Dynamic Collectives and their Identities

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Abstract. Galton (2004) has highlighted a class of phenomena, multi-aspect phenomena (MAP), that due to their spatio-temporal complexity possess a 'multiaspect nature': depending on how they are viewed, they may take the form of objects, events or processes. For example a tornado can be seen as an event, which happens, or as an object that comes into existence, moves along a path, changing as it does so, and finally disappears. This paper discusses MAP with particular reference to questions concerning their identity. To conclude, a list of key questions is given, indicating a plan for my further research.

1 INTRODUCTION

Imagine a multi-agent simulation used to show the movements of a set of individuals as they go about their tasks. At a given point in the simulation the individuals seem to gather around a central point. At a higher level, this cluster can be seen as a collective. Over time, the movement of the collective as a unit is easily seen over and above the movement of the individuals. Eventually, the simulation sees the collective disperse and terminate. Such a simulation could be used to model crowd behaviour.

Such modelling systems have been designed to simulate the behaviour of individual agents (Ali and Moulin 2005, Moulin et al 2003), but precisely because they focus on the level of individuals it is a challenge to extract from them information about the behaviour of the collective as a whole — yet it is often at this level that such phenomena are most meaningful to us.

2 DYNAMIC COLLECTIVES

Processions, queues and protest marches are all examples of *multi-aspect phenomena* (MAP) (Galton 2005). An important subclass of MAP comprises those which consist of a possibly large group of spatially distributed units whose collective behaviour is essential to the phenomenon as a whole. These are referred to as *dynamic collectives* (DCs) (ibid.). As each individual unit might only participate in the collective for a small part of its lifetime and the collective behaviour must be recognised, the DC is not just an

Florian Probst and Carsten Keßler (Eds.): GI-Days 2007 - Young Researchers Forum.
IfGIprints 30. ISBN: 978-3-936616-48-4

aggregation of the individual components. Instead, the history of the collective is an aggregation of episodes each of which represents how a particular individual participated in the phenomenon over a specific time.

Galton's proposed formal definition allows both the object-like and event-like aspects of the phenomenon to be modelled:

- Key to the definition is the notion of a *'lifeline'* - the 'set of spatiotemporal positions occupied by a continuant [c] in the course of its existence'.

  $$Lifeline(c) = \{<s, t> \in S \times T \mid s \in pos(c, t)\}$$

  Where *pos* gives the position of an individual at a time.

- The event-like aspect, represented by the 'collective dynamic' (CD), is a set of episodes from two or more individual units' lifelines.

- This CD can then be used to derive the object-like aspect (i.e. the DC), which is defined as the continuant whose lifeline is the aggregated set of episodes of the CD. Galton denotes this $Lifeline^{-1}$ ($\bigcup C$), where C is a collection of episodes

A CD could consist of an 'arbitrary' collection of episodes that has been chosen from an 'arbitrary' set of individuals but this is unsatisfactory. In a 'bona fide collective' there exists a 'genuine connection' between the collective's members whereas a 'fiat collective' is just deemed to be one. Galton suggests a number of possible 'genuine connections, but these all raise questions regarding identity (Hornsby and Egenhofer 2000, Medak 2001).

3 SELECTING EPISODES

Galton (2005) suggests three reasons why an individual could be considered a member of a DC: there is causal interaction—i.e. the individual affects or is affected by the DC's other members, or an external factor affects both it and the other members; the motions of the individual and the DC's members are correlated; or the individual is deemed to be a member either by itself, by other members of the DC or by a third party.

All these solutions are plausible but can be questioned. The correlated motions could be due to causal interaction or chance. Individuals might only take part in a DC for a section of their lives; they can leave the collective, return after a period and may not even be present when the collective is created. Consider two different individuals, one present from the beginning of the DC's lifeline who left midway through and one who was only a member for the last quarter of the collective's existence. The motion of these two individuals is unlikely to be correlated. However, there could be

a chain of correlation, with each member's motion correlated to those of its neighbours.

4 OBJECT IDENTITY

A number of ways that a collective could be created is given (Galton 2005): existing individuals come together and begin acting in a co-ordinated way; the collective emerges over a period of time with no particular point of creation; or the collective is created as soon as it has been deemed to exist.

How could the problem of the identity of specific DCs be solved? Could it be the way in which the collective in question is created? Can we use operations such as *aggregates to*, *disaggregates* and *identify* (Medak 2001)? DCs consist of a number of individuals and therefore the concepts of aggregation and parts must be considered. Medak (2001) also suggests two ways to model a 'whole-part' situation: keep a list of the identifiers of the 'composite object' or tag onto each 'partial object' the aggregate's identifier. Could either of these methods be used?

5 THE KEY QUESTIONS

This paper has highlighted the areas researched so far in respect to DCs but key questions still remain.

- What further examples of DCs exist?
- When can you group a set of episodes into a DC? More fundamentally can we formulate a workable set of criteria? Would humans find the criteria 'natural' and does this matter?
- Can DCs be accurately modelled and represented? If so, is Galton's proposed formalism suitable? The concept of a *lifeline* can also be found in Sinha and Mark (2005) - can this work be used to improve a DC formalism?
- So far I have focussed on MAP that are conceptualised as collectives, but are there any significant differences between these and those that are conceptualised as continua like weather phenomena? If not, is there a single universal formalism?
- For some CDs the individual elements are humans. As humans have their own cognitive abilities, could their behaviour be accurately modelled?
- Can work such as Hornsby and Egenhofer (2000) or Medak (2001) help to determine the basis of a DC's identity?

6 ADDRESSING THE KEY QUESTIONS

Many models have been proposed to simulate moving objects but there appear to be none that directly relate to DCs. However the concepts used in them could prove useful in developing a new model. This means future work will involve the analysis of proposed models such as Sinha and Mark (2005) and Batty et al (2003). Comparisons to Galton's formalism will also be made to see if integration would be possible or indeed beneficial. Currently the use of cellular automata and agent-based models are being investigated and in particular models proposed by Torrens and Benenson (2005).

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