Generative comics: a character evolution approach for creating fictional comics

Citation for the original published paper (version of record):
Nairat, M., Nordahl, M., Dahlstedt, P. (2020)
Generative comics: a character evolution approach for creating fictional comics
Digital Creativity, 31(4): 284-301
http://dx.doi.org/10.1080/14626268.2020.1818584

DIGITAL CREATIVITY
2020, VOL. 31, NO. 4, 284–301
https://doi.org/10.1080/14626268.2020.1818584

Generative comics: a character evolution approach for creating fictional comics

Malik Nairat, Mats Nordahl and Palle Dahlstedt

Division of Interaction Design, Department of Computer Science and Engineering, University of Gothenburg / Chalmers University of Technology, Gothenburg, Sweden

ABSTRACT
Comics can be a suitable form of representation for generative narrative. This paper provides an argument for this based on an analysis of properties of the comics medium, and describes a tool for character design and comic strip creation that applies interactive evolution methods to characters in a virtual environment. The system is used to interactively create artificial characters with extreme personality traits inspired by well-known comics characters.

KEYWORDS
Comics; narrativity; generative art; evolutionary algorithms; multi-agent systems

1. Introduction

The interaction between art and technology has led to a growing interest in generative art, where the computer plays a significant role in the creative process. This paper describes an interactive generative framework for designing characters and creating short comic stories from their interactions. We also argue that comics are particularly well suited for applications of generative processes.

Character is one of the most important elements in a dramatic work (Egri 1960). It is the driving force that moves the storyline ahead, and the core of any memorable story. Its development is the key element in story creation, and a close identification of it is often crucial to understanding the story. Characters often remain in our minds long after the setting, theme, and intricacies of the plot are forgotten. The concept of character refers to a textual representation of a human being or other creature. To understand a character one should focus on its personality: what he/she cares about, what makes him/her happy or sad, and how he/she behaves with others and responds to actions. In fiction, as in real life, we can evaluate a character in three ways: through what he/she says, does, and what others say about him or her (McKee 1997).

This contribution describes a tool for building short comic stories using interactive evolution methods to design characters in a multi-agent framework. The story skeleton is created from the actions of a group of agents/characters. The personalities of the characters are encoded in their genomes, which determine the dynamics of their internal states (emotions) and actions. The agents interact while the creator observes, and sometimes intervenes to provoke new behaviour. Agents with behaviour relevant to the artist's goals are selected for further development. When the artist is satisfied, comic stories can be generated from their interactions, either automatically or manually.

CONTACT Malik Nairat malik.nairat@gu.se

Creative tools using interactive evolution methods to generate novel solutions and ideas have found applications in various areas, including music and design (Dahlstedt 2001; Takagi 2001). Our aim is to show that this approach can be used in a character centred approach to narrative, in particular to create comic stories, and we argue that comics are particularly well suited to generative algorithms. This is both due to characteristics of the comics medium itself, and the fact that even simple agents with few internal states can be useful in creating comic effects and interesting narratives.

The simulations are initial investigations of the possibilities of the framework, where we have attempted to create simplistic and funny characters, often with strange and unusual emotional behaviour. They are compared to well-known cartoon comic characters, e.g. Disney characters such as Donald Duck and others (Disney 1988).

In section 2, we provide a brief review of generative storytelling and discuss characteristics of comics and their suitability as a medium for generative algorithms. In section 3, we describe the construction of our system including agent structure and the representation of agent personality, and the dynamics of interactions. Section 4 illustrates our methods by showing results from some simulations that develop agents for comics, and section 5 contains conclusions.

2. Background

2.1. Generative art

Generative art is a term used for artworks created using a computer system or algorithmic method. According to (Galanter 2016):

> Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art.

In (Boden and Edmonds 2009), an artwork was considered generative if at least part of it is generated by a process beyond the artist's direct control. Some artists use generative methods to manage an extensive space of decision making, while others use the ability of generative methods to provide surprise and unpredictability. Emergence is one of these reasons. Emergence (Gibb, Hendry, and Lancaster 2019) refers to situations where the outcome of a system is more than the sum of its parts. In (Monro 2009), emergence in generative art is described as:

> the observed behaviour or output of the artwork is unobvious or difficult to predict and evokes feelings of surprise, wonder, mystery and autonomy, even when we have complete knowledge of the construction system.

Emergence can also expand artists' conceptualization and move the boundaries of their idea exploration by creating an array of options. One approach uses algorithms inspired by nature such as genetic algorithms (Holland 1975) to create variation, while the user applies the selective pressure in an interactive evolutionary process.

2.2. Generative methods in storytelling

Various approaches have been explored in generating stories, including plot-based or deliberative, character- or simulation-based, and intermediate approaches. Most studies have dealt with story generation rather than story characterization, with focus on plot rather than characters. This follows a tradition in narrativity from Aristotle's Poetics (Halliwell 1987), while other authors (Egri 1960) have argued that character is the basis of dramatic structure. Our work takes the creation of character as the primary goal, and the plot is derived from interactions between characters.

An early example of a simulation based story generation system is TALE-SPIN (Meehan 1977), which generates stories about animals similar to Aesop's Fables. The behaviour of agents is generated by giving them individual goals and letting an inference engine continually generate actions based on those goals.

The notion of emergent narrative resulting from the interaction of autonomous agents was introduced by (Aylett 1999), and further explored, e.g. in (Louchart and Aylett 2004; Larsen, Bruni, and Schoenau-Fog 2019). To create more structured plots, a number of researchers introduced intermediate approaches where agents are guided in their actions. In the Oz project (Bates 1994), one agent was appointed as drama manager, as suggested by (Laurel 1986). A similar approach was used, e.g. in the Virtual Storyteller system (Theune et al. 2003), and in (Mateas and Stern 2003) and (Laclaustra et al. 2014).

The plot-based or deliberative approach focuses on achieving a well-structured and coherent plot with emphasis on character intentionality. Early work on AI planning in the computational modelling of plot is, e.g. (Young 1999). A discussion of the need to balance plot and character, and descriptions of the implementation of planning based systems can be found in (Riedl and Young 2004, 2010). Planning has also been introduced by using a hierarchical task network and letting the user influence a character to change its goal in (Cavazza, Charles, and Mead 2002).

Some recent work related to our approach, e.g. (Méndez, Gervás, and León 2014; Ryan, Mateas, and Wardrip-Fruin 2016) has focused on modelling emotions and the network of affinities between characters. Research on simulated emotions in autonomous agents, e.g. (Picard 1997), has also influenced the agent structure in our work.

Another way of distinguishing approaches to story generation is to consider the role of the human creator. We have built a creative tool for the artist's own creative practice, where the output is often processed manually to create the final product. Useful output may be entire stories, story fragments, or evolved characters that are reused in new stories. Our approach is similar to that of mixed-initiative interaction processes (Novick and Sutton 1997; Liapis et al. 2016) discussed, e.g. in the context of game content generation. The role of the artist in generative storytelling has also been emphasized by (Crawford 1999), who argued that humanly interesting stories need the cultural context knowledge provided by artists.

2.3. Evolutionary algorithms

Evolutionary algorithms recreate processes of variation and selection analogous to Darwinian evolution in a computer setting. They were introduced for optimization (Holland 1975), but can also be used to interactively explore spaces of creative possibilities (Dawkins 1986; Sims 1991).

Evolutionary approaches to computer creativity can be viewed as related to the blind variation and selective retention (BVSR) theory of creativity in cognitive psychology, introduced by Campbell (1960), and elaborated on by Simonton (e.g. Simonton 2011). Some neuroscientists have argued for a related neural basis for creative cognition (Jung et al. 2013). Other scientists have argued against an over-simplified Darwinian view, or extended these concepts to reflect the sequential and memory-based nature of human creativity (e.g. Gabora 2005).

Interactive evolution has been successful as a framework for creative tools in several domains, e.g. in music, where it has been used to search the high-dimensional parameter spaces of sound synthesis engines (Dahlstedt 2001), also in commercial applications (Dahlstedt 2009). There are also numerous applications in various design domains, see, e.g. (Takagi 2001; Von Buelow 2008).

Evolutionary methods have been used in story creation in (Nairat, Dahlstedt, and Nordahl 2011, 2013), and by others focusing more on the generation of plot than character, e.g. (Ong and Leggett 2004; McIntyre and Lapata 2010; Giannatos et al. 2011; Wang et al. 2018). The character based approach to story generation has some similarities to applications to sound synthesis. Stories emerge from the complex dynamics of interacting characters, which depends in an unpredictable way on the genome parameters that determine the agent personalities, and the evaluation also requires significant time since the behaviour of characters must be followed over time.

2.4. Comics as a representation medium

Comics pose different qualities than narrative media such as film or literature, which make comics suitable for a generative approach. According to (Duncan and Smith 2009), plots in comics can be simple narratives with a single problem and solution such as in children's comic books, complex narratives with subplots and complex settings and characters, or non-narrative comics focusing on aesthetic properties. The latter are particularly relevant to generative systems. Many comics are also serialized with settings revolving around the main character and without climax or final problem to resolve. Thus, for many forms of comics, a character-based approach may be suitable.

Comics also provide an open-ended framework for reader participation in constructing and reconstructing the narrative. The comics reader acts as a second author by joining story elements together and constructing an interpretation in both a linear and nonlinear way; thus, the reading process becomes interactive between story and reader. This conceptualization of interpretation or openness does not mean complete freedom of understanding, but rather a presence of multiple and interlinked interpretations unique to the story (Ahmed 2016).

While openness exists in other forms of narratives (Eco 1989), comics are unique in presenting the story verbally and visually through a network of images, icons, and words. This combination of visual and verbal signs can create movement, suggestiveness, and ambiguity that compel the reader to fill the gaps for the perception of the story, while provoking different, yet linked interpretations (Ahmed 2016). Suggestiveness in comics is achieved through figuration and self-reflexive iconicity, as well as obscured rendering of characters. These elements act as clues and messages that lead the reader in understanding the story and constructing an interpretation.

This hybrid feature of word-image interactions is an important features of comics which provides clues about characters and story elements (Mikkonen 2008). Ahmed states that the hybrid nature of comics lets them be seen both as story and visual art, a '*double temporalité*' (Ahmed 2016), where the medium provokes the reader to pause reading to appreciate the images themselves. This distinguishes comics from other hybrid media such as video or animation; comics give the reader control over time and space by pausing the reading or jumping to other panels.

Additionally, comics do not present each moment of time like motion pictures; only a selection of important moments are rendered into panels. This encapsulation lets the reader fill the gaps between the panels and cognitively construct a comprehensive story (McCloud 1994; Eisner 2008; Duncan and Smith 2009).

Many scholars agree that comics is an art form where the pictorial images are mostly drawn (Carrier 2000; Gravett 2013). Drawing styles are individualistic, yet have significant impact by provoking different emotional reactions and understanding from readers (Duncan and Smith 2009). Although this could apply to other media such as animation, it is rare due to the extensive amount of drawings. In the proposed system, images are constructed from a library of parts that are joined to form complete panels. For comics this library does not have to be comprehensive to apply different styles for different outputs. In this work we use a simple cartoony drawing style appropriate to the type of characters created.

Furthermore, exaggeration and simplification are important features of comics; therefore, the stylized characters, iconic and detailed representation are essential for better understanding of stories. Poses and expressions are exaggerated to provoke a stronger emotional response from readers.

There is a growing interest in applying generative approaches to comics, e.g. for generating visual representations. Some approaches have dealt with story structure and its visual representation through abstract comics (Martens and Cardona-Rivera 2016), and others with creating a comics representation of game events (Chan, Thawonmas, and Chen 2009), or the relation between story planning and visual representation (Cassell and Young 2012).

2.5. Why comics?

We believe that a framework based on interacting agents, whose interaction determines the dynamics of their internal states (emotions) can be used in creating cartoon characters for comics. Characters in a realistic drama, or interface agents designed to emulate human emotions, require a larger number of internal states, resulting in greater complexity and difficulty in evaluation. The openness of comics is important to generative approaches; one reason is that these often provide limited information about story events, e.g. by sampling the agents' actions. A medium that encourages users to fill the gaps and create their own interpretations can then be suitable.

Cartoon characters differ in the complexity of their personality and their world. Our main interest is simple narrative characters with clear-cut characteristics, suitable for computational modelling. (Wright 2005; Finander 2010) suggested various distinguishing features of cartoon characters: they are simpler than real-life ones and express clear and direct personalities, and also have less complex emotions, and more limited and focused actions. They can portray exaggerated forms of personality, actions, emotions and visual appearance, and create a simpler form of storytelling that may not require a homogeneous plot or story structure to the same extent.

In comics, Disney characters are better models for our work than, say, Tintin, who carries out more complex plans of action. Characters such as Donald Duck and Mickey Mouse have limited sets of emotions and actions, and their personalities reflect an exaggerated comic form. Their cartoony visual design creates more modest reader expectations than realistic characters. However, Mickey often acts as a detective, or hero who saves the situation. Even if his internal states are simple, the plots may be complex. Donald is a more relevant Disney character for a comparison to the characters we create, because of his simple exaggerated personality.

According to (Finander 2010) his most important traits are: a high temper that he fights to keep down, optimistic with joyful heart, starts his day in a happy mood then something spoils his day, his anger is problematic for him, helpful and sensitive with aggressive nature especially towards his nephews, brave but irrational, regretful if he hurts anyone, arrogant and proud of himself, with obvious emotions, stubborn but committed, lazy but persistent, jealous of Mickey and wants his job as Disney's greatest star, terribly misfortunate, and his personality is clearly displayed through his actions. In the examples below, the system was used to interactively create an artificial comic character with similar traits.

3. Methods

3.1. Agent structure and dynamics

Agents are characterized by a set of continuous internal states S, which change dynamically during interactions with other agents, a finite set A of actions, and a genome G, which remains constant in a simulation but can be changed by the artist between simulations in an interactive evolutionary process. The personality of an agent is determined by the structure of the dynamical system that describes internal state changes and actions.

This approach is related to research on simulated emotions in autonomous agents, (e.g. Egges, Kshirsagar, and Magnenat-Thalmann 2004). However, it introduces a more general representation of personality, which does not rely on low-dimensional parametrizations based on personality models from psychology, e.g. the five-factor model (Digman 1990). When creating comics characters, we prefer to allow personalities that might not resemble realistic humans. By introducing a suitable representation of the functions for action selection and state changes, the space of agent personalities can be searched systematically, for example using interactive evolution. These representations resemble simple neural network models (linear and nonlinear perceptrons), and allow genetic changes through mutations and crossover in a natural way.

Each agent has a small number of internal states, which are updated during the interactions with other agents. The state change depends on the action, the current state, and the genome, so that characters behave according to different genetically determined personalities, but their reactions also depend on their current emotional state. There are three categories of internal states, represented by real numbers in the range −1 to 1:

- **Resources** $(r_1 \ldots r_R)$ which change as a direct result of interactions with other agents.
- **Emotions** $(e_1 \ldots e_E)$ which are affected indirectly by the actions of other agents.
- **Feelings** $(f_1^{(k)} \ldots f_F^{(k)})$ for $k = 1 \ldots N$, where N is the number of agents, represent the F attitudes of an agent toward each of the agents. This includes feelings the agent has toward itself (which could result in a character punishing itself or committing suicide out of self-contempt).

The complete internal state of an agent has dimension $R + E + N \times F$ and is given by $S = (r_1 \ldots r_R, e_1 \ldots e_E, f_1^{(1)} \ldots f_F^{(1)}, \ldots, f_1^{(N)} \ldots f_F^{(N)})$.

The model also contains a finite set of actions $A = \{a_1 \ldots a_A\}$ that an agent can perform towards other agents. These can be specific to each agent (e.g. Ignatz throwing a brick at Krazy Kat (Herriman and Blackbeard 2001)), or generic. Actions have labels and visual representations chosen freely by the artist. The effect of an action on the state of another agent can be pre-determined (e.g. for resources), but is typically determined by the genome of the receiving agent (so that being hit by a brick can be interpreted as an act of affection).

Actions are performed sequentially, with pairwise interactions between agents. The interaction order is determined by selecting a random agent each time for interaction, or by letting an agent respond to an action with some probability to encourage sequences of reciprocal actions. In some simulations, characters are evolved by exploring interactions only between a main agent and one other agent at the time; in that case, the agents perform alternating actions. Random external events can affect the internal states of characters with a small probability.

The action of an agent j interacting with another agent k depends on its current internal state, its genome, and the identity of agent k. There is no explicit dependence on previous actions, but a record of these can reside in the internal state values, resulting in positive or negative feelings towards the other agent.

Actions are selected using a partition of the agent's internal state space into 2^M regions defined by M hyperplanes $v_i \cdot S + c_i = 0$ for $i = 1 \ldots M$, where each region is associated with an action. The parameter M is a design choice, and the vector v_i of the same size as S, and the scalar c_i are stored in the agent's genome. The state S is mapped to a binary string $B = b_1 \ldots b_M$ of length M by letting $b_i = 1$ if $v_i \cdot S + c_i > 0$ and $b_i = 0$ otherwise. The binary string B is used as index in a lookup table of size

2^M that associates an action to each string, which is generated at the start of the simulation.

The internal states of both agents are updated when they interact. We first consider the change in the internal states of agent j that performs an action a directed at agent k. The state is updated by adding a contribution that only depends on the action itself, and another that also depends on the current state. States are restricted to the interval $[-1, 1]$ by applying $g(x) = \tanh x$. For the state components $(f_1^{(k)} \ldots f_F^{(k)})$, only the feelings between agents j and k are updated in the interaction. In the formula below, this is taken into account by using a projected state vector of dimension $R + E + F$ which only includes the relevant feelings, resulting in the following state change for agent j:

$$S_j^{(\text{new})} = g\left(S_j^{(\text{old})} + D_j^{(a)} + \sum_l W_{jl}^{(a)} S_l^{(\text{old})} \right)$$

For the agent k which receives the action, the state change is given by:

$$S_k^{(\text{new})} = g\left(S_k^{(\text{old})} + d_k^{(a)} + \sum_l w_{kl}^{(a)} S_l^{(\text{old})} \right)$$

The parameters $D_j^{(a)}, W_{jl}^{(a)}$ and $d_k^{(a)}, w_{kl}^{(a)}$ are obtained from the genomes of agents j and k respectively. This means that an agent's genome consists of the real-valued parameters $G = (v_i, c_i, D_j^{(a)}, W_{jl}^{(a)}, d_k^{(a)}, w_{kl}^{(a)})$, for $i = 1 \ldots M, j, k = 1 \ldots R + E + F$, and $a = 1 \ldots A$. In the evolutionary search process, this genome can be subjected to random mutations and crossover following common procedures for genetic algorithms (e.g. Holland 1975).

In the experiments, the number of internal states was kept small. Even two emotional dimensions can result in interesting personalities. For comics this is suitable, since characters can be highly stylized with simplistic personalities. The internal state labels are arbitrary, but can serve as inspiration for the artist's interpretation of the observed events, and in that way influence the final artistic results. The labels of internal states and actions can be predetermined, or decided later in the artistic process, e.g. using interactive evolution.

3.2. System structure and simulation details

The workflow when using the system consists of four main phases (see also Figure 1):

(1) System initialization, where basic features of the story environment are determined, and initial states of the characters are randomly generated or recalled from memory.
(2) Character evolution, where individual characters are evolved in a process of observing their interactions.
(3) Story generation, where sequences of interaction between evolved characters are generated and chosen for rendering.
(4) Comics rendering, where the selected action sequences are rendered to panels.

In the system initialization phase, actions and internal states of the agents are defined and labelled, agents and actions are provided with preliminary visual representations, and initial genomes and internal states of the agents are generated. As an example, in the simulations below all agents had internal states with two resources and four emotions, and a single feeling towards every other agent. Eight different actions with inspiration from original comic stories were defined, some with differentiated action strengths (examples of action label were: Say hi, Give a gift, Talk, Play, Date, Fight, Chase, Attack). One example of state labels was to label resources as health and wealth, emotions as temper, fear, regret and happiness, and feelings as love/hate. The labels of emotions and feelings are arbitrary choices for the artist, and can be changed to provide multiple interpretations of an interaction sequence.

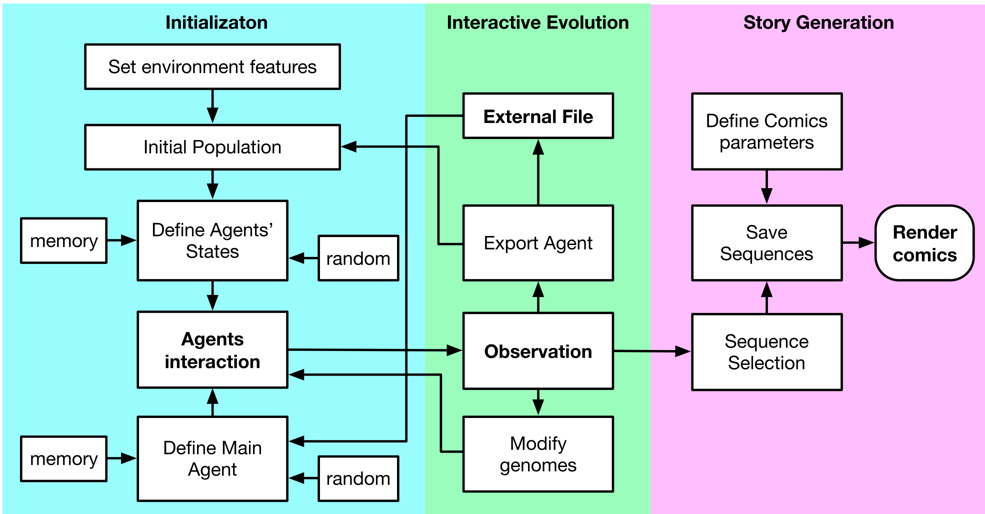

Figure 1. System overview as a flow diagram.

A small population of agents is used. One main agent is singled out, which has an identical state structure to the other agents, but is treated differently in the user interaction. The purpose is to simplify the evolutionary process and minimize the amount of evaluation by primarily evolving one agent, while other agents are changed more rarely, or not at all. Initially the agent genomes are recalled from storage or generated randomly. The initial internal states of the agents are generated randomly or set to zero (e.g. feelings toward other agents).

In the character evolution phase, characters are developed in an evolutionary process where the user can evaluate a character and its behaviour and decide if it is interesting for story creation. The evaluation involves observing repeated interactions between the main character and one or more other characters. Genomes can be saved for further iterations, or subjected to random or directed changes, and the evaluation can be repeated. Interesting sequences of actions can also be stored at this stage.

In the story generation phase, evolved characters are allowed to interact, and some sequences of interaction are stored for rendering into panels. In the rendering phase, a set of panels is rendered either by hand by selecting certain points in time in an interaction sequence, or automatically using built-in functionality in the system. Visual modifications can be made in this phase, e.g. by changing the visual representation of characters and actions, or using artistic freedom to introduce other changes.

The workflow was developed and modified in the first author's creative practice. In particular, the need to simplify the evolutionary process by focusing on one agent at the time, for greater interpretability and speed of evaluation, became clearer with use of the system.

3.3. User interface

The interactions are monitored in the user interface of the system, by following the time evolution of agents' internal states and actions, and through an animated cartoon story showing the agents in their environment. The first method provides a detailed understanding of the agent's actions and reactions, while the latter provides a better way of observing their behaviour.

The interface is divided into five parts (see Figure 2): Part 1 and 2 provide visual

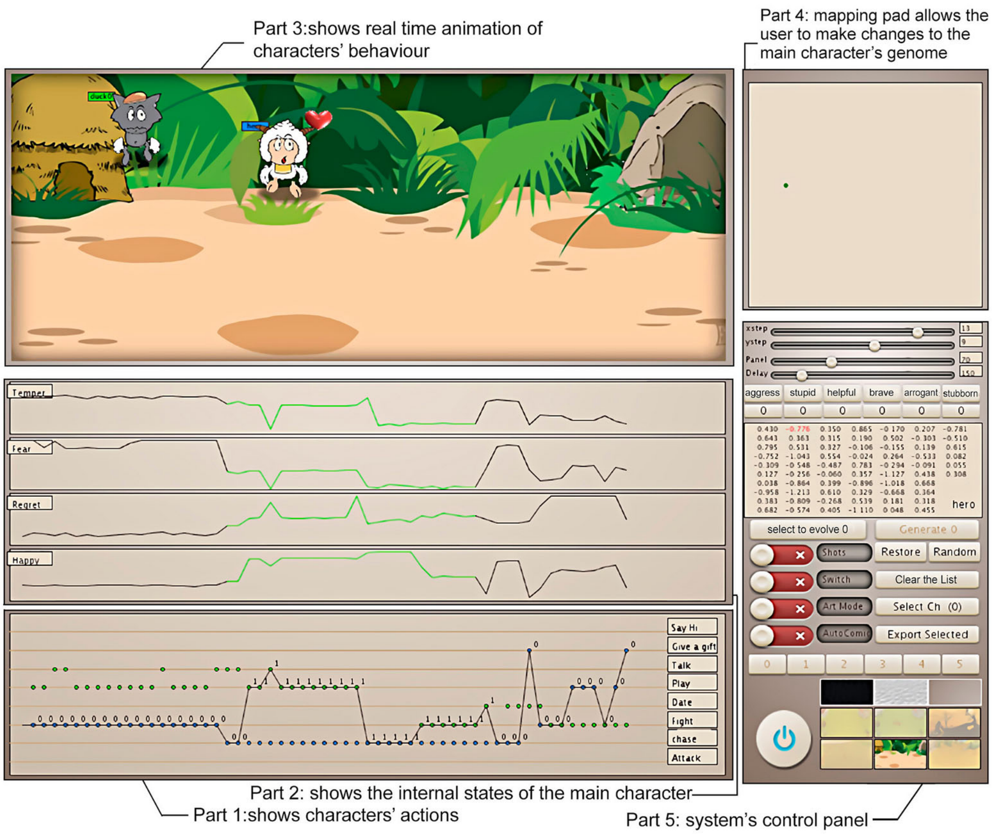

Figure 2. The user interface where the user can observe the behaviour of the agents and change their parameters.

information about an agent's actions and internal states as real-time graphs, which provide insight into its personality and emotional dynamics. Part 3 renders the emerging story as an animated cartoon. The control panel (Part 4) lets the user modify a character's genome through small random changes or explicit changes of the genome. The genome space can be interactively explored using a two-dimensional representation.

Part 5 contains tools that control the evolutionary process and the interface, including selecting which characters are allowed to interact, saving their genomes, modifying animation settings and switching between different scene themes and characters customs, and creating comic strips from the emergent stories as pdf files. The comics generating process can be automated with encapsulation of the panels created by the system, or manual, allowing the artist to define the panel contents with the animation window as a source.

3.4. Generative comic styles

Conventional comics can be created from a generative system using two-dimensional or three-dimensional approaches. A 2D approach uses images, icons, and drawings to construct comic panels. The visual style of the source images may be changed through stylistic effects or textual figurations. Another way to create panels is to combine graphical images from a library designed for the system. A more complex 3D approach can use a game engine to construct and control the agents' behaviour and environment.

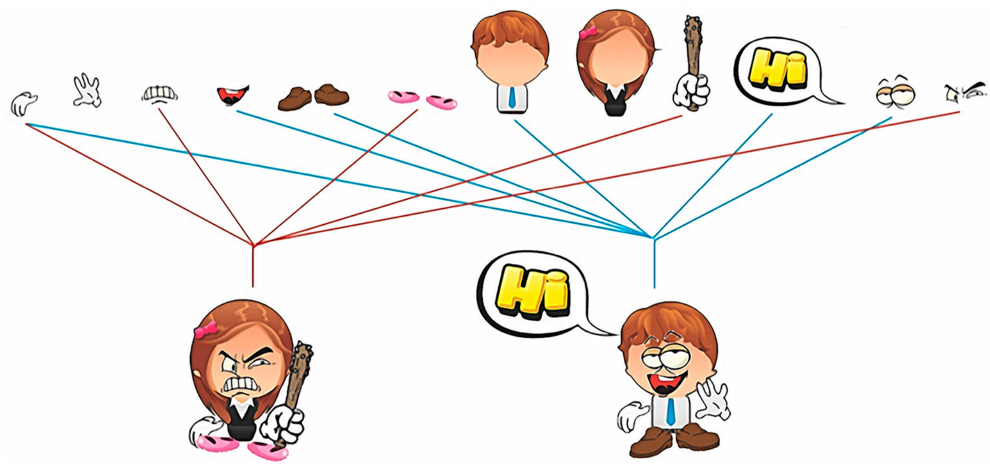

Figure 3. Constructing characters and their poses, actions, and expression from a set of graphical elements.

Here, we employ a 2D approach where comic panels are constructed by combining graphical elements to form characters and their poses, actions and expressions. In this way, a set of graphical elements can construct a combinatorial variety of images (Figure 3). This approach has similarities to drawing; in (Cohn 2014) it is argued that drawing resembles a process of combining visual elements from memory and imagination more than a result of observation. In the animation window of the interface, a fixed hand-designed mapping from internal states (emotions and resources) to facial expressions and poses was used.

4. Results – examples of evolved characters

In the simulations, we attempted to create agent characters with extreme personality traits, e.g. unstable temper with unpredictable bursts of anger, sometimes triggered by nice actions by other characters. A number of simulations were carried out, and a set of comic strips were created. In the examples, we illustrate this through the actions and internal states of evolved characters, both as simulations showing the dynamics of internal states and as comic strips.

These characters share some of the extreme personality traits of Donald Duck, such as his hot temper and tendency towards exaggerated actions. Figure 4 shows the main character behaving similarly. This shows an animated representation at the top, where the main character is distinguished by a blue rectangle labelled ‘hero’. Her emotions are shown as functions of time in four graphs in the middle of the figure, and the actions over time by both characters in the bottom graph.

Our character becomes angry without clear or rational reasons. At the beginning and end of the simulation, aggressive outbursts are followed by an increase in regret and temporary nice actions and apologies, and then followed by renewed aggressive behaviour. In the middle of the time sequence in Figure 4, a period of mutual nice actions gradually breaks down as the happiness of the main character decreases, leading to recurring aggression.

This behaviour is relevant for comics, since we are not concerned with developing realistic or believable characters, but rather with characters for cartoons and simple narrative comic stories. These can have simple yet extreme and exaggerated personalities, which can result in more interesting stories, and need not behave in a realistic manner. Rapid and unpredictable mood changes may well be desirable.

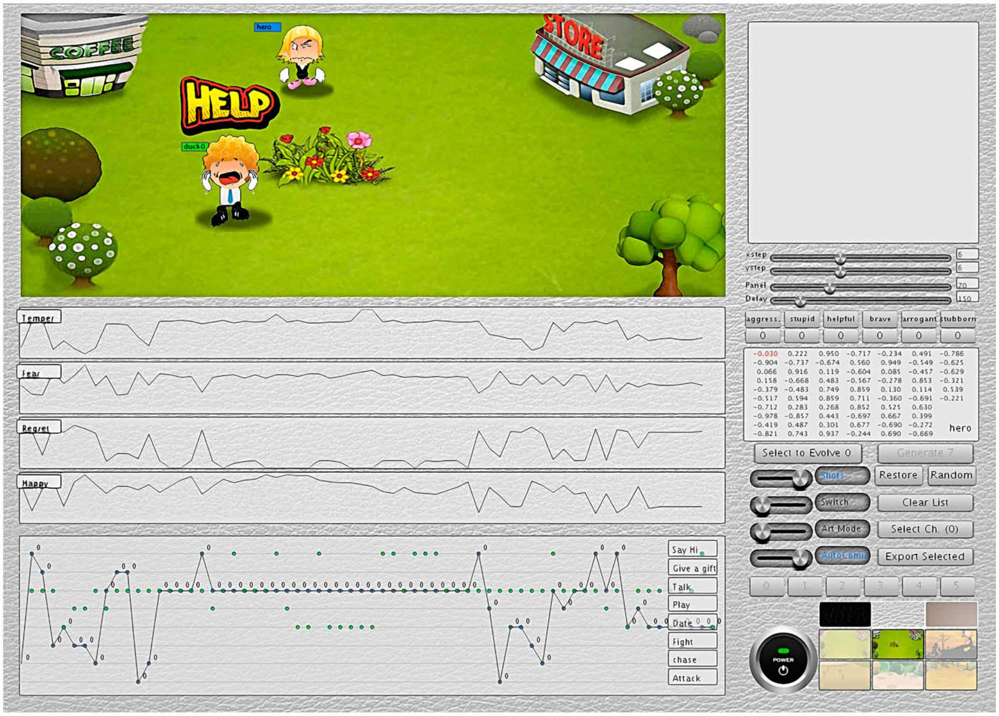

Figure 4. A simulation where the main character combines high temper and exaggerated actions. Four graphs below the animation show the time evolution of internal states. Actions are shown in the bottom diagram (the main character's connected by a solid line).

A related personality trait that we tried to achieve in the character was aggressive behaviour towards other agents that try to be nice. An example from Disney comics is the aggressive behaviour of Donald towards his nephews and the two squirrels, despite their efforts to be nice to him. His nephews suffer from his behaviour, while the two squirrels view him as a friend, but repeatedly cause him trouble anyway.

Figures 5 and 6 show another main character displaying similar behaviour. The kind attitude of the other character (e.g. giving the main character gifts) tends to make him angry; he starts chasing and attacking the other and ignores greetings. The persistent kind attitude by the other character only triggers further aggressive behaviour.

Figure 6 was created from 12 screenshots at selected points in time during the simulation in Figure 5. The graphics are automatically generated as described in Section 3.4, and depend both on internal states (resources and emotions) and actions. In particular, a hamburger represents a low resource value interpreted as the character being hungry, and the facial expressions and poses reflect emotions. Some of the frames show actions, such as one character hitting the other with a stick in the second frame, while the following five frames only show changes in internal states.

The same character can also behave nicely in other situations, just like Donald Duck can be polite with his uncle Scrooge and his girlfriend Daisy, or when he is scared or regretful. In Figure 7, the evolved main character shows similar behaviour as he tries to resolve the confrontation with a character that persists in fighting him. Figure 8 illustrates a comic strip created from the later part of this simulation, where the main character repeatedly brings

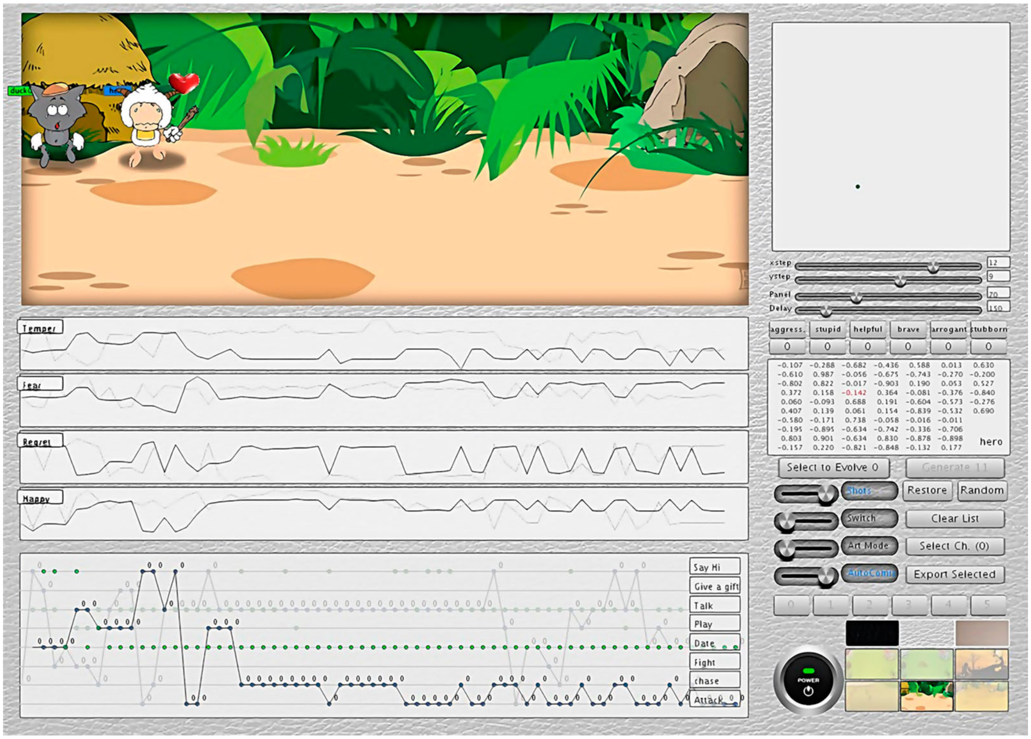

Figure 5. An example of an aggressive behaviour by the main character. A longer history of emotions and action is shown in light grey.

Figure 6. Comic strip created from snapshots of the interactions in Figure 5.

gifts or attempts to play with the other character, but is continually rejected and becomes increasingly unhappy and regretful.

The descriptions of the time evolution of actions and states involve some artistic interpretation, e.g. in the labels of internal

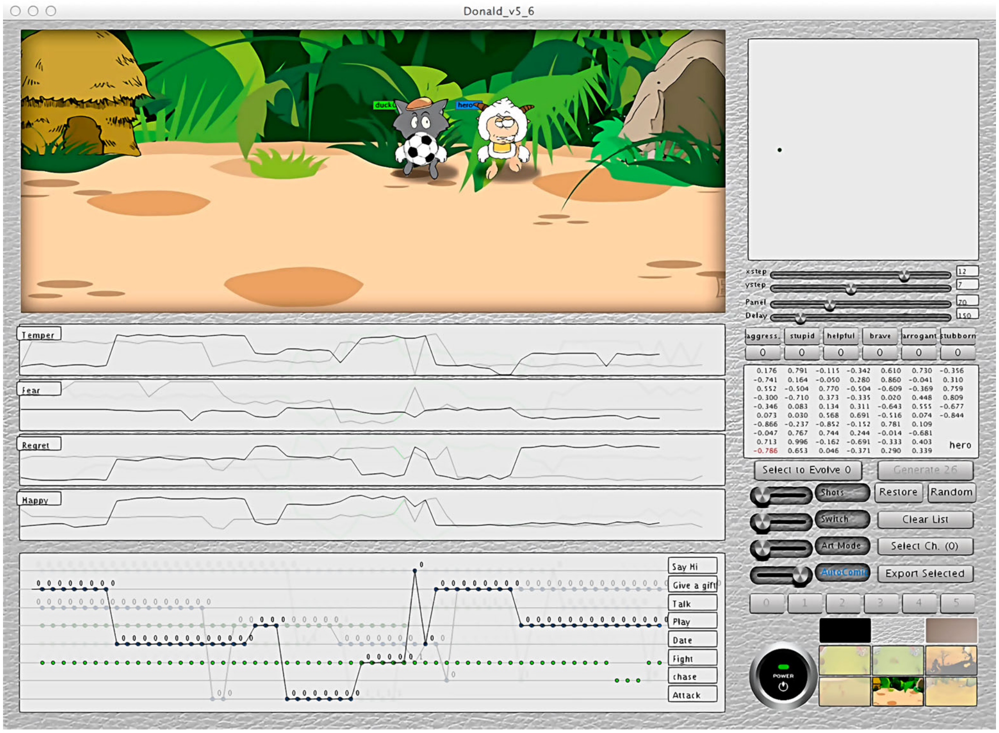

Figure 7. A simulation showing persistent nice behaviour of the character from Figure 5.

Figure 8. Comic strip output based on Figure 7.

states. However, the created comics show amusing results and can be interpreted in multiple ways and illustrate unexpected stories. This underlines our main point, that the system can generate sufficiently interesting and weird characters, and unexpected sequences of actions, and can serve as an inspirational creative tool when creating comic stories. Figure 9

Figure 9. Manually modified comic output, with panels selected and arranged in a conventional comic layout.

shows an example of output (from the simulation in Figure 4) that was modified manually to create a more traditional comic layout.

5. Conclusions and discussion

We have described a tool for character design and comics creation based on interactive evolution methods. We also argued that comics as a narrative medium are particularly well suited to generative approaches due to their openness of interpretation. Agents with a simple internal state structure were argued to be suitable for the creation of cartoons and comic strips, where simplified and exaggerated actions and personalities are common.

A parametric representation was introduced to encode agent personality in terms of functions for action choice and internal state changes, designed to allow appropriate small changes through mutation and other genetic operators. This was used in an interactive evolutionary process. Because of the time demands of the character evaluation, this was often structured as an interactive hill-climbing process, where one agent was developed while observing its interactions with others.

The stories emerging from agents' interactions were represented as real time cartoon animations and comic strips as outputs. Agents express their internal states through facial expressions and body gestures. The simplicity of visual representation has great impact on the visual rhetoric of the created comics; this could be improved by introducing more features from comics such as different panel layouts, better encapsulation, and cinematic views. The characters' appearance could also be improved by including interactive algorithms to assist the process of their visual design.

The system has so far been evaluated through its use in the artistic practice of the first author. An important topic for future work is more systematic evaluation. Several researchers have recently begun to explore evaluation of the user experience of creative tools, e.g. (Boukhelifa et al. 2017; Wang et al. 2018), who studied interactive evolution for visual exploration. Another development would be to explore applications to animation and characters in games.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Notes on contributors

Malik Nairat (b. 1973) has a BSc in architectural engineering and MSc in information technology specialized in art and technology, he worked as a lecturer at both of the faculty of fine arts at An-Najah University, and the multimedia department at the Arab American University in Palestine, he also worked as visual designer, artist, and researcher in both of Palestine and Sweden. Currently, he is a PhD candidate at the University of Gothenburg; his research deals with methods of generating comics and story characters using evolutionary algorithms and agent-based systems.

Mats Nordahl has a PhD in theoretical physics from Chalmers University of Technology. He was previously responsible for the Art & Technology international masters programme at the IT University in Gothenburg. He is also the founder of two successful startup companies that apply AI in applications ranging from computer support to new interface technologies. Current art and technology research also involves a collaboration with artist Mikael Lundberg, where large scale video documentation of movement patterns in public space is used as a foundation for further artistic development.

Palle Dahlstedt (b.1971), artist, composer and researcher from Sweden. He has studied piano, composition and electronic music (MFA, MA), and has a PhD in evolutionary computation for artistic creativity. Dahlstedt studies the deep entanglement of art and advanced technology, particularly in relation to creative and aesthetic implications. He develops new technologies for improvization, composition and art, and is especially interested in technologies that allow for embodied performance on electronic sounds, and new kinds of interactions between musicians, based on a system view of emergence from human-technology interactions. He has contributed technologies and theories to the field of computational creativity, and has received extensive artistic research funding from the Swedish Research Council. Dahlstedt has collaborated with international universities such as University of California Berkeley (CNMAT), Stanford University (CCRMA), and Monash University, Melbourne. Currently, he is part a research project funded by Princeton University, about the electronic instrument design. Dahlstedt was 2015–2018 Obel Professor in Art & Technology at Aalborg University, Denmark, and is currently Associate Professor in Computer-Aided Creativity and head of the Interaction Design Division at the Department of Computer Science and Engineering, Chalmers, and also lecturer in electronic music composition at the Academy of Music and Drama, Gothenburg.

Bibliography

Ahmed, M. 2016. *Openness of Comics: Generating Meaning Within Flexible Structures*. Jackson: University Press of Mississippi.

Aylett, R. S. 1999. “Narrative in Virtual Environments: Towards Emergent Narrative.” In *Narrative Intelligence: Papers From the 1999 AAAI Fall Symposium (Technical Report FS-99-01)*, 83–86. Menlo Park: AAAI Press.

Bates, J. 1994. “The Role of Emotion in Believable Agents.” *Communications of the ACM* 37: 122–125.

Boden, M. A., and A. E. Edmonds. 2009. “What is Generative Art?” *Digital Creativity* 20 (1-2): 21–46.

Boukhelifa, N., A. Bezerianos, W. Cancino, and E. Lutton. 2017. “Evolutionary Visual Exploration: Evaluation of an IEC Framework for Guided Visual Search.” *Evolutionary Computation* 25 (1): 55–86.

Campbell, D. T. 1960. “Blind Variation and Selective Retentions in Creative Thought as in Other Knowledge Processes.” *Psychological Review* 67 (6): 380–400.

Carrier, D. 2000. *The Aesthetics of Comics*. University Park: Pennsylvania State University Press.

Cassell, B. A., and R. M. Young. 2012. “A Comprehension Based Cinematic Generator for Virtual Environments.” *1st Workshop on Intelligent Cinematography and Editing, Foundations of Digital Games*.

Cavazza, M., F. Charles, and S. Mead. 2002. “Character-based Interactive Storytelling.” *IEEE Intelligent Systems, Special Issue on AI in Interactive Entertainment* 17 (4): 17–24.

Chan, C. J., R. Thawonmas, and K. T. Chen. 2009. “Automatic Storytelling in Comics: A Case Study on World of Warcraft.” *CHI’09 Extended Abstracts on Human Factors in Computing Systems*, 3589–3594.

Cohn, N. 2014. *The Visual Language of Comics: Introduction to the Structure and Cognition of Sequential Images*. London: Bloomsbury.

Crawford, C. 1999. “Assumptions Underlying the Erasmatron Interactive Storytelling Engine.” In *AAAI Fall Symposium on Narrative Intelligence*, 112–114. Menlo Park, CA: AAAI Press.

Dahlstedt, P. 2001. “A MutaSynth in Parameter Space: Interactive Composition Through Evolution.” *Organised Sound* 6 (2): 121–124.

Dahlstedt, P. 2009. “On the Role of Temporary Storage in Interactive Evolution.” In *EvoWorkshops 2009, LNCS 5484*, 478–487. Heidelberg: Springer.

Dawkins, R. 1986. *The Blind Watchmaker*. Harlow: Longman.

Digman, J. M. 1990. “Personality Structure: Emergence of the Five-Factor Model.” *Annual Review of Psychology* 41: 417–440.

Disney. 1988. *Walt Disney’s Mickey and Donald. (7)*. Prescott: Gladstone Publishing, 25–34.

Duncan, R., and M. Smith. 2009. *The Power of Comics: History, Form and Culture*. New York: Continuum.

Eco, U. 1989. *The Open Work*. Cambridge, MA: Harvard University Press.

Egges, A., S. Kshirsagar, and N. Magnenat-Thalmann. 2004. “Generic Personality and Emotion Simulation for Conversational Agents.” *Computer Animation and Virtual Worlds* 15 (1): 1–13.

Egri, L. 1960. *The art of Dramatic Writing: its Basis in the Creative Interpretation of Human Motives*. New York: Simon and Schuster.

Eisner, W. 2008. *Comics and Sequential art: Principles and Practices From the Legendary Cartoonist*. New York: W.W. Norton.

Finander, L. 2010. *Disneystrology: What Your Birthday Character Says About you*. Philadelphia, PA: Quirk Books.

Gabora, L. 2005. “Creative Thought as a Non-Darwinian Evolutionary Process.” *Journal of Creative Behavior* 39 (4): 262–283.

Galanter, P. 2016. “Generative Art Theory.” In *A Companion to Digital Art*, edited by Christine Paul, 146–180. Malden, MA: Wiley Blackwell.

Giannatos, S., M. J. Nelson, Y. Cheong, and Georgios N. Yannakakis. 2011. “Suggesting New Plot Elements for an Interactive Story.” *The 4th*

Workshop on Intelligent Narrative Technologies. AIIDE: AAAI Press.
Gibb, S., F. Hendry, and T. Lancaster, eds. 2019. *The Routledge Handbook of Emergence*. London: Routledge.
Gravett, P. 2013. *Comics Art*. New Haven: Yale University Press.
Halliwell, S. 1987. *The Poetics of Aristotle: Translation and Commentary*. London: Duckworth.
Herriman, G., and B. Blackbeard, eds. . 2001. "A Happy Lend Fur Away." In *Krazy & Ignatz 1925-26: A Happy Land Fur Away TP: The Komplete Kat Komics 1925 and 1926*. Seattle: Fantagraphics Books.
Holland, J. H. 1975. *Adaptation in Natural and Artificial Systems*. Cambridge, MA: MIT Press.
Jung, R. E., Brittany S. Mead, Jessica Carrasco, and Ranee A. Flores. 2013. "The Structure of Creative Cognition in the Human Brain." *Frontiers in Human Neuroscience* 7 (330): 330–330.
Laclaustra, I. M., José Ledesma, Gonzalo Méndez, and P. Gervás. 2014. "Kill the Dragon and Rescue the Princess: Designing a Plan-based Multi-agent Story Generator." *5th International Conference on Computational Creativity, ICCC2014*, 347–350.
Larsen, B. A., L. E. Bruni, and H. Schoenau-Fog. 2019. "The Story We Cannot See: On How a Retelling Relates to Its Afterstory." In *Interactive Storytelling, ICIDS 2019*, 190–203. Springer.
Laurel, B. 1986. "Toward the Design of a Computer-based Interactive Fantasy System." Ph.D. thesis, Ohio State University.
Liapis, A., Georgios N. Yannakakis, Constantine Alexopoulos, and Phil Lopes. 2016. "Can Computers Foster Human Users' Creativity? Theory and Praxis of Mixed-Initiative Co-Creativity." *Digital Culture & Education* 8 (2).
Louchart, S., and R. S. Aylett. 2004. "Narrative Theory and Emergent Interactive Narrative." *International Journal of Continuing Engineering Education and Lifelong Learning* 14 (6): 506–518.
Martens, C., and R. E. Cardona-Rivera. 2016. "Generating Abstract Comics." In *International Conference on Interactive Digital Storytelling*, 168–175. Springer.
Mateas, M., and A. Stern. 2003. "*Façade: An Experiment in Building a Fully-Realized Interactive Drama*." *Proceedings of the game developers conference, Vol. 2*, San Jose, CA, March 4-8.
McCloud, S. 1994. *Understanding Comics: The Invisible Art*. New York: HarperPerennial.
McKee, R. 1997. *Story: Substance, Structure, Style and the Principles of Screenwriting*. New York: ReganBooks.
Mclntyre, N., and M. Lapata. 2010. "Plot Induction and Evolutionary Search for Story Generation." In *The 48th Annual Meeting of the Association for Computational Linguistics*, 1562–1572. Stroudsburg: ACL.
Meehan, J. R. 1977. "TALE-SPIN, An Interactive Program That Writes Stories." *IJCAI'77, Proc. Of the 5th International Joint Conference on AI* 1: 91–98.
Méndez, G., P. Gervás, and C. León. 2014. "A Model of Character Affinity for Agent-based Story Generation." In *9th International Conference on Knowledge, Information and Creativity Support Systems, Limassol, Cyprus*, *Volume 11*.
Mikkonen, K. 2008. "Presenting Minds in Graphic Narratives." *Partial Answers: Journal of Literature and the History of Ideas* 6 (2): 301–321.
Monro, G. 2009. "Emergence and Generative Art." *Leonardo* 42 (5): 476–477.
Nairat, M., P. Dahlstedt, and M. Nordahl. 2011. "Character Evolution Approach to Generative Storytelling." In *IEEE Congress of Evolutionary Computation (CEC)*, 1258–1263. New Orleans: IEEE Press.
Nairat, M., P. Dahlstedt, and M. G. Nordahl. 2013. "An Interactive Approach for Story Characterization." In *IEEE Symposium Series in Computational Intelligence (SSCI 2013)*, 56–62. Singapore: IEEE Press.
Novick, D., and S. Sutton. 1997. "What is Mixed-initiative Interaction?", Papers from the 1997 AAAI Spring Symposium on Computational Models for Mixed Initiative Interaction, Stanford University, Technical Report SS-97-04, AAAI Press.
Ong, T., and J. J. Leggett. 2004. "A Genetic Approach to Interactive Narrative Generation." In *15th ACM Conference on Hypertext and Hypermedia*, 181–182. New York: ACM.
Picard, R. W. 1997. *Affective Computing*. Cambridge, MA: MIT Press.
Riedl, M., and M. Young. 2004. "An Intent-Driven Planner for Multi-Agent Story Generation." In *Third International Joint Conference on Autonomous Agents and Multiagent Systems. Vol. 1*, 186–193. Washington, DC: IEEE.
Riedl, M. O., and R. M. Young. 2010. "Narrative Planning: Balancing Plot and Character." *Journal of Artificial Intelligence Research* 39: 217–268.
Ryan, J., M. Mateas, and N. Wardrip-Fruin. 2016. "A Simple Method for Evolving Large Character

Social Networks." *Proc. Social Believability in Games*.

Simonton, D. K. 2011. "Creativity and Discovery as Blind Variation: Campbell's (1960) BVSR Model After the Half-Century Mark." *Review of General Psychology* 15 (2): 158–174.

Sims, K. 1991. "Artificial Evolution for Computer Graphics." *ACM SIGGRAPH Computer Graphics* 25 (4): 319–328.

Takagi, H. 2001. "Interactive Evolutionary Computation: Fusion of the Capacities of EC Optimization and Human Evaluation." *Proceedings of the IEEE* 89 (9): 1275–1296.

Theune, M., Sander Faas, Anton Nijholt, and Dirk Heylen. 2003. "The Virtual Storyteller: Story Creation by Intelligent Agents." In *Proceedings TIDSE 03: Technologies for Interactive Digital Storytelling and Entertainment*, 204–215. Fraunhofer IRB Verlag.

Von Buelow, P. 2008. "Suitability of Genetic Based Exploration in the Creative Design Process." *Digital Creativity* 19 (1): 51–61.

Wang, K., Vinh Bui, Eleni Petraki, and Hussein A. Abbass. 2018. "Human-Guided Evolutionary Story Narration." *IEEE Access* 6: 13783–13802.

Wright, J. 2005. *Animation Writing and Development: From Screen Development to Pitch*. Amsterdam: Focal Press.

Young, R. M. 1999. "Notes on the Use of Plan Structures in the Creation of Interactive Plot." In *Narrative Intelligence: Papers From the AAAI Fall Symposium (Technical Report FS-99-01)*, 164–167. Menlo Park: AAAI Press.