An Exploratory Model of Remembering, Telling and Understanding Experience in Simple Agents

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Abstract. Given the importance of narrative for the way humans perceive the world and exchange information about it, it is surprising how little we know about the procedures by which reality is represented as narrative. This is in part due to the well known fact that humans are bad at being aware of their own though processes. It is also influenced by the fact that the ability to generate and process narratives is so pervasive that everybody takes it for granted. Although this is not a worrying issue in general terms, it is a significant problem for recent efforts to construct computational models of this narrative ability. The present paper describes an elementary computational model of a society of agents driven by a need for information, where the ability to represent and communicate reality as a sequential stream of symbols can be shown to provide advantages in terms of maximising the amount of information compiled by a given agent over a given period. This model is not intended as a plausible model of human cognition. The human narrative ability has broader range and significantly higher complexity. However, the model is phrased in terms of elementary principles that can also be seen to underlie more complex models. The paper discusses consequences and insights arising from this model that may be relevant for wider consideration of narrative.

Keywords: computational creativity, narrative, computer simulation

1 Introduction

Narrative has been considered as an elementary cognitive ability relevant for human beings [19, 4, 10]. Yet the process by which a particular experience of reality gets transformed into a narrative in the classic sequential sense that we consider a “story” is poorly understood. Part of the problem faced here is that for a very long time there has been no obvious representation for the experience of reality that can be considered prior to our traditional rendering as narrative. However, the advent of the digital age has progressively changed this. Computers do not represent memories in terms of narrative. Rather they allow for direct storage of experience in terms of flows of perception – audio, video – or abstractions intended for conceptual representations – temporally [20] and/or geographically tagged data [13]. Although these alternative means of representing and storing experience present their own peculiar affordances, it has nevertheless become apparent that there is a large conceptual gap between the representation of the world used by computers and those traditionally used by humans. There are a number of efforts to bridge this gap by means of technologies for recognising actions from video [21], summarization of videos [14] and semantic annotation of videos [5]. However, these are still relatively basic procedures that generate a conceptual representation of the experiences captured in the video at a level that remains far from the narratives that a human would have used to describe the same experience. Given access to a video, or even to the results of these various processing techniques to annotate it, any human would be able to produce a brief and concise narrative about what happens in it. Yet this task is way beyond the current capabilities of machines.

An important obstacle that faces this challenge is the fact that humans are notoriously poor at identifying the processes that they apply in processing reality [16]. The field of narratology has devoted significant efforts over the years to studying narrative [1]. However, this effort has traditionally considered narrative in its final form with little reference to the way it is constructed from human perception. In recent years there has been a significant effort to relate narrative to the study of human cognition [10]. It is clear that this line of research constitutes a major challenge, given the levels of complexity involved in both narrative and human cognition. The grand picture to be considered is enormously complex and full of open questions. Existing examples of narrative can only very rarely be paired with any kind of alternative record of the experience that led to them. This constitutes a significant obstacle for applying a data-driven approach to solve this problem computationally, as these approaches require instances of both the input that lead to the communication impulse and the narrative that arose from it. Efforts to obtain insights into the processes that lead to the production of narrative have resulted in the appearance of creative writing as a specific discipline, different from traditional approaches to literature in the humanities. The current disconnect between these two radically different views of the same cultural artefact – narrative – has been identified as an open question that needs solving [11].

Whereas this lack of consensus as to the nature of the processes actually involved in the production of narrative presents a considerable difficulty for the computational modelling of narrative production, there is a possibility that computational efforts may provide useful insights that might help to clarify some of the elementary aspects that characterise the problem. Disciplines such as social psychology have long accepted the role of computer simulation as a useful tool for addressing research problems that are difficult to represent linguistically or mathematically [17]. This approach has been particularly successful in providing insights on problems that involve social interaction [2]. In the particular case of narrative, existing effort of computational modelling have focused on the traditional view of the author as an individual that works in isolation [6]. Only recently has the social aspect of narrative as means of communication between an author and an audience been considered in computational terms [8]. An important difficulty is that the consideration of narrative is complex enough if the problem is considered exclusively in terms of the process that the writer needs to apply. Consideration of the wider social context while maintaining an acceptable level of complexity in the representation of both narrative itself as a product and the cognition of the author increases the complexity of the problem beyond what can sensibly be represented in a computer simulation. Yet the social aspects clearly play a very significant role and they may be worth studying for their own sake.

The present paper describes an exploratory model where some basic abilities of narrative-generating agents are represented in a small society driven by an accepted need for collecting information about the world, and obeying basic constraints such as a limited range of perception and a limited life span in the context of a record of time that extends over generations of agents. The need to know about a wider world, when an agent's ability to perceive the reality outside him is limited spatially by a given range perception and a given life span, creates circumstances where the ability to share fragments of experience with other agents constitutes an advantage. The consideration of the mechanics of communicating experience in this fashion, in relation to elementary operations of perception and cognition, establishes criteria both for how stories themselves need to be constructed, and how agents decide what and when to share stories with other agents.

2 Previous Work

For the purpose of this paper we want to model the way in which cognitive agents construct sequential discourses that encode a fragment of their personal experience to be conveyed to other agents, the way in which other agents interpret such discourses to enrich their own stored knowledge about the world around them, and the way such behaviours affect the management of information over a network of such agents as a whole. To support the approach followed in the paper, three areas of previous work need to be considered: the use of computer simulation in social psychology, basic approaches to agent-based modelling, and existing computational models of narrative composition.

2.1 Computer Simulation for Social Phenomena

As the model we intend to build will capture the social nature of discourse as a communication device, we need to consider previous work on the use of computer simulation for social phenomena.

Ostrom [17] argues that computer simulation can provide an alternative symbol system in which to express theories in social psychology. He argues that simulations should be undertaken especially when the complexity of the theoretical processes exceeds the ability of the theorist to hold all relevant postulates in mind and to accurately generate predictions. He also describes five complexities inherent to social behaviour that are difficult to address using symbol systems other than computer simulation. They mostly concern the difficulty in observing a latent variable – a construct that cannot be observed directly but must instead be inferred on the basis of its observable manifestations. This is particularly true of the process of construction and interpretation of narrative from reality, in which most of the elements that would need to be captured in a computational model of the process correspond to latent variables. Ostrom's five complexities are: the fact that a single latent variable may have multiple manifestations, the influence of qualitative cognitive and social structures, the connection between latent variables and their overt expression, the interaction between multiple latent variables, and the fact that these phenomena evolve over time. These issues need to be considered for the current study.

Neches [15] outlines three possible views of the role of computer simulation in cognitive psychology: an extreme one where computer simulation is seen as a superior formalism for theory specification, and two more pragmatic ones, one where it is seen a means of exploring or validating psychological theories, and one where it is seen as a source of useful concepts. The third view relies on the view that a computer implementation of a theory may provide insights on the mechanisms involved in the phenomenon under study, by making us aware of the constraints that govern them. This third view is the most interesting for the present paper.

2.2 Agent-based Modelling

Because we want to address the way in which each agent constructs and interprets discourse, we need to consider agent-based modelling.

Helbing [9] provides an overview of agent-based simulation in which he explains that such simulations, when applied for scientific purposes, intentionally make simplifications to focus on the particular aspects under study. In this way, they may restrict to modelling very few of the properties known to be relevant to a given phenomenon, in the hope of achieving a more realistic representation of those properties. Helbing outlines a number of principles to be followed in agent-based modelling. These include: the need to describe the evidence to be explained, the importance of clarifying the purpose of the simulation, and the need to formulate a hypothesis as to the underlying socio-economic processes or fundamental mechanisms leading to the behaviour of the system – making sure that these mechanisms should be at least one level more elementary than the evidence to be understood.

In the spirit of the third approach described by Neches, we intend to develop a computer simulation that does not pretend to be an accurate model of human behaviour but rather models some very specific and very elementary aspects that are known to play a role in the communication between humans by means of discourse. Instead of building a complex model in the hope of obtaining predictions applicable to real-life situations, we hope to achieve a simple model that exhibits interesting properties that may be shared with its more complex counterparts and may provide insights as to basic constraints that may also underlie those. The approach should be seen as a computer simulation version of the synthetic psychology advocated by Braitengerg [3].

2.3 Existing Computational Models of Narrative Composition

Roger Schank stated that the way in which memory works is not only based on processes that manipulate mental data, but instead as continuous recalling and adapting process of previous stories that define our world [19, 18].

Bruner [4] addresses the role of narrative in the way people achieve knowledge of the world, arguing that experience and memory of human happenings is organized mainly in terms of narrative. Bruner presents ten features of narrative that help characterise the particular view of narrative that he is considering in his argument. These ten features are: narrative diachronicity, particularity, intentional state entailment, hermeneutic composability, canonicity and breach, referentiality, genericness, normativeness, context sensitivity and negotiability, and narrative accrual. These features capture a number of important characteristics of narrative that would ideally need to be considered in any computational account of narrative. However, not all of them need to be considered in a specific model, if that model is focusing on a particular aspect.

León [12] presents an architecture of narrative memory that combines pragmatic requirements arising from the need to represent aspects of narrative deemed relevant in computational approaches with cognitive considerations. As in the case of Bruner, a number of the features captured in this approach address characteristics of narrative that are beyond the simple modelling considered in this paper.

The ICTIVS model [8] describes the process of composition of discourse – understood as a vessel to convey a message from a composer to an interpreter – in a setting where the message is complex in nature and structure but the discourse to be employed is restricted to a linear sequence of propositions. The model includes a series of iterations where the composer progressively revises a tentative discourse that she attempts to interpret following procedures that the interpreter is expected to be using. The iterations stop when the interpretation of the result satisfies the expectations of the composer in terms of how the original intended message will be reconstructed by the interpreter.

Gervás [7] presents a computational approximation to the task of composition of a narrative discourse to describe a selected subset of the moves in a given a chess game. In this case, the record of the complete chess game is understood as a source representation of reality, and the composed discourse as a narrative representation of that reality as understood by a particular composer agent.

3 A Model of Remembering, Telling and Understanding Experience

According to the principles outlined by Helbing, we will consider a population of agents that act in the world – come to life, move, interact with other agents, die

–, perceive a small subset of the world that is close to them, store information on what they have experienced, and may communicate fragments of this stored information to other agents. Our hypothesis is that the underlying mechanism that governs the interactions between these agents is a pressure to maximise the perceived amount of information that each agent has managed to compile on the world at end of its life-span. Given basic considerations of limited perception, finite life-span, and limited resources in terms of time to invest in either exploring the world or communicating with other agents, procedures for sharing information with other agents as linear discourses should provide a competitive advantage when adopted by the society of agents. The behaviours resulting from such an approach should present significant similarities with the established way of exchanging information in the form of narratives.

3.1 Basic Model

The construction of a model such as we require involves the establishment of:

- a definition of the world to be experienced
- the definition of agents as participants in the world (and thereby as objects experienced by other agents)
- a definition of agents as cognitive actors (or subjects of experience who perceive a partial view of the world and store information about it in some format)
- the establishment of a communication mechanism whereby agents may share information

The World We consider the world to be a two-dimensional space of discrete cells, such that a single agent can stand in a given cell. Each cell can be identified by its horizontal and vertical coordinates with respect to a given reference point. Although many different configurations could be used, the initial tests have been run with an 8 x 8 cell, with the reference point established at the bottom left corner.

Agents as Participants Agents are identified by capital letters. Agents are capable of moving and talking. They can move over the world in vertical or horizontal directions, one cell at a time. An example of a succession of states of the world is shown in the first column of Table 1. The behaviour of each agent is controlled by a set of modules that encode the heuristics to decide when and where it will move and when it will talk. These modules can be configured in different ways, to allow for different degrees of mobility and garrulousness over the full set of agents. The values for these configurations parameters may play a role in determining the success of individual agents and/or the overall success of the social communication strategy. Specific modules also control reproduction behaviour and agent's demise. Each agent is spawned at a random position in the world.

	a	b	c	d	e	f	g	h
1								
2					A			
3						C		
4								
5								
6			B					
7								
8							D	

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	A			X
3	X	X	X	X		C		X
4	X	X	X	X				X
5	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1								
2				A				
3								
4						C		
5								
6				B				
7								
8						D		

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X				X
4	X	X	X	X		C		X
5	X	X	X	X				X
6	X	X	X	X	X	X	X	X
7	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1								
2				A				
3								
4								
5						C		
6					B			
7								
8						D		

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4	X	X	X	X				X
5	X	X	X	X		C		X
6	X	X	X	X	B			X
7	X	X	X	X	X	X	X	X
8	X	X	X	X	X	X	X	X

Burst of discourse (absolute)

```
time 00
C at f3
A is at e2

C move to f4
A disappears

C move to f5
B appears at e6
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Burst of discourse (relative)

```
time 00
C at f3
A is nw

C move s
A disappears

C move s
B appears se
```

Table 1. Succesion of views of the state of the world, partial views of the world as observed by agent C and the discourse burst that C might produce to convey its experience to other agents.

Agents as Cognitive Subjects Agents are assumed to have perceptive abilities that allow them to perceive all actions that happen within a given radius of their current position. This is considered the range of perception. The range of perception is set at one cell in all directions – including diagonals – to ensure that agents that do not move have a limited perception of the world, and that agents wanting to report their experience at a given point in time have a limited amount of information to deal with.

Agents store their perception of the world around them as a partial view – determined by their current position and their range of perception – of the map of the world at a given point in time. As agents move, their perception will shift to a different portion of the world. Agents are capable of converting their perception of the world into this type of view. The overall record of a given agent will therefore be a sequence of snapshot of such partial maps. An example of a succession of such partial maps is shown in the second column of Table 1.

Communication Mechanism The purpose of the simulation is to explore the effects of the hypothesized pressure to compile information about the successive states of the world on the different strategies for constructing messages, sharing them with other agents, and interpreting those received from other agents.

It is clear that agents limited to perceiving the world as they move around are unlikely to reach high levels of coverage over the absolute space of all states of the world over time, due to their limited perception. The possibility of sharing their partial views with other agents would significantly increase the coverage they can collectively achieve.

In an ideal setting, an agent would be able to share all its memories with any agents within its range of perception. However this would be unrealistic. We need a model of communication that incorporates restrictions on the time devoted to communication. The amount of information conveyed should have some correlation with the time invested in communicating. This places pressure on the selection of what information to communicate and on the format used to communicate it, which are some of the features we are interested in.

This establishes some initial constraints on the format of communication of information. If at a given point in time agents were to communicate a full description of the NxN square that they perceived at some other moment in time, the listening agent would be restricted to a one shot view of the world, with little change of dynamic information. Even if the ratio between the processing ability for perception and interpretation were changed, the possibilities of covering appreciable segments of the world in this way would be small. So some procedure of optimising the encoding of experience must be put in place. This is one of the aspects of the simulation that can be tested during exploration.

Any such messages – given that they may refer to location, moments in time, and agents other than the current ones – must explicitly encode location, time and protagonist[1] in such a way as to allow an interpreting agent to place them

[1] We are at present conflating the roles of protagonist and narrator, as we assume that any such basic communications would necessarily be phrased in the first person.

in the appropriate context. An example of discourse bursts is shown in the third column of Table 1. A discourse using absolute values for locations constitutes a compact representations of the set of partials views it encodes. The use of speaker-centric relative values for describing locations is even more compact.

As agents need to construct this type of message, different solutions to this task may have different impact on the overall success of both individual agents and the collective as a whole. These aspects will be explored in the simulation.

Each agent must be capable of converting any messages received into its own representation of the world. Table 2 shows an example of how the knowledge of the world held by agent B, before and after processing the example discourse generated by C (see Table 1). Again, the procedures for this need to be explored in the simulation.

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X
5	X				X	X	X	X
6	X		B		X	X	X	X
7	X				X	X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X
5	X	X				X	X	X
6	X	X		B		X	X	X
7	X	X				X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4	X	X	X	X	X	X	X	X
5	X	X	X			C	X	X
6	X	X	X		B		X	X
7	X	X	X				X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	A			X
3	X	X	X	X		C		X
4	X	X	X	X				X
5	X				X	X	X	X
6	X		B		X	X	X	X
7	X				X	X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X				X
4	X	X	X	X		C		X
5	X	X						X
6	X	X		B		X	X	X
7	X	X				X	X	X
8	X	X	X	X	X	X	X	X

	a	b	c	d	e	f	g	h
1	X	X	X	X	X	X	X	X
2	X	X	X	X	X	X	X	X
3	X	X	X	X	X	X	X	X
4	X	X	X	X				X
5	X	X	X			C		X
6	X	X	X		B			X
7	X	X	X				X	X
8	X	X	X	X	X	X	X	X

Table 2. Succession of partial views for agent B (top row) and the result of enriching B's knowledge of the world (bottom row) after processing from C the discourse given in Table 1

4 Competing Configurations of the Model

Each of the elements of the model needs to be configured to behave in particular ways. The different possible configurations interact with one another. To explore

Subsequent efforts may delve into the details that may arise from considering more elaborate approaches.

the full set of possibilities is beyond the scope of this paper. However, some basic possible configurations are reported to demonstrate the potential of the approach.

4.1 Movement

Agents can move freely around the board. The way in which they decide to move will affect the amount of information that they have available at the end of their life-span. Agents may prefer to remain near fixed positions as this may maximise their personal perception of relative information coverage. Since they are unaware of other locations, they may reach the end of their life-span under the conviction that they know all there is to know about what happened in (their limited view of) the world. However, appearance of another agent coming from other parts of the world may disturb this brittle impression, as their stories may identify far away places (and may set the listener wondering about what may have happened there).

Alternatively, agents may decide to wander, traversing the world to explore what can be found beyond their range of perception. This type of agent is likely to discover a larger subset of the overall available space, but as a result it will develop a lower personal perception of relative information coverage.

4.2 The Role of Communication

Agents need to decide how they approach the task of composing the type of message that is being passed around. Although agents are in theory free to compose messages as they see fit, it is clear that comparative advantage will only be achieved if some agreement is reached between the way in which agents compose their messages and the way other agents interpret them.

A baseline procedure for carrying out this task can be imagined by considering analogies with the way humans go about similar tasks.

Agents may optimise the encoding their partial view of the world at a given point in time in two different ways: by restricting what is reported in a message to exceptional elements – themselves carrying out some action, an action by another agent being seen, another agent being visible, becoming visible or disappearing as a result of some action –, and by describing their perception in terms relative to themselves.

By following these two strategies, agents describe only the highlights of their partial view in terms relative to their position at that point in time. This allows for several moments in time to be so described within the space equivalent to a full perception of the view at a given moment (which would also include encoding for the empty spaces). In order for other agents to be able to interpret this correctly (see below), the first segment of such a representation is devoted to establishing the position and the moment of time of the telling agent at the start of conveyed span of experience. As these spans may be passed on from one agent to another, the next segment of the representation indicates who the protagonist agent of the span is. To avoid the use of overloaded terms that might cloud the issue – such as story or narrative, which may bring in preconceived notions of the reader – we will refer to this medium of communication as a *burst of discourse*. An example of these various mechanisms at work can be seen in the discourse burst produced from a partial view of world shown in Table 1.

An important advantage of the relative approach to description of perception, is that the interpretation of busts of discourse of this type can be achieved by reusing the procedure by which a perceiving agent constructs the map view of experience that it would have if experiencing the events conveyed by the message.

5 Discussion

The approach described in the present paper constitutes a preliminary description of a computer simulation that is currently under construction. The basic infrastructure for handling a number of agents in the type of environment described is already available. Implementations of the type of epistemic agent described, capable of perceiving the world in the manner described and storing information obtained from those perception in the manner outlined is already available. Basic implementations of some of the possible approaches to composition of bursts of narrative discourse of the type described are under way.

The description of the model as presented in the paper already permits the identification of a number of problems that any computational model of narrative would have to take into account.

First, Ostrom's five complexities need to be considered as they affect the modelling of narrative. The description provided at the level of detail required for modelling the phenomenon in this fashion, ilustrates the fact that a number of crucial aspects – such as the specific procedures used for composition and interpretation of bursts of discourse – may be playing the role of latent variables, in the sense that they cannot be observed directly but only as they affect the results that are exchanged betwen the agents. In the particular case of studying narrative as it occurs in the world, the problem is further compounded by the fact that the actual perception (or conception if narrative is understood in broader terms to encompass fiction as it mostly does) that the composer wants to convey also becomes latent in a similar way: it is unavailable for observation. The proposed model has the advantage of providing a controlled experimental setting in which this perception of reality is indeed observable as it is explicitly modelled outside the agent. Nevertheless, Ostrom's concerns about the interaction between multiple latent variables and their evolution over time are also relevant for this approach, and computer simulation may provide the means of exploring them.

Second, Helbing's observation that an agent-based modelling approach need to formulate a hypothesis as to the fundamental mechanism that drives the behaviour of the system – at least one level more elementary than the evidence to be understood – has been followed in the present proposal by restricting the set of features explicitly represented in the system to elementary aspects of cognition and perception. The main hypothesis underlying the proposed approach is that such features constitute a basic network of constraints that establish the fundamental form of discourse that humans can employ to communicate narrative. Although this constitutes a very crude representation of the much more complex phenomena that need to be addressed for narrative – such as interest, affect, emotion –, it provides a valuable guideline which may help in the search of meaningful baselines to implement the various procedures that would be required to obtain an operational version of the described architecture.

Third, the proposed approach is restricted to a small subset the ten features of narrative described by Bruner. Overall, the described model is indeed based on the way in which man achieves knowledge of the world – which Bruner lists as the original motivation for his discussion –, and considers explicitly the interaction between perception and transmission between agents. The underlying framework for representing the world and the solution used to represent agent's knowledge stores satisfy narrative diachronicity. The representation considered only deals with burst of discourse concerning particulars, so they lack the additional layer of acting as tokens of broader types. The remaining features that Bruner considers would correspond to more elaborate layers of understanding and representation than considered here, but it is our belief that even those more elaborate layers would need to operate within the constraints established by the more elementary features concerning this particular type of communication of experience between agents.

6 Conclusions

The present paper proposes a computational model of basic interchange of information about the world between agents that have their own perceptions but may learn about the world also from the perceptions of others. Elementary issues of the ratio between the information compiled versus the effort invested in its acquisition are interpreted into a set of constraints that drive possible solutions for communication mechanisms between agents into formats surprisingly similar to those observed in the human approach to telling stories. This is considered a promising insight.

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