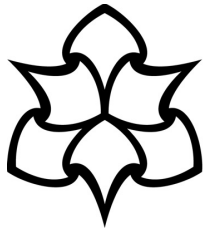

Prospects for using context to integrate reasoning and learning

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Slides available at: http://cfpm.org/slides

Part 1:

Human Context-Sensitivity

The Elephant in the Room

- Many aspects of human cognition are known to be highly context-sensitive, including: memory, preferences, language, visual perception, reasoning and emotion
- There is a mountain of qualitative research that has documented instances where a specific context is essential to understanding the observed behaviour
- Simple observation and introspection tells us that behaviour in different kinds of situation is not only different but decided on in different ways (e.g. in a lecture or a birthday celebration)

Action within a Social Context

- Without having to do anything conscious we effectively ‘inhabit’ each social context
- Adapting fluidly to each
- Applying context-specific knowledge there
- Using the social affordances there as an extension of our perception and action

However despite this…

- Almost all formal models of human behaviour (mathematical, statistical, logical or computational) are generic – they do not exhibit this sharp context-dependency
- Another stream of models (models fitted to or tested against data) consider a single model (at a time) against a set of data that derives from many different contexts
- Despite our ability to swap between kinds of situation with unconscious fluency, we often reason with crisp, identifiable beliefs

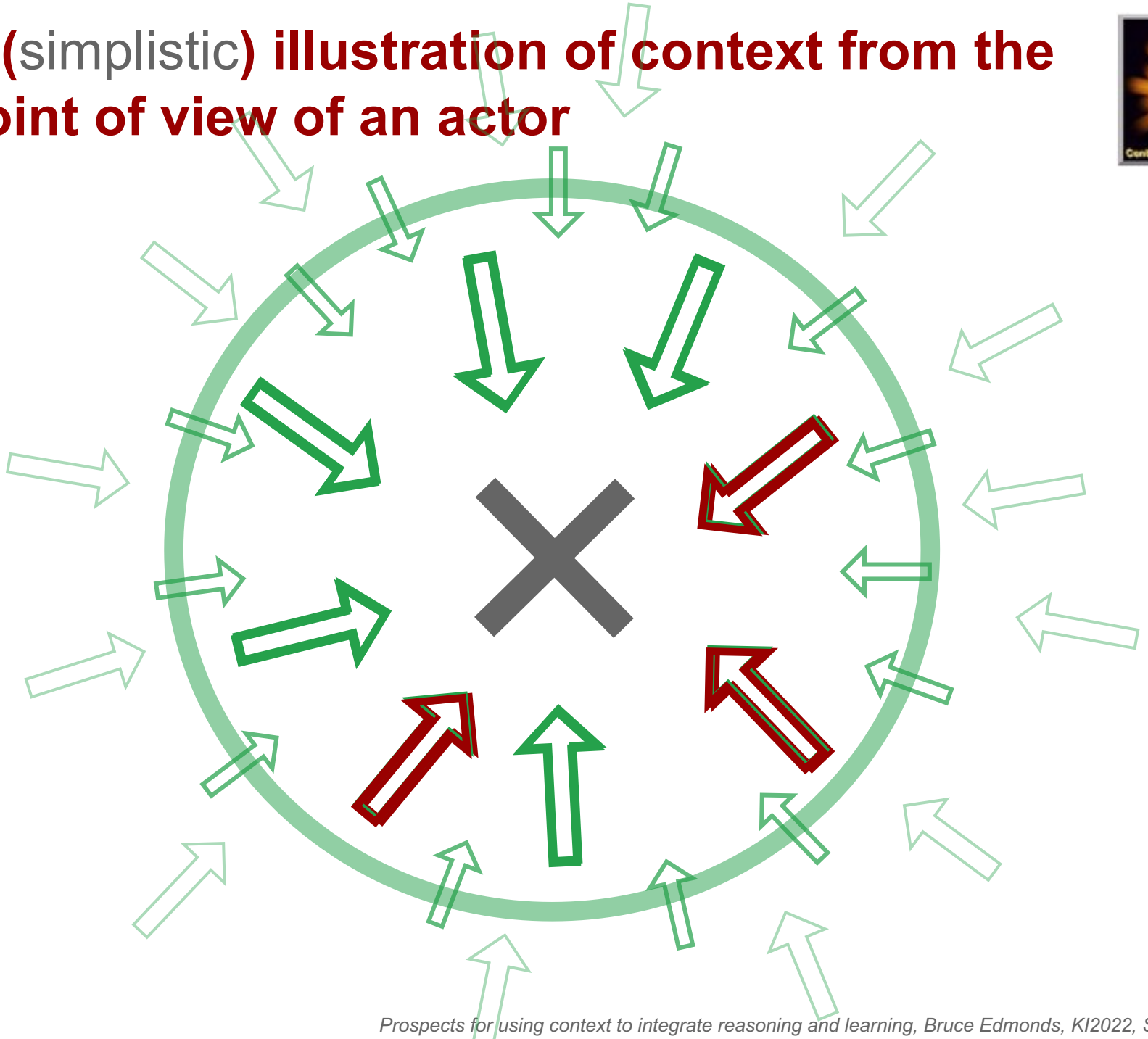
Part 2:

Talking about “Context”

The Difficulty of Talking about Context

- The word “context” is used in many different senses across different fields
- Somewhat of a “dustbin” concept resorted to when more immediate explanations fail (like the other “c-words”: complexity & creativity)
- Problematic to talk about, as it is not clear that “contexts” are usually identifiably distinct
- Mentioning “context” is often a signal for a more “humanities oriented” or “participatory/involved” approach and hence resisted by “scientists” who are seeking general laws

A (simplistic) illustration of context from the point of view of an actor



Situational Context

- The situation in which an event takes place
- This is indefinitely extensive, it could include anything relevant or coincident
- The time and place specify it, but relevant details might not be retrievable from this
- It is almost universal to abstract to what is relevant about these to a recognised type when communicating about this
- Thus the question "*What was the context?*" often effectively means "*What about the situation do I need to know to understand?*

Cognitive Context (CC)

- *Many* aspects of human cognition are context-dependent, including: memory, visual perception, choice making, reasoning, emotion, and language
- The brain somehow deals with situational context effectively, abstracting *kinds of situations* so relevant information can be easily and preferentially accessed
- The relevant correlate of the situational context will be called the *cognitive context*
- It is not known how the brain does this, and probably does this in a rich and complex way that might prevent easy labeling/reification of contexts

Social Context

- Since humans are fundamentally social beings…
- …social context is often most important
- *e.g. an interview, a party or a lecture*
- But social context may be *co-determined*, since:
  - Special rules, norms, habits, terms, dress will be developed for particular social contexts
  - The presence of special features, rules etc. make the social context recognisable distinct
- Over time social contexts plus their features become entrenched and passed down
- Social Context arises and is so recognisable as a result of cognitive and external features (*a lecture hall, zoom etc.*)

Part 3:

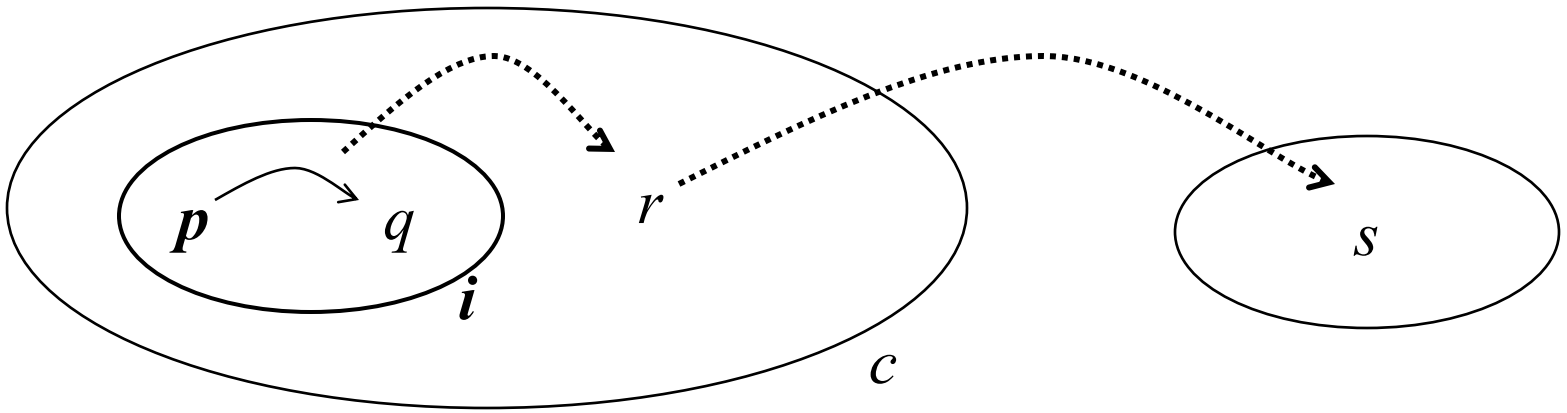
Implementing Context-Sensitivity

Context In GOFAI

John McCarthy (1971), *Generality in Artificial Intelligence*

$$c : ist(i, p)$$

"p is true in context i" asserted in context c



Context In ML

Main purposes:

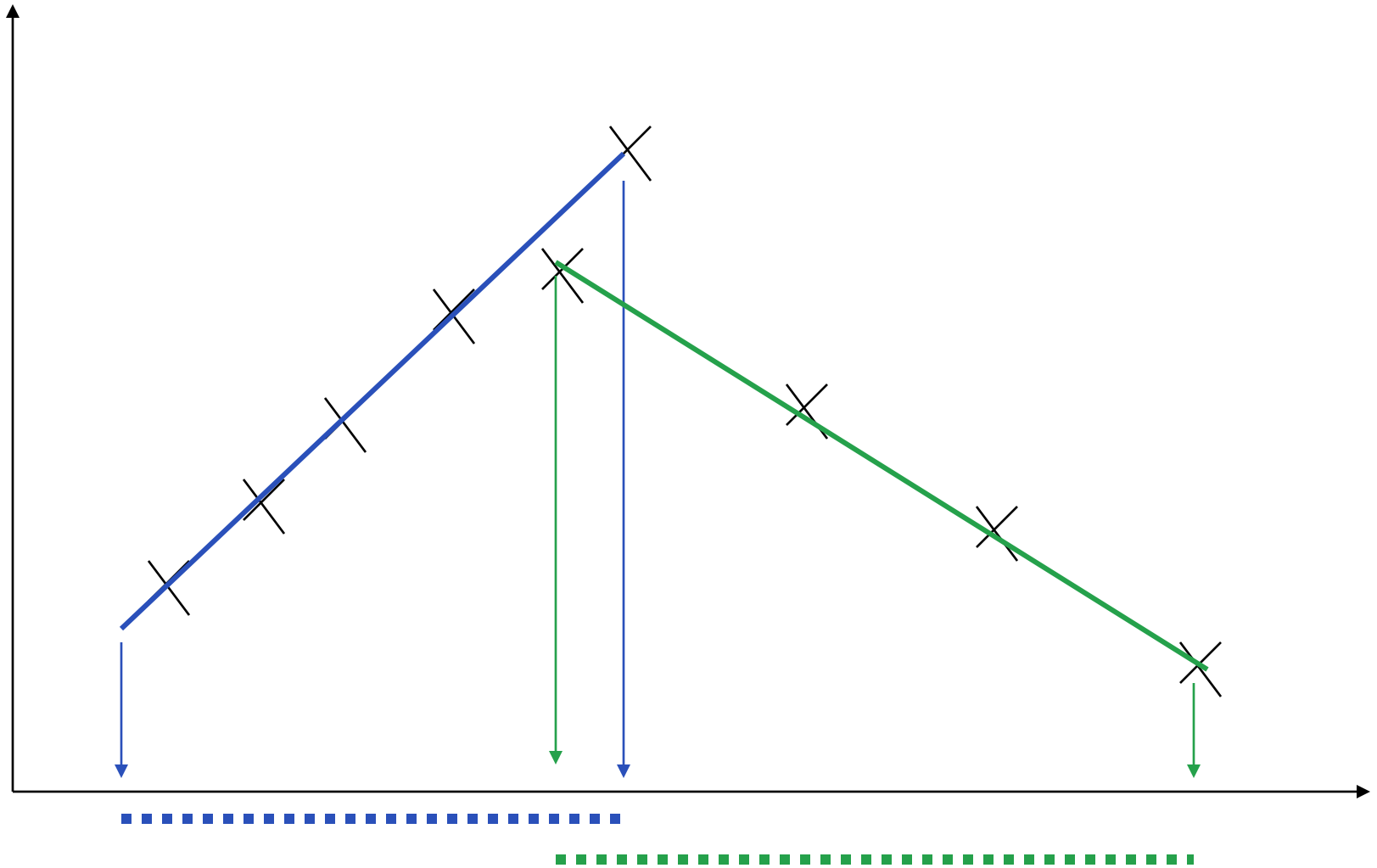
- to maintain learning when there is a hidden/unexpected change in context
- to apply learning gained in one context to a similar context
- to utilise already known information about contexts to improve learning

The Problem

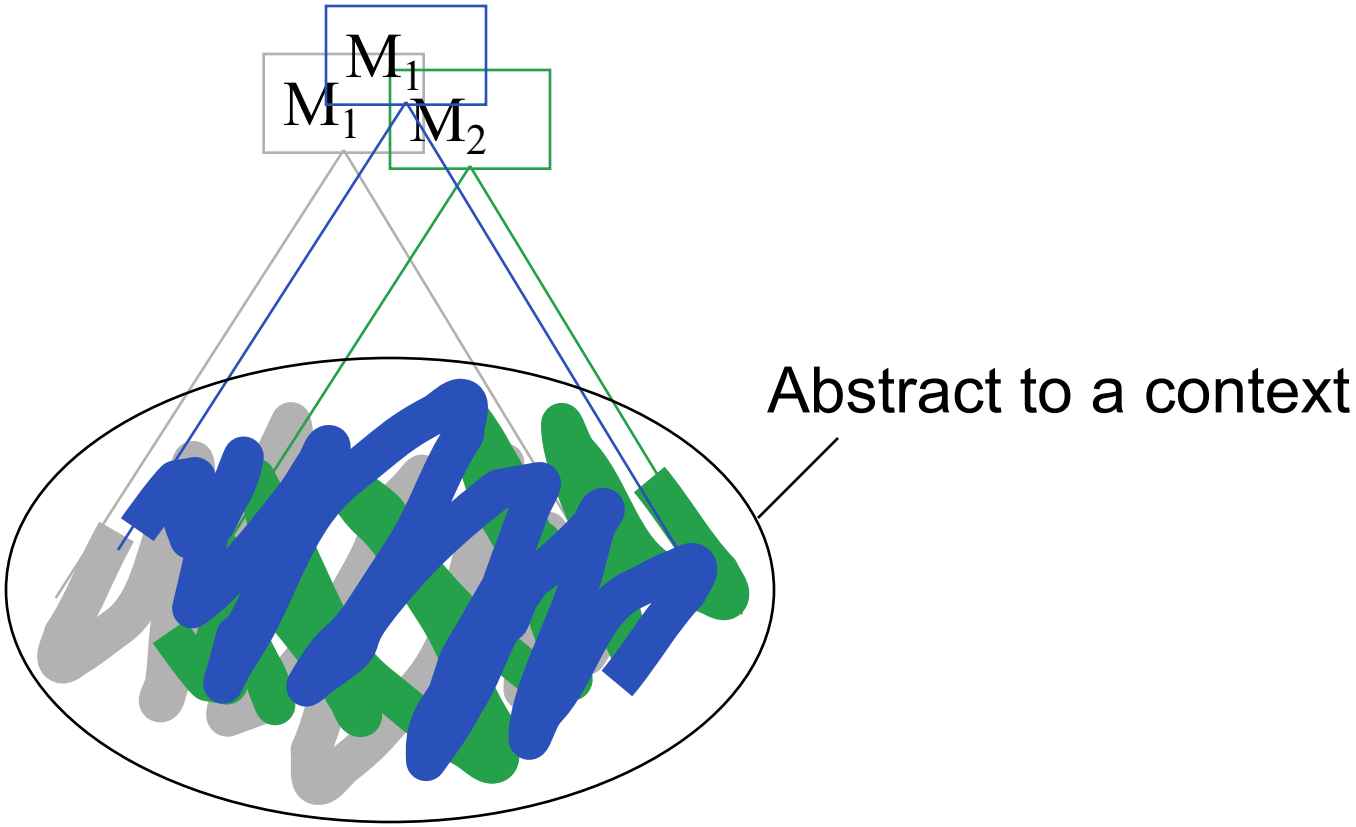
some choices:

- Use Global Approaches
  - *But inference and learning can be hard*
- Specify all the contextual information
  - *Can be onerous*
- Learn Contextual Information with Content
  - *Need an algorithm*
- Leave it to the layers of a NN, hope that this deals with it

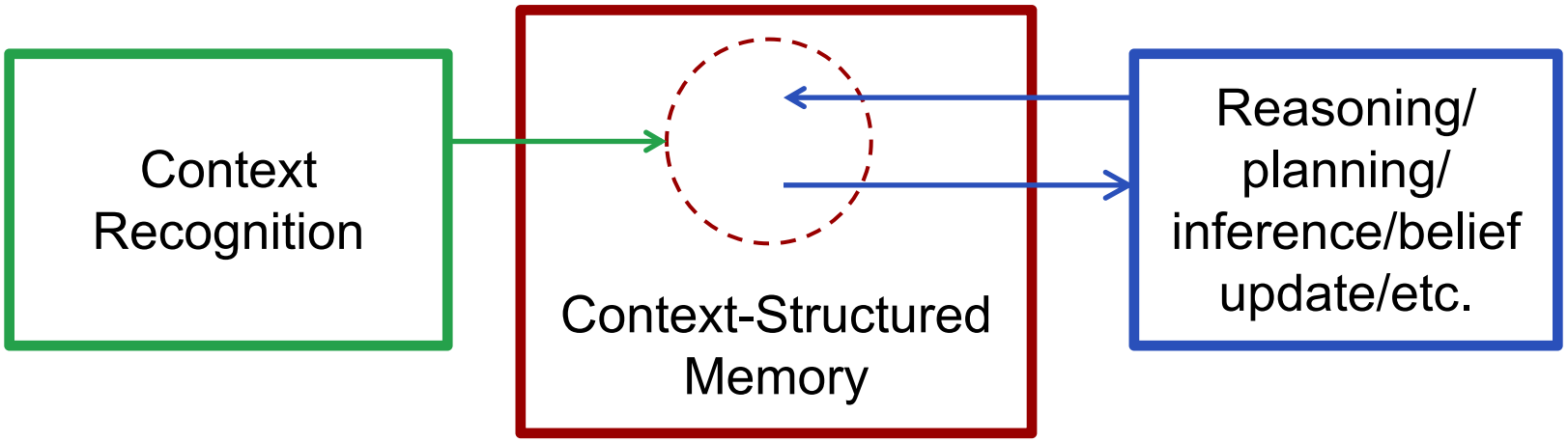
Fuzzy Domain & Crisp Content



Coincident Clusters of Domain&Content make a Context



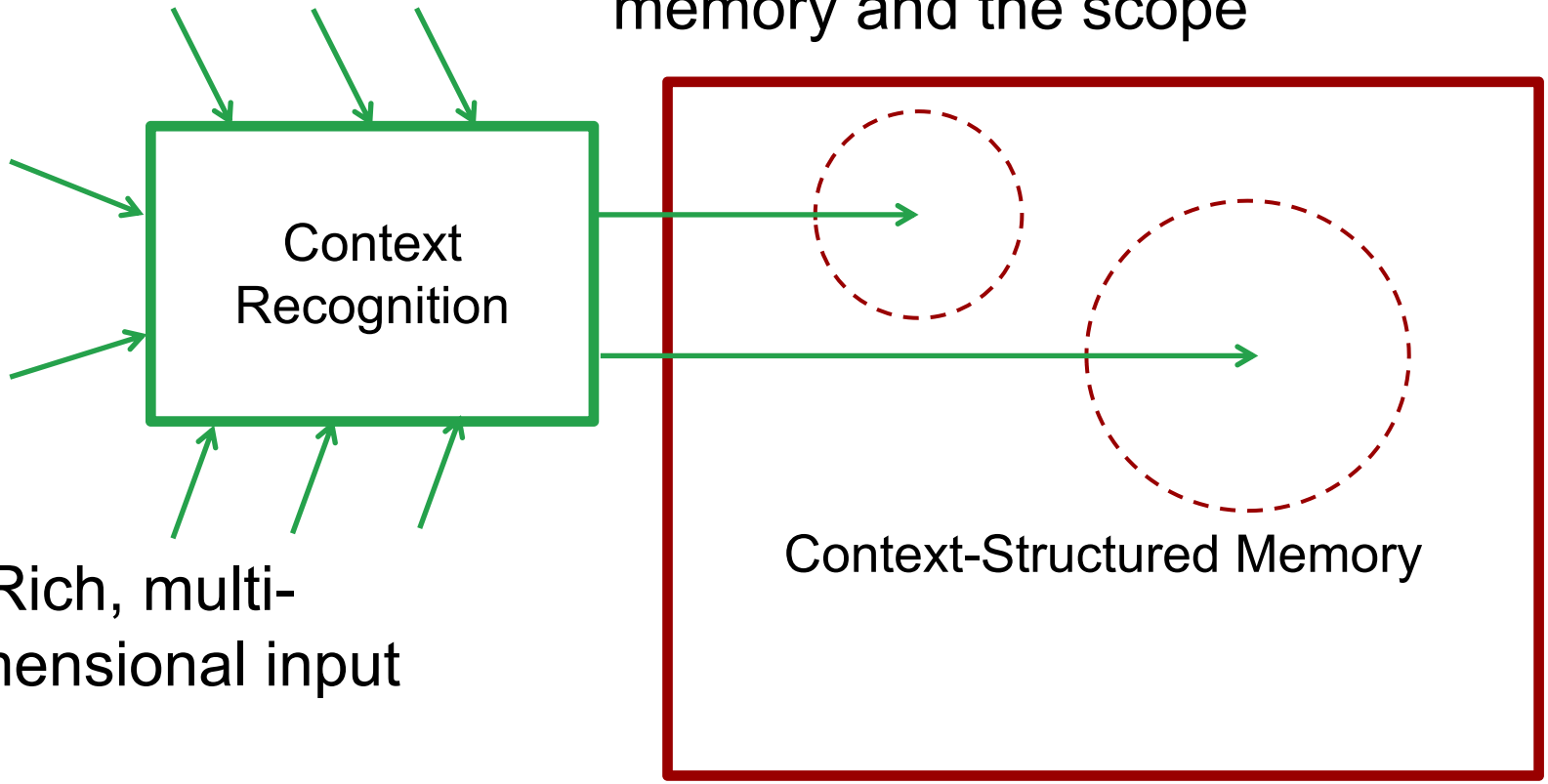
Basic Cognitive Model



- Rich, automatic, imprecise, messy cognitive context recognition using many inputs (including maybe internal ones)
- Crisp, costly, conscious, explicit cognitive processes using material indicated by cognitive context

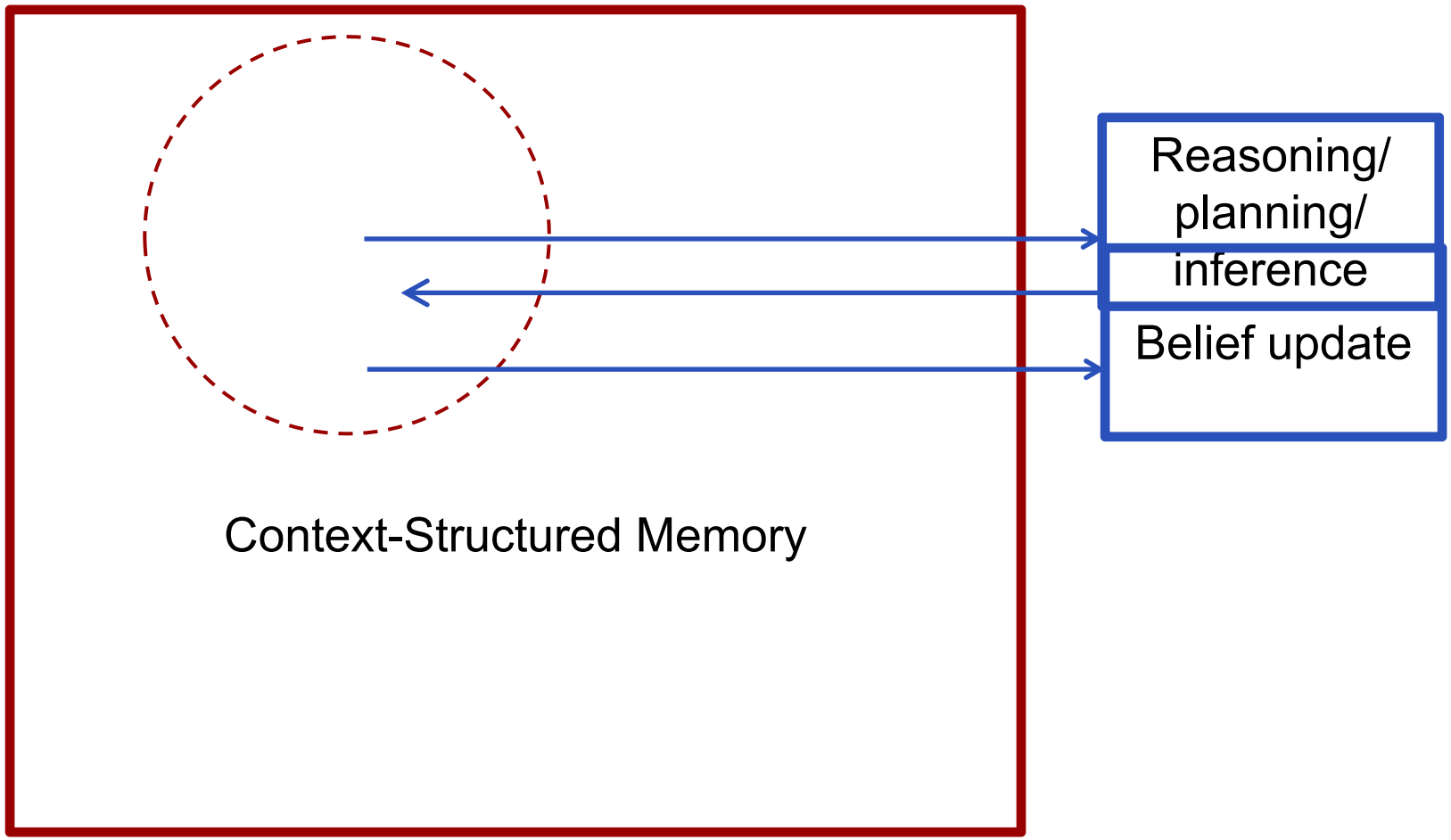
ML context recognition

2. Fuzzy identification of area of memory and the scope



1. Rich, multi-dimensional input

Reasoning/belief update



The Problems of Under- and Over-Determination

1. Under-determination
   - Neither α nor $\neg\alpha$ can be inferred

     Choose a more specific context

2. Over determination
   - Both β and $\neg\beta$ can be inferred

     Choose a less specific context

Universal learn and infer loop

repeat

learn and/or up update beliefs

deduce intentions, plans and actions

until finished

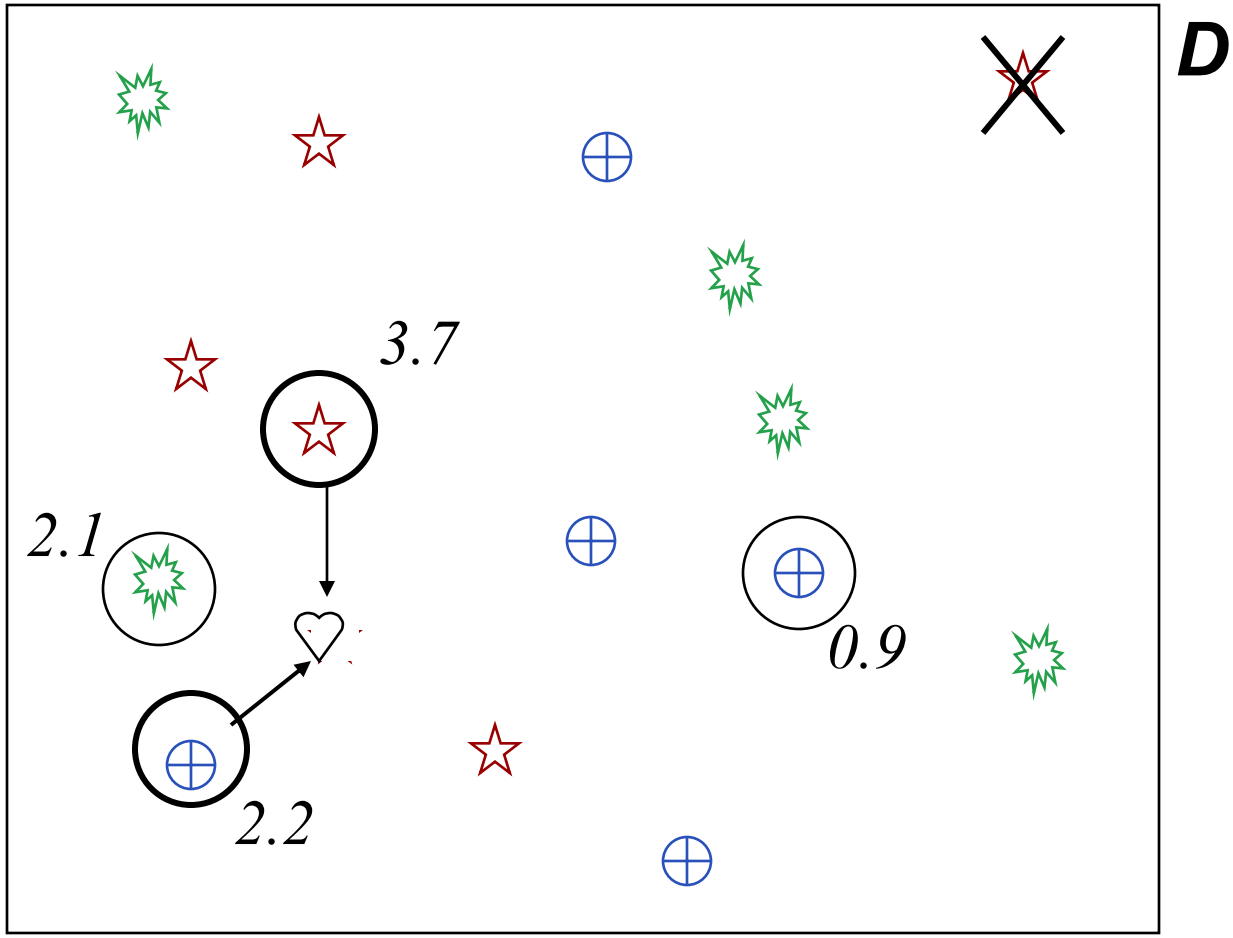
Learn and infer loop using context

repeat
    repeat
        recognise/learn/choose context, *c*
        induce/update beliefs in *c*
        deduce predictions/conclusions in *c*
    until predictions are possible, consistent
            and actions/plans can be determined
    plan & act (starting from *c*)
until finished

Part 4:

Example Proof-of-concept in Trading Agents

An Evolutionary Algorithm



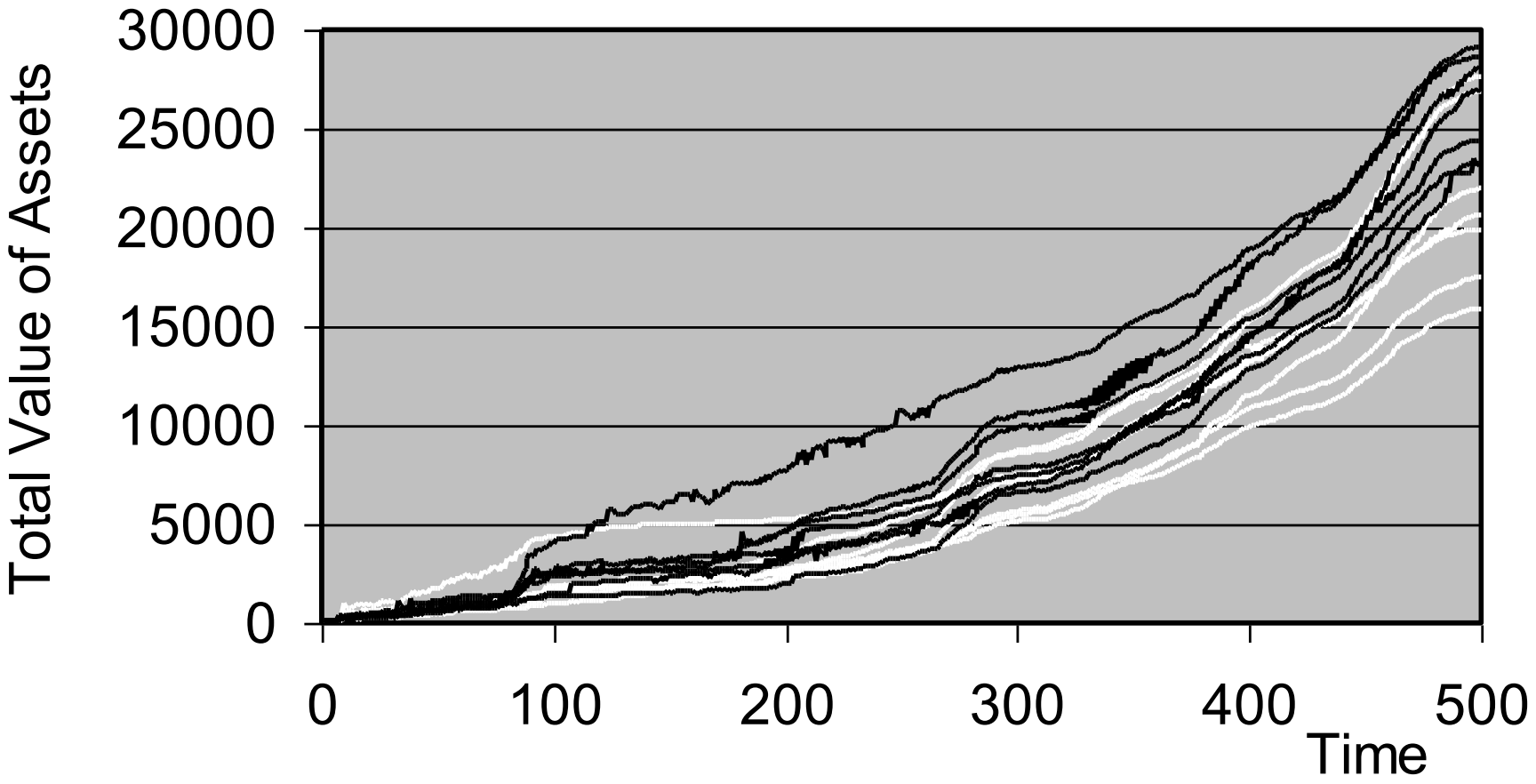
Some Space of Characteristics

Comparison in an Artificial Stock Market

Environment:

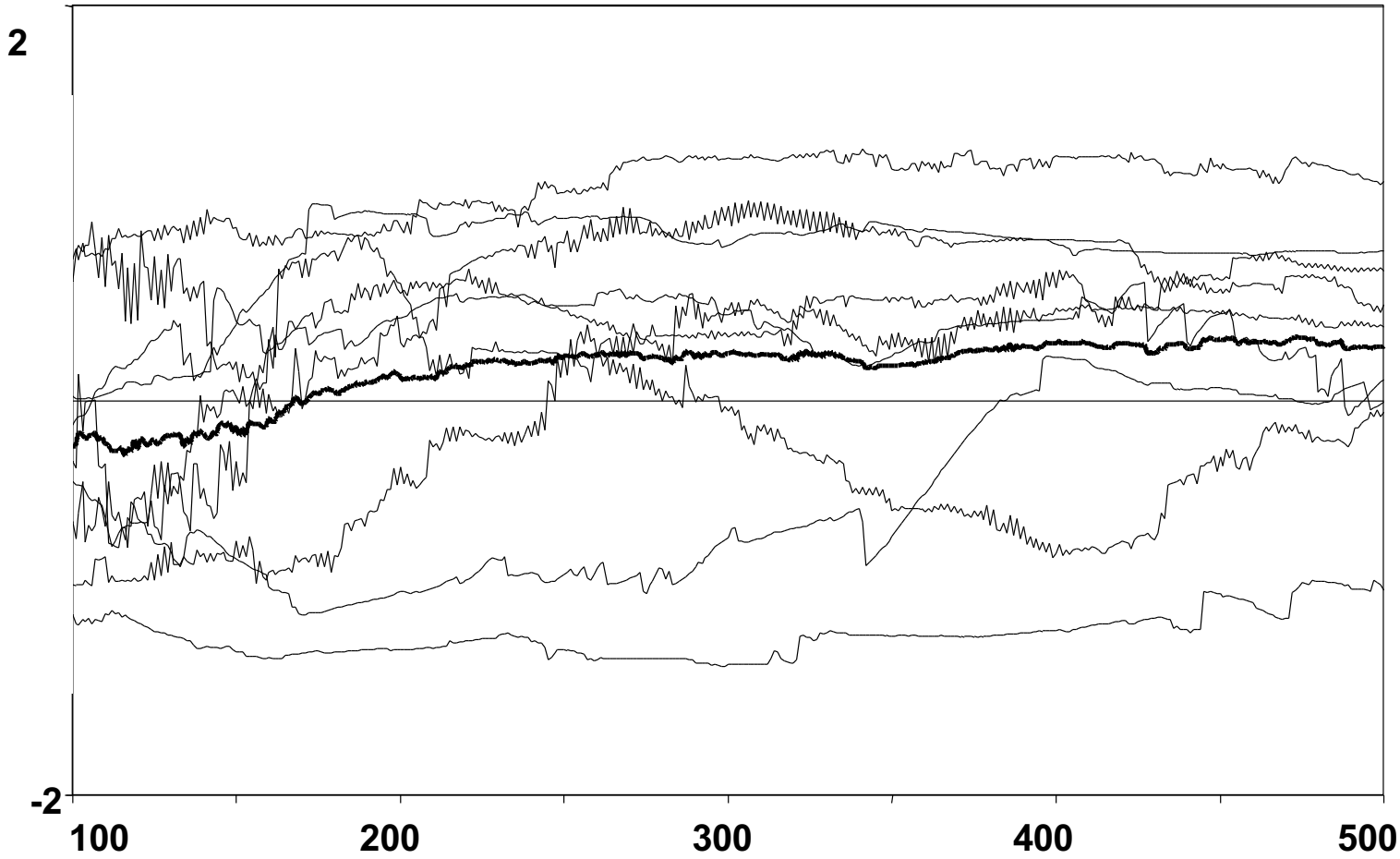
- Traders (*n* context, *n* straight GP)
- 1 Market maker: prices and deals: 5 stocks
- Traders buy and sell shares at current market price, but do not have to do so
- Traders have memories, can observe actions of others, index, etc.
- Modelling ‘arms-race’
- Actions change environment

Total Assets in a Typical Run



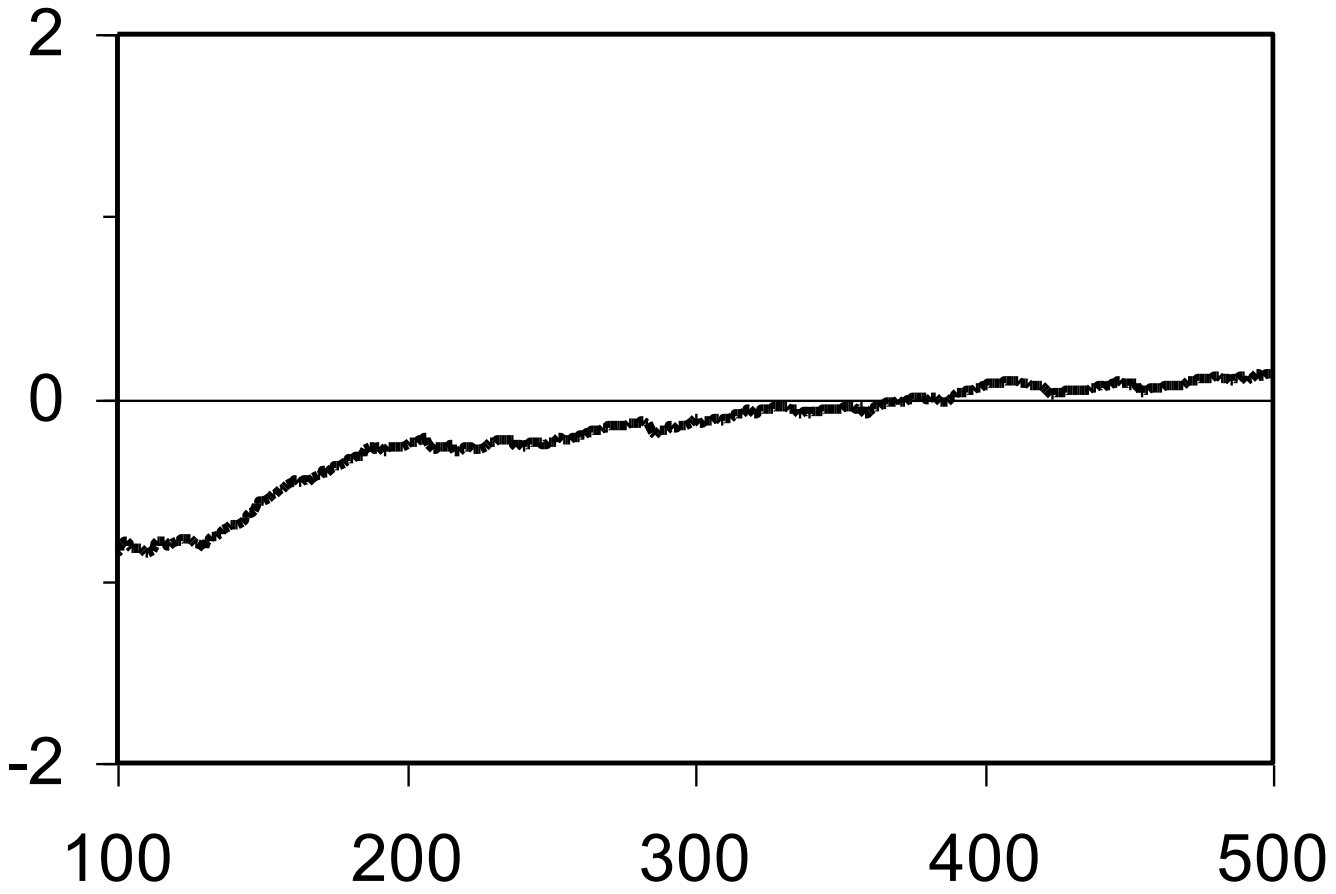
Black=context, White= non-context

Total Assets of Context Traders – Total Assets of Normal Traders, scaled by standard deviation of assets (7 agents of each type, 9 runs)

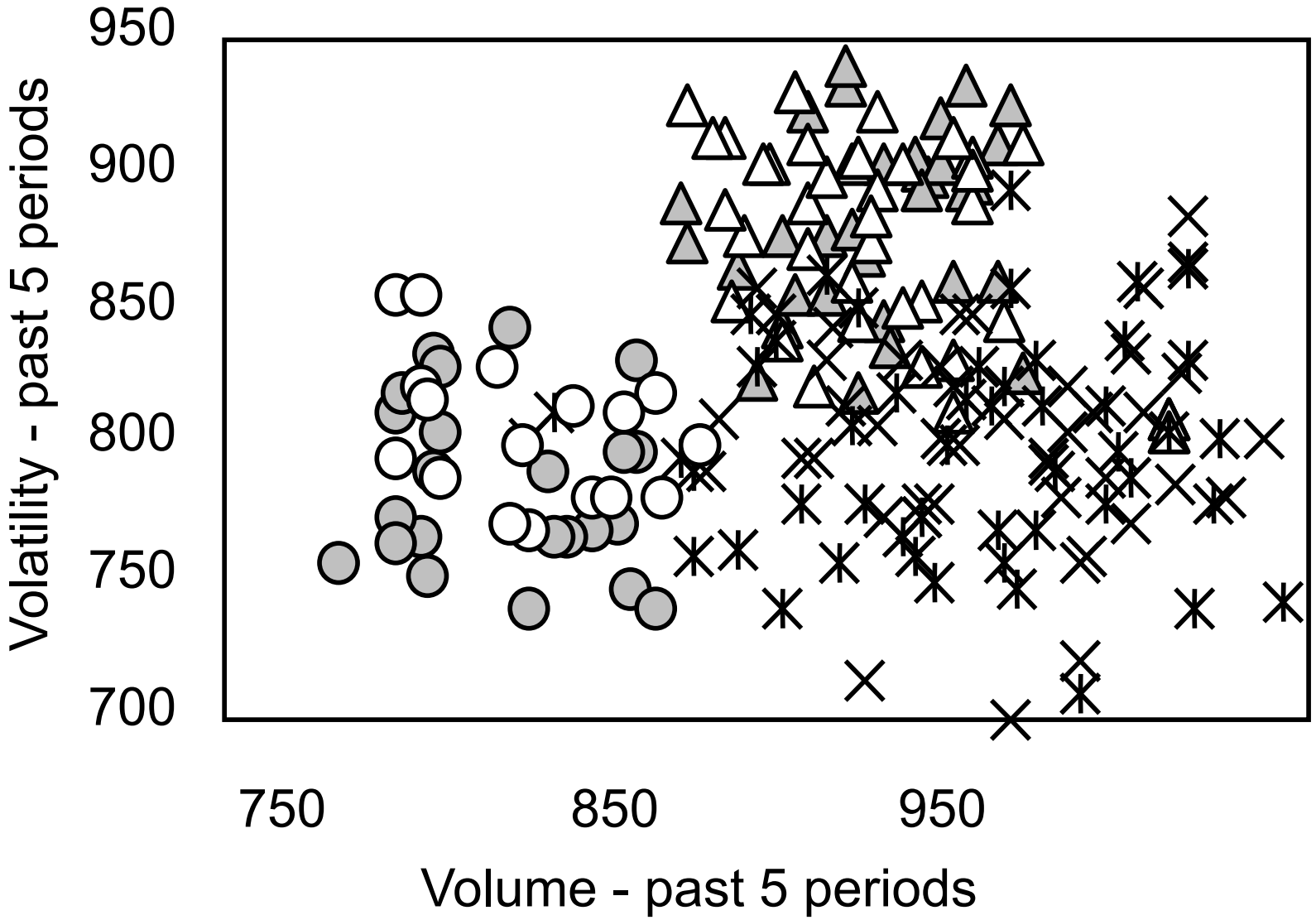


(Bold=average, Light= scaled difference for one run)

Average advantage for context traders for 10 runs with 3 traders of each type



Snapshot of model domains in one trader



But *some* model contents are very simple!

model-256	priceLastWeek [stock-4]
model-274	priceLastWeek [stock-5]
model-271	doneByLast [normTrader-5] [stock-4]
model-273	IDidLastTime [stock-2]
model-276	IDidLastTime [stock-5]
model-399	minus [divide [priceLastWeek [stock-2]] [priceLastWeek [stock-5]]] [times [priceLastWeek [stock-4]] [priceNow [stock-5]]]

Part 5:

Analysing Data in a *more* Context-Sensitive Manner

(work by ***Claire Little***)

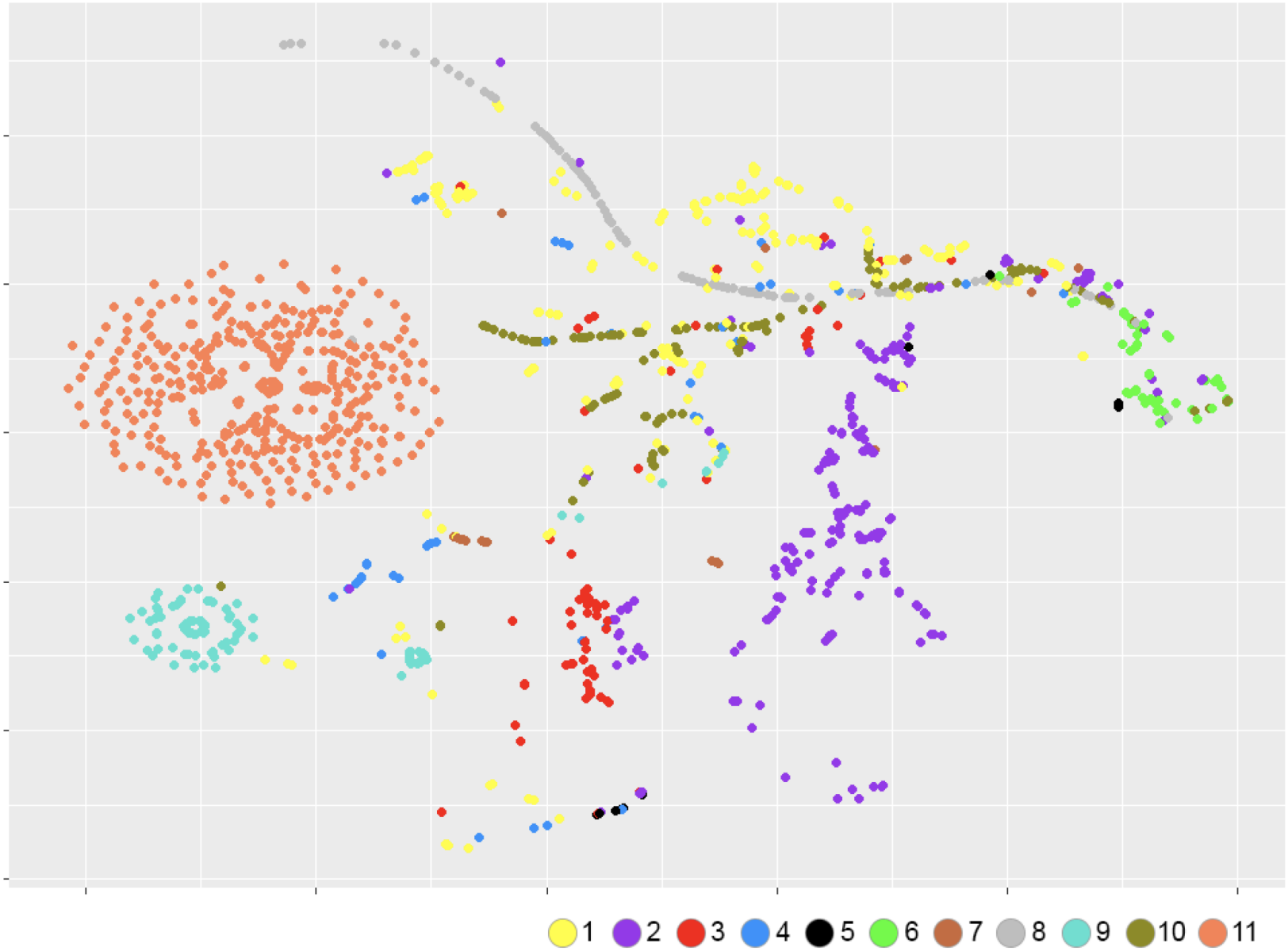
“Troubled Family” Data & I2I Project

- A local authority (LA) negotiated a series of data deals which meant that it could link different data sets around many individuals & families in the area for research purposes only
- This included: input from social worker actions and family relationships (for core families), DWP records, criminal records, school attendance, etc.
- We got a pseudo-anonymised version of this data under strict conditions
- It focused on 2155 families with an intervention between 1st August 2011 and 31st July 2015 funded by the “Troubled Family” program

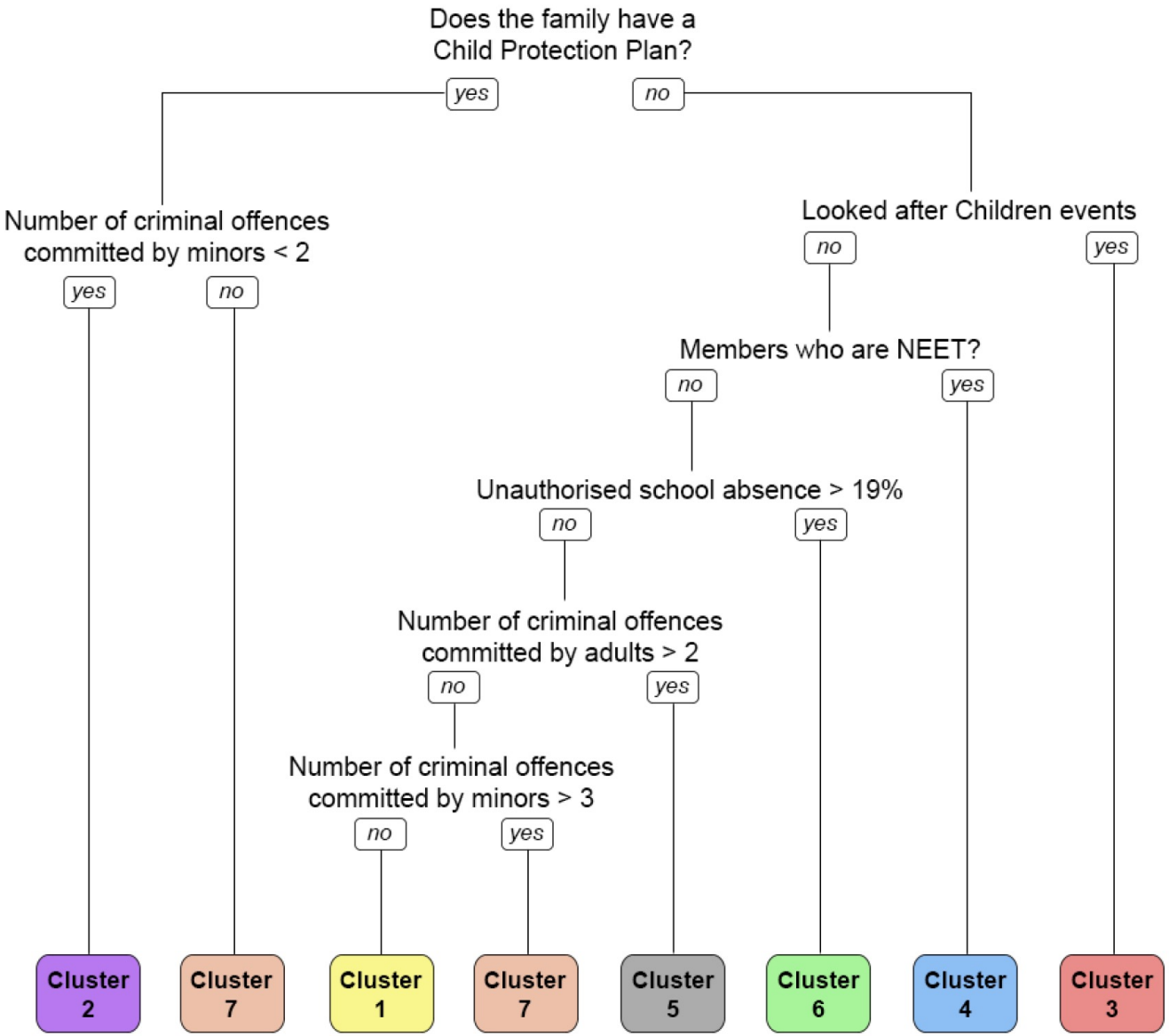
Using ML to divide TF into 11 clusters

Cluster	1 n=291	2 n=335	3 n=115	4 n=61	5 n=21	6 n=54	7 n=25	8 n=223	9 n=243	10 n=182	11 n=605
Receiving DWP benefits	48%	46%	35%	57%	57%	57%	**28%**	42%	36%	42%	40%
Changed address at least once	46%	53%	**73%**	49%	48%	48%	64%	**30%**	54%	42%	36%
Percentage of single person families	8%	3%	4%	10%	14%	0	12%	3%	2%	4%	**41%**
Drug/Alcohol Events	2%	5%	2%	5%	0	4%	0	1%	3%	4%	1%
Domestic Abuse Events	14%	17%	7%	5%	**33%**	6%	20%	0	13%	14%	0
Percentage with no children (aged < 18)	11%	0.3%	0	18%	**48%**	0	4%	0	1%	0	**50%**
Percentage with no adult (aged >= 18)	4%	8%	7%	5%	0	7%	8%	13%	10%	13%	8%
Pre-existing CPP	5%	10%	6%	2%	10%	2%	4%	12%	1%	3%	3%
Pre-existing LAC	1%	1%	1%	2%	0	0	4%	2%	0	0	1%

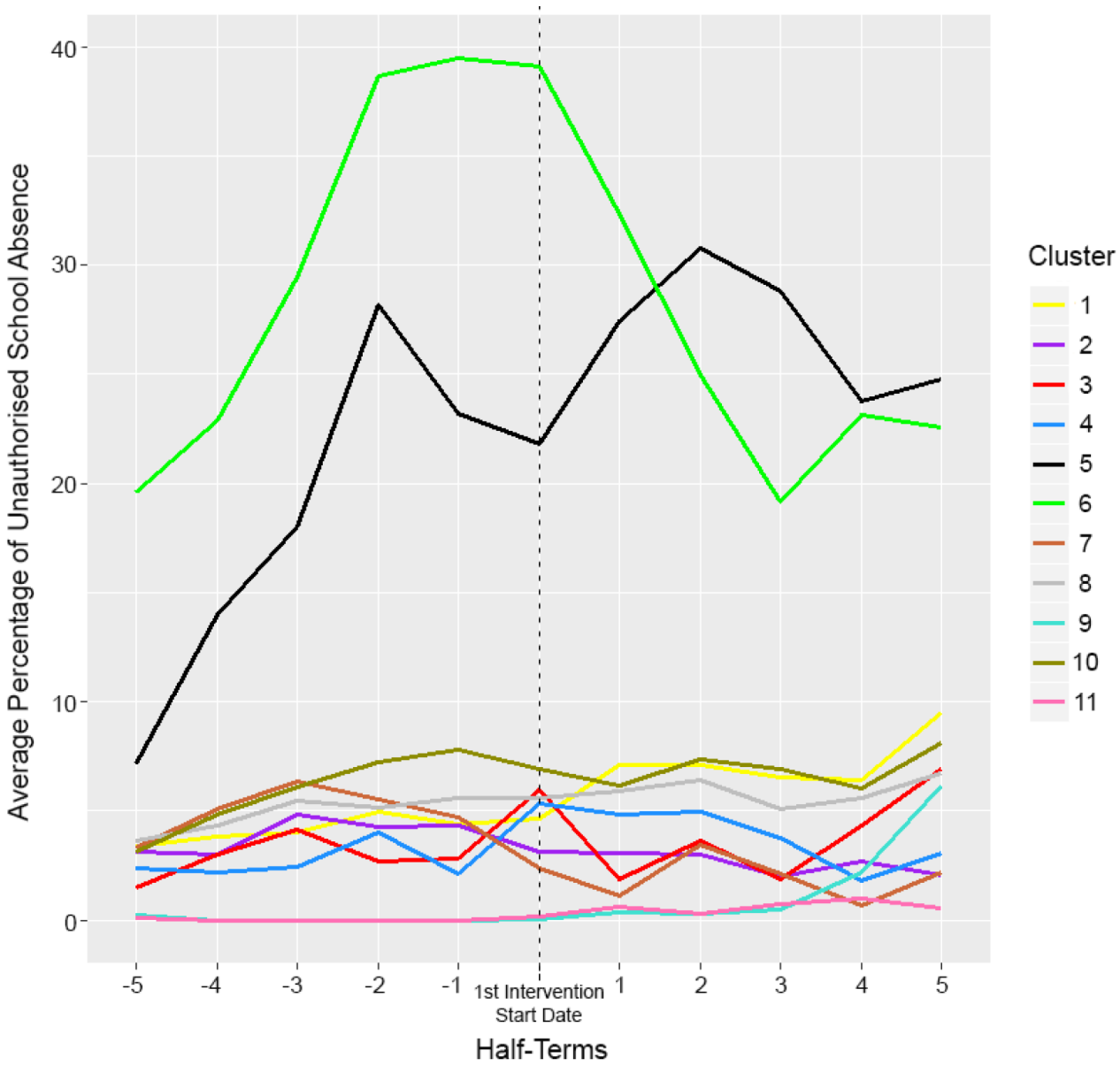
A 2D projection of these clusters



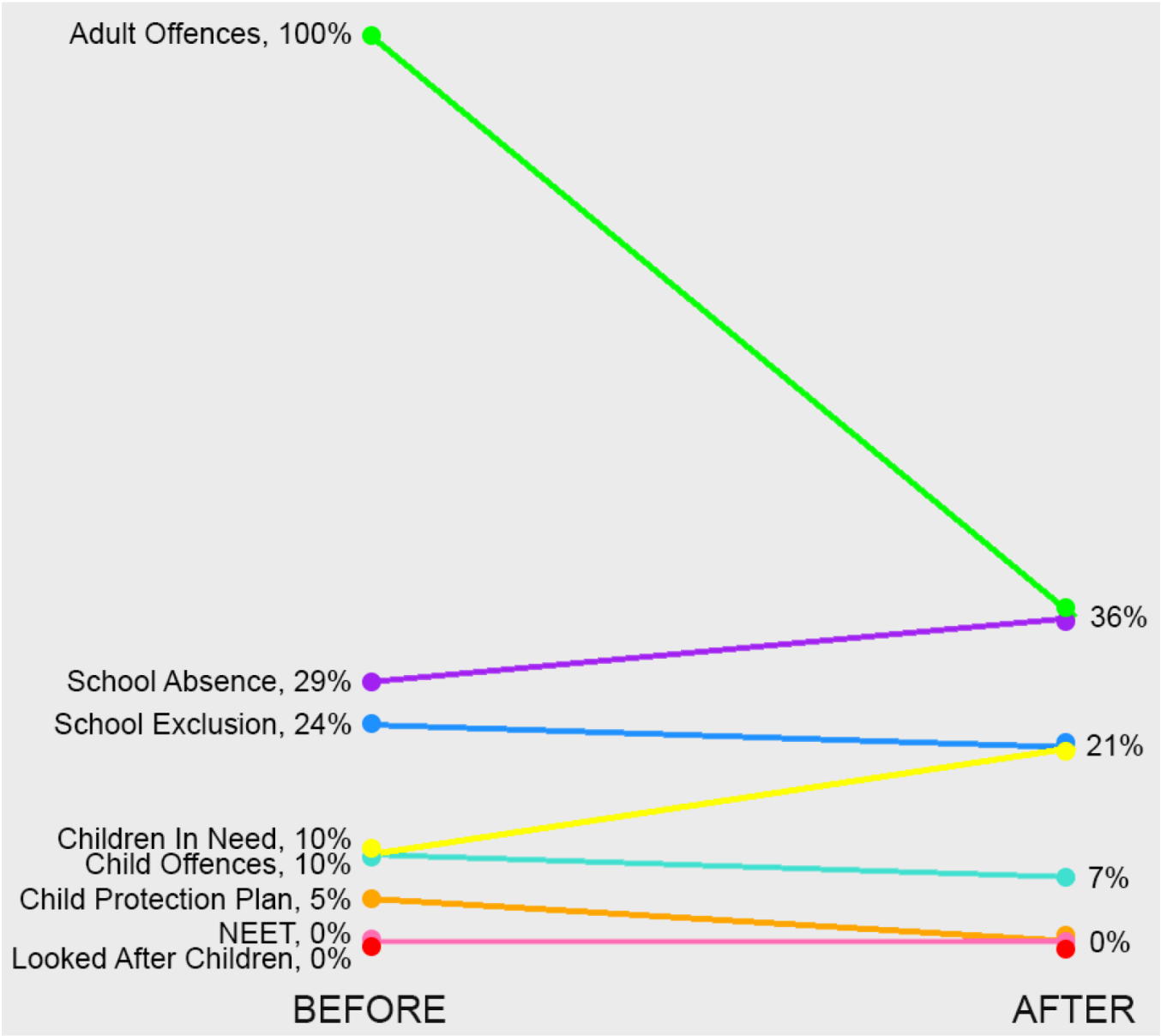
Post Hoc Tree Analysis of Clusters (1-7)



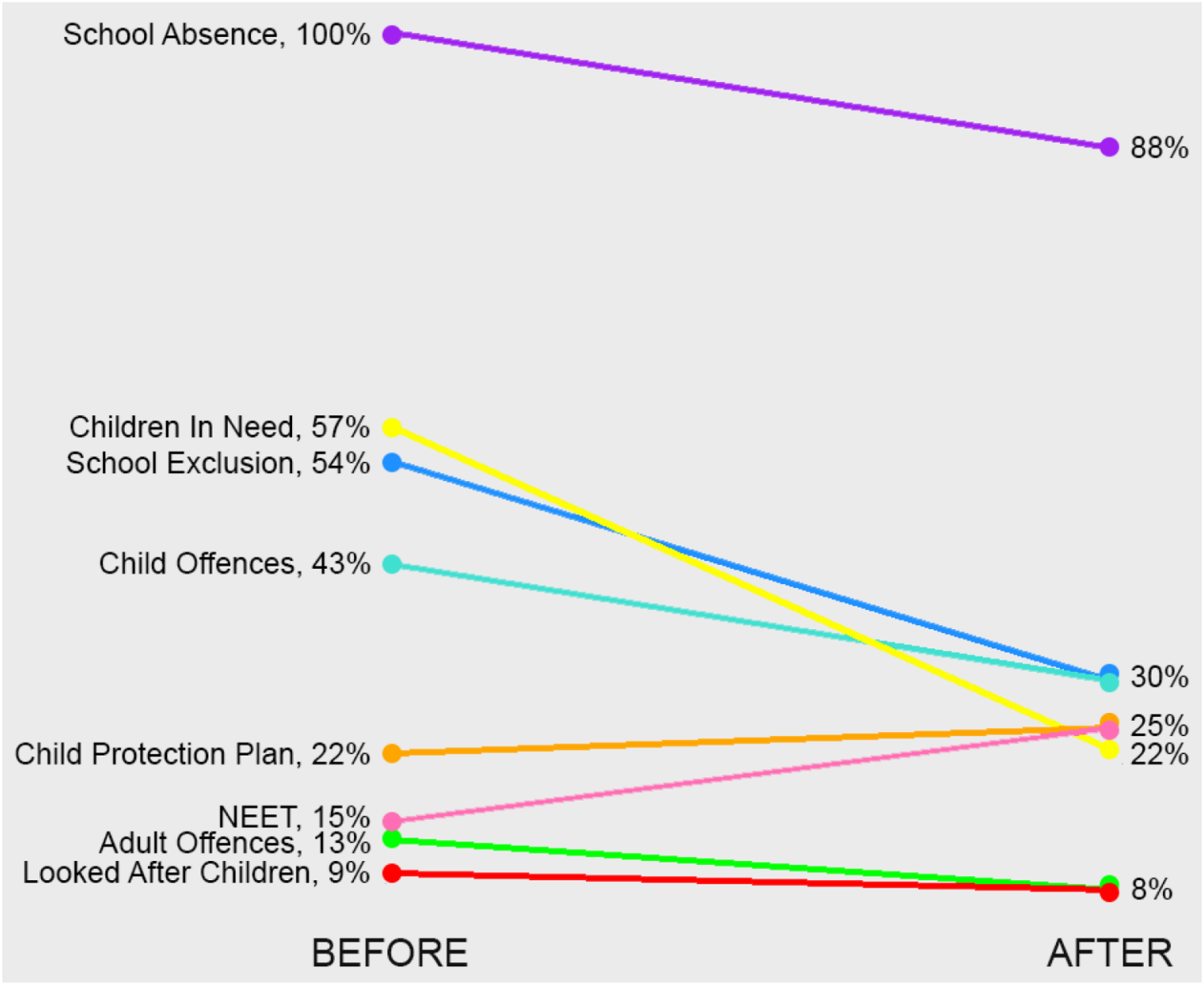
School Absences Before and After TFI



1 year Before and After Cluster 5



1 year Before and After Cluster 6



Work Done by Claire Little

As her doctoral research in conjunction with the LA.

For the detail (!!!) see her thesis at:

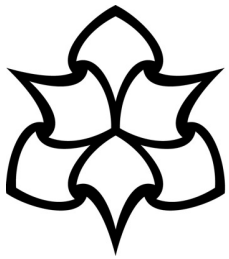
Little, C. (2018) *Machine Learning for Understanding Complex, Interlinked Social Data*. PhD Thesis, MMU, CPM-2018-211. http://cfpm.org/discussionpapers/219

Part 6:

Concluding Discussion

Conclusions

- If context-dependency is an inherent part of how humans perceive, reason, learn and act, then we should take this on board in data analysis
- Context provides a principled way of integrating rich ML algorithms with thinner but crisp inference and belief update approaches
- It also makes crisp belief update and inference FAR more feasible



The End!

Funders

EPSRC
Engineering and Physical Sciences Research Council

HORIZON 2020

These slides are available at: http://**cfpm.org/slides**

Collected papers and slides of mine on context at:
http://bruce.edmonds.name/context