A Survey on Story Generation Techniques for Authoring Computational Narratives

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***Abstract*—Computers are often used as tools to design, implement, and even visualize a variety of narrative forms. Many researchers and artists are now further attempting to engage the computer actively throughout the development of the narrative itself. Any form of computational narrative authoring is at some level always *mixed-initiative*, meaning that the processing capabilities of the computer are utilized with a varying degree to automate certain features of the authoring process. We structure this survey by focusing on two key components of stories, *plot* and *space*, and more specifically the degree to which these are either *automated* by the computer or authored *manually*. By examining the successes of existing research, we identify potential new research directions in the field of computational narrative. We also identify the advantages of developing a standard model of narrative to allow for collaboration between plot and space automation techniques. This would likely benefit the field of automated space generation with the strengths in the field of automated plot generation.**

***Index Terms*—Automated storytelling, computational narrative authoring, procedural content generation, story generation.**

I. Introduction

The computer is frequently used as a platform for the creation, consumption, and sharing of narratives. The potential for interaction between humans and computers has also led to new methods for experiencing narratives, as seen with the rise in popularity of interactive narratives, hypertext, and video games. The possibilities of human–computer interaction have even significantly influenced the authoring process of narratives in that when authoring a narrative computationally, the computer always contributes in some form. When using a text editor, the collaboration on behalf of the computer is minimal, but significant research has been dedicated to using artificial intelligence and procedural techniques to allow the computer to generate components of narrative automatically.

While it may appear that the goal of this research is to remove the human author altogether, in practice, the range of stories which may be generated is still largely dependent on the information input to it by a human author. Whether authoring the narrative itself, or constructing the brain of a complex artificial intelligence for storytelling, one cannot remove either the human or the computer from the process of authoring computational narrative. It is this cooperation between computer and human that is commonly labeled a *mixed-initiative* approach. As originally proposed by Negroponte [1] and later outlined by Lubart [2], a mixed-initiative approach is usually most successful when the author maintains complete control over content, and the computer's duty is to provide important services for the author. The computer must also be able to adapt to the author's intent and way of authoring; otherwise, the presence of the computer will be more of a nuisance than an assistance. This is especially true in cases where the computer has some control on the creation of story content. It is, therefore, important for the design and evaluation of any mixed-initiative system to understand to what degree specific elements of narrative are created automatically by a computer, how they integrate with the remaining authored elements, and what level of control is provided to the author in the whole process.

There have been several surveys in the field of computational narrative focusing on elements such as creativity [3], interactive narratives [4], [5], drama management [6], plan-based narrative generation [7], and the application of several theories of narratology to the field of computational narrative [8]. Our focus is specifically on author and computer collaboration; we further make three main contributions in our survey.

1) We provide a thorough survey of the field of story generation, an area of computational narrative which has been active for close to 40 years.
2) We classify a large body of research, methods, and tools according to the extent story components are *automatically* generated or *manually* authored.
3) Utilizing a formal model of narrative derived from structuralist narrative theory, we explore the existing definition of narrative generation to identify which elements of story are most commonly generated.

We structure the remainder of the survey as follows. In Section II, we introduce our definitions for both narrative and the degrees of automation, grouping them into four distinct categories of research. In Sections III–VI, we examine specific examples of research and software from each of the four categories. We discuss several interesting results of this categorization in Section VII and conclude in Section VIII.

II. Terminology

In this section, we discuss the terminology used throughout the survey and present our categorization of the field of narrative generation. We use the term *computational narrative* to refer to

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any form of narrative, which occurs as the result of a collaboration between one or more human authors and a computer, and, if applicable, we use *authoring tool* to refer to any software which is used. We define the *author* as being the individual who provides content during the authoring process, be it for plot, space, constraints, images, etc.

In the case of interactive narratives, we explicitly distinguish the narrative, which is authored in advanced, and an *instantiated narrative*, which is the particular narrative experienced by a particular individual while interacting with the system. This separation is based upon the distinction used by Koenitz *et al.* [9]. We will use the term *interactor* for this individual and resist any strict definition as the interactor may take on a number of roles, such as being a coauthor and contributing parts of the instantiated narrative, being an actor and taking the role of one of the characters, or simply observing a story as it unfolds. Furthermore, we restrict the work discussed in this survey to systems and tools which explicitly state their *storytelling intent*. We define *narrative generation* as the field of research concerned with the automatic generation of narrative. We define *degree of automation* as the extent to which an authoring task is automatically performed by a computer. This can range between a task completely performed by the computer, an *automatic* task, and one which must be performed entirely by the human, a *manual* task. Chen *et al.* formally define the term *authorial leverage* as being a measure of the variety and complexity of plots which may be created inversely to the authorial burden it places on the human author [10]. In this sense, higher *authorial leverage* relates directly to our concept of automation, where an increasing amount of work is done by the computer, in order to reduce the burden placed on the human author.

A. Components of Narrative

We use the following definitions for narrative, and its components.

1) *Narrative* is defined as having a *story*, pertaining its main content, and a *discourse*, which is the particular telling of a story.
2) *Story* is the main content of the narrative; this includes what happens in the narrative, the *plot*, and the *space* in which the narrative occurs.
3) *Plot* is a set of *events* with an overall structure which represents both the temporal ordering, and the causal relations between the events. Events typically consist of one or more low-level *actions*, instigated by and/or affecting a number of entities in the space.
4) *Space* includes the characters, settings, props, and anything which is present either physically or abstractly in the space of the narrative also called the *existents*. Because existents change and evolve over time, the space also consists of an *initial state* which contains the set of all existent states as they exist before the start of the plot.
5) *Discourse* is the particular telling of a story. This may include the style of the space, the ordering and duration of the events in the plot, etc.

For the definitions, we drew upon the narrative structures proposed in the above surveys, and more specifically, the structuralist narrative theories provided by Barthes [11], Abbott [12], and Chatman [13]. All three authors explicitly separate the content of the narrative from the way in which this content is presented to the reader. The terms *narrative*, *story*, *discourse*, *plot*, and *space* come directly from Abbott and Chatman. Our definition of plot and its events and structure are based upon the similar definitions given by Kukkonen [14]. The definition of space is likewise strongly influenced by the definitions used by Ryan [15], in which space is also viewed to have a spatial structure as well as a temporal structure that is dependent on the duration and effects of events in the plot.

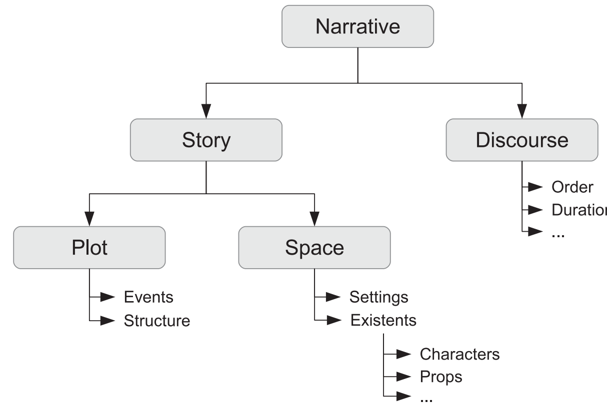

Fig. 1. Proposed structure of narrative, with the main terms emphasized

Finally, although in this survey we are focused solely on story generation, there also exists a significant body of research dedicated to discourse generation. Three prominent examples are Montfort's CURVESHIP [16], which generates discourse for a given story using Genette's formal categories of discourse (order, duration, frequency, mood, and voice) [17], Jhala and Young's DARSHAK system for cinematic discourse [18], and Goguen and Harrell's GRIOT system [19] for generating style and figuration.

Fig. 1 shows our definition of narrative. While not intended as a complete formalization of narrative, it does allow us to classify existing narrative generation research according to precisely which components of narrative are generated. We found that most existing research obeys this structure of narrative (although space is sometimes referred to as *world* or *game world* depending upon the context of the research).

B. Degrees of Automation of Plot and Space Generation

As our focus is on the generation of story, we propose to map *space* and *plot* automation onto a set of orthogonal axes, between 0 and 1. 0 indicates that the particular story component is entirely manually authored, whereas a 1 means that the story component is entirely automated; see Fig. 2. Most systems lie somewhere between 0 and 1, with some components being created manually and others being created automatically.

We identified several degrees of automation of plot and space generation, which allow us to investigate how plot and space generation interact, and whether differing automation degrees of plot generation inhibit or support space generation. In addition, they help to delineate where the human author is able to exert control on the content of the produced narrative.

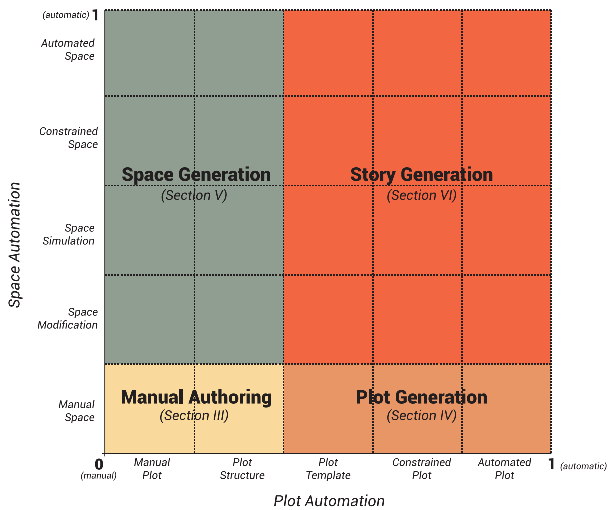

Fig. 2. Story automation range, expressed in terms of the degrees of automation for *plot* and *space* generation. For convenience, we identify four sections in this range; the four colours indicate the sections of the survey which discuss the systems and techniques which lie in the corresponding area in the chart.

We identify and define the following five degrees of plot automation.

1) *Manual:* A manual plot system provides no tools for plot automation. The computer is present at a mostly invisible level. The structure and content of plot is entirely authored.
2) *Structure:* The computer provides the plot structure to the author, but none of the specific events or orderings. The author is, therefore, still manually authoring the majority of the content, but is forced to respect the model of plot provided.
3) *Template:* In a plot template system, a sequence of ordered events is returned to the author, but without any specific characters or objects, so that the events are not linked to any of the existents in the space.
4) *Constrained:* In this system, the plot is fully generated, including filling the roles of the plot with existents. The automation, however, constrains the plot to obey certain features, be they author goals or plot structures. Thus, the final plot still contains several authored features.
5) *Automated:* An automated plot system attempts to minimize author involvement as much as possible.

We identify and define the following five degrees of space automation.

1) *Manual:* A manual space system provides no tools for space automation. The structure and content of space is entirely authored.
2) *Modification:* The content of the space is entirely authored, however the computer explicitly modifies elements of the space automatically, often to improve plot generation.
3) *Simulation:* New content for the space may be generated by simulating interactions between existents. The result of this simulation is an initial state.
4) *Constrained:* New content for the space may be explicitly generated, obeying certain authored constraints on the plot or on specific existents which need to be included within that space.
5) *Automated:* An automated space system attempts to minimize author involvement as much as possible.

We group this table into four sections for the purpose of this survey. We define *manual authoring* as systems and tools, which leave the bulk of the authoring to the human author. We likewise discuss systems which generally approach either *plot* or *space generation* specifically in their own sections. Finally, we discuss systems which automate elements of both plot and space in the final section, which we label *story generation*, since each element of the story is automated to some degree.

III. Manual Authoring

We again stress the importance of the unavoidable influence of the computer on virtual authorship; however, quite frequently techniques or tools are designed to minimize the perceived presence of the computer. We avoid here a discussion of low-level tools such as text editors and word processors, as there are a variety of these and they often differ far from the specific goal of creating narratives. We do, however, wish to outline several types of authoring tools which present an important intervention on behalf of the computer, but one which still leaves the authoring of the narrative largely in the hands of the author.

A. Manual Plot and Manual Space

1) Authoring Tools for Interactive Stories: Interactive stories are stories wherein the interactor plays a role in the development of the plot and has influence over the space. Two such examples are *hypertext* and *interactive fiction* (IF) stories, which differ mainly at the level of interaction. In hypertext, control is given over the selection of events in the plot by having certain points within the story where the next event can be chosen from a number of options. IF stories allow the interactor to insert events into the plot, by means of a parser. Many authoring tools for hypertext [20], [21] or IF stories [22] do not restrict any form of plot or space structure, allowing the author to structure the story as they see fit.

2) Authoring Tools for Educational Purposes: A complaint about many story authoring systems is that their complexity inhibits their acceptance by nonexperts and artists, even though they are often considered the target audience of these systems. However, the complexity inherent to computational narratives can be exploited in such a way that trying to author a narrative also involves learning programming skills. The purpose of these authoring tools lies not in what is created, but in how it is created, and what is learned in this process. Two such examples are Storytelling Alice [23] and Scratch [24]; neither example contains any form of space or plot automation, but both explicitly position themselves as having a storytelling intent, although their true intent is to teach programming skills.

3) Authoring Tools for Therapy: Story authoring has also been assumed to be of therapeutic use for treating certain disorders. *Narrative exposure therapy* (NET) refers to the treatment of posttraumatic stress disorder by allowing the patient to retell events from their life in a narrative manner, often with visual aids [25]. For these purposes, as with the educational systems, the process of creating the narrative is as important as the narrative itself. Argaman [26] and the Multimodal Memory

RESTRUCTURING SYSTEM [27] both involve the patient manually recreating their memories as narratives as part of the therapy. Both make their storytelling intent clear; however, the focus is mostly on defining a space from memory, while the events are discussed more personally between the patient and therapist.

B. Plot Structure and Manual Space

In this section, we explore several systems where the author is expected to manually author the entire narrative, but uses a structure for plot enforced by the computer, constraining the content to fit within this structure. Lubart referred to the role of the computer in such systems as the "nanny," in that basic structures are provided as an assistance to the author, allowing the author to be creative while keeping them within the expectations of what constitutes a narrative [2].

SCRIVENER [28] and STORYBOX 2 [29] are two examples of story authoring tools, which explicitly state their storytelling intent and enforce structures on the plot. STORYBOX 2 uses scenes, chapters, and acts to divide the authors work into different sections, and SCRIVENER uses templates to format the story content in the style of short stories, screenplays, novels, etc. In both examples, the software functions similarly to a word processor, so that the author is free to be as creative as possible with the actual content. The structure provided is not intended to be oppressive, but rather to assist the creative process by allowing authors to organize their thoughts into a proper story structure.

Screenplays have also been the target of research and authoring tools. A screenplay is different from a traditional story, since the screenplay is not intended to be read, rather it is used to describe a scenario which will eventually be presented visually (or through audio). The MOVIE AUTHORING AND DESIGN SYSTEM (MAD) [30], for example, uses a story-board style system, where the author may attach images, sound, music, or even video to their scene description. The detailed structure of the MOVIE SCRIPT MARKUP LANGUAGE (MSML) aimed to capture all aspects of a movie script [31]. Within this structure, a movie script is divided into four main components: scene, manufacturing, timing, and animation. While the majority of MSML is oriented toward discourse, it still contains formal definitions of space and plot, mainly in the scene component.

INSCAPE [32] is an interactive story authoring tool which departs from text and focuses specifically on visual narratives. The visual discourse forces authors to include graphical realizations of their narrative and, on a more technical level, describe the behaviors and emotions of characters. Plot is structured using a basic story–board interface to control events, ordering, and the different paths the interactor may take through the narrative. STORYTEC [33], a later system inspired in part by INSCAPE, provided more distinct structures for plot and space by including both a *story editor*, for plot and ordering, and a *stage editor* for defining the space in which the story occurs.

IV. PLOT GENERATION

A large focus within the field of computational narrative has been the automated generation of plot, with the space component of narrative being manually authored by the authors or by the creators of the system. In this section, we will explicitly focus on the research surrounding plot generation. We focus first on the generation of *plot templates*, which are sequences of events that are not linked to any specific space. We then proceed to examine how the computer may be used to generate complete plots, obeying different *constraints* provided to it by the author. Finally, we examine systems wherein the plot is generated automatically, using minimal input from the author.

A. Plot Template and Manual Space

The vision that plot generally obeys fixed structures and is guided by inherent rules has guided many researchers to develop some form of *plot grammar*. Historically, the development of a general story grammar was intended to determine the mental structures used by humans to reconstruct stories from plot fragments, and how stories were stored in the brain [34]. While the story grammar approach was criticized [35], [36] and eventually abandoned from the psychological point of view, it became of interest to those wishing to construct a plot generation tool, as a plot grammar is defined in a strictly formal fashion, with a clear division between plot and rules for structuring plot, and is easy to automate with a computer.

An early and classic structural definition for Russian folktales was proposed by Propp [37]. Within Propp's work, he breaks down the Russian folktale into 31 sequential *functions* describing specific events in the plot and seven key roles, relating to the character stereotypes such as the *hero*, *villain*, etc.

While not explicitly a grammar, Propp's functions were eventually used by Lakoff [38] in the construction of a plot grammar, which used *rewrite rules* to generate a plot. A rewrite rule consists of a symbol and a symbol expansion. Applying a rewrite rule typically consists of searching a given structure (e.g., a string or graph) for an occurrence of the symbol (e.g., a substring or subgraph); if found, the symbol is rewritten using the symbol expansion. For Lakoff, this involved representing a plot as a string, with Propp's functions being represented as a set of rewrite rules. The building of the plot thus occurs by progressively applying any one of the valid rewrite rules until the folktale is complete. The folktale structure and concept of narrative functions remains a popular topic within the research community and a decent summary of several such systems may be found in the survey by Cavazza and Pizzi [8].

Grasbon and Braun used Propp's morphology in the construction of an authoring tool for IF [39]. In this tool, the author manually creates segments of a narrative for each of the functions defined by Propp. The tool then generates IF stories guided by the rules of Propp's grammar. Lakoff's grammar and Grasbon and Braun's engine show two different approaches to the automation of plot. While both systems rely on the same underlying structure, the first approach fully automates the plot, while the second approach tackles the challenges of creating interactive narrative experiences by guiding the player along a certain story path. This approach is often called a *drama manager* [6], [40], which refers to regulating certain features of an interactive story during a play-through, such as suspense or drama, or even generating new content to help structure the interaction into a more coherent narrative experience.

Champagnat *et al.* created an interactive storytelling system using Campbell's Hero's Journey to create a generalized plot grammar, which could be customized to fit various stories [41]. Similarly to Grasbon and Braun's work, the author must manually create content for each of the stages in the Hero's Journey, with the computer mainly being responsible for generating the high-level plot structure.

Colby developed a noteworthy grammar, focused specifically on aboriginal folktales [42]. Colby's grammar is contrasted with Propp's structure in that rather than defining a strict sequence of events, Colby's grammar created a string consisting of three main categories of events, *motivation*, *engagement*, and *resolution*. The initial rendering of plot consists of a string representing a sequence of these events, which are generated according to a set of rewrite rules. The final generation step is then to assign a specific event (called an *eidon*) to each event category. Colby's push away from Propp's imposed sequential structure allows for more unique and varied plot structures, not necessarily by needing to create more events, but by using a system which does not enforce an ordering on events.

B. Constrained Plot and Manual Space

All the previous examples focused only on the creation of plot structures, with the space and additional content all being authored manually. Most techniques and systems, however, also allow the computer to automatically fill roles with existents from a manually authored space to create full stories. Typically, the author has little control over the plot generation in these systems, except to specify *constraints* which must be met by the final plot. These may take the form of rules for the selection of existents to fill certain roles, rules for the causal or temporal structure of events, different states of space which must be true at different points in the plot, etc. As there are many noteworthy examples of such systems, we split this discussion into seven parts based on different domains or methods.

1) Grammar-Based Plot Generators: By linking a plot grammar to a space, it becomes possible to generate complete stories. In these generators, the plot grammar often contains authored rules that determine which existents may be linked to which events.

Pemberton's GESTER is a plot generator which relies on a detailed plot grammar of Old French epic narratives [43]. Its grammar is divided both into specific events with causes and effects, but also a set of rules which defines the relations between existents in the space. Pemberton's approach is unique to many of the previous grammars in that these relations would influence the plot generation, closely linking space and plot.

BRUTUS used plot grammars among many other formalizations of narrative for its construction of *betrayal* narratives [44]. BRUTUS was considerably successful in creating complex stories, but was geared specifically toward the generation of *betrayal* plots, limiting its potential as a generative system, but further highlighting the complexity which arises from moving from general descriptions of narrative and simple folktales to generating fully realized narratives.

TEATRIX [45] is an interactive narrative system which used Propp's grammar to create templates based upon the folktale functions. In TEATRIX, both the author and the interactor are responsible for authoring content, with the author manually creating the templates and initial state of the space, and the interactor being able to select which existents will appear in the story, and which actions the different characters will take. The computer serves two roles in generating plot content, by automatically selecting the next plot template based on both the choices made by the interactor and the rules of Propp's grammar, and is also capable of automatically simulating character actions for characters not controlled by the interactor.

GEIST [46] again uses Propp's grammar to procedurally create templates for interactive stories. The stories are unique in that they are represented in augmented reality and meant for tourists visiting new cities. Events in the plot occur at different locations in the real world, allowing the tourist to experience the story, while also visiting real-world locations and learning more about the history of the city they are visiting. GEIST's space is unique in that it is divided between the manually authored characters in the story, and also the real-world location which is intended to be the backdrop of the story.

SQUEGE [47] utilizes a manually authored space and a grammar of plot structures. It uses rewrite rules to progressively build more complex plot structures, selecting characters or items arbitrarily from the space to fill certain roles in the plot.

REGEN [48] takes the concept of using a grammar coupled with graph rewriting rules, but extends it to account for relationships between characters in the game world, and how these relations change due to events in the plot. For this, REGEN loosely examines the use of *character goals* for guiding plot generation, where the plots are created according a simulated model of characters and their relations.

2) Planning-Based Plot Generation: A popular approach for plot generation in the storytelling AI research community is using *planning-based* plot generation. The basic concept behind planning-based plot generation is that the generation process should yield a story that achieves a provided goal. This goal may take many forms and is often represented as a a desired state of one or more existents (e.g., relations, attributes, etc.) within the story space, and it is not uncommon for a system to have multiple goals, subgoals, or even changing goals. While there are many different types of goals, it is most common to either have the goals be provided by the author as a way enforcing that their intentions, or to have the goals be assigned to specific characters in the space. There will be many examples of planning-based plot generation throughout this survey, and in the following section, we only present those which do not automate space.

UNIVERSE [49] is an early planning-based plot system and specifically aims at generating "soap-opera" styled plots. Planning is used to generate events which aim to cause melodramatic conflicts between characters. The modeling of character emotions is often considered important in the plot generation community [4], since it provides useful details which can improve the emotional impact of the plot. This is especially important within dramatic plot generators, such as UNIVERSE, and allows the generators to move away from the heavily stereotyped *roles* seen in the folktale grammars. UNIVERSE uses an emotional model with several simple rankings on elements such as *wealth*, *moodiness*, and *intelligence*, as well as a set of character goals and even stereotypes, such as *socialite* or *party-goer*. These traits can act as constraints for certain events, for example, the author may state that only characters with a low niceness and high promiscuity may engage in affairs with other characters. UNIVERSE was also important in that it intended to run indefinitely, consistently creating new plot twists to keep in tune with the long-running soap-opera television series which inspired it. This was achieved by having the author create a number of plot fragments, each with its own goal, as well as an overall goal for the plot itself. By mixing and combining different fragments, new plots could be continuously created.

Barber and Kudenko's GADIN [50] provided a similar "soap-opera" oriented system, but one which allowed for interactivity, letting the interactor act as a character within the virtual soap-opera rules. In such a way, the interactor also makes changes and guides the creation of a final instantiated story.

STORY CANVAS [51] uses a similar planning technique to UNIVERSE and presents itself as a novice authoring tool for interactive stories. In STORY CANVAS, the author creates their goals as well as the rules for plot generation at a high level using hierarchical task networks. These are automatically converted into behavior scripts for each of the existents in the story. The space is also manually authored, using visual storyboards to select characters and set the relations between them.

Porteous *et al.* used planning to adapt as a means to adapt the story dynamically to account for actions taken by the interactor [52]. The system presented an interactive version of Shakespeare's *Merchant of Venice* and planning was used to account for the potential player deviations from the original plot. The system worked by decomposing the original plot into a sequence of *constraints* on the story space and then using planning to iteratively build the plot. Replanning occurs whenever the interactor modifies the story space through some form of interaction. The interactor is further provided the option of viewing the plot from different *points of view*, in which the planner emphasizes certain events in the plot to allow for interpretations about different characters, for example, by emphasizing discriminatory events against one character to position them as a victim. Constraining the plot is interesting for interactive stories, in that the author is able to create a specific experience, but the automation of the computer allows for the interactor to further explore and influence the space without the concerns of ever deviating too far from the intended plot. A later version of the same system [53] provides an interesting mixed-initiative approach for authoring, where authors are able to scroll through their plot via a time-line and change specific plot events. The plot is then updated accordingly, and the author can cycle through later events in the plot to see how they have been modified. Plot constraint techniques have also been used to author plots for serious games, where the interactor is expected to experience a fixed scenario, but have the ability to view the scenario from different perspectives based on their actions [54].

While Porteous *et al.* were interested in constraining planning to accommodate particular plot events, Barros and Musse's FABULATOR [55] aimed more specifically toward maintaining tension arcs in interactive narratives, as well as preventing the potential deviation of the interactor from the plot. To prevent deviation, the planner is able to modify the plot in such a way as to deter or warn the interactor if they appeared to be deviating too much in action from the plot, or even risking creating a *dead-end*, a point from which it is impossible for the interactor to reach the end of the story. Such issues highlight the challenges associated with generating interactive narratives compared to noninteractive or highly restricted hypertext narratives. In an interactive narrative, the interactor also has the ability to modify the space or even plot, and in this sense they may, intentionally or not, modify the space or plot in a way unintended by either the author or the computer. This is one of the advantages of automatic generation, since fail-safes, such as the *constraints* or *warning* techniques of the previous two systems, may be used to prevent failure. Manually authored content, on the other hand, cannot repair itself, and the interactor deviation can significantly damage or even break the plot and space itself. A classic example may be found in *Morrowind* [56], an RPG world where the interactor may kill any character in the game world. If the interactor kills a character crucial to the plot, then the game provides a message chastising the interactor for their deviation and informing them that if they do not return to an earlier game, then they can never hope to finish the story.

While many of the above systems viewed planning as a way of controlling the events present in the plot, Bae and Young instead focused on using constraints to guide the planner towards creating surprise [57] within the structure of the plot. The planner, called PREVOYANT makes explicit use of two narrative devices, foreshadowing and flashback, to create a sequence of events where certain events will appear surprising to the reader. Thus, while the plot is largely automated, the constraints provided are more to ensure certain reactions when reading the narrative. In a similar vein, Ware *et al.* developed planning techniques to generate conflict in the plot [58]. This again involved creating a model of conflict and, then, constraining the planner to enforce the presence of conflict in the resulting stories. This is a different approach to earlier examples, like UNIVERSE, where it is the burden of the author to author events which already contain a conflict embedded within them.

3) Interactive Narratives: Façade [59] is widely regarded as one of the most successful attempts at an interactive story game to have come out of the research community. In *Façade*, one takes the role of an acquaintance of a married couple and one is able interact with both characters using natural language text input. The plot uses constraints to ensure that certain dramatic situations occur and uses a detailed authored space to provide depth and personality to the main characters. The constraint is in the form of a dramatic arc that each story is expected to adhere to, and dramatic situations are defined as events that change certain values assigned to each of the characters (such as love or anger). Each change to a specific value is called a *beat*, and the game selectively picks beats one after the other such that the resulting story obeys the dramatic arc provided.

IDTENSION is an interactive drama that aimed to create conflict for the interactor, as well as characters within the narrative [60]. As in *Façade*, events in the story are picked one after the other, and the system attempts to enforce a plot that creates conflict between characters. IDTENSION uses a set of moral values, toward which each character has a certain adherence. Characters with a lower adherence toward a certain moral value will be more likely to take actions which are defined as immoral with respect to that value. This results in a set of conflicting values that form the conflict in the instantiated narrative.

MARLINSPIKE takes yet another unique approach to constraints [61] in that it attempts to create the narrative in such a way that the actions taken by the interactor become necessary to reach the stories conclusion. As with the above systems, the narrative is built incrementally with events, allowing the interactor to take an action each time. After each action, the system views a history of the interactor's actions and, then, attempts to pick an event that occurs as the result of one or more of these actions. The technique, dubbed *reincorporation*, aims to make the interactor feel directly involved in shaping the narrative dramatically with each action.

Prom Week [62] utilizes a detailed social engine to model the various social interactions of high school, including gossiping, flirting, bullying, etc. An interactor can play any of the many characters within the game world and is given social goals to achieve, creating much of the emergence from the interactor's interaction between different characters. Plot in this instance is constrained both by the author, who defines several key events, most noticeably the prom itself, and by the interactor, whose interactions form events in the instantiated narrative.

VERSU [63] is an interactive story system which relies largely on the simulation of an authored world. VERSU creates hypertext stories, in which the interactor may pick one of many potential actions a character in the world may perform. These actions, and the reactions from other characters, are all chosen procedurally based upon a detailed manual description of the space and a model of each character's personality. The author may additionally propose constraints on the plot to ensure that each instantiated narrative contains certain desired events. VERSU, like *Prom Week*, is unique in that the interactor may play from the perspective of any character within the story, and the choices they are presented will be appropriate for the chosen characters.

Baceviciute *et al.* [64] designed an interactive story system which is used during counseling sessions with deaf children. The child models their school, giving specific personalities to different students. The system then generates conflicts between the students and the child's character during game-play. The counselor then helps the child to find solutions to these in-game conflicts, which they could then use in real life when similar situations arise.

While many of the above examples focus on giving the interactor the ability to interact and even modify the space and plot, certain research instead aims to support the interactor's experience of the work by generating plots adapted to their interests or skills.

The PASSAGE system monitors the interactor's actions and uses them to create a computational model of that interactor [65]. The AI was implemented in a sample game built in the AURORA TOOLSET [66]. The game contains multiple, generally manually authored, possible quest plots, each with annotations stating which type of interactor will most appreciate that particular plot. After completing a specific quest, the next subsequent quest is chosen by comparing the similarity between its preconditions and the current interactor model. The interactor model may also be updated based upon their behavior within each quest.

Zook *et al.*'s military scenario generation tool [67] is another application of an adaptive generation tool. The aim of the system is to generate particular simulated scenarios for the interactor to train with. As the intention is to learn through repetition, the system intends to keep track of the learned experience of the interactor given their performance in the scenario. Generation is used so that the interactor does not succeed solely through trial and error, but is instead forced to learn the logic behind each scenario. For a survey on how authors, characters, and interactors may influence interactive narrative, we recommend the paper by Riedl and Bulitko [4].

4) Case-Based Reasoning: Gervás *et al.* generated plots using case-based reasoning with authorial constraints [68]. Their work once again makes use of Propp's grammar, and the author's only role is to declare which functions need to appear in the final plot, and the initial state of the space and their roles. The system then adapts pieces of similar plots, ensuring that all functions are included in the new plot and that all the conditions of the functions are met. The final plot is, therefore, a mixture of several similar story plots, with the roles filled by the space provided by the author.

MINSTREL [69] is a complex plot generator which aimed at modeling creativity and even modeled a form of author intent by providing each story with a moral message, which must be conveyed through the generated plot. The stories created in MINSTREL were limited to singular stories which were about half a page in length. MINSTREL was again dependent on a large volume of manual authoring in terms of the space of the story. The system did, however, use a detailed model of individual character goals, beliefs, and desires in conjunction with its authorial intent, so that the resulting plots make sense with respect to their emotional and physical effects on the characters in the story space. Furthermore, new events could be created by recalling and modifying past events used in the generation process.

MEXICA [70] uses a cognitive model of creativity to formulate a story by piecing together a number of plot fragments, which are constrained by a set of pre- and postconditions. The system makes use of previous stories, taking them as input to evaluate and reflect upon the current story being generated. In MEXICA, characters, and specifically relations between characters, are explicitly modeled. The plot is incrementally built by examining potential new events, each event having preconditions relating to patterns that must exist inside the space.

5) Genetic Algorithms: HEFTI [71] uses a genetic algorithm approach to narrative generation. In this system, the author must specify a basic structure, or "story thread" which must be met by the plot. The fitness of a story is determined by the events, each of which must be rated by the author based on their like/dislike of a given event. The genetic algorithm thus attempts to achieve the best possible result according to the author's ratings while still ensuring that the requirements of the story thread are met. This genetic algorithm is also used to modify the plot if there are any interactor deviations.

Although this section presented a number of different approaches to the generation of plot, each approach followed a basic principle that using constraints is a means of enforcing a certain level of quality or intent. Tighter constraints lead to a more limited set of stories, for example, the grammar-based plot generators are often restricted to creating stories in one particular genre. Looser constraints allow for more story variance and are often used to guide the generation process rather than explicitly control it. This often leads to a greater diversity of stories, and in interactive stories, this is used to encourage multiple experiences of the work. Tighter constrains, however, produce more reliable results and allow for more nuanced or subtle changes in the plot.

C. Automated Plot and Manual Space

Chang and Soo [72] created a planning-based story generation system set inside a detailed recreation of the setting of Shakespeare's *Othello*. They further based their models of emotion upon the mental states prominent in *Othello*, such as deception, love, misjudgment, etc. Chang and Soo's system was clearly aimed at forcing an emergence of the original *Othello* story, or at least a similarly dramatic story, using a detailed space reconstruction rather than plot constraints. The results were a mixture of both similar and dissimilar stories, reinforcing the difficulty in ensuring a certain narrative when using emergent systems.

Cavazza *et al.*'s EMOEMMA [73] also modeled the virtual space upon an established fictional world. The interactive story here was based directly off of the novel *Madame Bovary*, with characters personalities and relations being modeled as closely as possible to those in the novel. The interactor may verbally interact with these characters and have them respond appropriately. Here, even though the plot is generated, it relies on the quality of the space to give emotional depth to the plot. Unlike Chang and Soo, the EMOEMMA system was not intended simply to recreate the original plot, but was an interactive story that allowed the interactor to experience multiple possible plots within the fictional world established by the novel's original author.

V. SPACE GENERATION

Space, the world in which the stories occur, has throughout the previous sections been mostly authored. In manual authoring systems, this is a given. Plot generators, in turn, frequently use an authored model of space to allow the generation to assign roles and create full stories. In many plot generators, changes to the space based on events may be maintained, such as ensuring dead characters do not feature in later events in the plot; however, there is no intent to generate content or creatively modify the existing space.

There exist few to no systems within the computational storytelling community which have focused solely on space generation. Admittedly, limiting ourselves to only examples with a storytelling intent, we avoid a discussion of many of the procedural content generation tools for common elements of space, such as terrain, vegetation, cities, etc. [74]. We did, however, identify several systems that focus on the representation of a story space in 2-D or 3-D worlds. These systems have a strong element of discourse generation, in that they focus on conversion of a textual to a visual representation. From the space perspective, however, we are interested in what Ryan describes as *spatial dimensions* [15], in that in these systems a new space must be automatically created and organized to represent the same story but now in a higher dimensional space, independently of the discourse. We first discuss two story-focused examples of systems which build visual representations from a provided textual story. We then examine several systems, which take structured plots, and create a virtual space to visualize the story.

A. Manual Plot and Constrained Space

Delgado *et al.* present a text-to-image system [75] which processes full news stories, selecting appropriate images for each line of text within the story. The system is limited to which photos are available, and the result is a slide-show in which the reader can see both the images and text side by side. This creates a form of visual storybook in which the space generation largely consists of finding images to reinforce the space which is already defined within the news story.

Schwarz *et al.*'s text-to-video system [76] found unique problems relating to the disconnect between creating a satisfactory space from a given story. The generator was tested with news stories, for which it performed well. However, given that a news story is based on real-world locations, it is simple for the system to find an image directly related to the story. The problems arose when the system attempted to select images for fictional stories, where complex elements such as metaphors, and allusions could produce unsuitable visual results. While performing image processing actions, such as maintaining a consistent color palette, may improve results, there is still a mismatch between the capabilities in generating the space for a factual, straightforward, simple story and trying to generate space for a fictional, complex, and figurative story.

B. Plot Structure and Constrained Space

SCRIPTVIZ [77] is a movie script visualization tool which takes authored movie script templates and automatically generates an animated 3-D visualization of this space. The plot is structured as a sequence of well-formed scene descriptions, and the author is restricted to working within this structure. The system automatically parses each scene into a high-level plan containing all necessary information needed for the final scene. The system then automatically creates characters, locations, and props relating to the script. The resulting animation is rendered in real time, and elements such as spatial arrangement of characters may be edited by the author, allowing for a mixed-initiative approach in which the author may still exert some control over the space generation. Similar script visualization tools have been proposed for film [78], and television [79], all involving the same steps of taking the manually authored plot, extracting the basic space requirements and constraints using the plot, and automating the remaining space generation within a visual environment.

The *Skyrim* RADIANT QUEST [80] system allows new characters or items to be automatically created and placed within the game world upon the creation of a quest. A RADIANT QUEST is a plot structure which must be manually authored; however, the author uses only roles instead of characters. When generating the quest in a game, the roles are filled with either current characters and items, or by automatically creating new characters/items which are then placed into the game world.

GAMEFORGE [81] is a space generation system for role-playing games that takes a story as an input and outputs a valid space. A story in GAMEFORGE is represented as a sequence of plot points, as well as the initial state of the space, which includes all the existents. GAMEFORGE then uses a genetic algorithm to create potential spaces, which contain the initial state provided by the author, but also complete terrain, cities, and other features necessary for a fully realized game world. The fitness function for the genetic algorithm is customizable and can be used to favor spaces with certain features, for example, size and number places the interactor may visit, etc. GAMEFORGE is interesting in that it is largely a procedural game-world generator; however, it uses the story as a set of constraints that must be realized in the final world.

The previously described systems have been largely designed to achieve artistic purposes. However, space generation also has an impact in more scientifically oriented simulations. Here, the term *scenario* is used over story. However, the general definition of scenarios is the same as our definition of story so we use the terms interchangeably. We avoid a large discussion of such systems here, focusing instead on a few noteworthy examples.

OPENENERGYSIM [82] is a simulation program for simulating road traffic and, more specifically, the impact of different traffic scenarios on the environment. The plot of such traffic scenarios must be reasonably specific, in order to provide the simulation with an accurate evaluation of the environmental impact. To facilitate the development of such scenarios, a *scenario markup language* [83] was developed. The markup language allowed the authors to manually author scenarios from a high-level point of view, focusing specifically on the important events which need to occur and when these events will occur. The system then takes these high-level events and generates the required space for such events to occur. This may include generating cars, traffic, and pedestrians and then laying out these objects within the space. The simulator must also generate the appropriate movements of each object needed for the simulation, for example, drunken drivers must swerve as they move and crashes must involve two cars colliding.

CARSIM [84] is an analysis tool for taking car accident analysis reports and converting them into 3-D reproductions of the crash. CARSIM accepts the crash reports in natural language format. The system then processes the report and converts it into a structured set of events, the plot, which may be understood by the system. By allowing a natural language input, CARSIM provides a better mixed-initiative environment in which the author may communicate naturally using natural language and the computer automates the conversion of this text into the more rigid structure needed for generation. The space is generated based on the plot structure, which in essence contains the *scene* information (weather, time of day, etc.), the *road objects*, and the *collisions* between these road objects. The resulting crash is animated within the 3-D reconstruction of this space.

Charles *et al.* devised a system for medical use in which patient education documents are converted into simple interactive narratives [85]. The goals of such a system are that presenting the documents in an interactive and visual manner will be easier for the patient to follow and understand. In this system, the space is built up according to which actions and interactions the patient will be able to perform within the system. This includes locations, procedures, objects, and characters, generated into an interactive environment.

VI. STORY GENERATION

In this section, we will examine the approaches taken towards automating both plot and space. We categorize such systems as *story generation* systems in this survey since they focus on automating elements of both plot and space. We first examine planning-based systems which are given the ability to modify the space in order to assist plot generation. Second, we discuss systems which generate new existents in the space which are constrained either by an author or by the plot. Third, we examine how a simulation of a manually authored space may be used to dramatically modify or generate content. We conclude by examining one example of a computer simulation game which generates most of the space manually, using a limited set of interactor constraints.

We identify several systems in this section as EMERGENT story generation systems. Emergent systems attempt to create stories simply out of the unique interactions afforded by complex systems. This often involves the creation of a simulated space with sophisticated virtual agents, generally complex human characters, whose interactions and conflicts are expected to give rise, eventually, to some form of narrative. Often these systems aim for what Abbott defines as *narrativity* [12], and which is a fuzzy term that roughly relates to how much a causal series of events feel as though they form a narrative. Emergent systems are unique in that the author typically has little to no influence over the plot and is focused instead on creating the initial state of the space.

A. Constrained Plot and Space Modification

Since space and plot are both able to directly influence each other, the story resulting from any generation technique may suffer from issues of quality in either component. In this sense, some researchers argue that while generating plot, changes should be made to the space if this allows or improves the current plot generation [86].

This attempt at space automation according to plot constraints may be seen on a small scale in the *initial state revision* (ISR) algorithm implemented in the FABULIST [87] system. FABULIST is a planning-based plot generator, unique in its goal of merging both author and character goals, so that the resulting story would be satisfactory to the human author, while ensuring that the actions taken by the characters make sense to the reader. In terms of space, however, FABULIST uses the ISR algorithm in which, during the generation of the plot, the initial state of the space may be modified to fulfill certain aspects of the plot [86]. To allow this, the rules used for plot generation leave certain information as indeterminate. If these rules are used during the planning phase, then the system will modify the space in such a way that fulfills the missing information of the plot. The specific example provided by the authors involves the placement of a hidden weapon within the game world, so that one character is able to stealthily assassinate the other. The location of the weapon is left as indeterminate information, constrained by certain rules that state where the weapon may not be located. When generating the plot, the system then places the weapon in an appropriate location, automatically modifying the space in order to complete the plot. The space modifications provided by the FABULIST system show an application of limited automatic space generation, in which important space details related to the plot may be created automatically.

Swartjes *et al.* also explored a similar space modification technique called *late commitment* [88] in their emergent VIRTUAL STORYTELLING system. Late commitment, inspired by improvisational theater, allows the characters themselves to modify or generate new content for the space in order to achieve certain goals, for example, a character may desire to fight another character and can propose spawning weapons to meet the preconditions of the fight event. The system will then check to make sure there are no consistency violations in the space after making this change, and if so, then, the weapons will be created. The late commitment approach use consistency as a constraint to ensure that each change is *invisible*, i.e., a reader perceiving the story should not be aware when modifications were made, it should always appear that the space was defined this way.

The VIRTUAL STORYTELLER further makes use of a *story director* to help in the generation of plots [89]. The story director is an agent which contains a formal model of plot and a simulated understanding of storytelling and can selectively pick events within the simulated game world and combine them in such a way that the result is a story. The director also has a very specific influence over the game world and can introduce new characters or modify character goals in an effort to improve certain qualities of the resulting plot.

Modifying space may be also of use in preventing or accommodating for the interactor's actions in interactive stories. MIMESIS [90] is an interactive story system that uses a technique called *mediation* to modify either the plot or the space in order to balance interactor action against the intended plot. MIMESIS uses two forms of mediation: *reactive* mediation [90] and *proactive* mediation [91]. Reactive mediation occurs at the moment the interactor makes an action that may render the current plot invalid. In these situations, the system may either replan the narrative to allow this action or force the interactor's action to fail, such as having a gun jam if the interactor is intending to shoot a main character in the story. Proactive mediation aims to predict future interactor actions and modify the space in advance to make the action impossible to attempt, for example, by locking the drawer containing a gun to prevent the interactor attempting to shoot any of the characters in the first place.

TALE-SPIN [92] is an emergent storytelling system and is often considered one of the first story generation systems. Story generation in TALE-SPIN occurs by providing characters in the space with goals and personalities. In simulating the events surrounding the characters' attempts to achieve a goal, the system fashions basic stories. TALE-SPIN is a highly emergent system, relying almost entirely on stories emerging from the creation and simulation of character goals coupled with the unique personalities of each character. Its approach to space modeling is largely authored, although the space can be modified in order to ensure that the character goals could be achieved. TALE-SPIN is also an early system to stress how important elements of story, such as uniqueness and coherence, directly relate to the quality of the space, in terms of scale, depth of characters, and correctness (i.e., the space authored should accurately represent the space the author envisions). A poor quality space will inevitably lead to dull or even nonsensical and strange plots, nicknamed *mis-spun tales* by its creator.

B. Constrained Plot and Constrained Space

Li and Riedl explored the creation of fictional gadgets that may be added into a story generator which may then be used in the generation of plot [93]. Gadgets are created during generation, where the planner finds moments when it is either impossible or highly difficult to meet the subsequent goal in the story. The system then determines which goals need to be met and use analogy-based reasoning to find an object whose use is similar to the steps needed to achieve the goal of the planner.

Si *et al.* used space generation to assist during the authoring process for interactive narratives [94]. The author is able to specify their goals regarding the plot, and the system will automatically generate the goals of each of the characters such that the interactor is more likely to experience the author's intended vision when engaging with the narrative. The system further simulates different interactors, and their potential paths through the story, to highlight possible mismatches between the plot experienced by the interactor compared to the author's desired plot.

Swanson and Gordon's [95] system defies many of the conventions of previous systems and aims instead for a pure mixed-initiative approach, supported by crowdsourced knowledge mined from internet blogs. In this system, the author and computer take alternating turns writing one line of text for a story. The computer selects its line from a database of possible lines taken from internet blogs in a way that attempts to match the line to the author's intended story. In this sense, the computer's line may generate new elements of space just as much as the author's line. This approach may be the closest available to Lubart's original vision of working with the computer as a collaborator [2], although results showed that the stories generated with such a method generally lacked coherence.

SCHEHERAZADE [96] also attempts to generate interactive narratives using crowdsourcing methods. A number of anonymous authors were asked to provide linear stories for a bank robbery, which were then combined to create the final story. This plot contains branches in situations when different authors would create two alternate events occurring after a common event. The goal of this system is to create stories that have the knowledge and creativity of human authors, without the need to build this knowledge into a story generation system. The computer, in this case, mainly automates the final combination of all different plots and space into one final story.

C. Automated Plot and Space Simulation

Lebowitz implemented the automatic creation of characters in the UNIVERSE story generation process to validate the creation of certain plots [97]. To ensure the characters generated were valid, the history of the fictional world is simulated, and characters who are married are able to have offspring who are automatically created with certain features that will be explicitly used in the desired plots. This involved a certain degree of temporal coherence, for example, if the plot requires a new female character for an affair plot, then the character must be born several years before the start of the plot, to ensure her age value is within the correct bounds given by the constraints on the affair event.

D. Automated Plot and Constrained Space

Dwarf Fortress [98] is a game which includes a vastly detailed almost fully procedurally generated world with complete histories of each citizen and monster. Certain monsters may become famous, and the heroes who defeat them will also be famous for that defeat. Limited constraints on space are provided by the interactor at the start of the game, in terms of world size, presence of forests/minerals, etc. The remainder of the space, as well as all the histories, are procedurally created by simulating the space over several centuries, without the need for any manual authoring. Outside of the history generation, *Dwarf Fortress* is also known for its emergent stories, with interactors noting several instances where events in the game seem to form a causal structure closely resembling an instantiated narrative.

VII. Discussion

In Sections III–VI, we surveyed numerous examples of research relating to each of our degrees of automation, as defined in Section II. Here, we discuss several interesting topics which arose throughout the survey. First, we discuss the lack of space generation techniques in the computational narrative research community and provide some directions which could be used to approach this field of research. Second, we explore the ways in which an improved integration of plot and space may occur, either by using a standard model of narrative or by examining the degrees of automation of plot and how they promote/inhibit the automation of space.

A. Space Generation and Computational Narrative

In his survey on creativity and computational storytelling, Gervás identified two approaches to story generation [3]. The first involved generating the plot from the space, as evidenced, e.g., with TALE-SPIN [92]. For the second approach, he discussed Dehn's AUTHOR [99], a proposal for a story generation tool wherein the construction of the space would be automated according to the plot. TALE-SPIN relied on *character goals*, whereas AUTHOR relied on *authorial goals*. *Character goals* refer to the goals set by virtual agents inhabiting the space, while *authorial goals* refer to the intended story (or story components) of the author using the generation system. While both character and authorial goals have been used for plot generation, one would expect that space generation would be of use either to assist characters in meeting their goals, or to better realize the intended vision of the author. While the former was explored by Swartjes *et al.* [88], in practice, authorial goals have been more closely viewed as constraints, particular plot events, or structures which must be obeyed by the plot generators. In that sense, most plot generators have concentrated on guiding events to reach the author's intended goals, relying on minimal or no space generation. In traditional stories, space generation may amount to FABULIST's goal of dynamically generating space based on indeterminate information [86]. In interactive games, this amounts to modifying the space in order to block unwanted interactor actions using a form of narrative *mediation*, either by changing space as a reaction to a deviation, for example causing the interactor's gun to jam if they are going to shoot an important character [90], or by proactively making changes in the space to render some potential plot deviations impossible [91]. *Emergent* systems, on the other hand, may automate plot and space entirely, but may include some form of *story* or *drama manager* to form the character actions into some form of coherent plot [89].

It seems, however, that these methods are not quite in line with Dehn's original argument, that the space of the story is built to suit the plot. As stated by Dehn, the "storyworlds [spaces] are developed by authors as needed, often as post hoc justification for events that the author has already decided she wants as part of the story" [99]. We discussed several systems more closely related to this concept in Sections V and VI. However, most only make minor changes to the space or are considered distinctly separate to the computational storytelling community. Thus, in the majority of systems from within the storytelling community, the burden is on the author to create a space. Furthermore, the quality of this space often directly relates to the quality of the story [86], [92], [100]. This challenges Lubart's original intention of the computer as a collaborator, in that the success of the generation technique is still entirely dependent on a high-quality manually authored space.

By categorizing all of the major systems and techniques discussed, as shown in Table I, we can distinctly see a number of gaps relating to different combinations of plot and space generation. One interesting direction would involve exploring the space generation for plot templates. Since these templates leave open roles, a space generator would have more freedom to generate unique content with a greater reduction in terms of plot limitations. For example, it could present the author with a number of automatically created existents for each of the roles, which the author could then select from. It would also be of interest to explore the notion of fully automatic space generation, into which none of the systems surveyed could be categorized.

TABLE I
CATEGORIZATION OF THE MAJOR TECHNIQUES AND SYSTEMS SURVEYED, ACCORDING TO THEIR DEGREE OF PLOT AND SPACE AUTOMATION

	Manual Plot	Plot Structure	Plot Template	Constrained Plot	Automated Plot
Automated Space					
Constrained Space	[75], [76]	[77]–[82], [84], [85]		[93]–[96]	[98]
Space Simulation					[97]
Space Modification				[87]–[92]	
Manual Space	[20]–[24], [26], [27]	[28]–[33]	[37]–[39], [41], [42]	[43]–[52], [55], [57]–[65], [67]–[71]	[72], [73]

B. Integration of Plot and Space

Although many systems discussed in this survey present a similar description of stories, there is usually a significant level of difficulty involved in trying to integrate different components together. It seems then that it would be beneficial to develop a standard model for computational narratives, with more attention paid to the relation of plot and space. This may be grounded within concepts from narrative theory, as we have attempted in Fig. 1, but also with concepts developed within the research community (relations, character/author goals, etc.). We identified several examples which use markup languages, such as the scenario markup language from OPENENERGYSIM [83] or the MSML [31] and there exist workshops dedicated to further exploring various models of narrative [101], all of which provide interesting approaches to the problem of finding a standard model for narrative. It may, however, be more fitting to see how to create models of narratives for specific applications. For example, Tomai proposes new models for quest narratives in relation to computer role-playing games, and shows how a better model of the space can help the generation and adaptation of quests [102]. Nitsche *et al.* also explore a model of *expressive space*, where events are only used to give the interactor a certain experience within the space [103].

For an example more specifically related to the storytelling AI community, SLANT [104] is a recent effort to combine the plot generation of MEXICA [70], discourse generation of CURVESHIP [16], and the figuration generation techniques from the GRIOT [19] engine. This combination is assisted by a *blackboard* architecture, in which each generator has access to an XML schema of the current instance of the story. Each generator can then in turn have access to make changes to the story and write the new version back to the blackboard. The blackboard architecture allows the generators to be able to read and understand the XML, determine any modifications to make, and then write the modified story back to the blackboard using the same format. In this architecture, it would be straightforward to even allow intervention from human authors, and space generators to make modifications in this same procedure. Although this is only one approach to better integrating plot and space, this type of cooperation would be interesting as a form of dynamic collaborative narrative generation between author and computer.

VIII. CONCLUSION

In this paper, we surveyed a broad range of techniques and systems aimed at the computational authoring of stories. Focusing on the story component of narrative, we examined the *degree of automation* of both story components, *plot* and *space*, and, for each of them, identified five distinct categories that form a gradient between manual and automatic generation (see Fig. 2). Using these categories, we classified all research systems discussed in the survey (see Table I).

By examining the successes of recent story models (e.g., SLANT [104]), we believe that creating a standard model of computational narrative could allow different systems to interact with the same narrative, without being restricted by incompatible models and definitions. Furthermore, such a model would also facilitate research into generation of specific story components, e.g., allowing for multiple generators and even authors to collaborate on a given narrative.

We identified the convenience of furthering computational narrative research in the underexplored direction of space generation. Among other topics, one could investigate: how an entirely automated space generation system would work, and how this would influence the creation of plot; or whether this generation would eventually yield higher-quality stories, or if it would turn out that the core of the story's quality lies within its plot. How one can even evaluate the quality of space is also a challenging problem in itself. In short, investigating the possibilities of space generation poses unique challenges, with significant benefits to the research community.

Computers may be a primary tool for authoring narratives of any shape or form, but the complex goal of an automatic narrative creation tool still seems far and hard to achieve. Even by breaking down narrative into subcomponents and focusing strictly on story generation, there still seems to remain the large and inescapable presence of a human author. Attempting to do so, however, also reveals new promising directions for research, as well as a better understanding of the broad scope of the field of computational narrative. In this sense, even mixed-initiative or manual authoring methods may benefit from such research, as it gives insight into how a computer may not only *automate*, but also *collaborate* throughout the authoring process.

Narrative generation research is a very active and productive field. This thorough survey of where current research stands not only shows its present challenges, but hopefully pinpoints and inspires a variety of powerful possibilities for authors and computers alike.

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