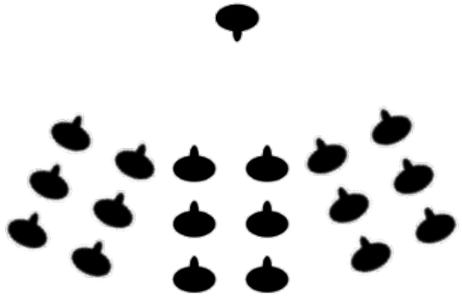


Extensive research on the shapes and patterns of dyadic interactions:

- Individual transactional segments overlap
- Closed versus open arrangements
- Open arrangements tend to have a *free bonding site*
- O-arrangement or H-arrangement or vis-á-vis or sociopetal arrangement
- More commonly used in face-to-face interactions: 0, 1, 2, 3, 4
- H-shaped for face offs or personal relationships
- L-shaped for superior-junior relationships

Limited observations of multi-party groups

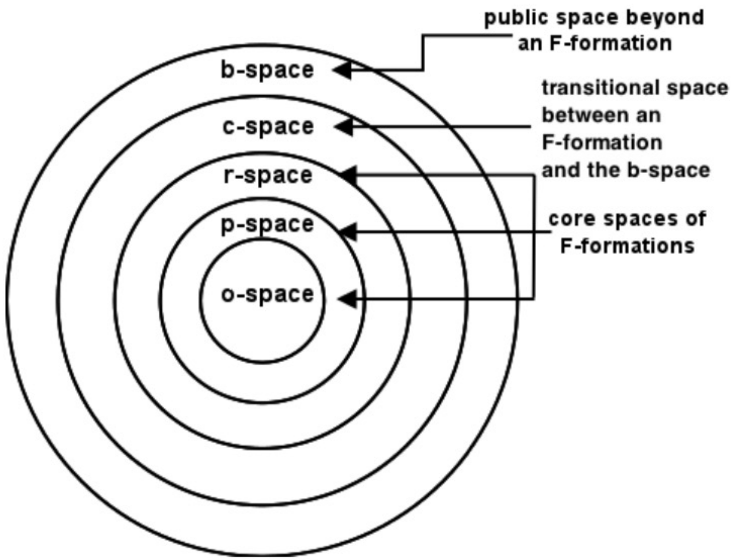
Pyramid arrangement



Horseshoe arrangement

Multi-party interactions are less explored; only few general observations:

- Conversational groups influence and are influenced by the wider space – reason why corridor conversations are short!
- If space is available, circle mostly (Scheflen, 1964)
- May be circular, triangular or square-shaped (Scheflen, 1975)
- Equal participation – circle; Unequal participation – triangle, semi-circle, clear head position, etc. (Kendon, 1973)



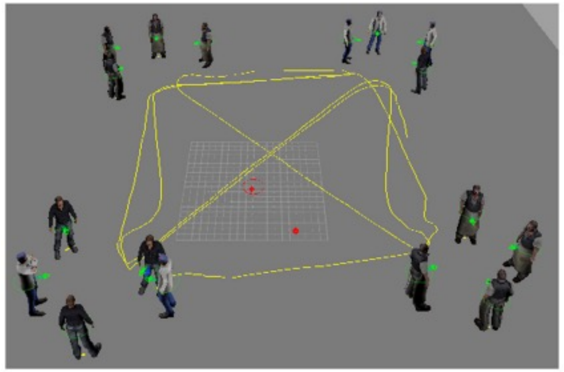
F-formations are temporally regulated systems, with different spatial zones:

- o-space: core region of an F-formation
- p-space: space for participants and their belongings
- r-space: buffer zone between F-formation and the World!

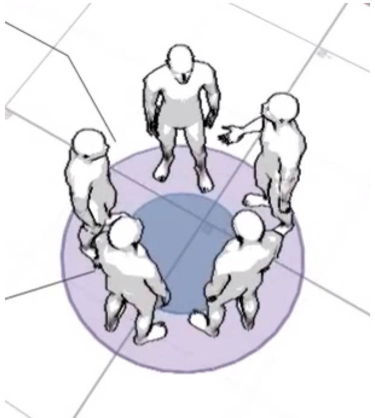
Cues from Artificial Life and Replication

- Earlier studies to understand cultures and cultural norms
- Now we have virtual worlds & robots
- We want them to learn our cultures
- They need algorithms rather than ethnomethodology

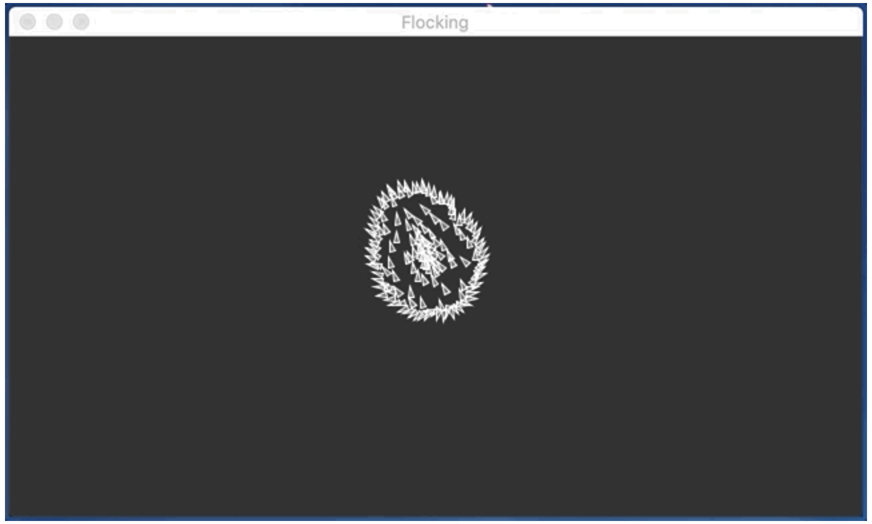
Jan and Traum's (2007) model



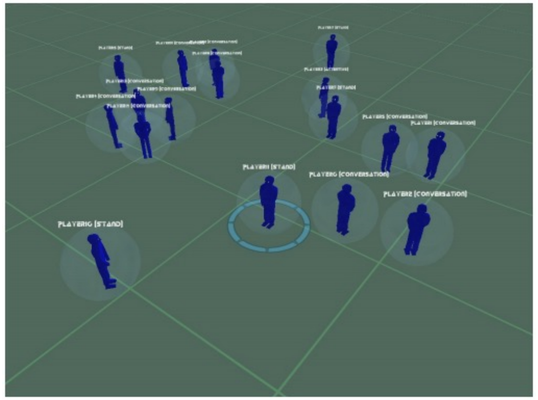
Karimaghalou et al.'s (2014) model



Pedica and Vilhjálmsson's (2012) model



Processing Example: Flocking Model



Pedica and Vilhjálmsson's (2008)

Salem and Earle's (2000) model

Circle, circle, circles everywhere!

- The spatial arrangements of conversational groups almost always a circle
- For dyadic and triadic conversations – vis-à-vis or triangular arrangements
- Same even in Robotics literature
- What's happening?
- Can we do better?
- Can we build on the principles of the geometry of conversational groups?

Computational Proxemics: Simulation-based analysis of the spatial patterns of conversational groups
Queen Mary, University of London (2016)

Inspiration from Braitenberg's Vehicle

Three versions:

- Random walk, stop and talk (Baseline)
- Commonly-used approach (Replication)
- Alternative approach (Contribution)

Replication attempt:

- A centroid based group repositioning algorithm

Alternative approach:

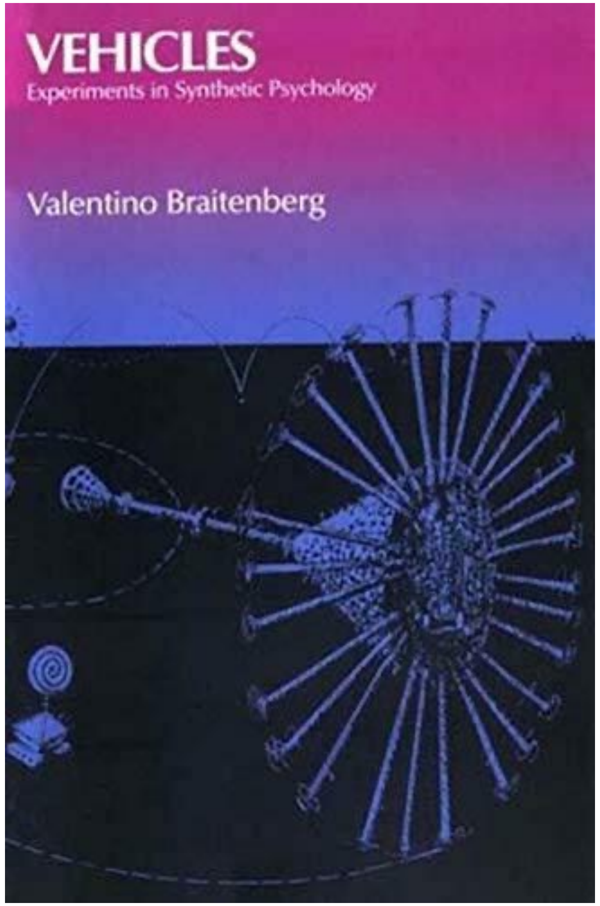
- Based on theory: personal zones, transactional segment, o-space & p-space

Local readjustment:

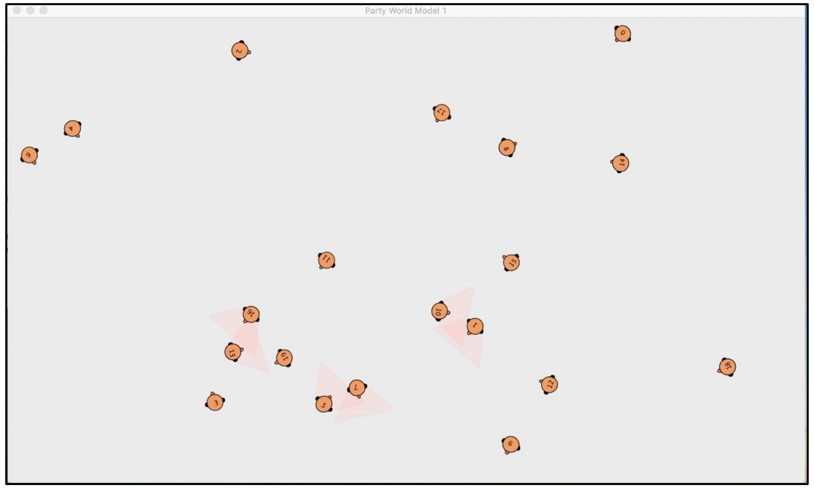
- Each individual readjusts their position and orientation only with respect to immediate neighbours

Extended readjustment:

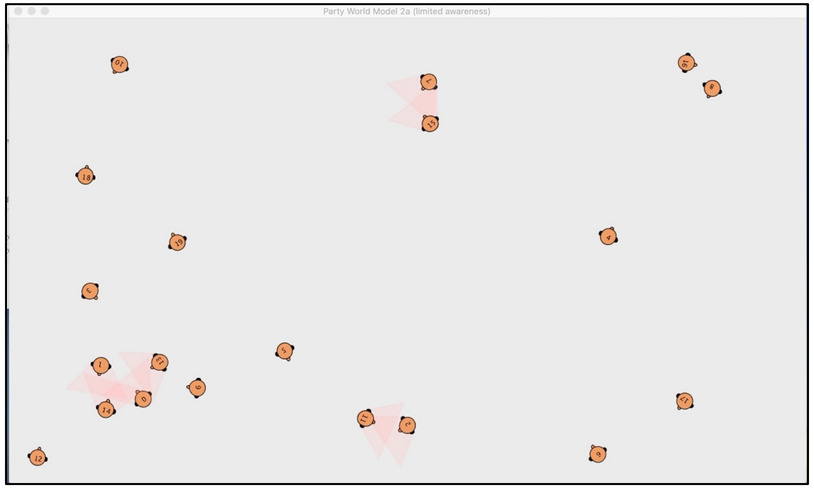
- Each individual readjusts their position and orientation with respect to everyone in the group



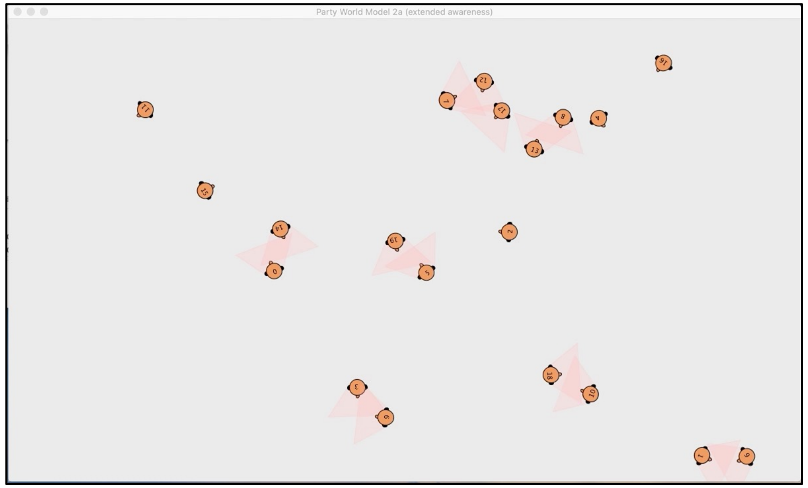
Party World 2D Simulations



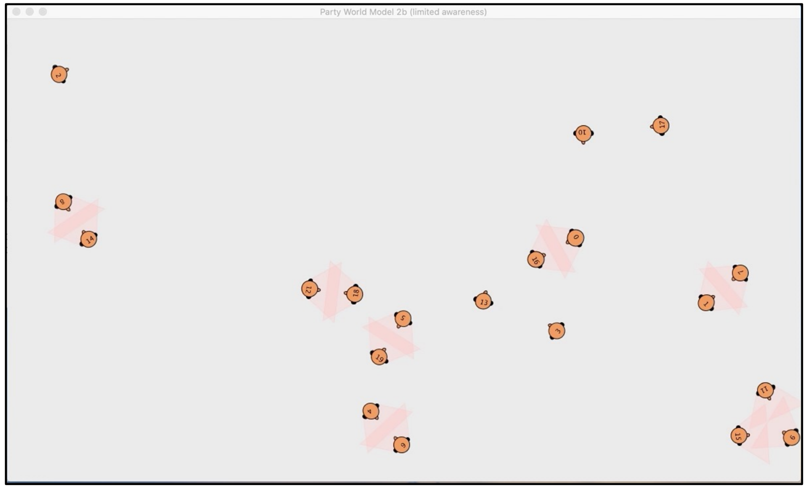
Model 1



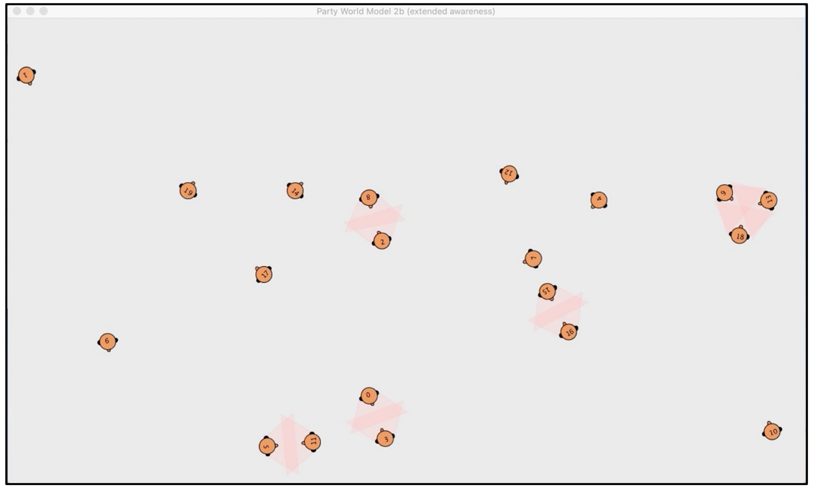
Model 2a LA



Model 2a EA

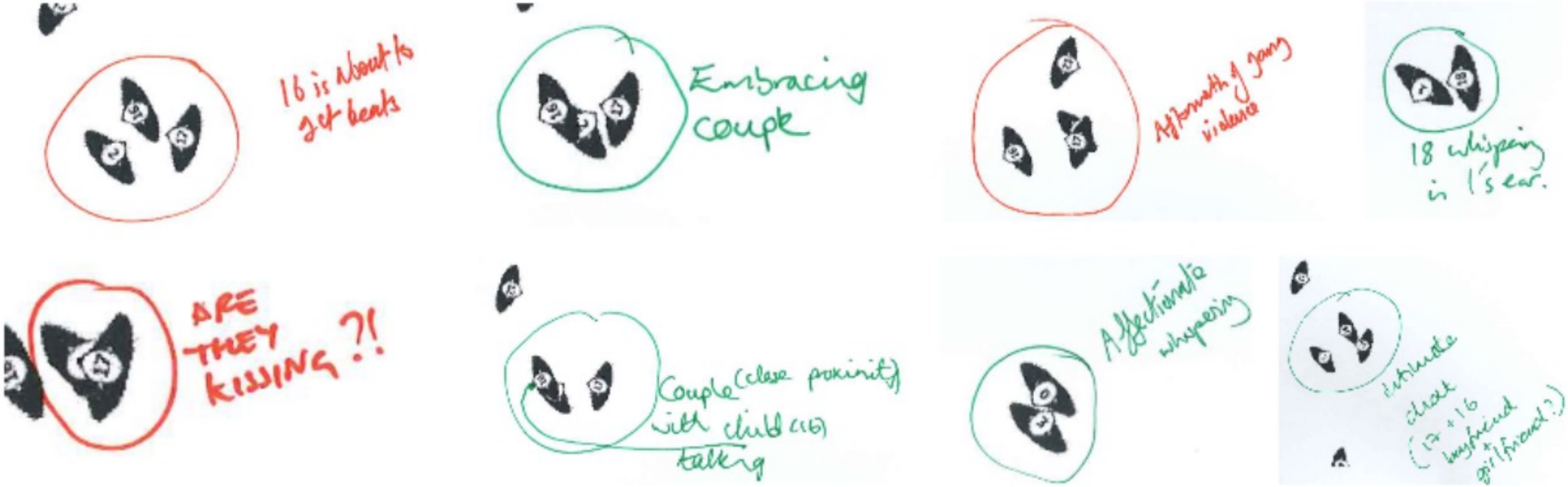


Model 2b LA



Model 2b EA

Validating the Models: Attempt 1

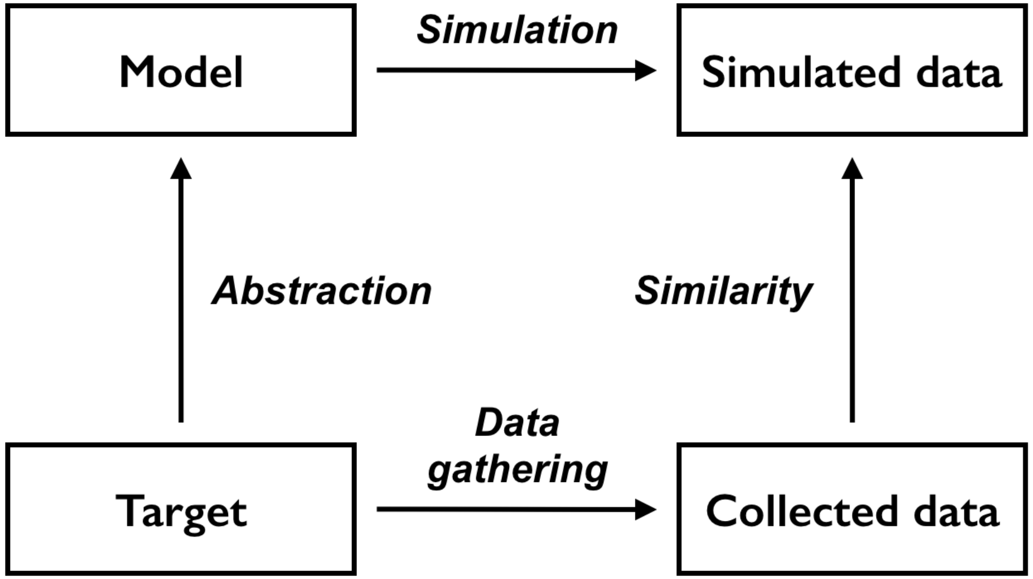


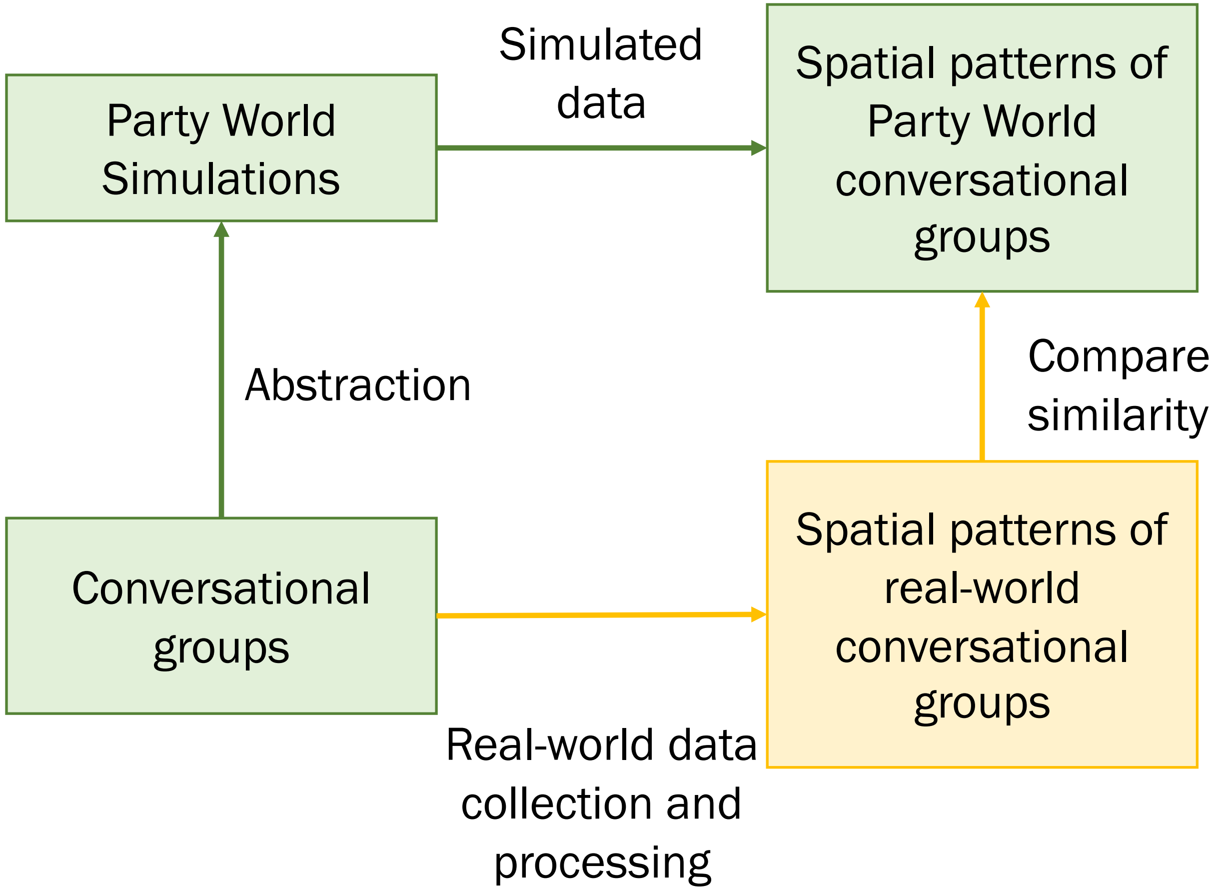
Validating the Models: Attempt 2

Watch it, we're around

https://vimeo.com/46091584

A more systematic approach to the problem

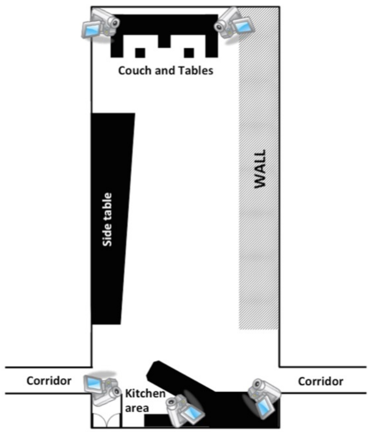


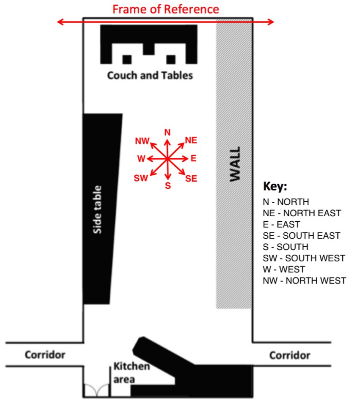


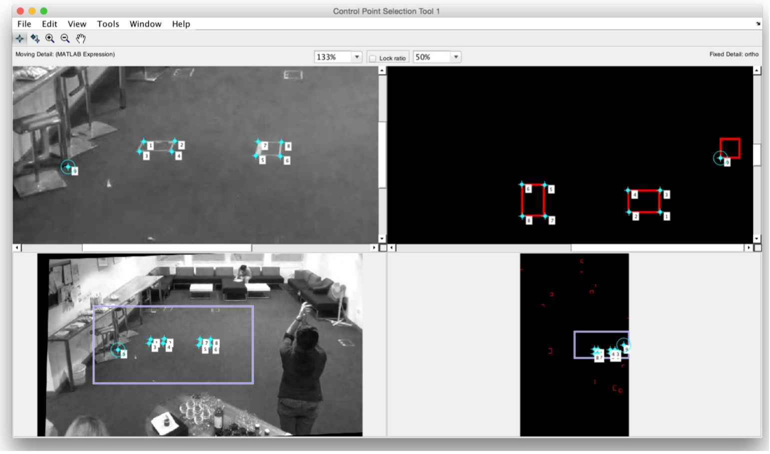
Gilbert and Troitzsch (2005) logic of simulation as a method

Drinks Reception Party Dataset

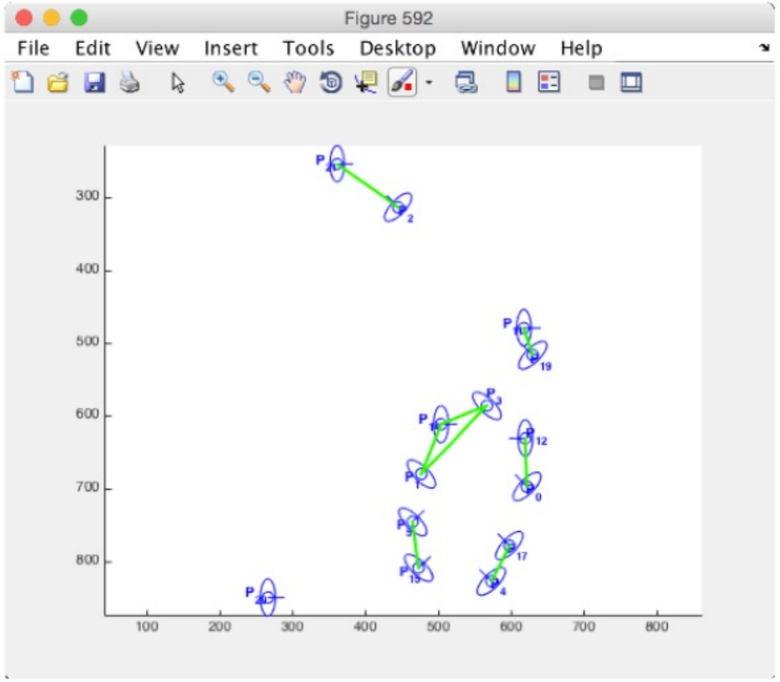
- Filmed a University drinks reception party
- ~ 20 participants for ~ 1.5 hours
- Five normal video cameras overhead in a 45° downward incline at different places in the Hub – a rectangular shaped room 11.89x7.07m
- Feeds from different cameras time synchronised & converted to images using ffmpeg
- Camera calibration algorithm (Bradski, 2000); Bird's eye view image transformation algorithm (Bradski and Kaehler, 2008); Image rectification algorithm (MATLAB and Toolbox, 2014) applied to convert camera images to bird's eye view dataset



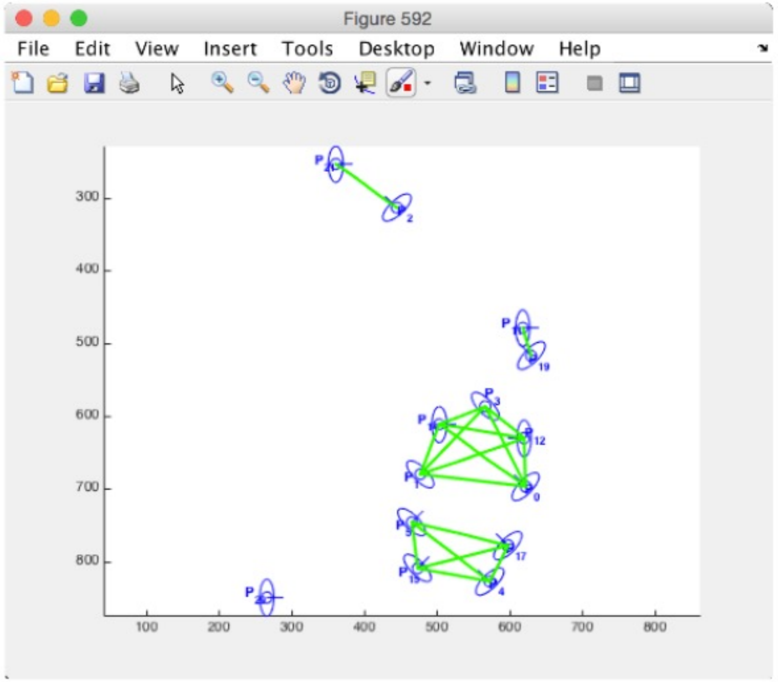




F-formation Detection Methods



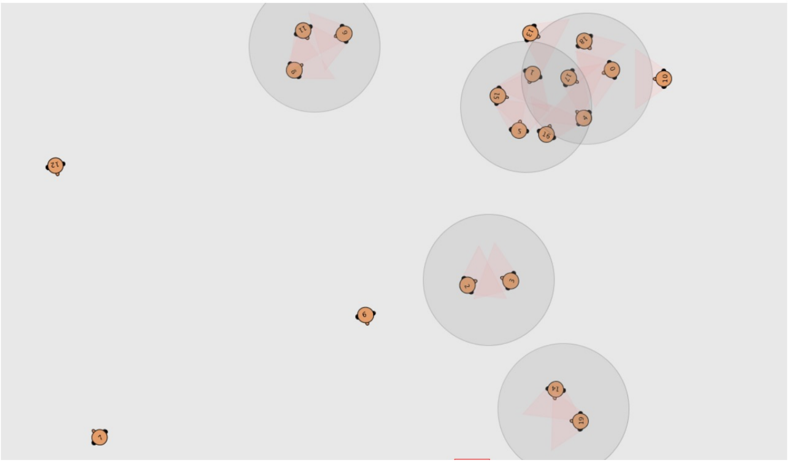
Stride = 20



Stride = 40

Graph-Cuts for F-Formation (GCFF)
https://github.com/franzsetti/GCFF

Hough Voting for F-Formations (HVFF)
http://profs.scienze.univr.it/cristanm/ssp/



Party World F-formation Detection (PWFD)
https://qmro.qmul.ac.uk/xmlui/handle/123456789/23843?show=full

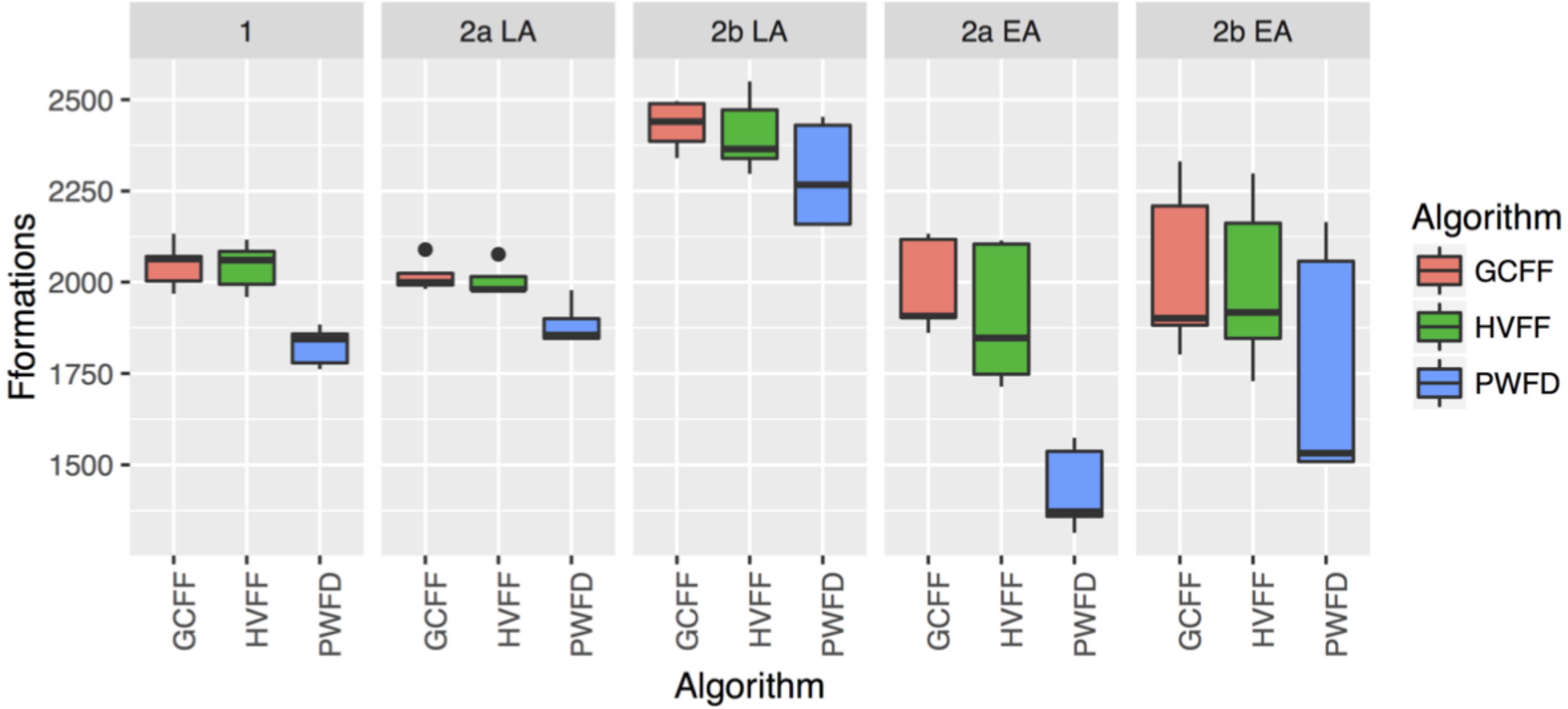
@kavinpreethi k.narasimhan@surrey.ac.uk SocSimFest2022

Comparability of Detection Methods

HVFF		GCFF		PWFD	
F-formation	Members	F-formation	Members	F-formation	Members
1	{1,4,5,15,16}	1	{1,4,5,15,16}	1	{1,5,15,16}
2	{6,8,11}	2	{6,8,11}	2	{6,8,11}
3	{2,3}	3	{2,3}	3	{2,3}
4	{10,18}	4	{0,13,17,18}	4	{0,4,17,18}
5	{14,19}	5	{14,19}	5	{14,19}
6	{0,17}	-	-	-	-

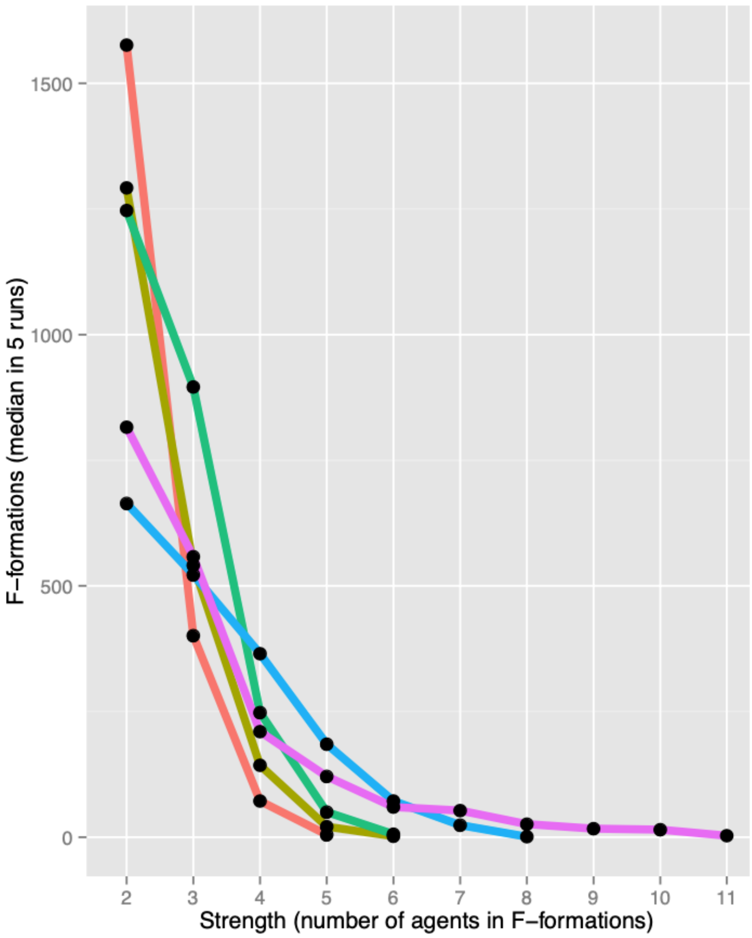
Narasimhan, 2016, https://qmro.qmul.ac.uk/xmlui/handle/123456789/23843?show=full

Comparisons of Real and Simulated Clusters

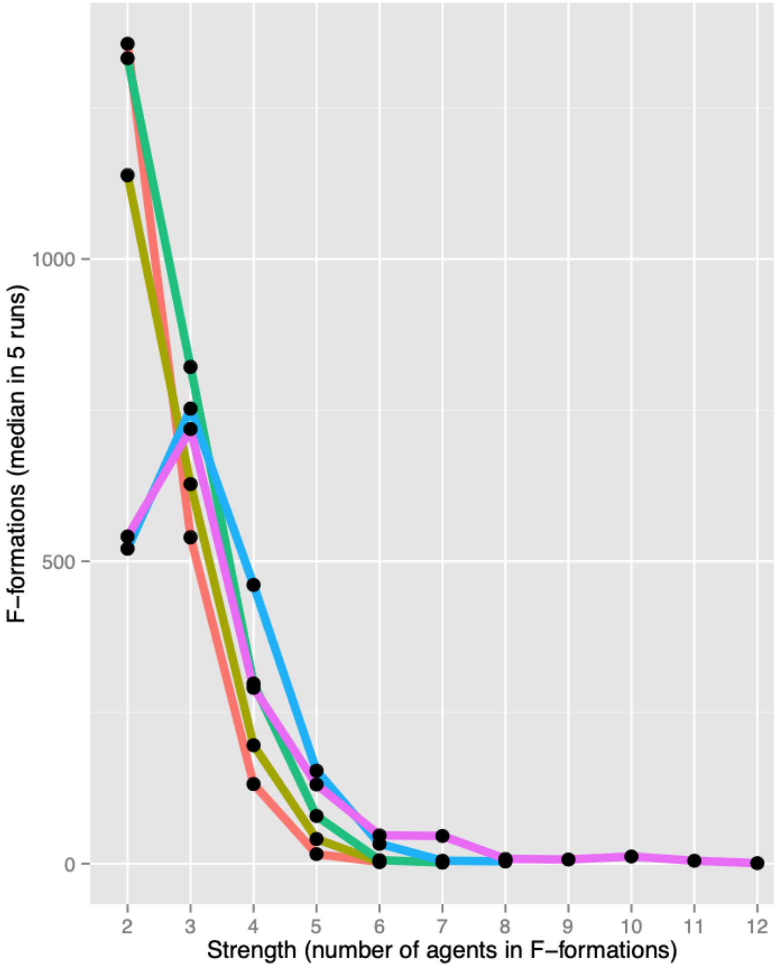


Average number of F-formations across multiple simulation runs detected in different models using different F-formation detection algorithms

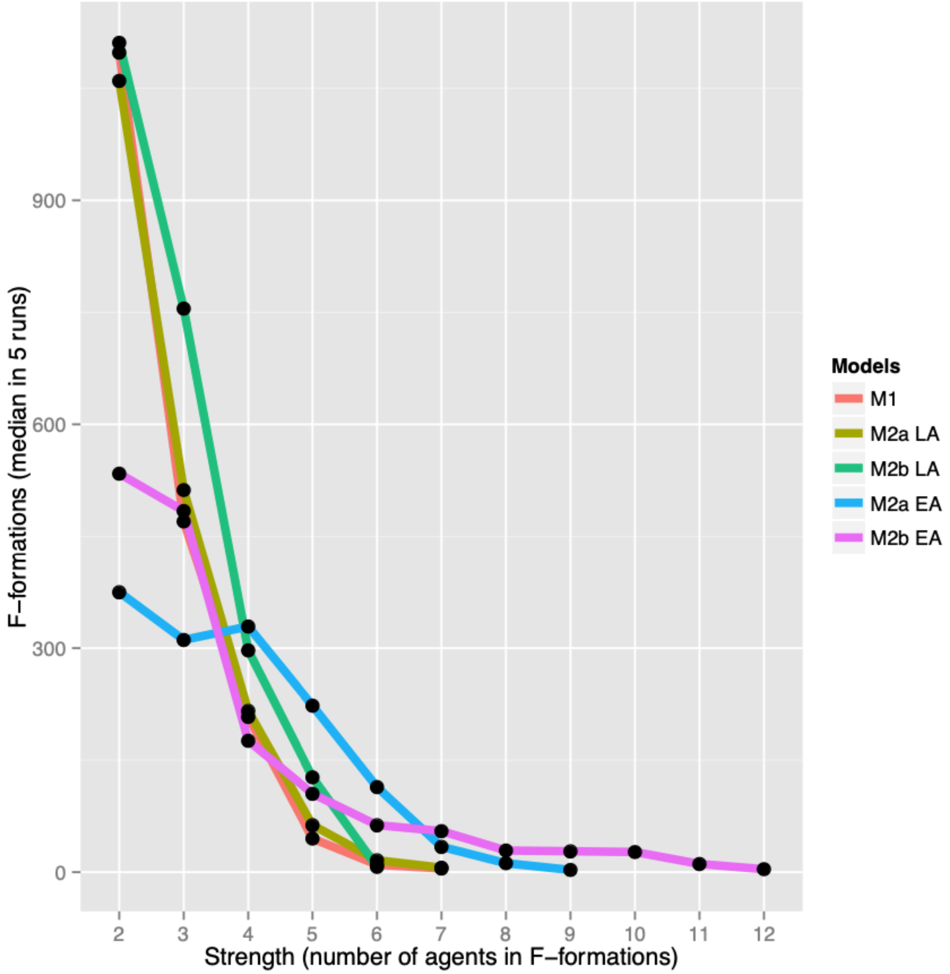
Comparisons of Real and Simulated Clusters



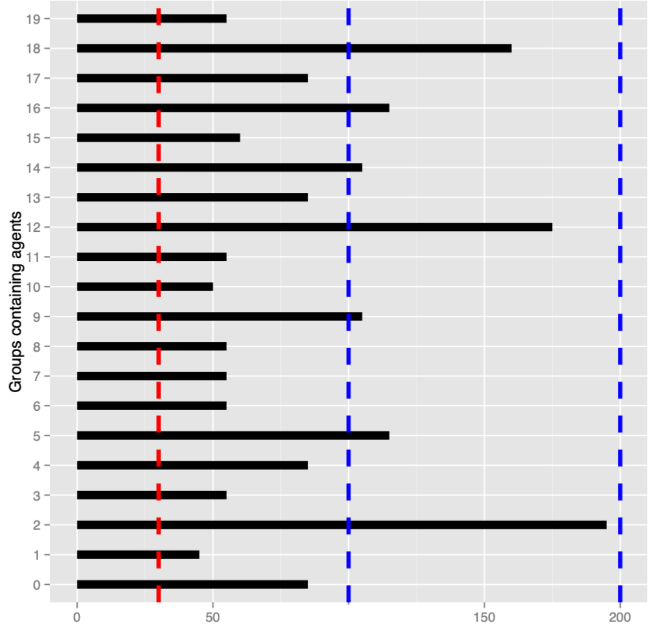
HVFF



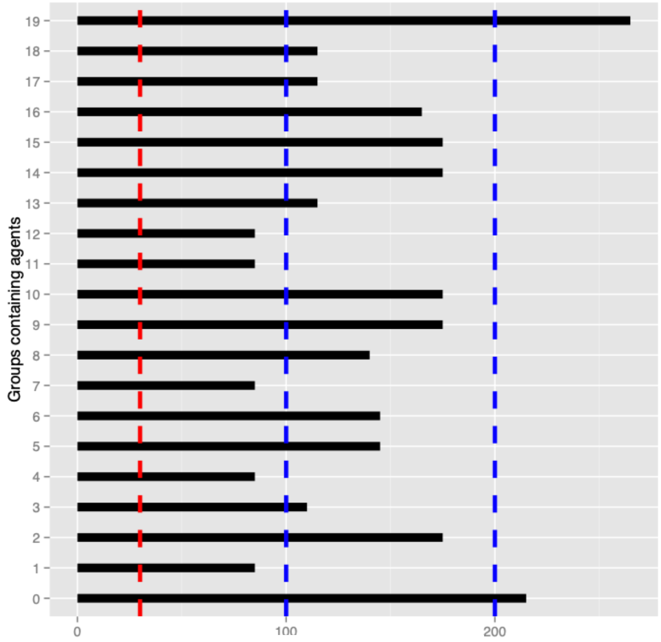
GCFF



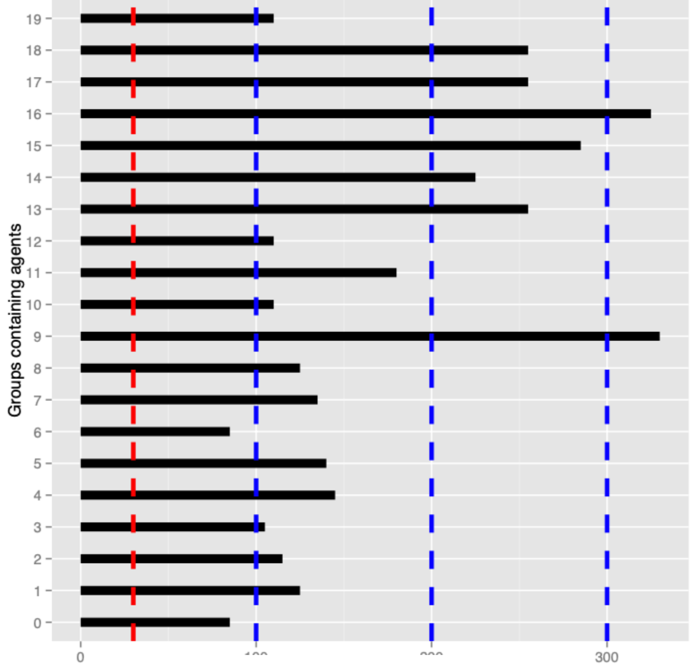
PWFD



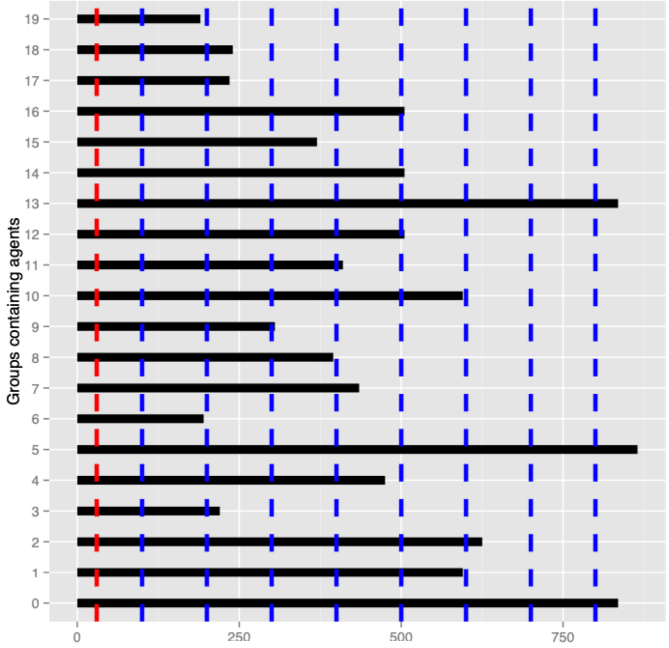
Model 1



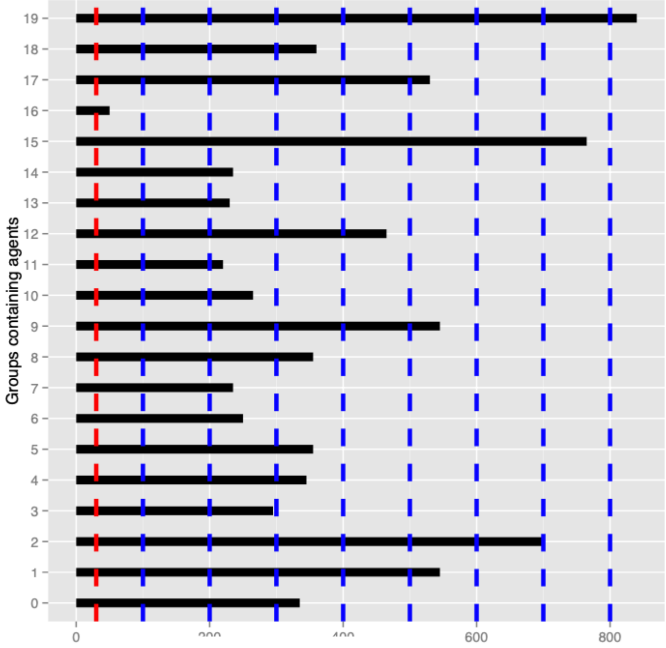
Model 2a LA



Model 2a EA

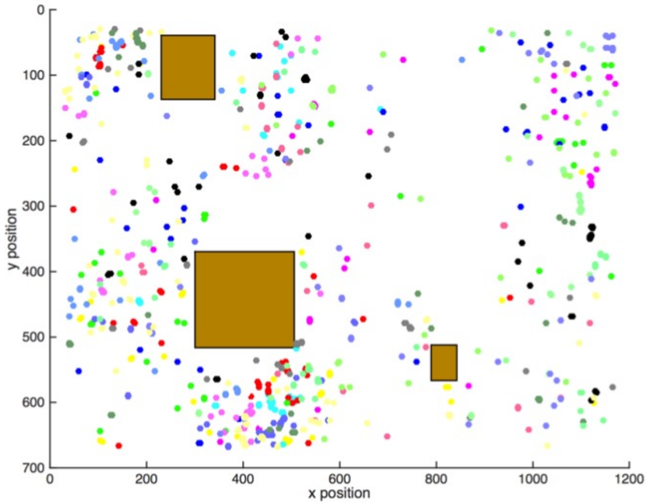


Model 2b LA

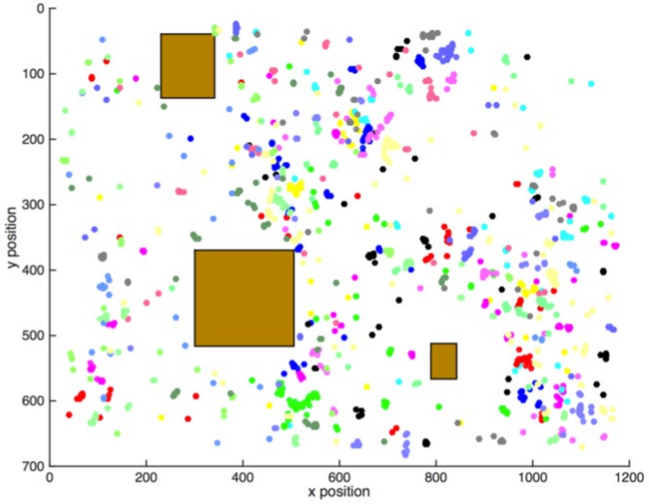


Model 2b EA

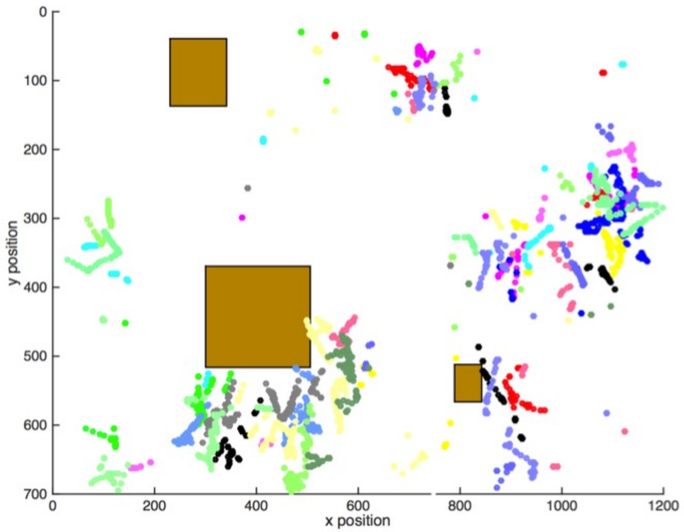
Maximum duration for which each agent participates in an F-formation



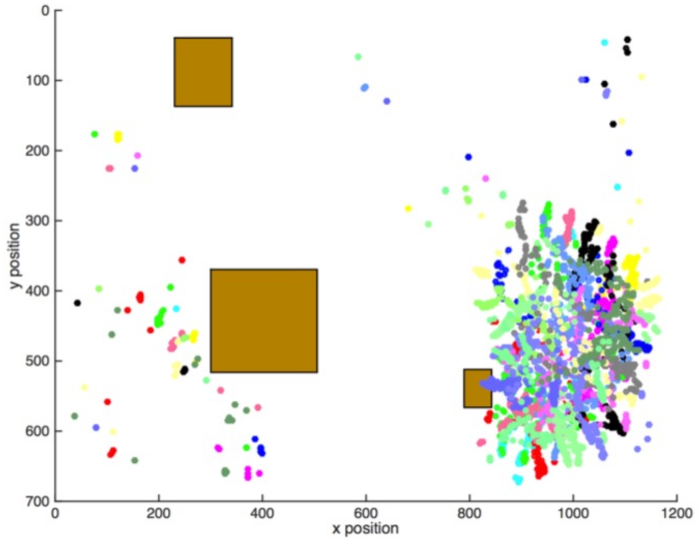
(a) Model 1



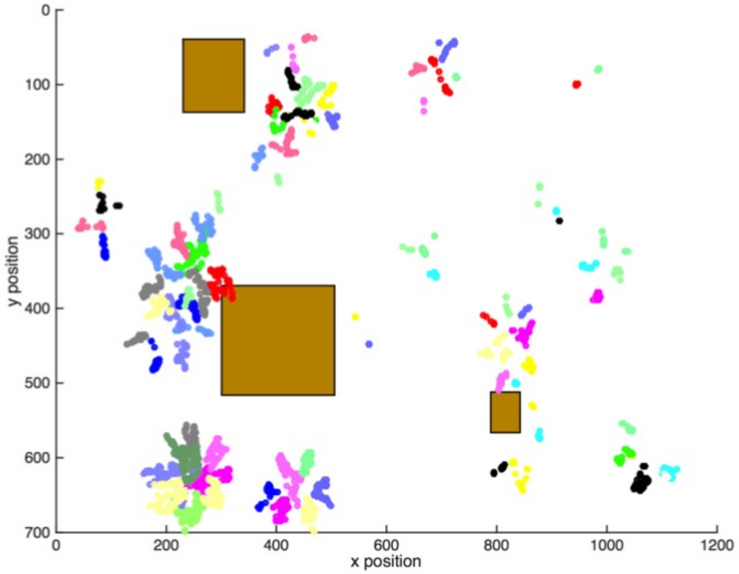
(b) Model 2a LA



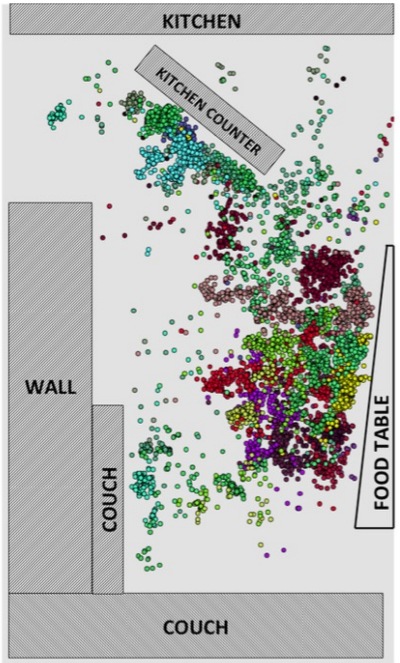
(c) Model 2b LA



(d) Model 2a EA



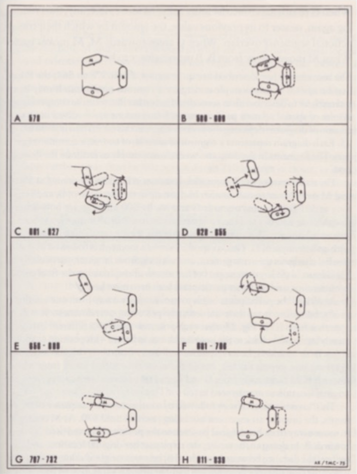
(e) Model 2b EA



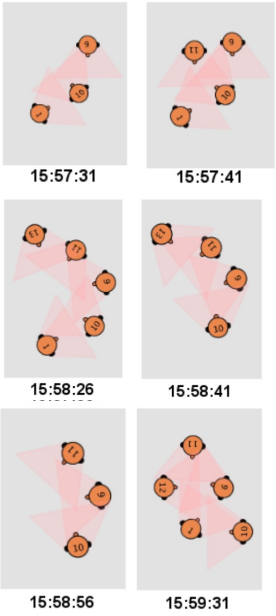
Drinks Reception Dataset

Findings after more comparisons

- The spatial, temporal and social characteristics of agent clusters vary significantly between different Party World models
- Model 1 generates mostly "queues"; the DR dataset had very few queues
- Current standard (~ Model 2b EA) generates unrealistic spatial patterns and dynamics of conversational groups; vis-à-vis, triangle, square/rhombus, pentagon or circle; DR dataset rarely had such regular shapes (furniture/obstacles may never allow such shapes!)
- Our alternative, the field-of-view model (Model 2a), produces more realistic dyadic arrangements - similar shapes (H, N, V, C, L and I arrangements) were observed in the DR dataset
- Readjustments based on local and extended neighbourhoods: the former results in smaller groups (2 to 6 or 7), while the latter produces bigger groups (10 or more)
- Model 1 (baseline) and Model 2b EA (current standard) perform poorly in comparison to all the other Party World models
- Model 2b LA performs better, but Models 2a LA and 2a EA perform the best when taking into consideration the different characteristics of conversational groups in the DR dataset



Kendon, 1990



Narasimhan, 2016

References Part I

Narasimhan, 2016	Computational Proxemics: Simulation-based analysis of the spatial patterns of conversational groups https://qmro.qmul.ac.uk/xmlui/handle/123456789/23843?show=full
Processing Flocking Example	https://processing.org/examples/flocking.html
Braitenberg's Vehicles	http://users.sussex.ac.uk/~christ/crs/kr-ist/lecx1a.html
Graph-Cuts for F-Formation (GCFF)	https://github.com/franzsetti/GCFF
Hough Voting for F-Formations (HVFF)	http://profs.scienze.univr.it/cristanm/ssp/
Goffman, E. (1961)	Encounters: Two studies in the sociology of interaction. Bobbs-Merrill
Goffman, E. (1963)	Behaviour in public places: notes on the social order of gatherings. The Free Press, New York
Goffman, E. (1971)	Relations in public: microstudies of the public order. New York: Basic Books
Kendon, A. (1973)	The role of visible behaviour in the organization of social interaction. Social communication and movement: Studies of interaction and expression in man and chimpanzee
Kendon, A. (1979)	Some emerging features of face-to-face interaction studies. Sign language studies, 22(1):7–22
Kendon, A. (1990)	Spatial organization in social encounters: The f-formation system. Conducting interaction: Patterns of behavior in focused encounters
Kendon, A. (2010)	Spacing and orientation in co-present interaction. In Development of Multimodal Interfaces: Active Listening and Synchrony, Springer
Scheflen, A. E. (1964)	The significance of posture in communication systems. Psychiatry, 27(4):316–331
Scheflen, A. E. (1975)	Micro-territories in human interaction. Organization of Behavior in Face-to-Face Interaction, pages 159–173
Hall, E. T. (1966)	Distances in man: The hidden dimension. Double Day, Garden City, New York
Birdwhistell, R. L. (1952)	Introduction to kinesics: an annotation system for analysis of body motion and gesture. University of Louisville Press
Birdwhistell, R. L. (1970)	Kinesics and context: essays on body motion communication. University of Pennsylvania Press Philadelphia
Jan, D. and Traum, D. R. (2007)	Dynamic movement and positioning of embodied agents in multiparty conversations. In Proceedings of the Workshop on Embodied Language Processing, pages 59–66. Association for Computational Linguistics.
Karimaghalou, N., Bernardet, U., and DiPaola, S. (2014)	A model for social spatial behavior in virtual characters. Computer Animation and Virtual Worlds, 25(3- 4):505–517
Pedica, C. and Vilhjálmsson, H. (2012)	Lifelike interactive characters with behavior trees for social territorial intelligence. In ACM SIGGRAPH 2012 Posters, SIGGRAPH ’12
Pedica, C. and Vilhjálmsson, H. (2008)	Social perception and steering for online avatars. In Intelligent Virtual Agents, pages 104–116. Springer.
Salem, B. and Earle, N. (2000)	Designing a non-verbal language for expressive avatars. In Proceedings of the third international conference on Collaborative virtual environments, pages 93–101. ACM
Bradski, D. G. R. (2000)	Camera calibration with opencv https://docs.opencv.org/2.4/doc/tutorials/calib3d/camera_calibration/camera_calibration.html
Bradski, D. G. R. and Kaehler, A. (2008)	Learning Opencv, 1st Edition. O’Reilly Media, Inc., first edition.

Audience Engagement

Which discipline (or disciplines) do you develop models in? (Sociology, Economics, Ecology, Artificial Life, Health Sciences, etc.)

Responses
behavioural economics
political science
psychology
sustainability science
Crisis Management
disaster risk management
human /natural environment interaction
sociology
sociology
climate change adaptation
Environmental sciences

The Advanced Beginner

Model of Energy use in Households

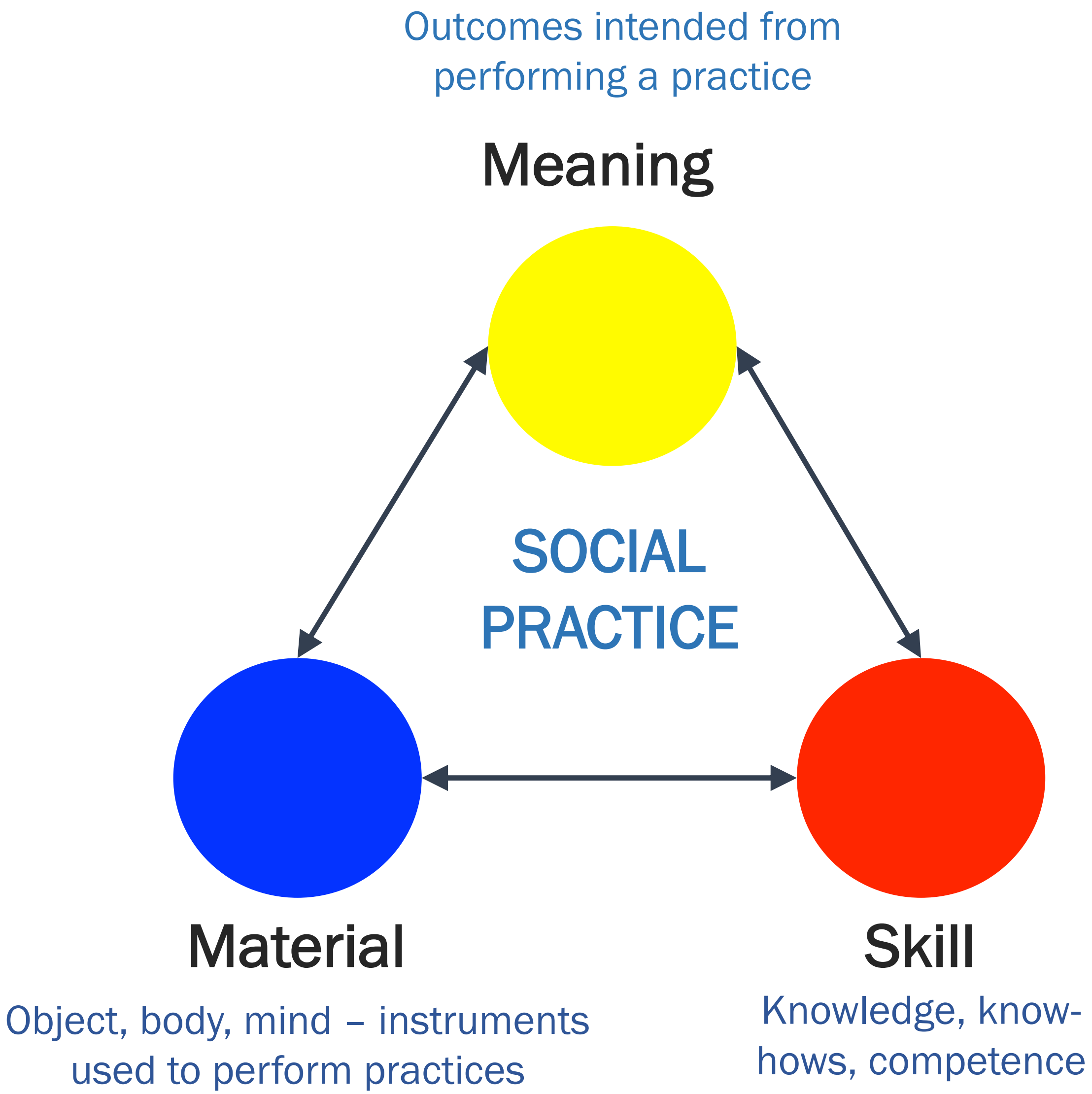
Departure to a Practice Theory Approach

- A move from Individuals (individual choice/nudges) to Practices; the unit of analysis is practices

- A body of work collectively referred to as theories of practice or social practice theory

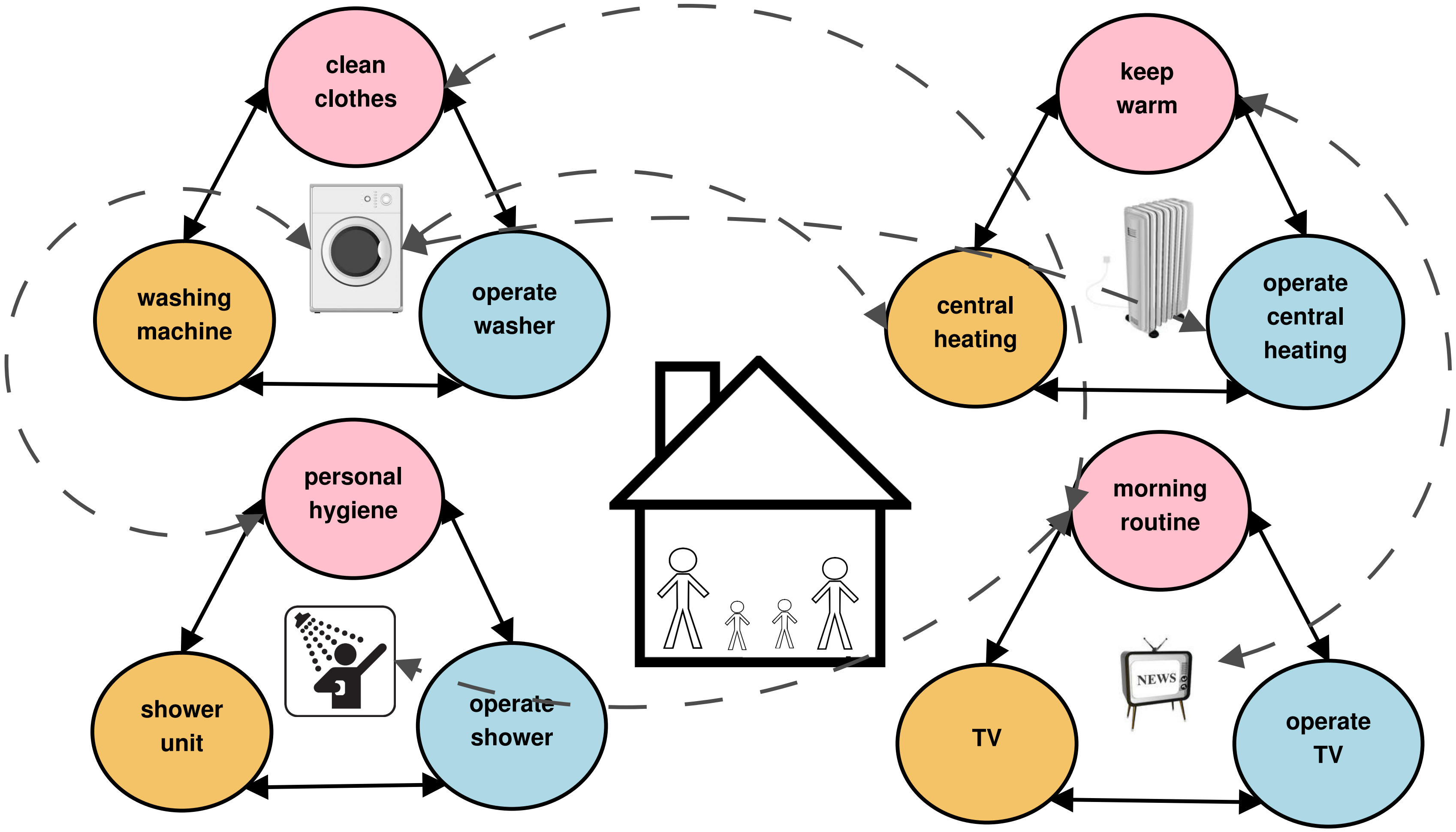
- Individuals might choose which practices to perform, but their choices are constrained by societal structures that shape and are shaped by the outcomes of human action

- Focus is on the performance, history and trajectories of practices

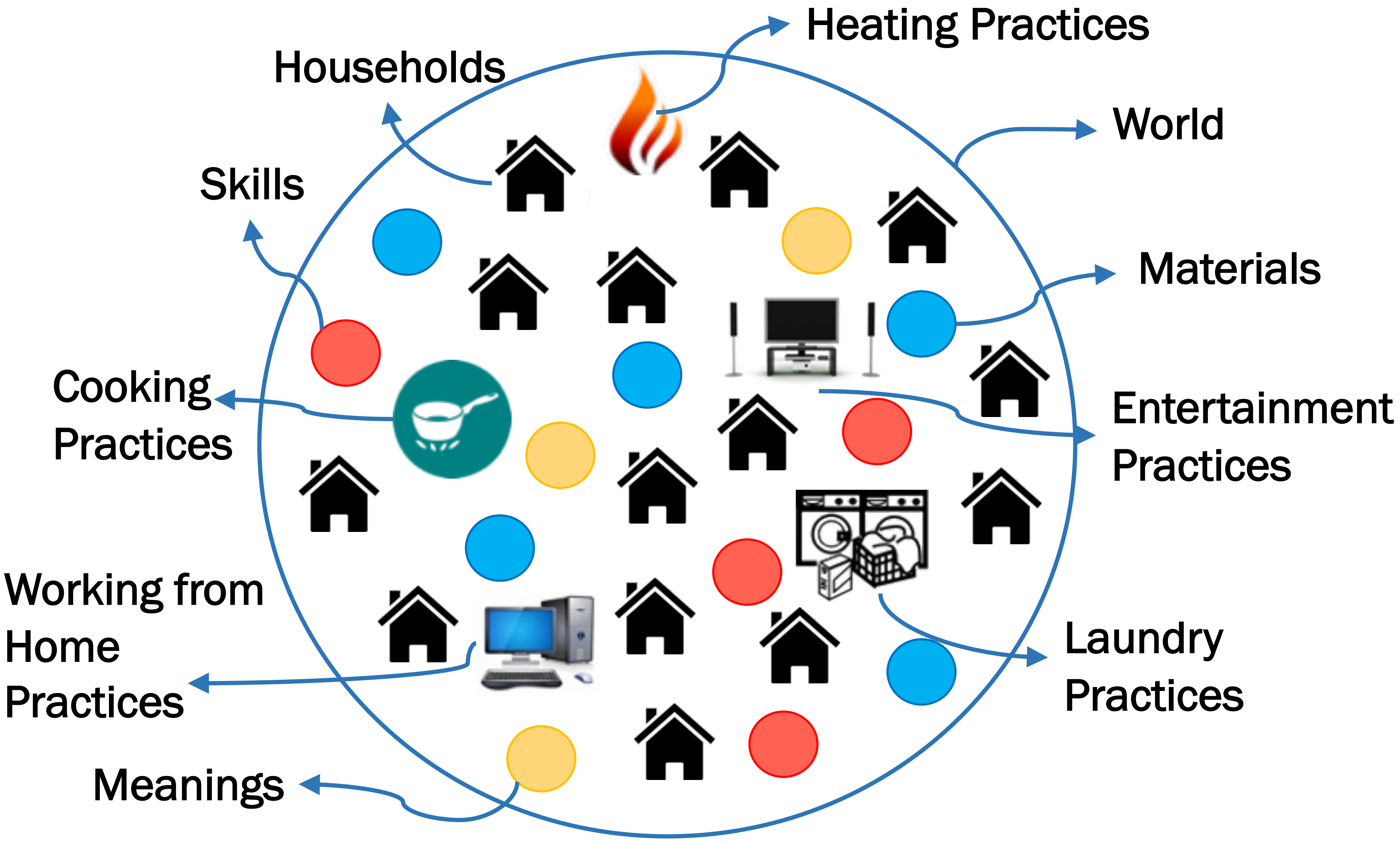


The interconnected performance of Practices

- A complex system of connections gets established between bundles (connected practices)
- Even the slightest change has a knock on effect across the network of links between practices



The HOPES model: Concept



Empirical basis for the model

Walking Interviews

- Researcher walks participants through their homes
- Participants talk about their daily routines using visual and verbal cues
- Participants talk about practices in the context they perform them

Web Survey

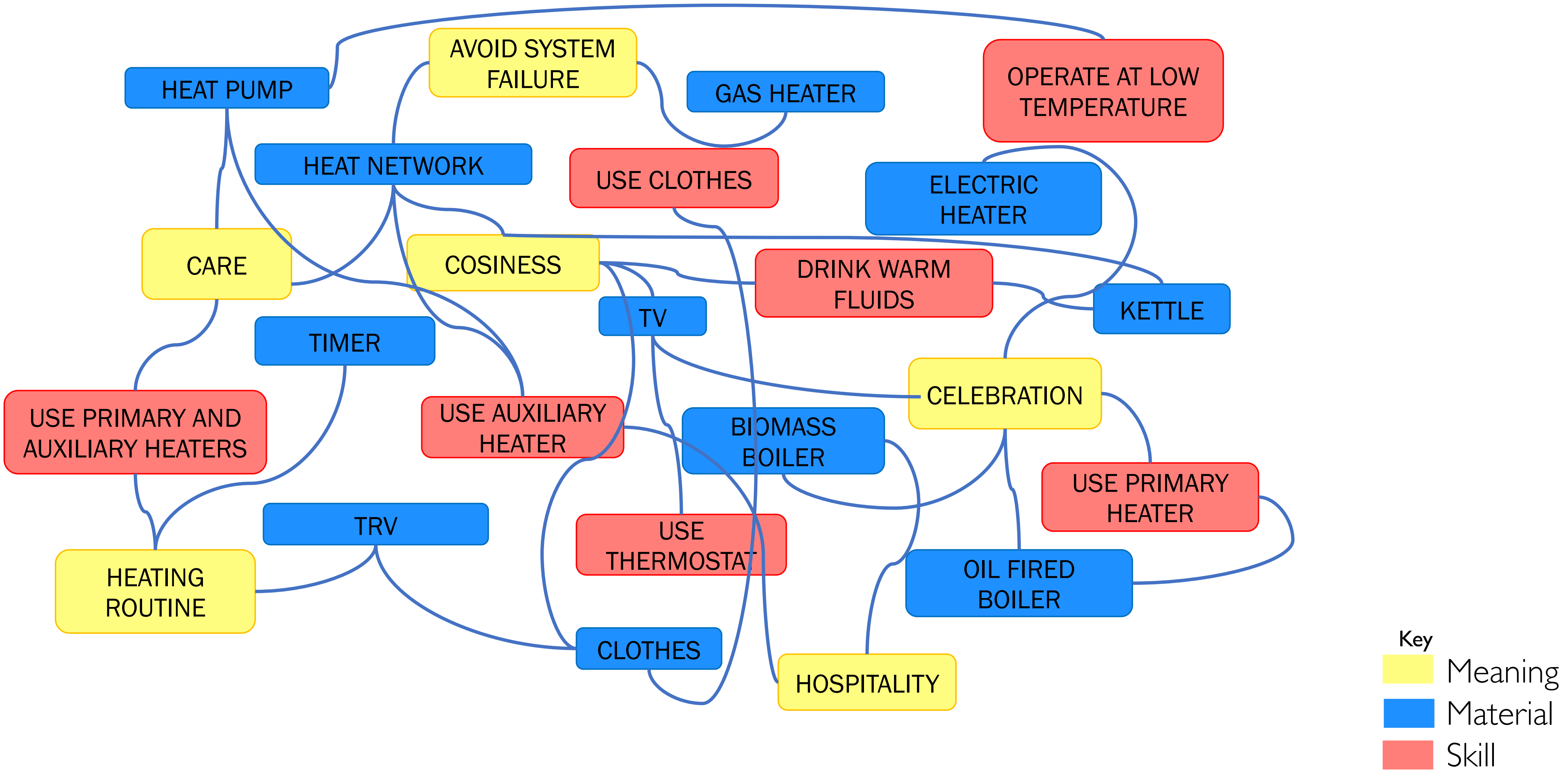
To gather information regarding

- People & their homes
- Energy consuming appliances
- Reflections regarding energy consuming activities

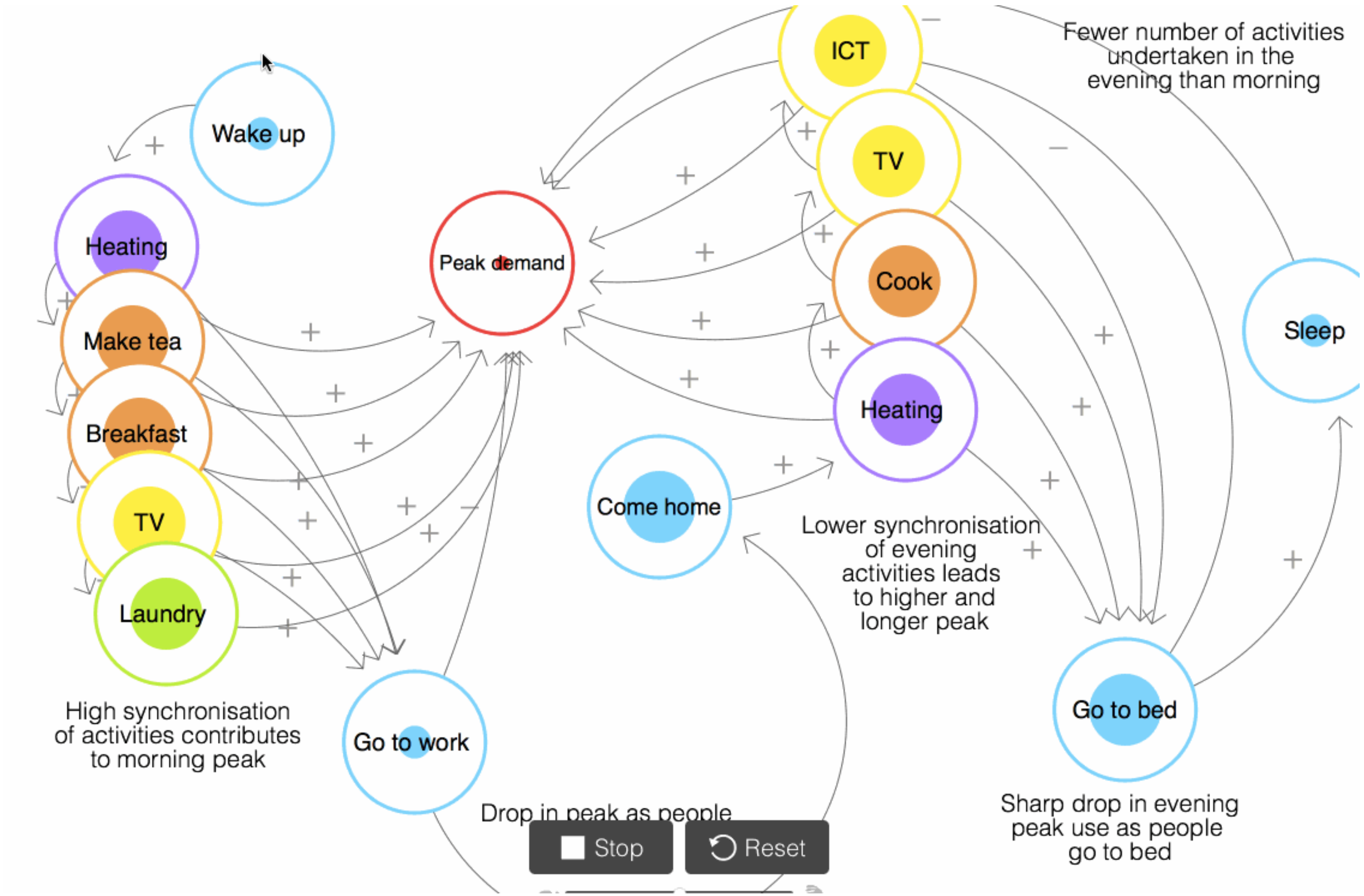
Energy monitoring in Households

- To gather energy usage data daily
- Includes both energy and gas monitoring data
- Monitoring individual appliances (e.g., washing machine) and appliance bundles (e.g., home entertainment)

Data: Links between Practices

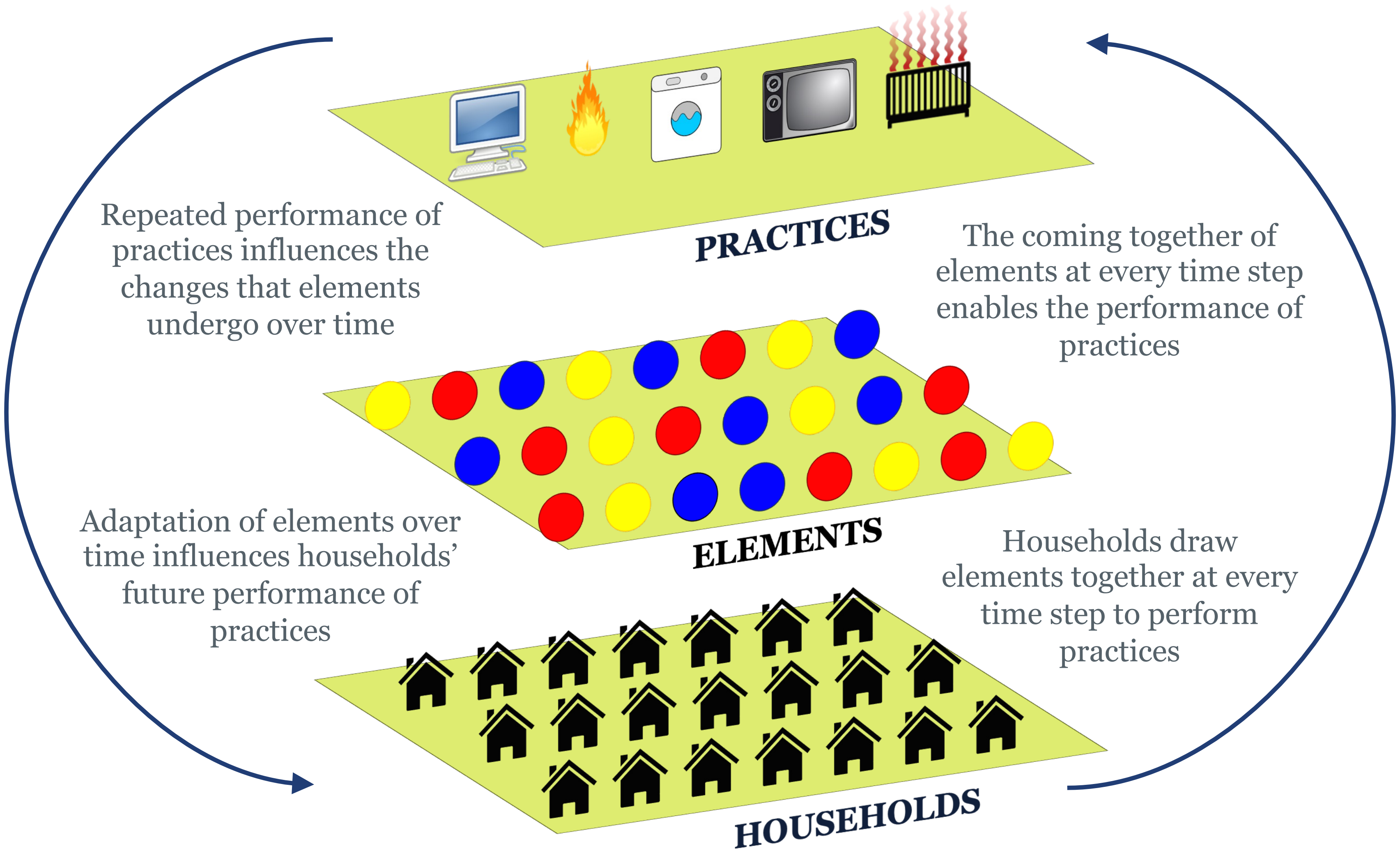


Data: Temporal Ordering of Practices



Model created using LOOPY https://ncase.me/loopy/

HOPES model: Implementation



HOPES implementation: First Part

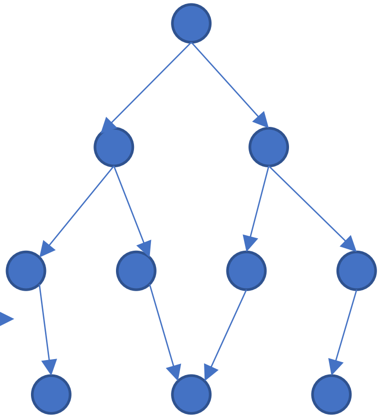
Walking Interviews

Survey

Reports

Household

Facts



Expert System: Rule Base and Inference Engine

Infer

Meaning
+
Material
+
Skill

Knowledge Engineering: Expert System

Households' choice of meaning, material and skills derived using a rule-based approach

Developed by organising qualitative data within HOPES

A rule-based system includes:

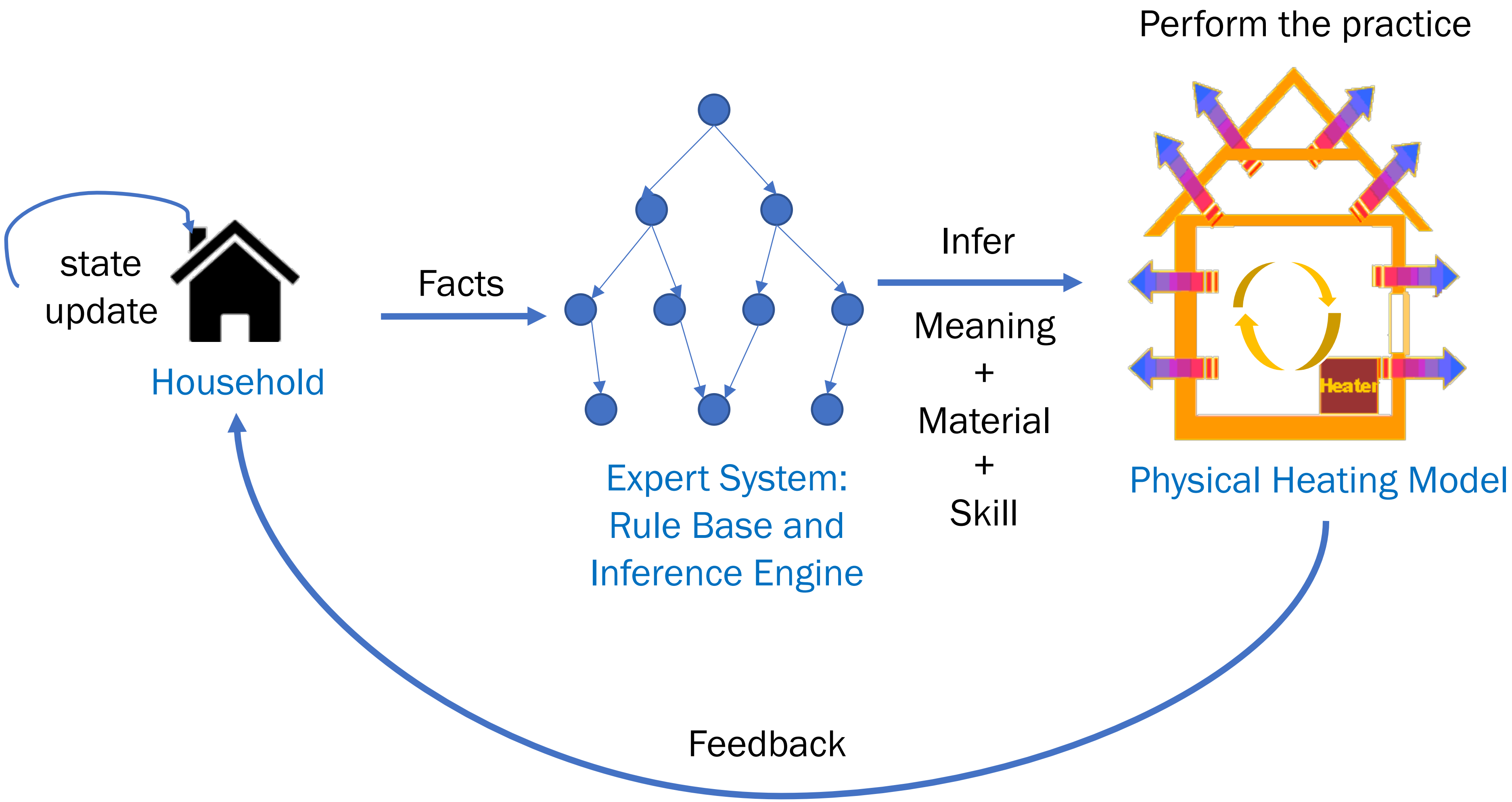
- working memory
- rule set
- matching scheme
- conflict resolution scheme

The rule-based system enables each household agent to make decisions based on individual preferences (initialised based on survey data) and interactions with other households in the system

```
(defrule check-requirement-met
(and (or (programmer (timer-enabled? ?m&:(= ?m "NO"))) (programmer (timer-enable
d? ?n&:(= ?n "YES"))))
(programmer (timer-on-now? ?o&:(= ?o "NO")))
(occupancy (at-home? ?p&:(= ?p "YES")))
(temp-diff (requirement-met? ?q&:(= ?q "YES"))))
=>
(bind ?*MOTIVATION-REQUIREMENT-MET* TRUE)
(assert (meaning-now (requirement-met-now? ?*MOTIVATION-REQUIREMENT-MET*)))
(bind ?*MEANINGS* (create$ ?*MEANINGS* "REQUIREMENT-MET"))
;; (printout t ?*MEANINGS* crlf)
;; (printout t "MEANING REQUIREMENT MET?" ?*MOTIVATION-REQUIREMENT-MET* crlf)
)


(defrule check-motivation-care
(and (or (programmer (timer-enabled? ?m&:(= ?m "NO"))) (programmer (timer-enable
d? ?n&:(= ?n "YES"))))
(programmer (timer-on-now? ?o&:(= ?o "NO")))
(occupancy (at-home? ?p&:(= ?p "YES")))
(temp-diff (too-cold? ?q&:(= ?q "YES"))))
=>
(bind ?*MOTIVATION-CARE* TRUE)
(assert (meaning-now (care-now? ?*MOTIVATION-CARE*)))
(bind ?*MEANINGS* (create$ ?*MEANINGS* "CARE"))
;; (printout t "MEANING CARE?" ?*MOTIVATION-CARE* crlf)
)


(defrule check-motivation-cosiness
(and (or (programmer (timer-enabled? ?m&:(= ?m "NO"))) (programmer (timer-enable
d? ?n&:(= ?n "YES"))))
(programmer (timer-on-now? ?o&:(= ?o "NO")))
(occupancy (at-home? ?p&:(= ?p "YES")))
(temp-diff (relatively-comfortable? ?q&:(= ?q "YES"))))
=>
(bind ?*MOTIVATION-COSINESS* TRUE)
(assert (meaning-now (cosiness-now? ?*MOTIVATION-COSINESS*)))
(bind ?*MEANINGS* (create$ ?*MEANINGS* "COSINESS"))
;; (printout t "MEANING COSINESS?" ?*MOTIVATION-COSINESS* crlf)
)

(defrule stopcase
(and (or (programmer (timer-enabled? ?m&:(= ?m "NO"))) (programmer (timer-enable
d? ?n&:(= ?n "YES"))))
```

Expert System implemented in JESS
https://en.wikipedia.org/wiki/Jess_(programming_language)

HOPES implementation: Performance of Practices



$$m_{roomair} = H_{floorarea} \times H_{ceilingheight} \times \rho_{air}$$

$$m_{heaterair} = \frac{H_{heateroutput} \times H_{boilerefficiency}}{C_{water} \times (T_{heater} - T_{room})} \times 3600$$

$$\frac{dQ_{gain}}{dt} = m_{heaterair} \times c_{air} \times (T_{heater} - T_{room})$$

$$\frac{dQ_{loss}}{dt} = \frac{H_{floorarea} \times (T_{room} - T_{outdoor})}{H_{rvalue-floor}} + \frac{H_{floorarea} \times (T_{room} - T_{outdoor})}{H_{rvalue-ceiling}} + \frac{\left(\frac{H_{floorarea}}{20}\right) \times (T_{room} - T_{outdoor})}{H_{rvalue-window}} + \frac{\sqrt{H_{floorarea}} \times 4 \times H_{ceilingheight} \times (T_{room} - T_{outdoor})}{H_{rvalue-wall}}$$

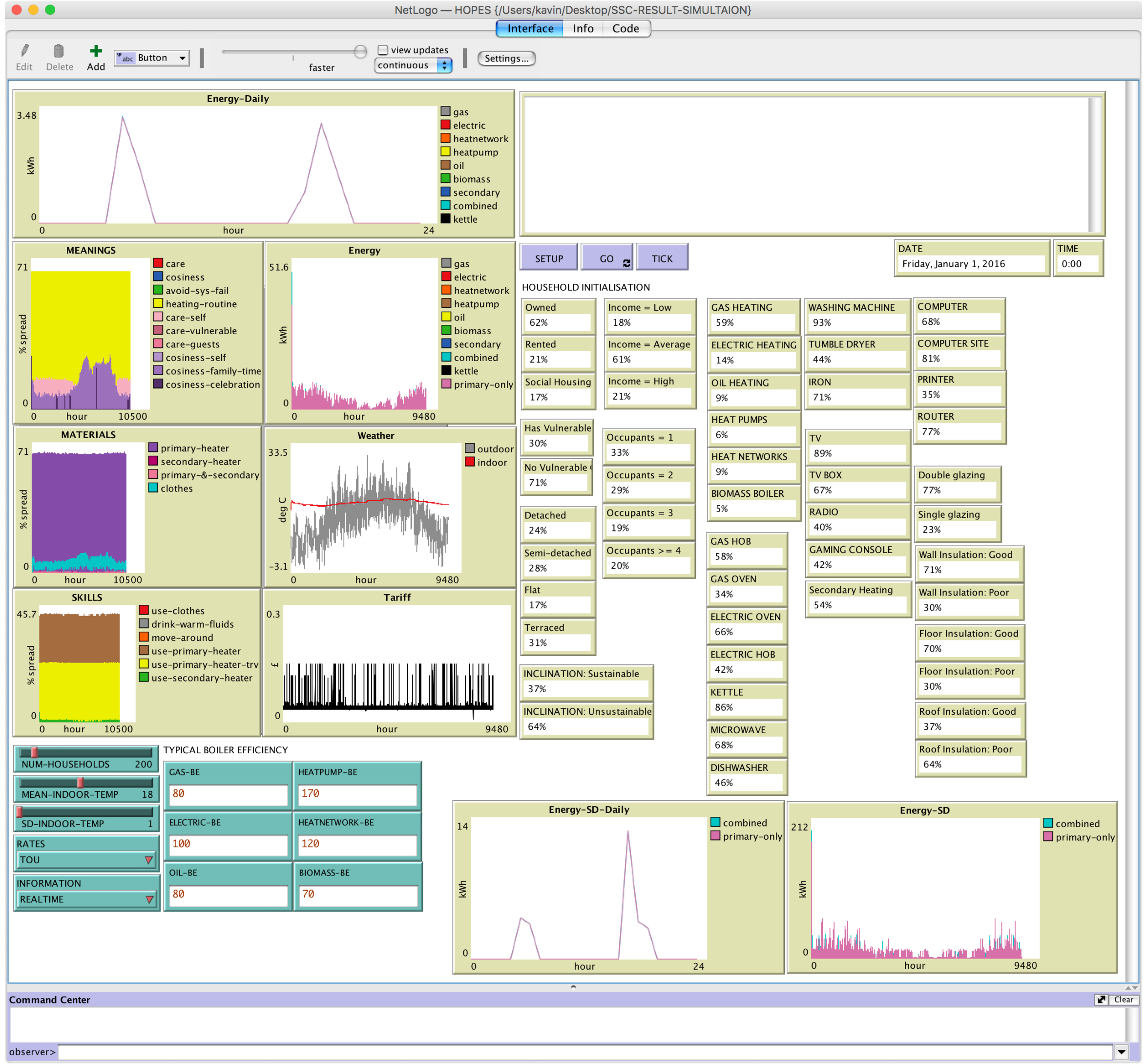
Rate of Temperature Change in the Room

$$\frac{dT_{room}}{dt} = \frac{1}{m_{roomair} * c_{air}} * \left(\frac{dQ_{gain}}{dt} - \frac{dQ_{loss}}{dt}\right)$$

See https://doi.org/10.15126/900313

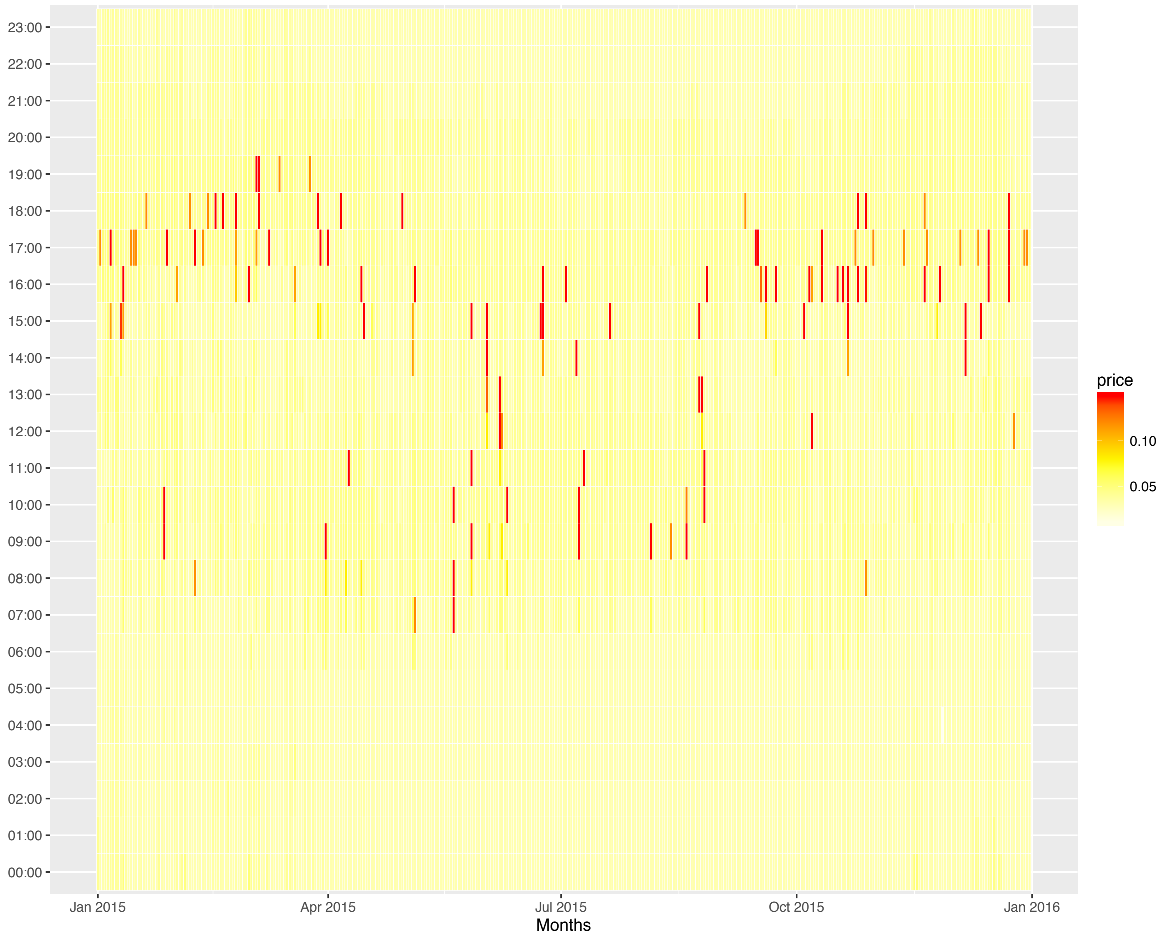
HOPES NetLogo Interface

- HOPES implemented in NetLogo
- Expert System implemented in JESS
- Interfaced with NetLogo using Extension https://github.com/Immoniz/NetLogoJess
- Reasonably detailed initialisation of socio-demographic information, building & appliance characteristics
- Each model time step is an hour; each model run is for a year
- Experiment: to compare heating consumption of households under a flat rate and time-of-use tariffs (ToU) scenario

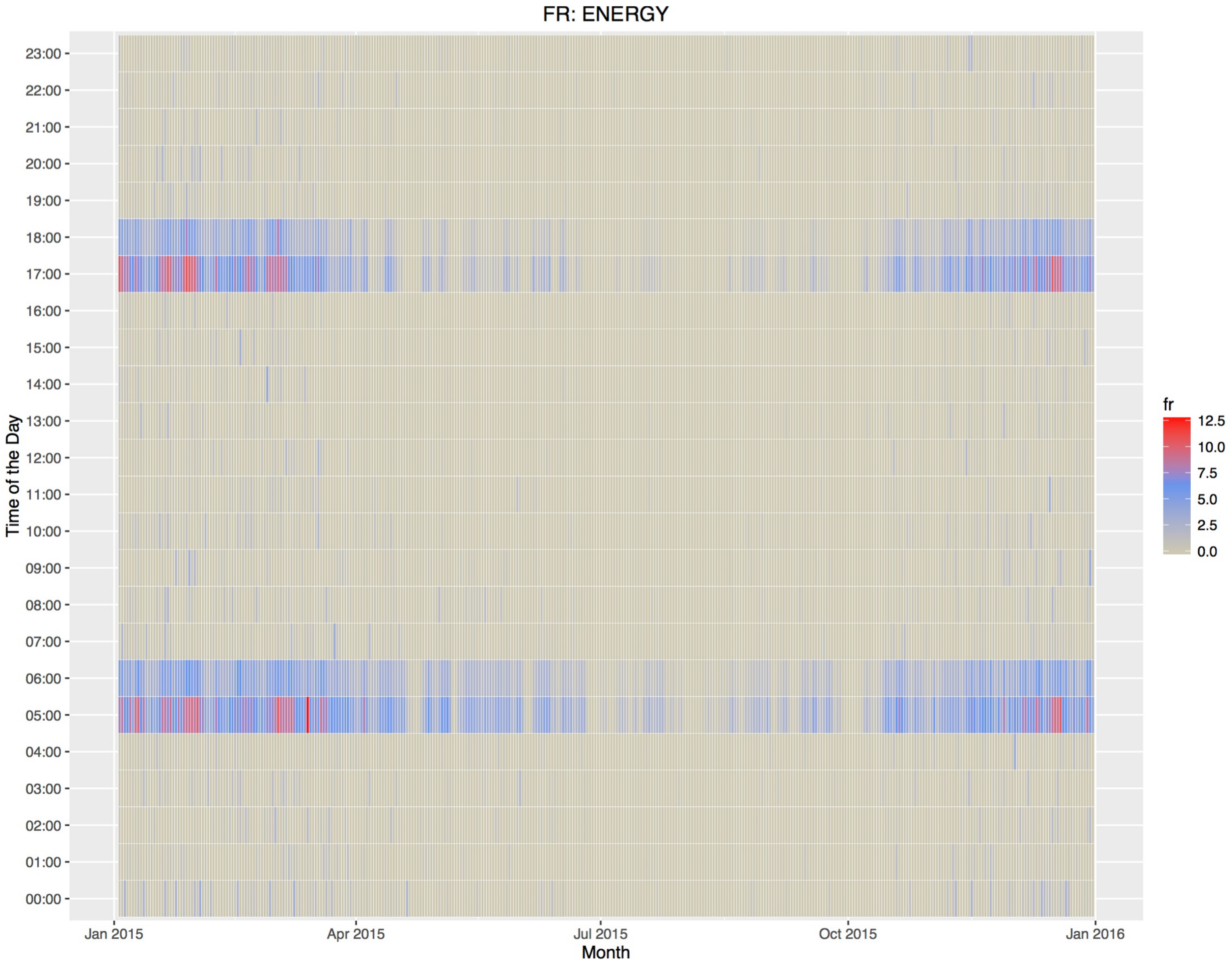


HOPES Experiment: Price Signals data

- **WeSIM:** a comprehensive electricity system analysis model that enables optimal decisions for investing into generation, network and/or storage capacity, in order to satisfy in real-time supply-demand balance in economically optimal ways and ensuring security of supply;
- Prices generated by running WeSIM with an assumption that demand is inflexible as by-products of an optimisation that WeSIM carries out;
- At each time step, Households in HOPES make a simple decision of classifying an incoming price signal as low (Tariff = low) or high (Tariff = high) by comparing it with the value of the tariff at the previous time step

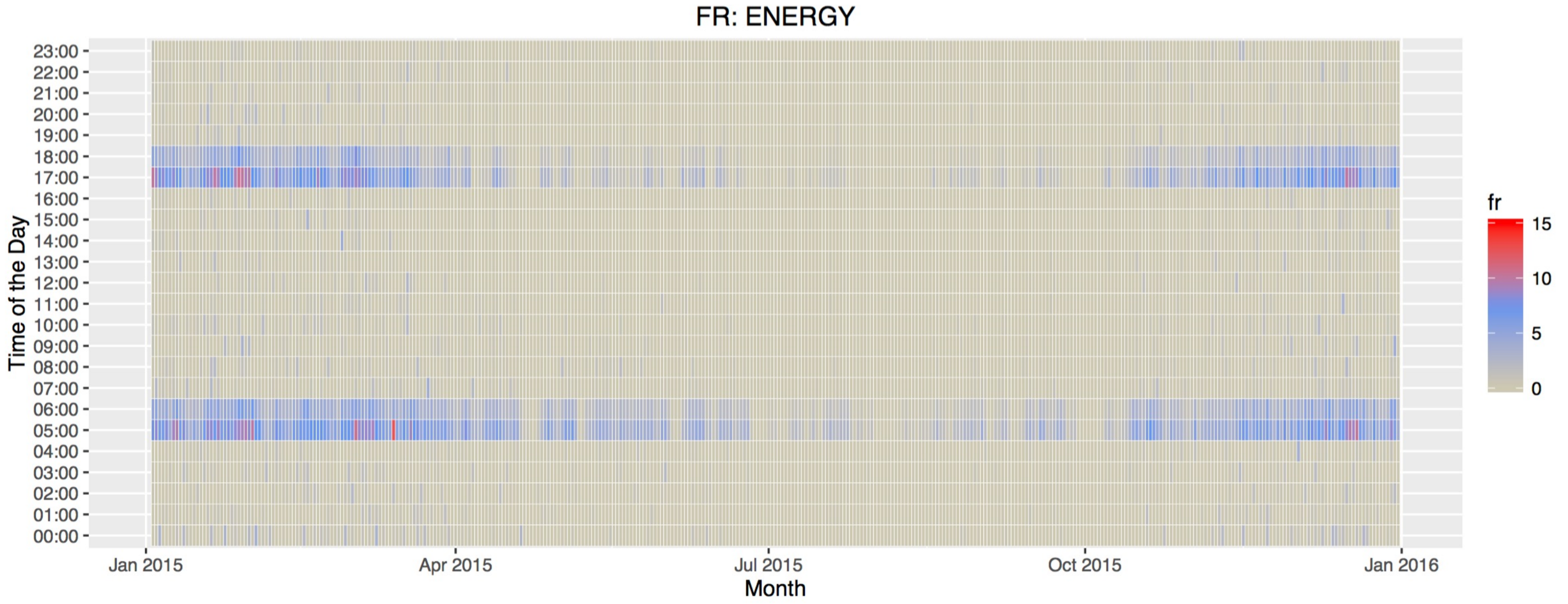


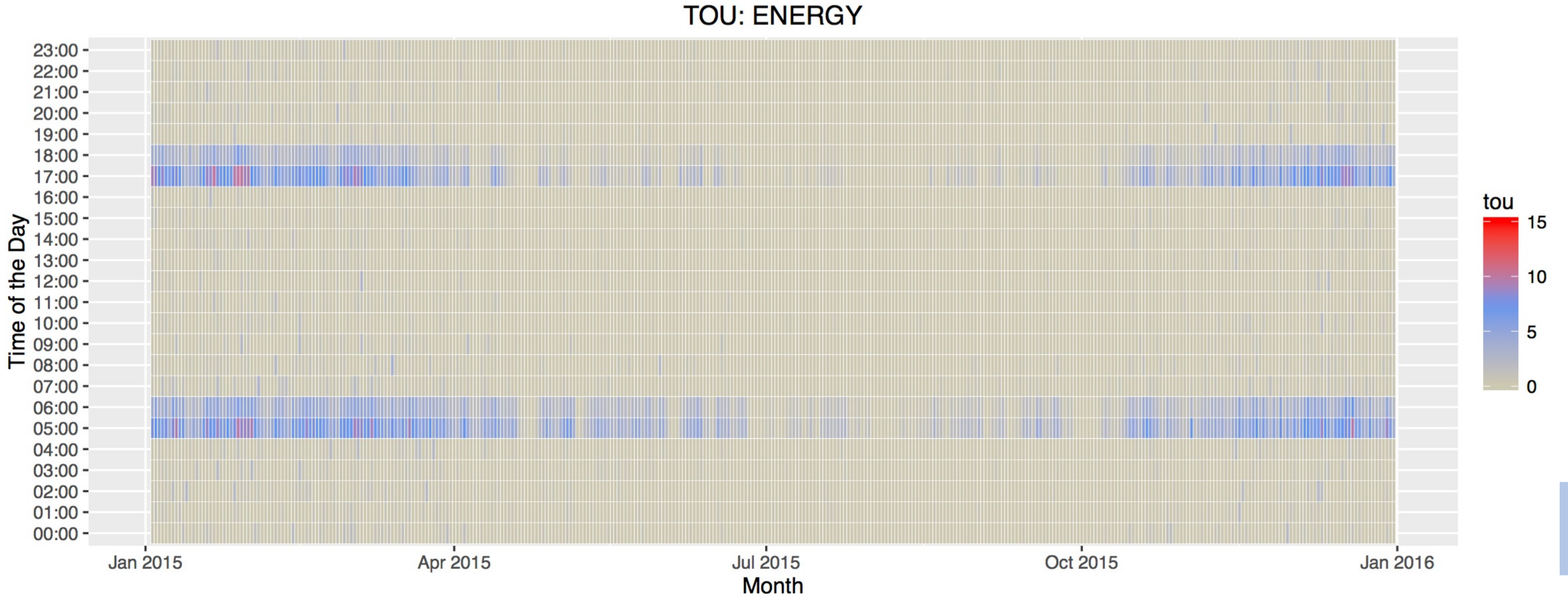
Heating Consumption in a Flat Rate Scenario



Heating Consumption: FR vs ToU

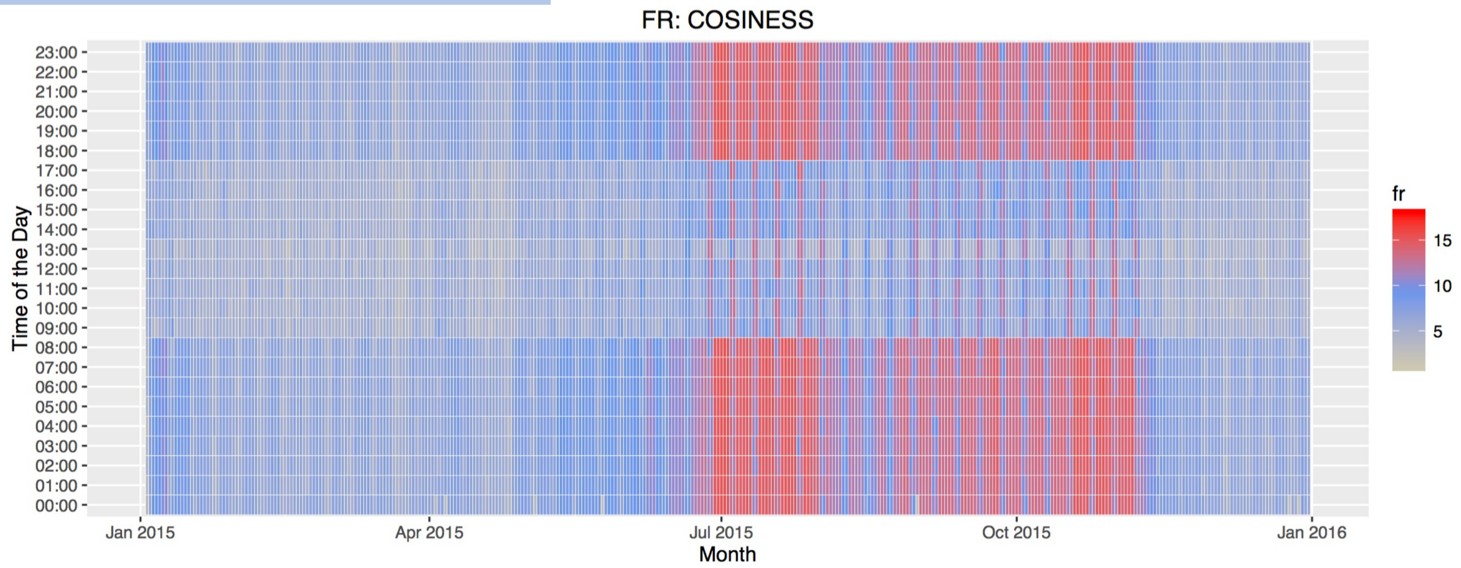
TOU does not result in a great deal of energy reduction; Sometimes, the average hourly energy use of households is equal to or higher than the FR scenario

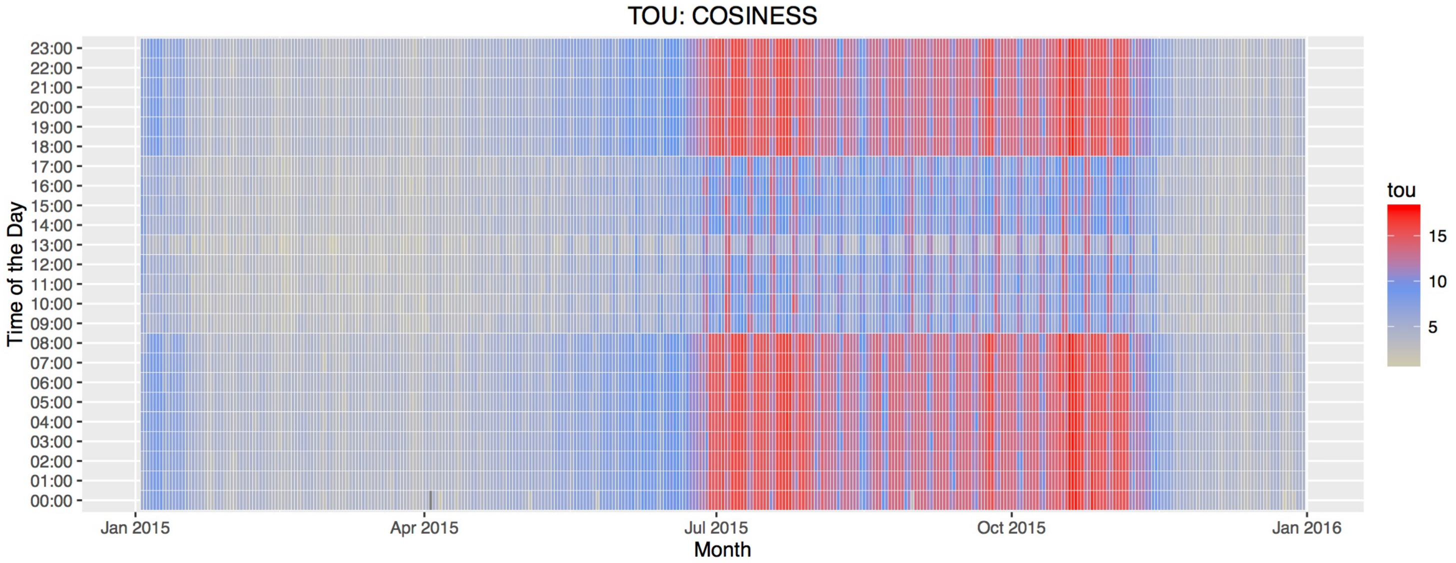




Practices-focused explanation of result

Responding to Peak Prices in the ToU Scenario makes Heating a Necessity (Meaning = Requirement) rather than a Comfort (Meaning = Cosiness) at other times of the Day





Some conclusions

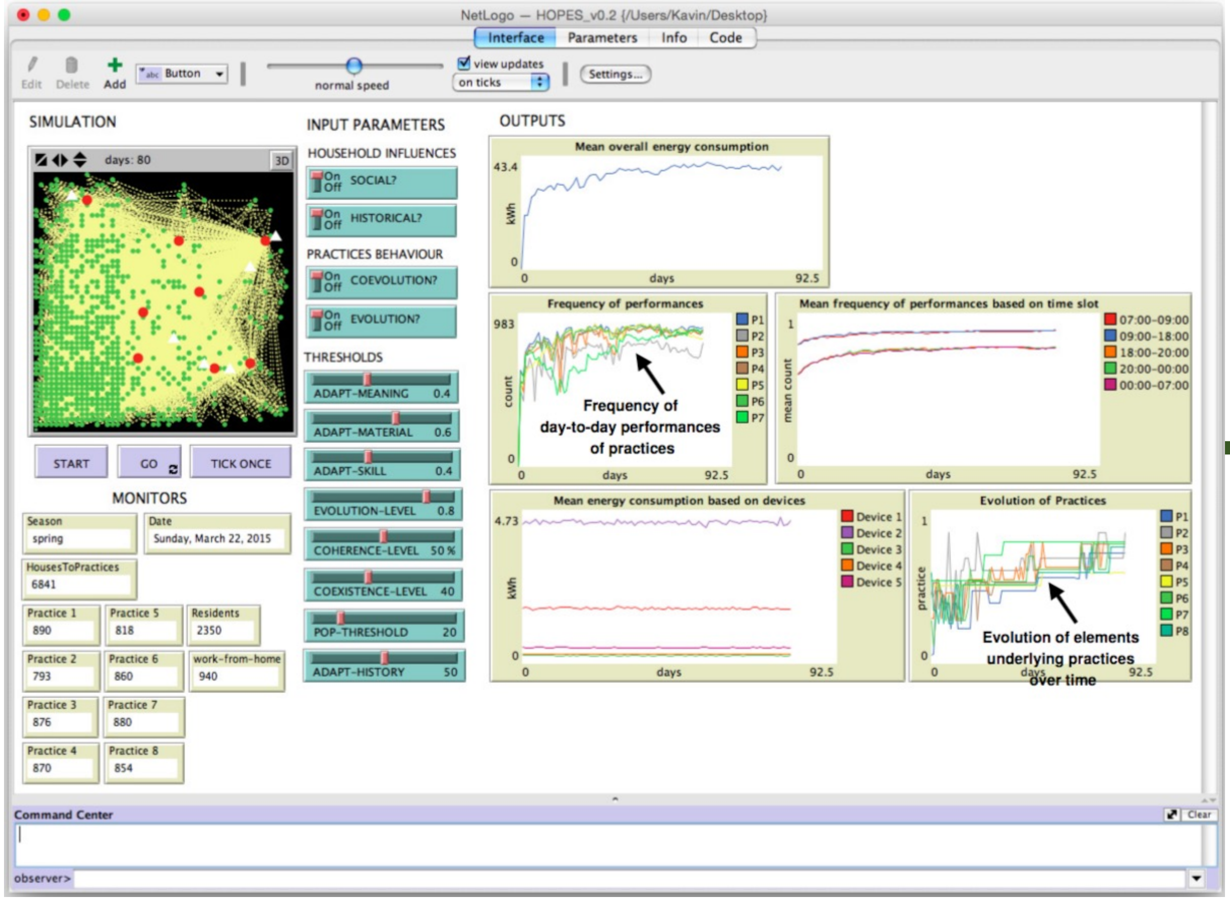
HOPES is an empirically-based practice-centric model of energy use in households, which

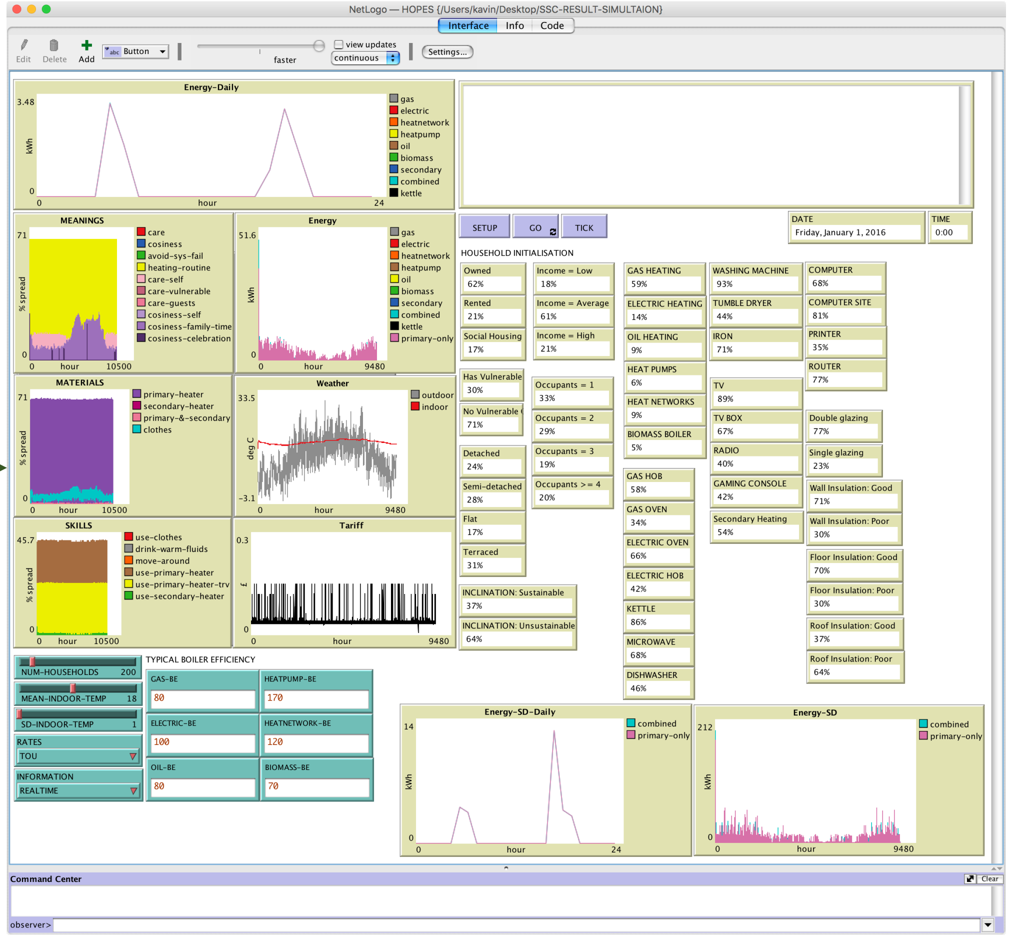
- is a contribution to overcome criticisms of the abstract nature of the theory
- has an expert system approach to improve model transparency and tractability
- is a logical tool to uncover some of the non-rational, routine and highly contextualized motivations for energy use in households, i.e., demystifying the demand sector

References Part II

Narasimhan et. al 2018 [HOPES]	Demystifying Energy Demand using a Practice-centric Agent-based Model https://doi.org/10.15126/900313
Gilbert et al. 2018 [HOPES]	Computational modelling of public policy: Reflections on practice https://www.jasss.org/21/1/14/14.pdf
Shove et al. 2012	The dynamics of social practice: Everyday life and how it changes. Sage publications.
LOOPY systems thinking tool	https://ncase.me/loopy/
JESS Rule Engine	http://alvarestech.com/temp/fuzzyjess/Jess60/Jess70b7/docs/index.html
NetLogo JESS extension	https://github.com/Immoniz/NetLogoJess

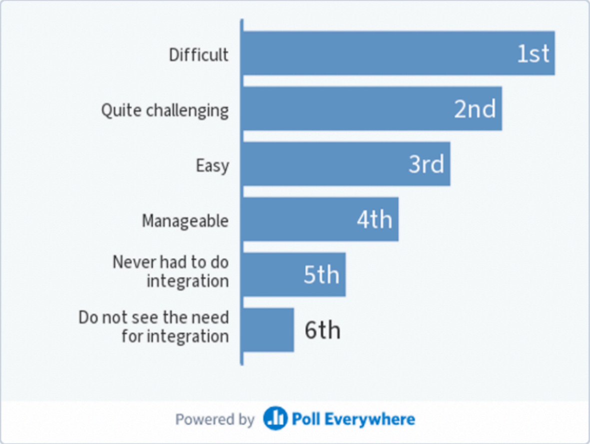
Reflection: Thinking about Policy Applications





Audience Engagement

How easy have you found it integrating agent-based models with other modelling approaches?



Response options	Rank
Difficult	1st
Quite challenging	2nd
Easy	3rd
Manageable	4th
Never had to do integration	5th
Do not see the need for integration	6th

Audience Engagement

What is the most exciting stage when developing a social simulation?

“ Thoroughly characterizing the model and finding out what might be artefacts ”

“ validation and calibration ”

“ building the model ”

Powered by Poll Everywhere

Responses
Thoroughly characterizing the model and finding out what might be artefacts
validation and calibration
building the model
Conceptualization/formalization
model design and thoery + data analysis in the deisng phase
When the model runs without crashing!
making the mental model
playing with it at the start before you get serious with it ;-)
conceptual modelling
design

Audience Engagement

What is the most challenging stage when developing a social simulation?

“ analysing and presenting results ”

“ getting the data one needs ”

“ Thoroughly characterizing the model and figuring out what might be artefacts ”

Powered by Poll Everywhere

Responses
analysing and presenting results
getting the data one needs
Thoroughly characterizing the model and figuring out what might be artefacts
Debugging
validation and calibration
bug fixing
validation
design
Conceptualization
validation

The (Competent) Cheerleader

Model of Community-based Water Management

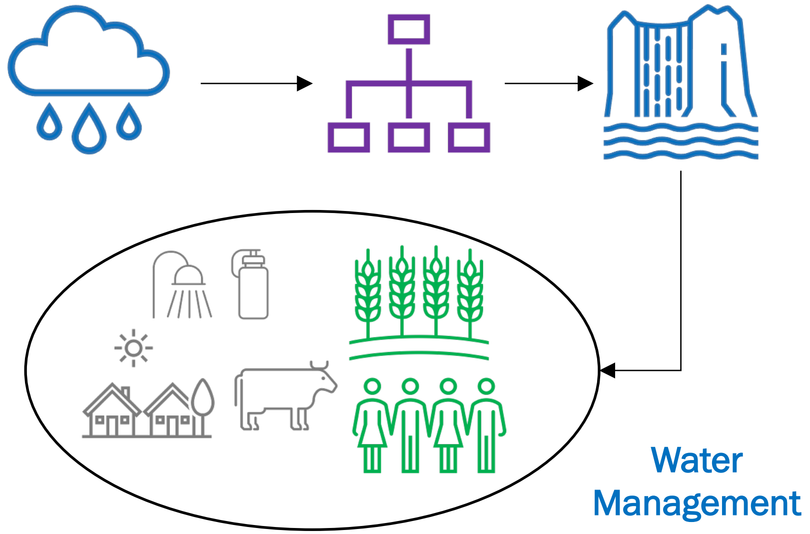
Decentralised Water Management: Background

- Huge investments in large-scale centralised irrigation systems in the 1950s and 60s

- Systems failed or underperformed due to improper planning, poor maintenance and overlooking local needs and traditions

- Irrigation management reforms in the 1970s

- Further push for decentralisation of water management in the 1990s Integrated Water Resources Management (IWRM) paradigm



Bali Rice Terrace

Lansing and Kremer, 1993; Wijermans and Schlüter, 2014

Water User Associations (WUAs)

WUAs are small-scale semi-formal or informal institutions with mandates like:

- Allocate water to users
- Operation & Maintenance of irrigation system
- Collect fees and fines

WUAs often struggle to fulfil mandates

- Expectation: irrigation performance -> agricultural productivity -> cost recovery -> user participation
- Disruptions: limited finances, management & technical expertise; inadequate inputs & market provisions; conflicting water uses

Surface irrigation.
Image credits Prof. Eric Ofosu Antwi
https://rcees.uenr.edu.gh/profile-dr-antwi-ofosu-eric/

Need to improve WUAs: Our Research

- Significant failures of irrigation schemes, but ongoing efforts to expand irrigation and introduce WUAs in sub-Saharan Africa

- Need to understand how WUAs work and explore management options to improve outcomes

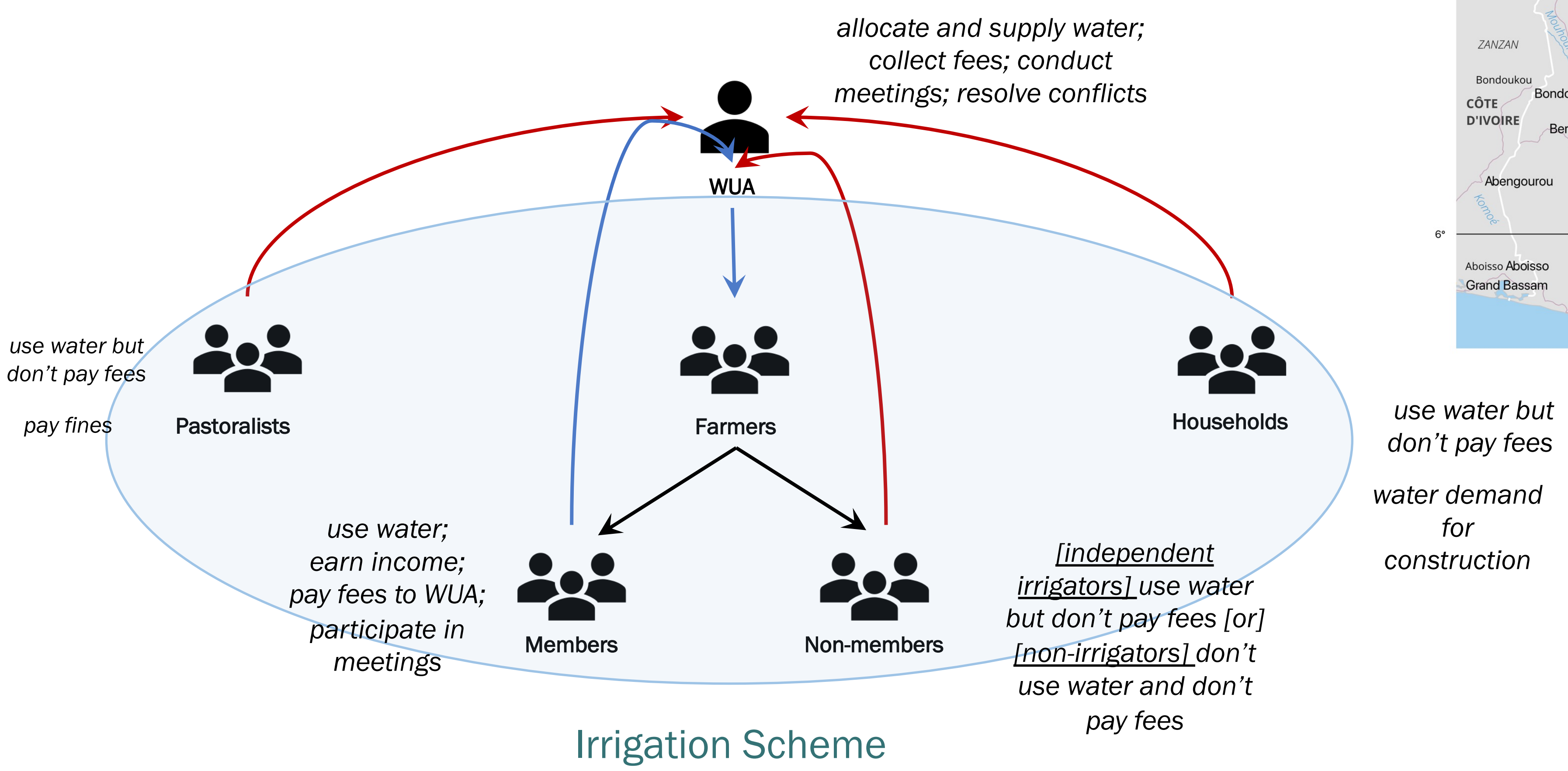
- Real-world experiments are expensive and time-consuming; computer simulations provide a tractable alternative

- **Question #1:** How does participatory irrigation management through WUAs work?

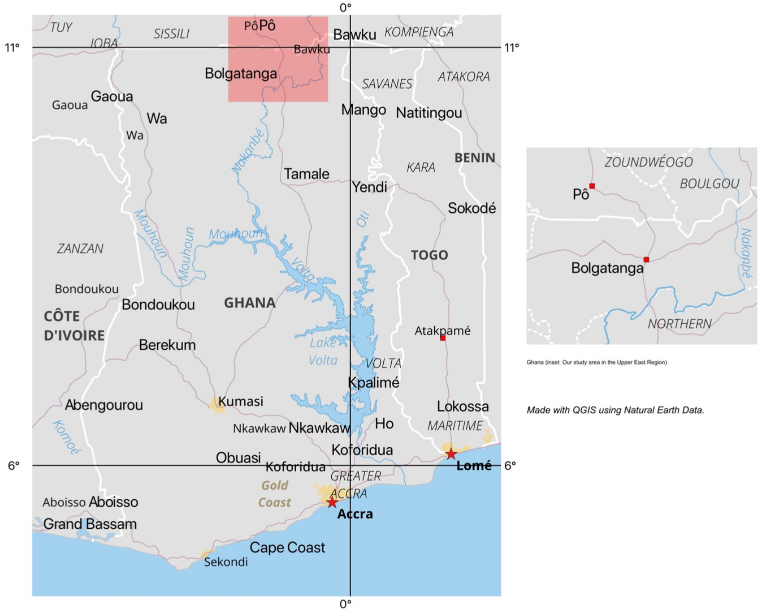
- **Question #2:** Which management option is better for improving the economic productivity of water users and WUA?

@kavinpreethi k.narasimhan@surrey.ac.uk

Decentralised Water Management through WUA



Key
WUA members
Sub-categories of Farmers
Not WUA members



Study Area: Bolgatanga, Upper East Region, Ghana

@kavinpreethi k.narasimhan@surrey.ac.uk SocSimFest2022

The WATERING model

- WATER user associations at the Interface of Nexus Governance
- A tool to explore and plan community-level water management:

  understand and explain the combined influence of WUA policies and community participation on water use and incomes in an irrigation scheme
- Agents are farmers, pastoralists, households and WUA
- The environment is a simulated irrigation scheme; built infrastructure (comprising of a reservoir and canal network)
- Social environment: neighbouring water users influence each other

WATERING: WUA Agent Actions

- Each year, WUA estimates annual water demand by month based on the cropping patterns of farmers
- Each month, WUA allocates water to members (proportional to their demand) based on the amount of water available in the scheme
- WUA collects fees from members
- WUA collects fines from water users, e.g., when livestock destroy crops
- WUA uses its income for Operation & Maintenance, e.g., to repair canals
- WUA loans money to members affected by income loss

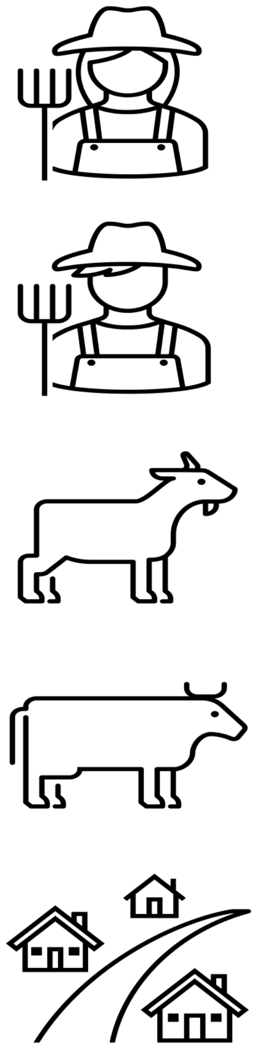
WATERING: WUA Management Policies

Options	Values	Meaning
Membership	Exclusive	Only scheme farmers can be WUA members
	Inclusive	Scheme farmers, Pastoralists and Households can be WUA members
Water allocation	Upstream downstream divide	Upstream users get water first followed by downstream users
	Equity	Water is divided equally across the scheme
Strictness	Enforce	Full restriction on water use beyond quota
	Incentivise	Limited restriction on water use beyond quota
	Relaxed	No restriction on water use beyond quota

WATERING: Water Users’ Reactive Behaviour

Every month, each water user:

- Adopts a reactive behavioural stance (cp or ncp)
- Calculates a utility to cooperate (Ui) with WUA’s quotas based on:
  - their own behavioural stance (cp or ncp)
  - the behavioural stance of their neighbours
  - WUA’s strictness (enforce, incentivise or relaxed)
- Calculate actual reduction in water demand based on Ui



Reduction in water demand has a proportionate effect on water users:

- less water results in reduced crop yields and lower income
- less water for livestock results in poor health or death

@kavinpreethi k.narasimhan@surrey.ac.uk

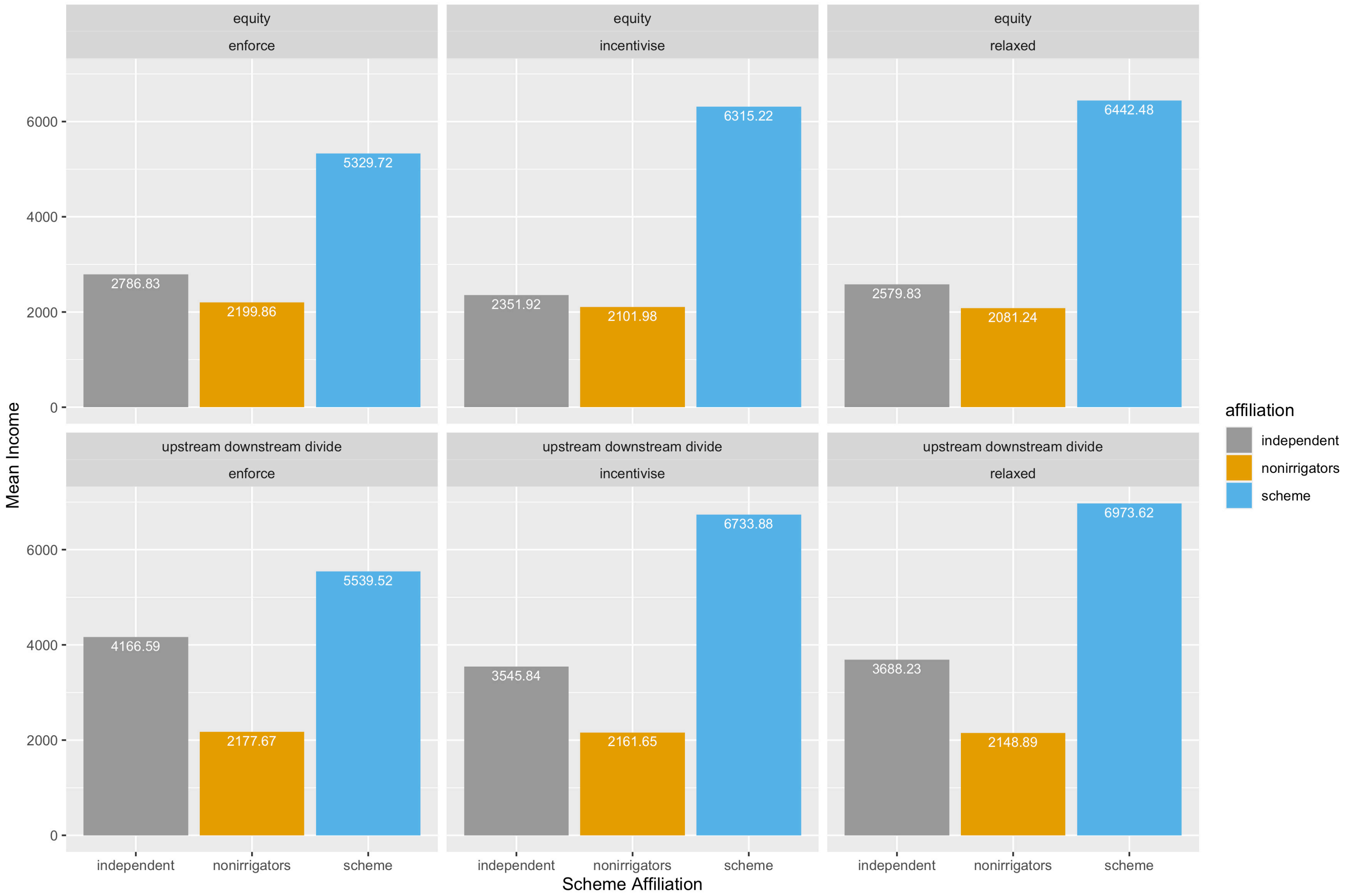
WATERING Simulations

Model Settings	Options	Values
WUA water allocation	2	Upstream-downstream divide Equity
WUA strictness	3	Enforce Incentivise Relaxed
WUA Membership	2	Exclusive to scheme farmers Inclusive of all member water users
Livestock damage?	2	TRUE: Livestock damage canal and crops FALSE: Livestock don’t cause any damage
Irrigation events	NA	No. of irrigation events each month: 30 Duration of each irrigation event: 6 Discharge rate: 8 m3/s Irrigation allocation: 60% of water at source Scheme efficiency: 0.6

Results: Income of Farmers

Summary:

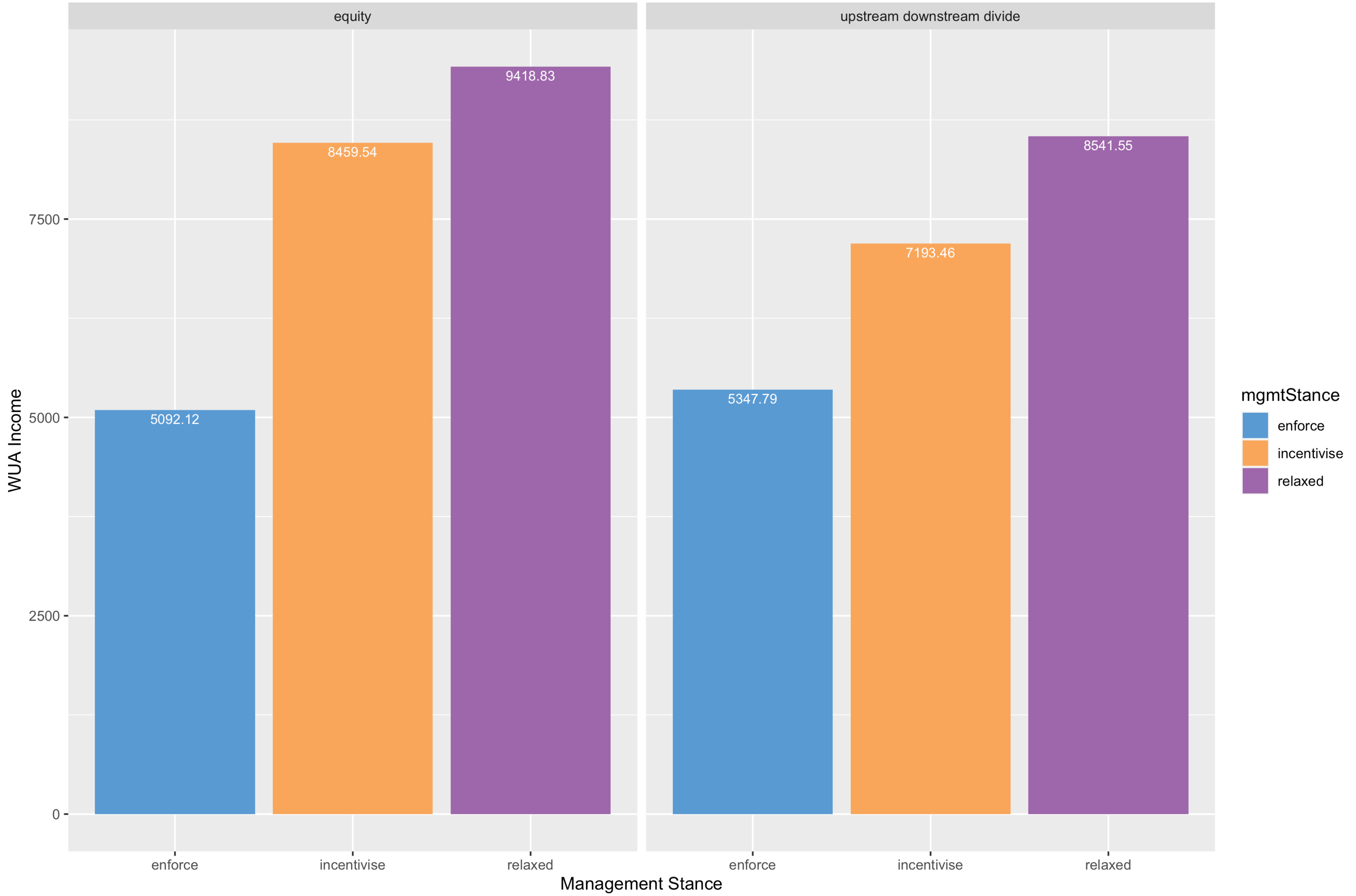
- Scheme farmers earn more than independent irrigators and non-irrigators (expected)
- Non-irrigators earn the least (expected)
- Farmers earn more with an upstream-downstream water sharing arrangement (also expected)
- Scheme farmers earn more when WUA is relaxed; (conversely) Independent irrigators earn more if WUA is strict – unexpected!



Results: Income of WUA

Summary:

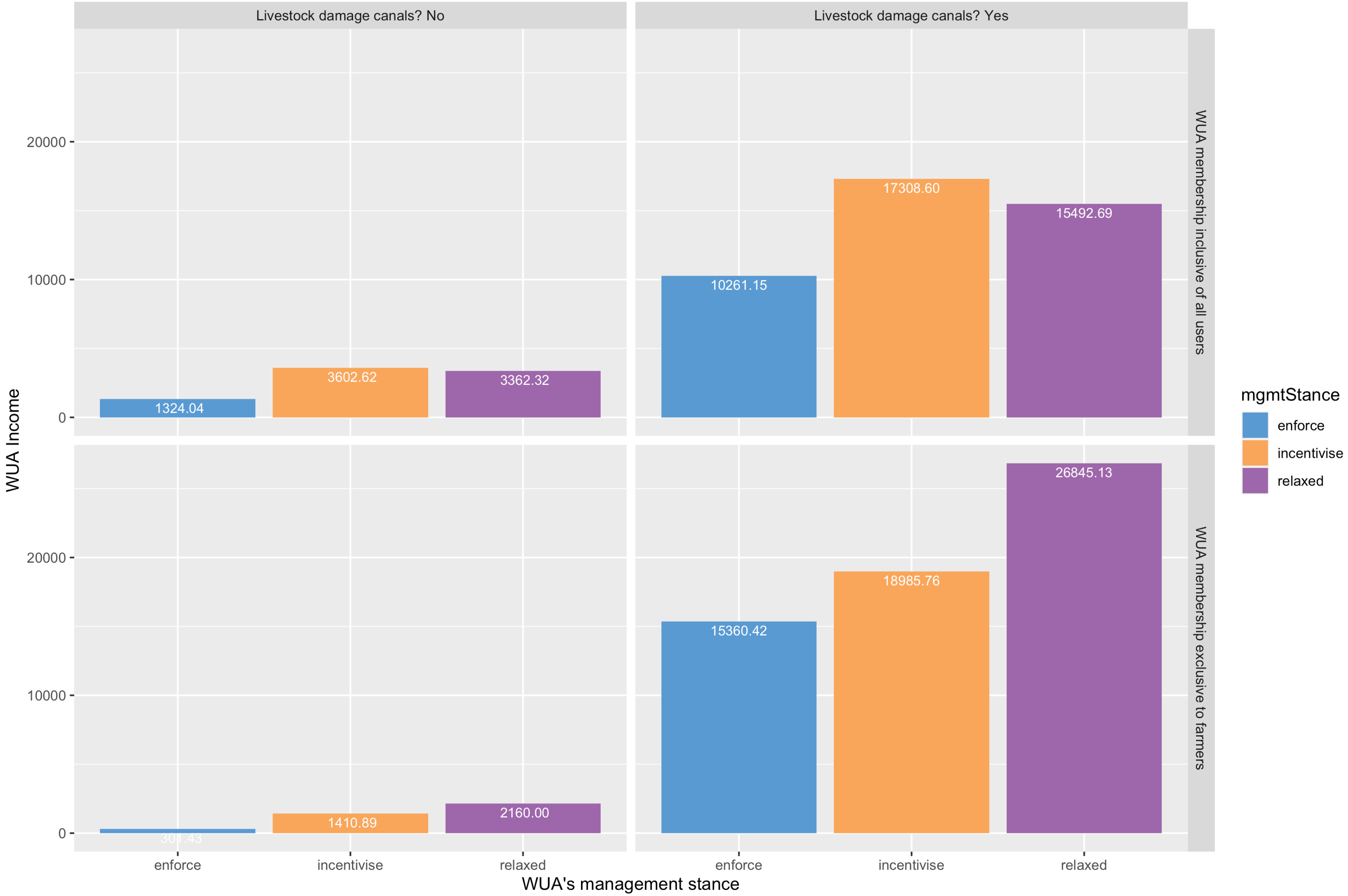
- Trend is reversed for WUA income based on water sharing – WUA earns more under an equity arrangement, because more users make marginal profit compared to fewer users making greater profit (in the upstream-downstream scheme)
- It is also in WUA's interest to be more relaxed with its water allocations (avoid strict rationing) to improve income
- With strict rationing, adopting an upstream-downstream water sharing policy might favour WUA income



Results: WUA membership dynamics

Summary:

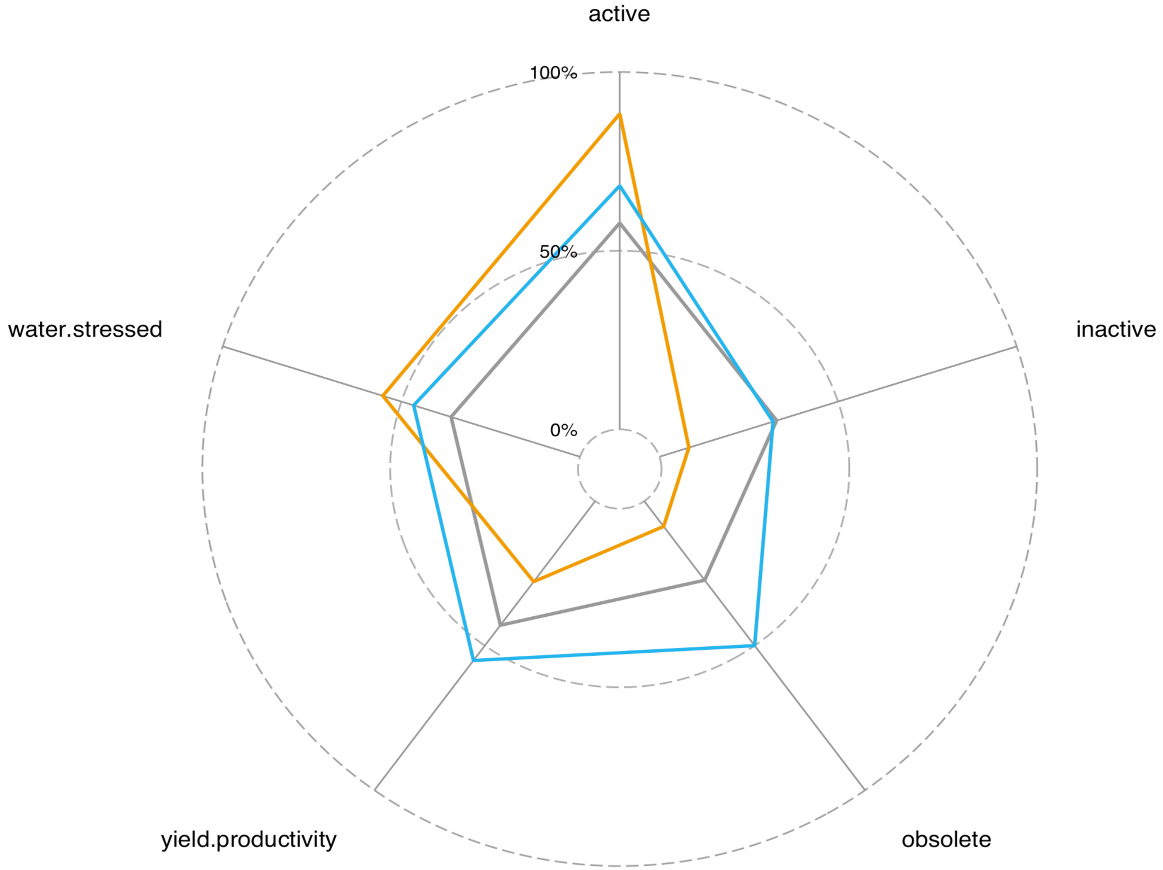
- WUA has more income if livestock damage canals; counter-intuitive result; stems from assumption that WUA recovers fines from pastoralists if livestock damage canals
- If livestock damage canals and WUA membership is exclusive to farmers, WUA has more income due to fewer and lower payouts to support members
- If livestock don’t damage canals, WUA has more income if membership is inclusive of all water users



Results: Economic Productivity

Summary:

- Even if their income is low, non-irrigators remain more economically active than scheme farmers and independent irrigators as they have no water use costs
- Scheme farmers are more water stressed than independent irrigators
- Scheme farmers have the highest yield productivity (crops harvested per unit of water consumed) compared to independent irrigators and non-irrigators



Radar chart showing the performance of:

- scheme farmers (blue)
- non-irrigators (orange)
- independent irrigators (grey)

against different measures

What Next?

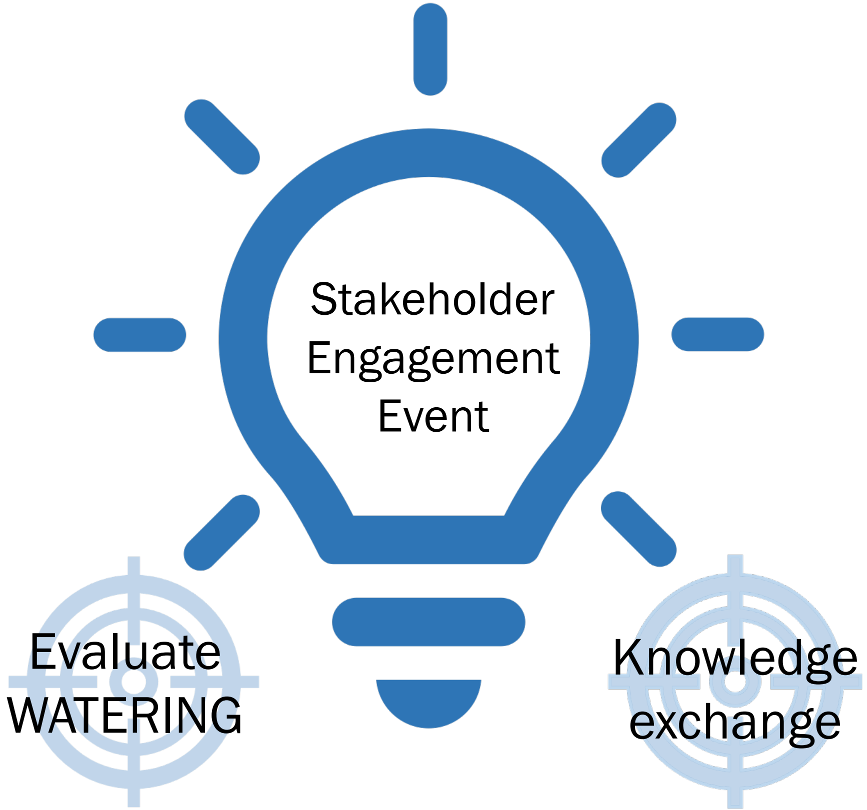
IS WATERING DOING THE RIGHT THINGS?

IS IT MISSING KEY ELEMENTS AND DYNAMICS?

WILL THE MODEL BE USEFUL TO STAKEHOLDERS?

SPARSE OR NO WUA LEVEL DATA!

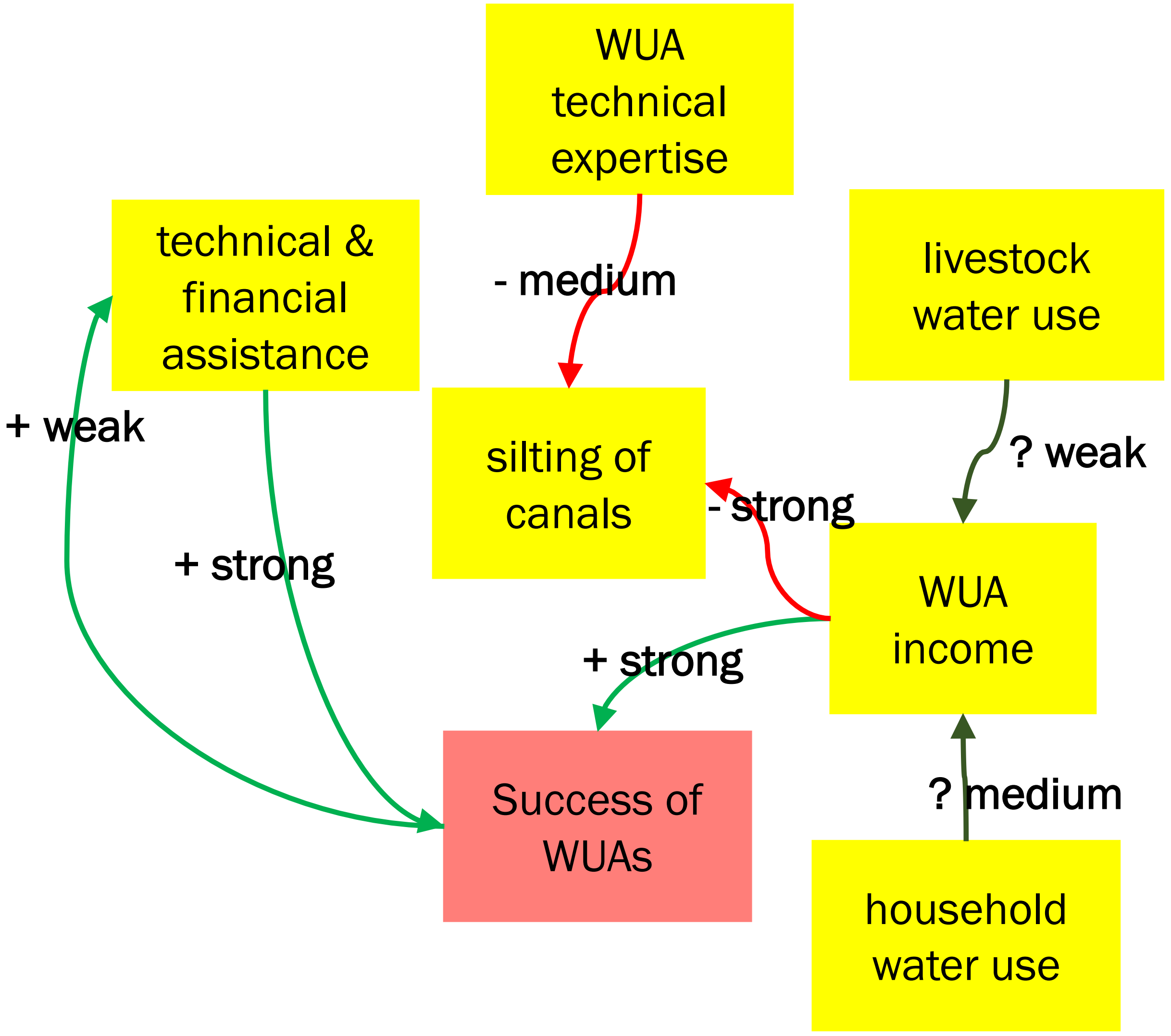
SO, HOW CAN WE KNOW?



WATERING Systems Mapping Session

Collaborative participatory activity to:

- Identify key factors
- Identify key connections between factors
- Clarify the nature of connections
- Consolidate understanding

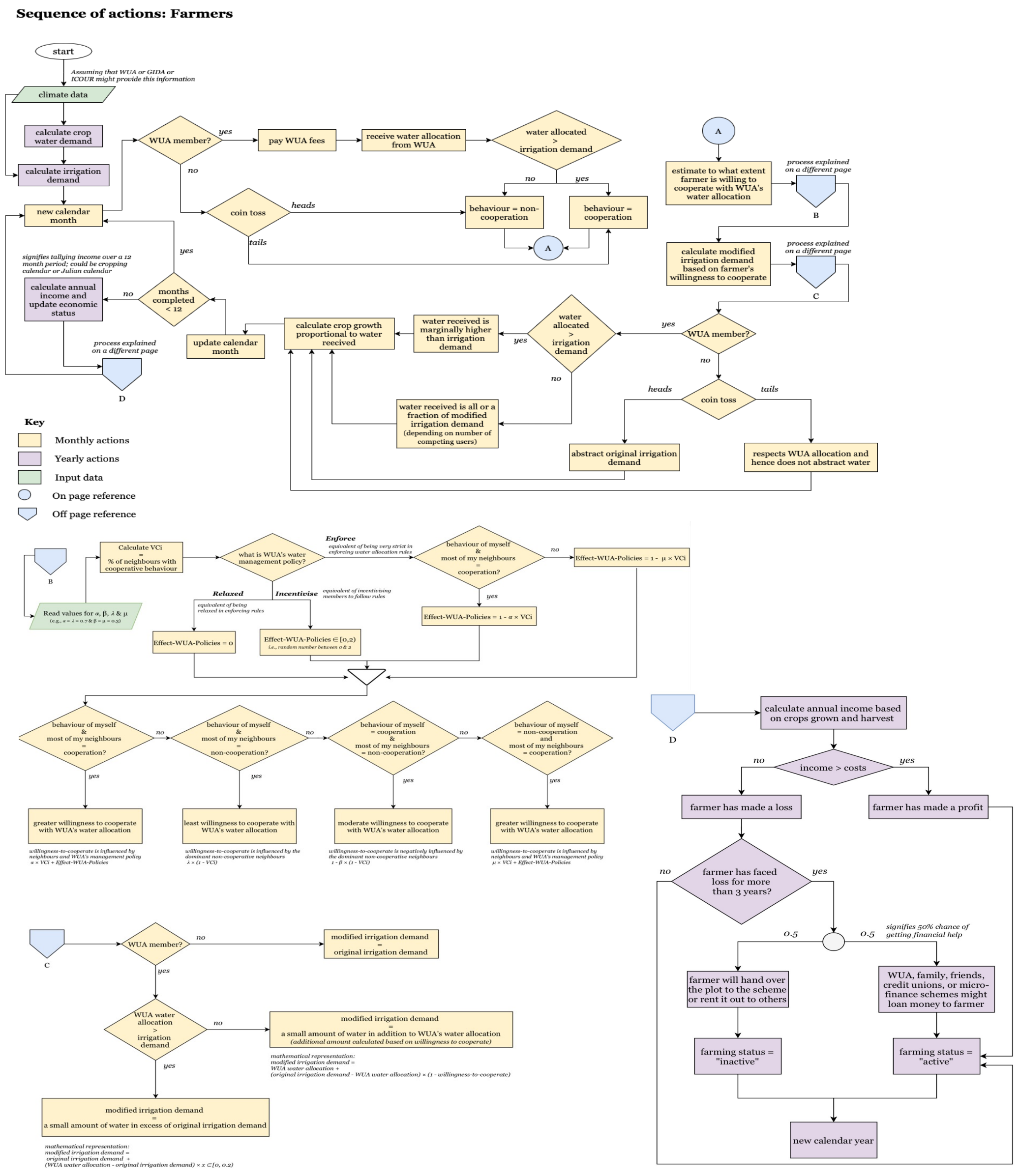


Thanks to Dr Alex Penn & Dr Peter Barbrook-Johnson for their guidance on PSM and Prof Nigel Gilbert for the PRSM tool and guidance. Visit
https://www.cecan.ac.uk/wp-content/uploads/2020/09/PSM-Workshop-method.pdf
https://prsm.uk/

WATERING Flowcharts Session

Collaborative participatory activity to review the sequence of:

- Four flowcharts; each describing a sequence of actions performed by specific actors
- Objective: To assess
  - Logic of actions
  - Ownership of actions
  - Preconditions for actions
  - Nature of actions
  - Type of actions
  - Timing of actions



WATERING Stories Session

Story #1: Our WATERING model simulates an irrigation scheme that has a reservoir, main canal and several side channels. The plots are on either side of the channels. Each plot is farmed by a farmer. There are three types of farmers:

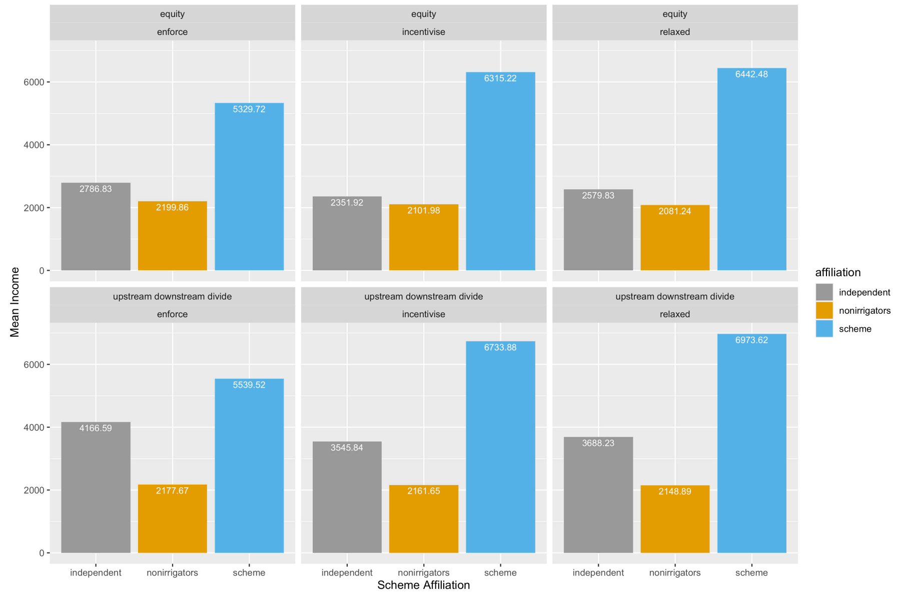
Scheme farmers (in purple) are WUA members, they pay water fees and WUA fees. Most of them are at the upstream end.

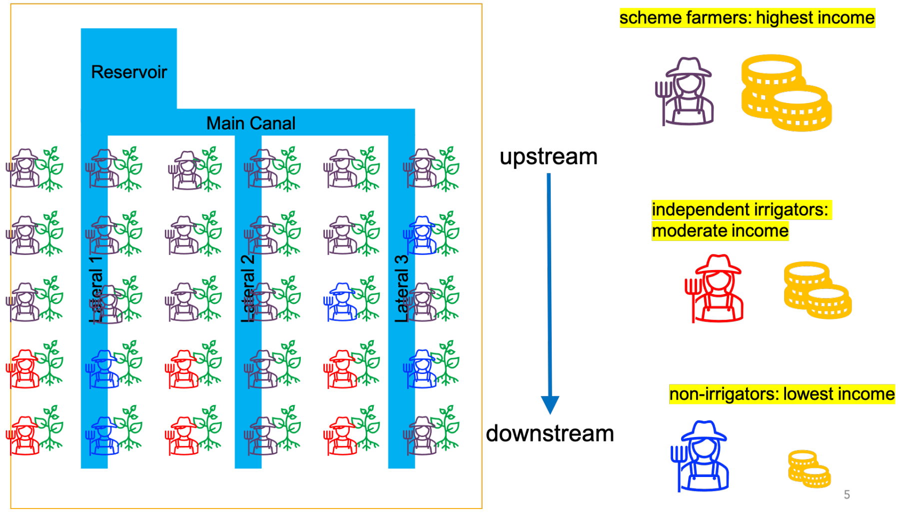
Non-irrigators (in blue) rely on rain for crop growth. They are not WUA members. They do not pay WUA fees or water fees.

Independent Irrigators (in red) are farmers who are not WUA members. They do not pay WUA fees or water fees, but still use water from the scheme. We call this unregulated water use.

Result: Upstream users get water first, followed by downstream users. We find that Scheme farmers have the highest income, followed by Independent irrigators. Non- irrigators have the lowest income because they only cultivate during rainy season.

Do you see this in your irrigation scheme?





@kavinpreethi k.narasimhan@surrey.ac.uk SocSimFest2022

Overview of Stakeholder Assessment

Model aligned with experience or expectations	○ WUA allocates water depending on supply and demand; collects fee and fines; performs O&M and loans money to members (experienced) ○ Water users tend to cooperate or not cooperate with WUA's water allocation; unregulated water use is prevalent (experienced) ○ Pastoralists and households should be allowed to become WUA members (expectation)
Model diverged from *(or partially aligned with)* experience or expectations	○ Area cultivated would be determined based on water available, so water shortages are unusual (experienced) ○ WUA strictness will increase cooperation with quotas (expectation) ○ Pastoralists and households becoming WUA members will boost its income (expectation; model aligned partially)
Further dimensions to consider	○ Regular WUA meetings enables members to cooperate more/better with WUA policies (experienced) ○ Success of WUA members would encourage others to join WUA (expectation)

WATERING: Transparency and Reusability

- Reusable modules in software development
- A reusable model to simulate water flow in an irrigation system https://doi.org/10.5281/zenodo.6323633
- A reusable model to simulate water flow and crop growth in an irrigation system https://doi.org/10.5281/zenodo.6323653

References Part III

WATERING irrigation system sub-model	https://doi.org/10.5281/zenodo.6323633
WATERING crop growth in irrigation scheme sub-model	https://doi.org/10.5281/zenodo.6323653
The Participatory Systems Mapping Toolkit	https://www.cecan.ac.uk/resources/toolkits/the-participatory-systems-mapping-toolkit/
PRSM mapping app	https://prsm.uk/
WATERING detailed model review: Webinar	https://www.youtube.com/watch?v=jWdK3z94fKA
Lansing and Kremer (1993)	Emergent properties of Balinese water temple networks: Coadaptation on a rugged fitness landscape. American Anthropologist, 95(1), 97-114
Wijermans and Schlüter (2014)	Agent-based case studies for understanding of social-ecological systems: Cooperation on irrigation in Bali. In Advances in Social Simulation (pp. 295-305). Springer, Berlin, Heidelberg.
Ofosu (2011)	Sustainable irrigation development in the White Volta sub-basin: UNESCO-IHE PhD Thesis. CRC Press.

Audience Engagement

Knowledge co-creation/Companion modelling/Participatory agent-based modelling processes: Have you tried? If yes, could you share your experience?

“ yes ”

“ No, haven't tried it yet ”

“ no ”

“ yes ”

Powered by Poll Everywhere

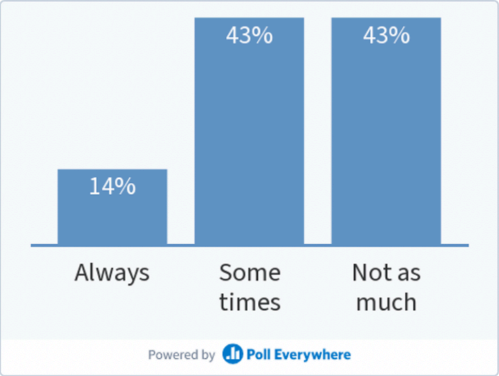
Responses
yes
No, haven't tried it yet
no
yes

29%
Engagement

4
Responses

Audience Engagement

I find it easy and motivating to make my models reusable (e.g., by providing the model code, documentation and experimentation methods free and open source)



Response options	Count	Percentage
Always	1	14%
Some times	**3**	**43%**
Not as much	**3**	**43%**

50%
Engagement

7
Responses

Audience Engagement

Reproducibility and model development, your take:

Response options	Count	Percentage
We are doing well and need to keep going	0	0%
We can do more	0	0%
We urgently need to do more	**7**	**100%**
I need more information about reproducibility to respond	0	0%
None of the above	0	0%

Acknowledgements

UNIVERSITY OF SURREY

UK Research and Innovation

Department for Business, Energy & Industrial Strategy

cress

wholeSEM

Future DAMS

essa

essa @work

NCRM NATIONAL CENTRE FOR RESEARCH METHODS

Queen Mary University of London

The Rabin Ezra SCHOLARSHIP TRUST

EMPOWER Empowering citizen adaptation to climate risks

COGNITIVE SCIENCE RESEARCH GROUP

Queen Mary University of London