

A Survey on Computational and Emergent Digital Storytelling

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Abstract: The research field of digital storytelling is cross-disciplinary and extremely wide. In this paper, methods, frameworks, and tools that have been created for authoring and presenting digital narratives, are selected and examined among hundreds of works. The basic criterion for selecting these works has been their ability to create content by computational, emergent methods. By delving into the work of many researchers, the objective is to study current trends in this research field and discuss possible future directions. Most of the relevant tools and methods have been designed with a specific purpose in mind, but their use could be expanded to other areas of interest or could at least be the steppingstone for other ideas. Therefore, the following works show elements of computational and emergent narrative creation and a classification is proposed according to their purpose of existence. Finally, new potential research directions in the field are identified and possible future research steps are discussed.

Keywords: digital storytelling; digital narratives; computational digital storytelling; interactive digital storytelling



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1. Introduction

Humans have always liked sharing stories. It is the most fundamental way we learn, encouraging both personal reflection and public discussion [1]. Storytelling is a widely used method for people across the world to engage emotionally, communicate, and project cultural elements and personalities. In addition, stories connect us with previous experiences and build bridges between the past and the present [2]. Narratologists agree that to constitute a narrative, a text must tell a story, exist in a world, be situated in time, include intelligent agents and have some form of a causal chain of events, while it also usually seeks to convey something meaningful to an audience [3]. Apart from humans, museums can be considered as “natural storytellers” [1]. Museums aim at making their exhibits appealing and engaging to an increasing variety of audiences, while also nurturing their role in conservation, interpretation, education and outreach [2]. Documentaries, films, video games, TV news, literature, theater, music and all kinds of art are ways of telling stories; true, fictional, or anything in-between. Even a board game, a religious ceremony, a sports event, or a dinner can be thought of as a storytelling procedure. Sometimes it is difficult to distinguish a narrative; instead it is easier to search in what ways any procedure can be considered as such. Narratives are often confused with *stories* and are erroneously considered to be synonyms. In this work, both are used interchangeably, even though their conceptual differences are well-known. In order to illustrate their difference, we can, for example, claim that the story of the modern Olympic Games is one, but there are countless narratives about the Olympic Games, expressing personal experiences and beliefs, for different periods and various games, happening around the globe. Some narratives may be famous already; others remain unknown and reach the listeners either from people who experienced them or from third parties. Narratives always contain personal aspects; according to Hills [4], a narrative is not merely a series of events, but a personification of

events through a medium such as language. Thus, as storytelling connects us with deeper emotions and experiences, it builds bridges connecting the past and present [2], becoming an extremely powerful medium for communicating messages and ideas.

In the digital era, storytelling derives its engaging power by integrating images, music, narratives, and voice, thereby giving a deeper dimension and vivid color to characters, situations, experiences, and insights [5]. Computers have been involved in the creation, storage, reproduction, sharing, and publication of stories. Initially, they were just side tools, but advanced and complex algorithms over a constantly and exponentially growing processing power brought them closer to the generative procedure of story-making. Stories also became interactive; listeners could intervene in their flow and decide, to some extent, how they would unfold. This is how the term of the *narrative paradox* came up; the freedom of choice in the formation of the story, as opposed to its prefabricated plot by the author. The user interaction with the medium conflicts with the narrative design [6]. Thus, there is always a tension between the story and freedom [7] and a balance has to be established to preserve the internal consistency of the story. Rules and boundaries are necessary to maintain the story trajectory and end up communicating messages that are desirable—as originally defined by the author—and not unpleasant.

Narratives can be linear following a specific trajectory or interactive (branching), which means they can follow several paths and the user has some level of control over the story outcome. Computers can participate in the creation of these narratives, in different ways and to varying degrees. Each story needs characters, space and a plot; algorithms may be involved in any of the precedent elements. Research in interactive narratives (IN) offers, in general, two approaches for the creation of narrative content [8]; the *bottom-up* approach, where the story is emergent and created as a result of user interaction with a system, and the *top-down* approach, where a drama manager is employed (in later papers referred to as an *experience manager*—EM—as stories are not always dramas) and which means that a set of rules and conditions are predefined during story creation, so that the story does not exceed certain limits. In the former case, there is huge freedom in story creation and an infinite number of paths can occur, but on the other hand, the potential of an unpleasant, unsatisfying story is high. In the latter case, when a user or system deviates from the desired trajectory of a story (as again originally intended by the author), the role of EM is to apply a mediation strategy called *accommodation* to transition the user to a new desirable trajectory. According to Ryan [9], the concept of *possible worlds* (PW) describes the spheres of a fictional system of reality and calls for an inquiry into the nature of possibility. Or, in simpler words, PWs are the possible “shapes” a fictional story can take.

A narrative act is an abstract, complex action in a narrative engine [10], usually described as a verb such as *promise*, *award*, *help*, *inform*, and so forth. These acts contribute to the narrative sequence, show potential and can take a central role when they are used as building blocks in combinatorial generative systems. An extensive catalog of more than 200 narrative acts has been created. In addition, a general three-level taxonomy is proposed, associated with an interactive visualization tool available online, allowing researchers and creative authors to consult and expand the catalog. Agency (a term mostly used in games), is the actual level of control that players feel while in the game world [3,11]. The more the agency increases, the more a user feels more engaged in the formation of the story and experiences it as a real event. On the other hand, the elevation of agency enhances the narrative paradox. Multiplayer interactive narrative experiences (MINEs) are interactive authored narratives in which multiple players experience distinct narratives (multiplayer differentiability) and their actions influence the storylines of both themselves and others (inter-player agency) [12].

More focused on cultural heritage, the utilization of multimodal storytelling mechanisms, in which digital information is presented through multiple communication methods/media (multimedia) is considered as a supplement to physical—traditional heritage preservation, activating users’ involvement—collaboration in integrated digital environments [13]. Thus, digital storytelling is one of the resources museums have in hand for enriching their

contribution to visitors and to society at large. Through narratives, museums can find new ways to enhance and represent their exhibits' stories to visitors, attracting their attention and increasing their interest through active engagement. Technologies such as *augmented reality* (AR) can influence the way museums can present their narratives and display their cultural heritage information to their visitors. AR can be seen as a form of mediation using interaction and customization that supports a form of narrative where visitors can engage or even create narrative scenarios in their cultural tour. There is an older review on narrative generation systems by Young et al. [14]. Additionally, an important attempt to categorize all DS authoring tools (IDN) was presented by Shibolet et al. [15]. Another taxonomy of authoring tools was contributed by Green et al. [16], where authors observe and discuss their experience from using these tools and also present Novella [17], their proprietary authoring tool. Selecting an authoring tool is directly associated with the result of a story. According to Kitromili et al. [18], many tools are bespoke; authors explore the world of authoring tools and try to figure out how each tool shapes a different type of story. To achieve that, they create the same story using different tools and report on the differences found between stories. These differences may not be that obvious when working on one platform only.

Mu [19] attempted a survey on the storytelling of an interactive documentary and a new theory model about the subject. A classic and important contribution to the narrative theory is the book of Marie-Laure Ryan [9]. In the extensive survey of Kybartas et al. [20], the authors presented techniques and tools used in the narrative generation and created a taxonomy for these projects, where algorithms generate parts of the plot, parts of the space, define characters, and offer templates for creators to speed up the creation processes, at a higher or lower level. Nevertheless, they conclude that computers will not be able to and should not substitute humans in the story creation process. As mentioned by Kasunic et al. [21], artificial intelligence (AI) work in storytelling can be categorized in three classes: (i) Teaching AI to generate and understand stories [22]; (ii) Helping human storytellers as a co-creator [23]; and (iii) Modeling story elements. As technology advances, research attention shifts to using AI to generate stories. Smart agents, text bots, advanced text-to-speech algorithms, and dialogue systems are just some of the AI products that show that tendency. Progress in natural language processing, generative art, language generation and deep learning (which is crucial to learn from the thousands of stories and tales produced by humanity at large), are some of the research trends that elevate the role of computers in the story creation procedure.

Thus, the research field of AI use in storytelling is still open, intriguing, challenging, and attractive for many researchers all over the world. It also carries a great ethical dilemma; is it right for computers to create our stories or should this remain a purely human quality? Humans can really benefit from their own stories and after all these years, we still learn and improve on telling stories [21]. On the other hand, stories coming from AI systems could potentially introduce bias, stereotypes, and prejudice about race, gender, color, nationality and religion.

Riedl [24] introduced the term of *narrative intelligence* as “the ability to craft, tell, understand and respond affectively to stories”. In his positional paper, he also refers to the term of *machine enculturation* which, in essence, is the way we—as humans—can transfer our culture(s) into a computer. Not an easy task, not even an easy concept to fully understand and digest. Nevertheless, this is an essential step in the procedure of computational narrative; otherwise stories with annoying, offensive, disrupting or no meaning at all may arise. Thus, in this paper, some concerns are raised to the creation of narratives by AI. In another work of Riedl and Harrison [25], the authors described “preliminary work on using stories to generate a value-aligned reward signal for reinforcement learning agents that prevents psychotic-appearing behaviors”. In other words, they argue about machines that are able to learn values, by reading stories. They refer to the term of *value alignment* as a property of an intelligent agent that can only pursue goals beneficial to humans. Stories reflect the culture of the society in which they were produced. In this respect, an important

question is whether it is possible for machines to be taught human values, using existing stories. This is important because, ideally, a general artificial intelligence system with the capability of creating stories would be desirable, but a system, especially one that is embodied, that shows deviating behaviors that can potentially harm humans would be undesirable. The problem of value learning has preoccupied researchers in the past, such as Soares and Fallenstein [26].

Figure 1 displays the evolution in computer use for storytelling. The circles represent four distinctive but overlapping storytelling periods. The further we go to the right, the more human writing tasks are assigned to algorithms. More capabilities, options, and flexibility are added to the story paths, but the role of the writers diminishes. Of course, we can always look back, since the use of technology has never been mandatory, as narrative creation characterizes humans and algorithms are not made to substitute them.

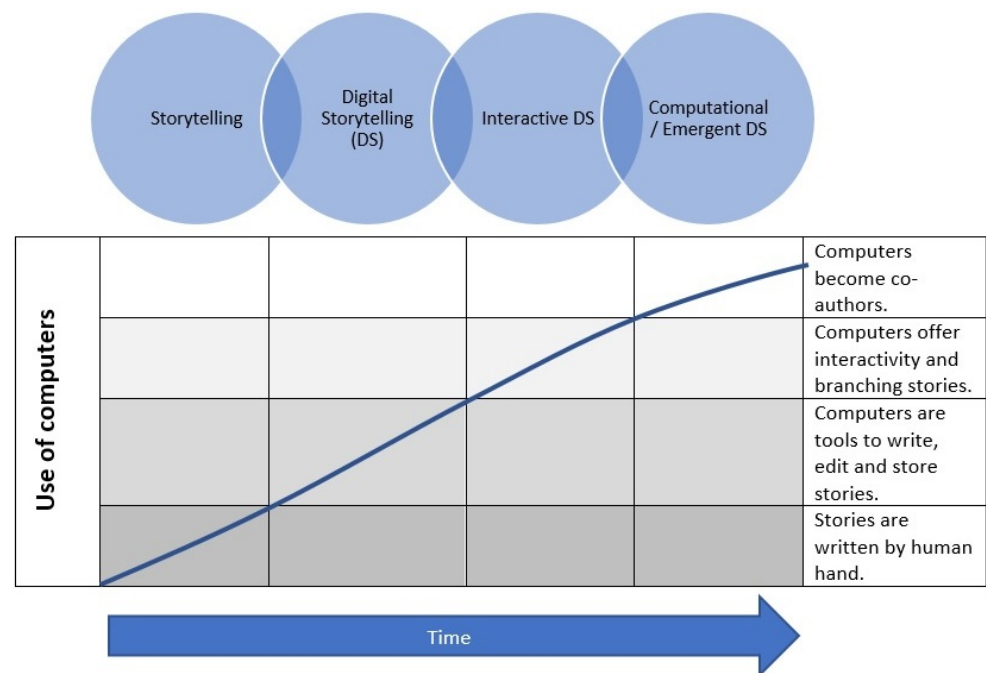


Figure 1. Evolution in computer use for digital storytelling.

Nevertheless, the current survey focuses on the research and collection of scientific works related to computational, emergent, interactive digital storytelling tools and methods. Hundreds of DS works have been collected and filtered according to their interactivity and potential for computational content creation. It is an attempt to bridge the gap between surveys published in the past by the authors mentioned above and the current state-of-the-art, in an effort to create an updated and useful survey for researchers in the field. In this respect, a taxonomy is proposed for contemporary DS works, according to their purpose and scope. Therefore, works published before 2015 have not been considered in this survey.

The works presented in this survey have been primarily retrieved from conferences related to emergent, computational, and interactive digital storytelling (Table 1). When an implementation was available, it was tested as well. Then the initial pool of works was expanded by considering their bibliographic references pertaining to the criteria discussed above (that is, published after 2015 and related to DS). Then, the final set of works was determined after expanding our search to scholarly databases such as Google Scholar and Semantic Scholar using the “*emergent*”, “*computational*”, “*interactive*” and “*storytelling*” search terms.

Table 1. Conferences related to computational DS.

No	Conference
1	International Conference on Interactive Digital Storytelling (ICIDS)
2	ACM Conference on Hypertext and Social Media (HT)
3	International Conference on Computer Graphics and Interactive Techniques (SIGGRAPH)
4	International Conference on Advanced Informatics Concepts Theory and Applications (ICAICTA)
5	Conference on Artificial Intelligence and Interactive Digital Entertainment (AIIDE)
6	Annual Conference of the Japanese Society for Artificial Intelligence (JSAI), AAAI Conference on Artificial Intelligence (AAAI)
7	Innovative Applications of Artificial Intelligence Conference (IAAI)
8	ACM/IEEE International Conference on Human-Robot Interaction (HRI)
9	International Conference on Soft Computing Models in Industrial and Environmental Applications (SOCO)
10	International Conference on Technologies for Interactive Digital Storytelling and Entertainment (TIDSE)
11	International Conference on Social Robotics (ICSR)
12	International Conference on Virtual Reality Continuum and its Applications in Industry (VRCAI)
13	International Conference on Interactive Experiences for TV and Online Video (TVX)
14	IEEE Integrated STEM Education Conference (ISEC)
15	International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)
16	Conference on Tangible and Embedded Interaction (TEI)
17	Foundations of Digital Games Conference (FDG)

The rest of the paper is organized as follows: Section 2 overviews related work in computational and interactive DS applications, where works are presented and then classified. Section 3 categorizes works based on the employed media and interaction. A discussion and criticism on the subject follows in Section 4 and the current survey is concluded in Section 5.

2. Related Work

Digital Storytelling, as a method or tool, can be used multimodally almost everywhere; in education, entertainment, cultural sites, health applications, arts and so on. By taking advantage of the strengths of AR and VR technology, stories can become more vivid, interactive, compelling and immersive, providing an intense experience to users.

All the works in this survey are firstly divided into three main categories, as identified by their analysis (Figure 2):

1. DS Authoring Tools

Tools specifically developed for the creation of stories are examined in this category. In this perspective, even a word processor (like Microsoft Word) may be viewed as an authoring tool, but in this survey, we focus on more complex, specialized tools that assist in the creation of stories by producing content in an automated way. Mitchell et al. [27] hosted a workshop discussion on whether authoring tools are really necessary. This is an interdisciplinary topic to discuss.

2. **DS Systems and Applications**
In this category falls mobile applications that use DS to enhance user experience, in various cases and fields of interest. There are also more complex systems, combining databases, special hardware, desktop software applications and technologies such as VR, AR, and robotic mechanisms. In either case, this category includes projects fully or partially developed, either for commercial or research purposes.
3. **DS Methods, Frameworks and Case Studies**
These are theoretical studies and designs for projects that use computational DS in various fields. Some of them are ongoing projects, in the middle of implementing a proof-of-concept, a demo or a complete application—system.

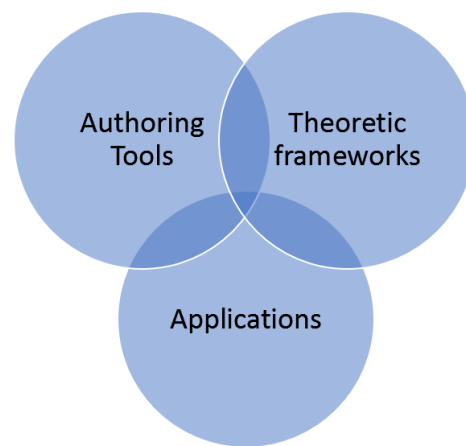


Figure 2. Categorization of DS works.

It is obvious that the above categories may overlap. In some cases, the researchers created their proprietary authoring tool in order to build their application (as, for example, in Narralive [28] and CHESS [29]). Equivalently, developed systems conclude in authoring tools, such as StoryAssembler [30] and Stories of the Town [31]. Additionally, there are authoring tools and DS systems that are still being developed and as such could be positioned also in the category of frameworks (e.g., Subject and Subjectivity [32] and Felt [33]). Table 2 presents all the 92 selected works considered in this survey, organized in the aforementioned three categories. The 18 DS authoring tools, 33 working systems and applications and 41 theoretical methods and frameworks were identified in total. The larger checkmark indicates each work's primary classification, while overlapping categories are marked with smaller checkmarks.

Table 2. Categorization of the 92 examined works.

No	Work Title/Authors	DS Authoring Tool	Category	
			DS System/ Application	Method/ Framework/ Case Study
1	Kawagoe S. et al. [34]	✓		
2	Kybartas B. et al. [35]	✓		
3	Subject and Subjectivity [32]	✓		✓
4	Scheherazade-IF [36]	✓		
5	Ink [37]	✓		
6	Mimisbrunnur [38]	✓		

Table 2. Cont.

No	Work Title/Authors	DS Authoring Tool	Category DS System/ Application	Method/ Framework/ Case Study
7	Szilas N. et al. [39]	✓		
8	StoryPlaces [40]	✓		
9	Green D. et al. [41]	✓		
10	Pujol et al. [29]	✓	✓	
11	The Story Maker [42]	✓		
12	Narralive [28]	✓	✓	
13	Molnar A. et al. [43]	✓		
14	Tracery [44]	✓		
15	Villanelle [45,46]	✓		
16	Novella [17]	✓		
17	Brown S. et al. [47]	✓		
18	ShowRunner [48]	✓		
19	Battad Z. et al. [49]		✓	
20	Felt [33]		✓	✓
21	Katsui T. et al. [50,51]		✓	
22	Battad Z. et al. [52]		✓	
23	CANVAS [53]		✓	
24	StoryAssembler [30]	✓	✓	
25	Stories of the town [31]	✓	✓	
26	WoTEdu [54]		✓	
27	Turning Point [55]		✓	
28	Revells and Chai [56]		✓	
29	M.Suckling [57]		✓	
30	De Kegel B. et al. [58]		✓	
31	Honey I'm Home [59]		✓	
32	Throwing Bottles at God [60]		✓	
33	storyMINE [12]		✓	
34	Nielsen T.L. et al. [61]		✓	
35	Adversario [62]		✓	
36	Letters to José [63]		✓	

Table 2. Cont.

No	Work Title/Authors	DS Authoring Tool	Work Category	
			DS System/ Application	Method/ Framework/ Case Study
37	Olegoru [64]		✓	
38	Vim [65]		✓	
39	Liang H. et al. [66]		✓	
40	Wicke P. et al. [67]		✓	
41	Tokunaga et al. [68]		✓	
42	Bowman A. [69]		✓	
43	Svensson T. [70]		✓	
44	The thousand autumns of Jacob de Zoet [71]		✓	
45	Green C.P. et al. [72]		✓	
46	Firebolt [73]		✓	
47	Faoladh [74]		✓	
48	Basaraba N. et al. [75]		✓	
49	Tell a Tail 360° [76]		✓	
50	Svensson T. et al. [77]		✓	
51	Stavarakakis N. [78]		✓	
52	Martin L.J. et al. [79]			✓
53	Leonid Berov [80]			✓
54	Chauvin S. et al. [8]			✓
55	Carolyn Miller [4]			✓
56	Schoenau-Fog H. [81]			✓
57	Womack and Freeman [82]			✓
58	Austin J. [83]			✓
59	Kreminski M. et al. [84]			✓
60	Szilas N. et al. [39]			✓
61	Martin L. et al. [85]			✓
62	Amos-Binks A. et al. [86]			✓
63	Xu W. et al. [87]			✓
64	Short E. [88]			✓
65	Koenitz H. et al. [89]			✓
66	Koenitz H. et al. [90]			✓

Table 2. Cont.

No	Work Title/Authors	DS Authoring Tool	Work Category	
			DS System/ Application	Method/ Framework/ Case Study
67	Bernstein M. et al. [91]			✓
68	Shelton et al. [92]			✓
69	Rizvic S. et al. [93]			✓
70	Smith A. et al. [94]			✓
71	Rizvic S. et al. [95]			✓
72	Rouse R. [96]			✓
73	Strugnell J. et al. [97]			✓
74	Kawano Y. et al. [98]			✓
75	Robertson J. et al. [99]			✓
76	Spawforth C. et al. [100]			✓
77	Cardona-Rivera R.E. et al. [101]			✓
78	Chu J. [102]			✓
79	Mapping Place [103]			✓
80	Chu S. et al. [104]			✓
81	Paradedá R. et al. [105]			✓
82	Paradedá R. et al. [106]			✓
83	Striepe and Lugin [107]			✓
84	Ozaeta and Graña [108]			✓
85	Ko et al. [109]			✓
86	Kampa A. [110]			✓
87	Bhide S. et al. [111]			✓
88	fanSHEN [112]			✓
89	Vox Populi [113]			✓
90	Project Orpheus [114]			✓
91	Pillai J. and Verma M. [115]			✓
92	Mu C. [19]			✓

At a second level of analysis, all works were classified according to their purpose and scope (Table 3). There are, for example, works that have been specially designed to engage museum visitors, others for educational purposes only, and some to assist the elderly to overcome loneliness. Nevertheless, there are a lot of research works that could be positioned in more than one category; in this case, a large checkmark designates the main classification and smaller checkmarks indicate the additional categories. In total, there

exist four categories referred to in the literature as “newer genres of IDN” and some works considered in this study belong to these genres. More specifically, the said genres appeared in the realm of interactive narratives during the last decade and exhibited some interest, as they evolve constantly and show more potential in the use of interactive digital narratives.

The last column of Table 3 is titled “General Purpose” and contains 34 out of the 92 works in total. As this is almost one-third of the examined works, it is explained in more detail in the following subsections.

2.1. General Purpose Computational and Emergent Storytelling Works and Systems

As already discussed, the proposed classification is based on the scope of each work. Thus, it could be assumed that “general purpose” means that many works could not fit in any category, or there was no specific purpose during their creation. However, this is not the case; all of these 34 works designate the effort of researchers to learn more about interactive digital narratives. They created apps, systems and designed frameworks to test them and find their potential strengths and weaknesses. The said works form the basis for new theories and new technologies, meaning that their stated purpose could be equally “learning more about DN” or “going a step further”. Thus, writing stories or narratives constantly shifts from the pure writing of texts, to writing algorithms, methods, frameworks, rules and structures, handling data and variables, creating the logic and taking decisions according to conditions. This is more akin to using programming languages and coding than creating meaningful and touching stories. Computational storytelling is hard and can lead to meaningless and even disturbing results if no boundaries are set and rules are followed.

Every researcher or group of researchers follows their path and methodology for creating computational narratives, making any analysis and categorization difficult. To start with, a couple of works are character- or player-focused. Berov [80] aimed at conceptualizing and implementing a computational storytelling system in which the plot emerges according to the characters’ embedded narratives. His work is still in progress. An architecture of emergent player-triggered narratives used in games was also proposed by Chauvin et al. [8]. They designed an interpretation engine whose role is “to make sense of the emergent world as it is changing and Inform the Narrative Processes with high-level story concepts such as actors and places”. Through these works, a lot of terms emerged and were explained. Berov used the term *tellability* (as used by narratologists) to describe the internal quality of the plot and Chauvin explained and used the terms *coherence*, *agency*, *possibility space*, *uncertainty* and *codirection*.

In other projects, knowledge or data graphs are preferred as the stepping stone for emergent stories. Battad et al. [52] developed a computational system that parses data graphs to create descriptive texts. The system distinguishes “normal” and “abnormal” events by identifying visual patterns on graphs and, in the end, applies descriptions on a storytelling template. One year later, the same researchers presented their project that builds upon the existing multi-modal storytelling system. They used it to organize and describe Rensselaer Polytechnic Institute’s library archives, and they discussed their results.

In a couple of other works, narratives emerged according to the user’s choices. For example, StoryAssembler [30] is an open-source generative narrative system that creates dynamic choice-driven narratives. As a case study, it was used during the creation of the Emma’s Journey game. Similarly, Ink created by Inkle Studios is a scripting language that creates choice-based interactive fiction (IF). Kenton et al. [37] described the way they used Ink to teach interactive design by having students create a choice-based interactive fiction story as a major course project.

Many projects give more emphasis in theoretical frameworks and do not always proceed with implementations. Through these projects, however, new definitions and fields of research have been developed. Miller [4] conducted in-depth research and analysis of the world of interactive storytelling, covering all basic principles and also including AI in digital storytelling, the use of technologies such as AR, VR and mixed reality. Additionally,

she presented numerous case studies that delve into the processes and challenges of developing works of interactive narratives. As another working example, the term *story shifting* was introduced by Ryan et al. [3] in order to define the selection of events that constitute a compelling story from a larger chronicle of events. Story shifting is one of the most challenging aspects of emergent storytelling but Kreminski et al. [33] attempted a first application by developing a system called Felt. Using query language and rules, they achieved a shifting of events and evaluated Felt in case study applications (Starfreighter, CMCK, Diarytown) in an effort of proceeding to a more sophisticated system for emergent storytelling. In the space-time theoretic approach of Schoenau-Fog [81], ideas, concepts and examples are examined with respect to how space-time may be used to organize events, while maintaining narrative engagement. More specifically, he proposed a system framework in IDS, which exploits the possibilities of the time-space continuum.

Some works are based on previously proposed theoretical designs and frameworks, with creators trying to implement and test them. For example, Szilas et al. [39] researched the central notion of conflict in drama. They used an algorithm to extract all kinds of conflict in a narrative and then they created a model of conflicts. Finally, a cluster analysis was performed, demonstrating that they can be reduced to three main “conflict groups”. The role of EMs in computational narratives is very important. Amos-Binks et al. [86] defined three desirable properties of a narrative trajectory (exemplar trajectories, narrative-theoretic comparison and efficiency) that EMs should handle and demonstrate how their plan-based Intention Dependency Graph addresses them. Kreminski et al. [84] attempted to map out the design space of storylet-based narrative systems in games. They refer to the term *storylet* as a discrete, reordable narrative chunk or module, found in a narrative database, usually for a game. During these games, storylets are redrawn from the database according to user actions in a way that they form a complete narrative. In their work, they also find and record common elements of storylet-based systems. Kybartas et al. [32] based their thinking on the theory of Ryan [9] and studied the potential of the PW model in an emergent narrative. They proceeded to a partial implementation (demo) and testing of such a tool and ended up with the conclusion that PWs afford several possibilities for emergent narratives and manage to quantify conflict in the system. The same authors, continuing their research [32], presented Subject and Subjectivity, “a conversational game that uses a possible worlds model of narrative and characters to support an exploratory dialogue system”. They came to the conclusion that a “dynamic and engaging dialogue system can be achieved, even with a small amount of content and a simple conflict model”.

A special approach to the creation of computational narratives is the use of *narrative acts* by Szilas et al. [10], which are, in a simple interpretation, complex verbs that contain a predicate and parameters that allow them to be linked to other acts. When used as building blocks in computational narrative systems, they could possibly create meaningful text. Along with the narrative acts, the authors created a very useful tool for IDS authors. Their online tool¹ is an interactive visual (sunburst type) catalog of the 223 collected narrative acts. This collection forms a hierarchical database of acts (each act is part of a higher level category named class and each class is part of a domain, where a total of six domains form the whole database). Their tool is updatable, which means that if new narrative acts arise, they can be easily added to the database. Artificial Intelligence technologies pave the way for other researchers. Stefnisson and Thue [38] have implemented an authoring tool named Mimisbrunnur that “incorporates AI in a variety of ways”. Specifically, the tool uses natural language processing and mixed-initiative exploration to “help the author create an outline, and stories from this outline can be previewed within the tool using the outputs of a story generator that uses AI planning”. Mimisbrunnur was used to create story outlines as defined by Thue et al. [116,117]. An outline has been described as a set of relations, true or false, that put boundaries on the way a story will start and on the way it will continue. Martin et al. [79] took the challenge of computational improvisational storytelling in open-world domains. The goal for them is the development of an intelligent agent that can sensibly co-create a story with one or more humans through

natural language. They discuss some of the challenges that need to be addressed and they propose two architectures that address some of these challenges as a starting point. Creating a computational, improvisational story is composed of finding the appropriate words from a collection and putting them together in sentences, in a way that meaning is created. Later on, Martin, along with other researchers [85], presented a technique for preprocessing textual story data into event sequences. They also presented a technique for automated story generation whereby the problem is decomposed into the generation of successive events and the generation of natural language sentences from events. GPT [118] (the current version during the writing of this survey is GPT3 [119]) is a very promising technology in the automated creation of text using complex AI algorithms. Austin [83] used GPT2, trying to learn how to write about a subject and additionally generate the topology for an encyclopedia. His work aims at fostering new research on using GPT2 as a computational storytelling tool.

All other works belonging to the “general purpose” category, follow their own unique way to deal with computational narrative creation. For example, Katsui et al. [50] proposed a creative support system that organizes the structure of entire stories. They start with two templates, one for the story structure and one for setting up the characters. Afterwards, they add four more functions, which are “creating unlimited profiles of characters, setting undulations of a story, drawing periods of each character appearing, and calculating the sentiment value of each period”. They have tested their system with authors who found the system useful for creating novels. The power of templates in the creation of computational narratives has been the research field of Kawagoe et al. [34]. The authors used four story templates to create stories with a computational method. Afterwards, they studied the efficiency of these templates, conducted experiments with real users, and they concluded that the backgrounds of characters are the most significant ingredient for the creation of attractive stories.

In another field approach, Womack and Freeman [82] presented a novel method for creating interactive narratives. Based on the literature approach for narratives, they considered that stories have genre and semantics and they added location-based context. Using a GPS geo-location, they try to anchor stories to the real world. The narrative structure is anchored to various locations, and they use a database of words, sentences, and phrases to select their data through machine learning procedures. Location data are also important in StoryPlaces (Figure 3). It is a platform presented by Hargood et al. [40] and focuses on locative narrative systems. Research in the field had been abandoned for some time, but the authors returned with an “open-source locative hypertext platform and authoring tool designed around a sculptural hypertext engine and built with existing Web technologies”. In other words, StoryPlaces can be used as an authoring tool for narratives that embed locative data and it has been tested and used in actual applications.

Green et al. [41] presented a three-stage design pipeline targeting the creation of interactive narrative authoring tools. To test their system, they proceeded with the creation of a new authoring tool, and they reported on the methodologies, analyses, and findings of each step. Xu et al. [87] emphasized the style of computational dialogues within the context of a narrative. They proposed an approach and demonstrated its feasibility through the support of deep learning techniques. Short [88] created a blog about the complexity of branching in narratives and the ways it could be more efficient, by dealing with some basic problems involved. Schoenau-Fog and Larsen [120] created a workshop to explore and address the challenges of creating interactive adaptive real-time story worlds. Participants in the workshop explored the potential of the field and presented their work. In another workshop, Koenitz et al. [89] studied the potential of card-based methods to create IDN prototypes.

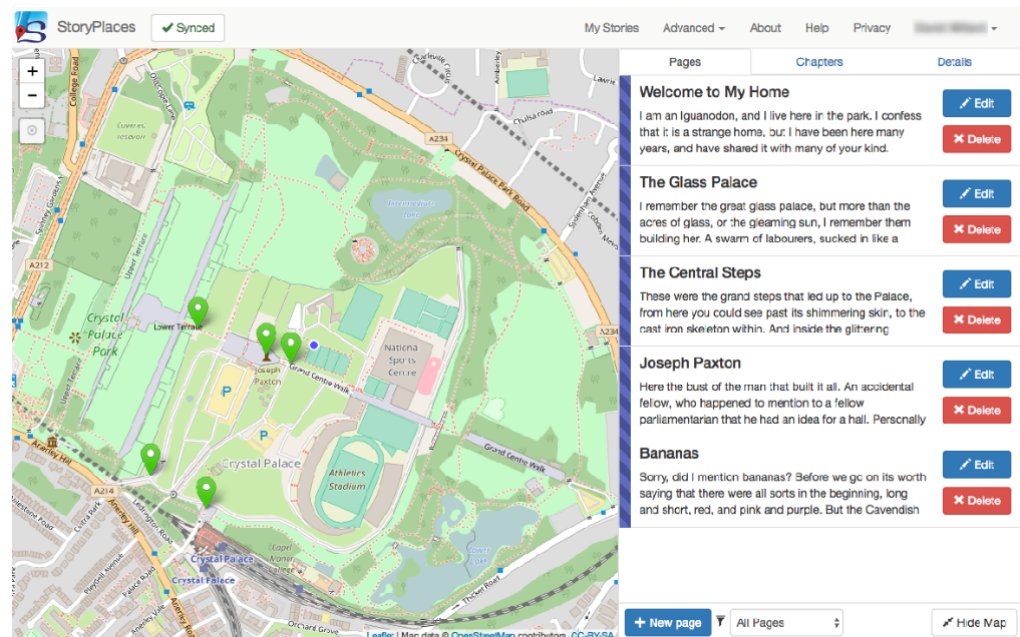


Figure 3. StoryPlaces [40].

There are narrative systems that do not create stories but use ready-made stories (i.e., created by hand or other systems) and transform them into movements, sounds, videos, animations, and so forth. For example, Kapadia et al. [53] presented CANVAS, a system that takes narratives and creates animations that could be used as prototypes by artists and directors. Stories of the Town by Miller [31] is another system that automatically generates narratives by synthesizing three distinct approaches to traditional narrative generation; context-free grammar, planning, and simulation. In this project, the authors try to balance narrative coherence and character autonomy. An open interactive narrative was introduced by Guzdial et al. [36], solving the problem of generating an interactive narrative experience about any possible topic. In addition, they presented an intelligent, open, interactive narrative system, Scheherazade-IF, that automatically generates interactive fiction about common topics. Scheherazade-IF uses crowdsourcing to learn a domain model for a given topic in a just-in-time fashion, meaning that it engages in domain knowledge acquisition during the development of the interactive narrative experience about a specific, requested topic. This work has been based on the previous work of Li et al. [121], in which crowdsourcing was used again to create domain models manually.

2.2. In the Field of Education

The impact of digital storytelling in education is huge, in terms of student engagement and satisfaction, ease of learning and memory retention. Nonetheless, according to Koenitz et al. [90], there has been no degree program in interactive narrative design, which indicates that many narrative designers are self-trained. By starting an educational program, the authors aimed to address this problem, using the opportunity to also include perspectives outside of games. The issue of the non-existence of a formal education discipline is also the subject of Bernstein et al. [91] according to whom it is a constant need, not yet fulfilled, because of the epistemological implications of the multiple disciplinary roots of the field. Shelton et al. [92], in their study on IDS in education, explored the use of interactive videos for a university hybrid course. The purpose of these videos is to support student learning and engagement and the results were very positive regarding student engagement, scaffolding learning, learning gains, and student accountability. Akin to the above, Molnar [122] used IDS in teaching microbiology and his research results show improvements in student engagement and participation.

Table 3. Classification of DS works according to their scope and purpose.

No	Work Title/Authors	Education	Cultural Heritage	Games	Healthcare	Performing Arts	Newer Genres of IDN Cinematic IN	iDocs	Interactive News	General Purpose
1	Koenitz H. et al. [90]	✓								
2	Bernstein M. et al. [91]	✓								
3	C.C. Shelton [92]	✓								
4	Rizvic S. et al. [93]	✓	✓	✓						
5	Smith A. et al. [94]	✓								
6	Olegoru [64]	✓								
7	Chu S. at al. [104]	✓								
8	Vim [65]	✓								
9	Liang H. et al. [66]	✓								
10	Ozaeta L. and Graña M. [108]	✓								
11	Mapping Place [103]		✓							
12	Svensson T. [70]		✓							
13	Rizvic S. et al. [95]		✓	✓						
14	Roussou et al. [2]		✓							
15	Rouse R. [123]		✓							
16	WoTEdu [54]		✓							
17	Turning Point [55]		✓	✓						
18	The Story Maker [42]		✓							
19	Revells T. et al. [56]		✓							
20	Narralive [28]		✓							✓
21	Letters to José [63]	✓	✓					✓		
22	Chu J. [102]		✓			✓				
23	Molnar A. et al. [43]			✓						
24	M.Suckling [57]			✓						
25	De Kegel B. et al. [58]			✓						
26	Honey I'm Home [59]			✓						
27	Throwing Bottles at God [60]			✓						
28	Tracery [44]			✓						✓
29	Strugnell J. et al. [97]			✓						
30	Kawano Y. et al. [98]			✓						
31	Robertson J. et al. [99]			✓						
32	storyMINE [12]			✓						

Table 3. Cont.

No	Work Title/Authors	Education	Cultural Heritage	Games	Healthcare	Performing Arts	Newer Genres of IDN Cinematic IN	iDocs	Interactive News	General Purpose
65	Schoenau-Fog H. [81]									✓
66	Womack and Freeman [82]									✓
67	Austin J. [83]									✓
68	Kreminski M. et al. [84]			✓						✓
69	Szilas N. et al. [39]					✓				✓
70	Martin L. et al. [85]									✓
71	Amos-Binks A. et al. [86]									✓
72	Katsui T. et al. [50,51]									✓
73	Xu W. et al. [87]									✓
74	Battad Z. et al. [52]									✓
75	Short E. [88]									✓
76	Koenitz H. et al. [89]									✓
77	CANVAS [53]					✓				✓
78	StoryAssembler [30]									✓
79	Stories of the town [31]									✓
80	Kawagoe S. et al. [34]									✓
81	Kybartas B. et al. [35]									✓
82	Subject and Subjectivity [32]			✓						✓
83	Scheherazade-IF [36]									✓
84	Ink [37]									✓
85	Mimisbrunnur [38]									✓
86	Szilas N. et al. [10]									✓
87	StoryPlaces [40]									✓
88	Green D. et al. [41]									✓
89	Paradeda R. et al. [106]				✓					✓
90	Striepe H. and Lugrin B. [107]									✓
91	Brown S. et al. [47]									✓
92	Wicke P. et al. [67]									✓

Rizvic et al. [93] discussed the benefits but also addressed the challenges of introducing IDS and serious games in the classroom, on topics such as cultural heritage. Smith et al. [94] targeted the student group aged 9–11 and tried to combine the teaching of programming courses with the creative process of writing stories. Thus, they proposed an approach in block-based programming in order to create interactive digital narratives. This way,

they aimed to engage upper elementary students in computational thinking and narrative skill development.

2.3. In the Field of Cultural Heritage

Digital storytelling has been applied in the context of museums and other cultural places for quite some time now. Stedelijk Museum in Amsterdam was the first museum to use recorded guiding stories and since then, most of the museums worldwide have used some form of technology to enhance the experience of visitors by telling stories and adding content to their guidance. Even though this field has been well-studied in the framework of DS, newer projects always try to enhance, transform and enrich the use of stories for a much richer user experience. To start with, Rizvic et al. [95] tried to create a methodology for creating IDS presentations for cultural heritage. The authors engaged for this project a group of multidisciplinary experts and as a result of their work, they wrote guidelines for other researchers. Guidelines to help shape design and development of interactive narrative projects in educational, museum, and heritage settings are also the result of a project by Rouse [123]. As she states, the telling of history has a long tradition of engagement with emerging technologies. She presents several case studies in which technologies such as AR and VR are combined, to promote cultural heritage, as a result of her long-time field research. She also focuses on the ethics of telling someone else's story. Roussou et al. [2] reported on a series of experiences involving the creation of several interactive rich-media museum stories. These digital stories were authored by experts who collaborated in numerous intensive, hands-on participatory design workshops held at high-profile cultural sites; the Acropolis Museum in Greece, the archaeological site of Çatalhöyük in Turkey and the Stedelijk Museum in Amsterdam.

Teenagers are a difficult audience in a museum, in terms of engagement and satisfaction. Turning Point [55] is a project that targets teenagers as museum visitors and tries to make museums interesting using gamification, and narratives, offering a rich user experience. It is based on a mobile application that was used in the Natural History Museum of Funchal (Madeira island, Portugal). The application is location-based and challenges visitors to explore the museum and unlock fragments of narratives that compose the main story. A richer experience for museum visitors was also attempted by WoTEdu [54]. It is an IDS project based on the Web of Things (WoT) paradigm and was designed for museums as storytellers, to enhance the interactivity between artifacts and visitors. As a case study, in collaboration with the Galata maritime museum in Genoa, Italy, narratives about nautical artifacts were written for a pilot application of the system.

A practical tool created to assist storytellers was presented by Vrettakis et al. [28]. The authors described the web-based Narralive Storyboard Editor (NSE) and the Narralive Mobile Player (NMP) app (Figure 4) as “developed with the objective to assist the creative process and promote research on different aspects of the application of mobile digital storytelling in cultural heritage settings”. These tools were developed during the implementation of the CHES project [29,124] (CHES authoring tool) and afterwards they were upgraded, altered, and used in the EMOTIVE project [125]. Narralive has no emergent storytelling elements but can speed up the writing of stories through templates. In a later project [42], the authors created an authoring tool called The Story Maker and experimented on previous works with branching narratives in cultural heritage. In the said project, they presented their tool which aims to foster the development of multimedia interactive narratives for cultural heritage. It is a web-based, JavaScript tool which contains two parts; the story design editor (SDE) for designing the story and the storyboard editor (SBE) that produces the final visitor experience.



Figure 4. Narrative [28].

An attempt to bridge the academic discipline of history with IDS has been made by Revells and Chai [56] who used VR technology, Maya and Unity software, along with a range of visual and aural historical sources from Republican-era China (1912–1949), for a digital demonstration of “the possibilities of combining interactive digital narrative with long-accepted materials and modes of historical production”.

2.4. In Games (Entertainment or Serious)

Every computer game is attached to a story, which can be minimal or more complex than any movie story, as it can branch in multiple directions, according to player choice. In games, there is always a tension between agents and narratives and that is a basic challenge for game designers. When the level of agents is high, the narrative loses importance and meaning, while focusing on the narrative leads to the loss of agent feel. Strugnell et al. [97] attempted computational narrative improvisation in games, according to players’ reactions, so that a good balance between agents and narrative could occur. Large-scale games demand long scenarios, much longer than a movie, as a result of their interactivity. Creating the plot is the first step to reaching a scenario, and Kawano et al. [98] created a framework for automated plot generation. In their evaluation experiment, they ended up with a result very close to automated plots and they worked on creating more complex stories than just plots. Molnar and Kostakova [43] used a game engine to create an authoring tool that facilitates the development of IDS-based games. They also created several games using their authoring tool and they used these games as case studies in their research.

Suckling [57] is developing a mobile game in which the story is partially generated procedurally. It is called *Dungeon Crawler*, a type of game in which players control one or more characters with whom they explore a dungeon. The narrative is not handled by an AI system or any complex algorithm, but is procedurally generated as a production system, built on probability triggers. De Kegel and Haahr [58] attempted narrative design innovation in the form of a system for the procedural generation of puzzles, for use in story-rich games or games with large open worlds. They used context-free grammar as the basis for both the generation algorithm and puzzle-solving, which guarantees that the puzzles are solvable. They are based on their previous survey [126] on procedural puzzle generation. Their work has also been the basis of a newer project called *Honey I’m Home* [59], where a 2D adventure game based on the SPHINX framework is presented, mostly as an evaluation tool. Kreminski and Wardrip[60] presented *Throwing Bottles at God*, an experimental narrative game in which predictive text is used and narratives are formed partially by the player and partially by algorithms. In addition, dialogues of NPCs are created by AI, in a specific style. This work has been influenced by a previous work named *Tracery* [44], which is an author-focused, generative text tool intended to be used by novice and expert authors. In other words, it is a tool for people who need computational

narratives for any purpose, without having to resort to messing, coding and algorithms. It exports content in several formats, such as HTML, SVG, and JavaScript.

A research area in AI for games focuses on the creation of personalized content for players, according to their reactions. Robertson and Young [99] studied the creation of a game engine that utilizes a *procedural content generation* (PCG) pipeline “to generate and control a range of gameplay experiences from an underlying IN experience management construct”. In other words, the authors created a computational narrative method and expanded their method to create procedural game content. Nielsen et al. [61] explored a method in which PCG was used to create virtual environments and embedded narratives. PCG is often used in game creation, usually by small groups of developers or even individuals, to produce games faster and cheaper. Many elements of the environment such as terrain and plantation would be time-consuming if created by hand, but PCG tools can take over all the boring, repeated work of creating environmental content. The authors created an online game ² as a case study and experimented with real users. In their game, there was a single narrative embedded in the environment and some of the users experienced a steady pre-made environment, while others a procedurally created one. Researchers concluded that levels of narrative engagement and coherency were similar in all cases. Spawforth et al. [12] explored the potential of Multiplayer Interactive Narrative Experiences (MINEs) in the world of storytelling. They introduced a model for MINEs based on sculptural hypertext and created a prototype based on that model. Their tool, called StoryMINE, is one of the first attempts at this novel category of storytelling. The basis of this project was a previous work by Spawforth and Miller [100], in which authors create a framework for multi-participant interactive narratives. The framework was built upon a systematic analysis of 56 interactions across 17 multiplayer games and tested on 3 novel multiplayer games.

For the rest of the projects in the Game category, different proprietary approaches were followed. Bhide et al. [111] experimented on virtual reality games and analyzed the spatial sound serving the storytelling. Adversario [62] is an implemented system for creating interactive narrative games where autonomous agents are guided by an adversarial planner which conflicts with player goals. The world and agents are created procedurally and interaction with users occurs via a text interface. Cardona-Rivera et al. [101] attempted to formalize the narrative design for games, using a method called GFI (Goals, Feedback, Interpretation). The GFI framework attempts to bridge the gap between narrative design, game development, story analysis and game research. The authors also attempted to elucidate the potential of GFI as a general method for creating game narratives. Martens et al. [45,46] presented a more advanced authoring tool called Villanelle (Figure 5) which automates the creation of characters for storytelling. Their approach is language-based and they created algorithms using behavior trees (BT). The authors chose BTs because of their wide adoption in the game industry by designers. Villanelle is an API framework but also a standalone tool to author every part of an interactive narrative experience. Finally, as discussed above, Novella [17] is a DS authoring tool that targets video game stories.

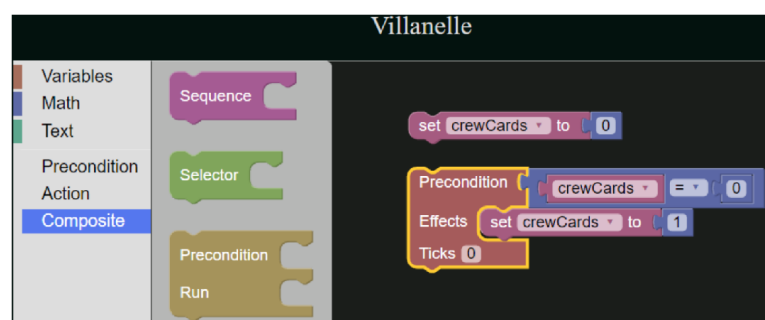


Figure 5. Villanelle [46].

2.5. Narrative Systems in Healthcare

Stories can indeed help people when in need, mentally or physically. Narrating the right story can work positively for the elderly, or for people in pain or discomfort. Bowman [69] used textual narratives against patient loneliness and isolation which originate from real patient experiences, gathered in interviews, and foster a sense of companionship. Companionship for the elderly was also the purpose of a social robot application created by Paradedda et al. [105]. This robot can entertain by choosing and narrating stories. Tokunaga et al. [68] proposed another robotic storytelling system that can improve the mental health and quality of life of older adults by conducting story dialogues. The purpose of these dialogues (sets of questions and answers) is to build resilience against cognitive decline because of age. The system is designed to be used as cognitive training on a daily basis.

2.6. Newer Genres in Interactive Narrative

The use of interactive narratives is less popular in some fields, either because the technology is not mature yet, or because the idea of using interactive narratives in these fields has not been developed enough. Researchers of IDN consider the following as newer genres in IDN.

2.6.1. Performing Arts

According to Rouse [96], digital storytelling traditionally used canned media, meaning that stories could be predefined or at least based on known data going in predefined directions. In theater and other performing arts, narratives emerge, and they are real-time and responsive. Real-time media dominate the 21st century, an era referred to by researchers as post-digital. Barnard [112] focused on the question of how theatrical and performative practices inform interactive digital narratives and vice versa, with the case study of fanSHEN, a theatre company advanced in interactive digital performances. Looking for Love was their first attempt on IF.

Vox Populi [113] is a card-based interactive theatre game that explores the mechanics of media narratives and representations of the European refugee crisis. It combines existing interactive narrative techniques and models, gamification and theatrical performance to produce new IDS forms. Green et al. [41] attempted to connect the audience's input with performer output during live performances using finite state machines. The authors developed a software called Data Generation Engine (DGE). With DGE, data are generated to be used by performers for creating and developing narratives. Additionally, DGE provides audiences with the opportunity of manipulating data generation and distribution. That way, performers and audience are connected and co-create narratives without the performance being disrupted. An unexpected mixing of technologies occurred in *The Thousand Autumns of Jacob de Zoet* [71], where students managed to mix a radio-broadcasted drama novel with VR. This experiment intended to explore new insights into the practice of storytelling for VR.

2.6.2. Cinematic Interactive Narratives

WCIN is a term referring to cases where cinematography theory and practices are blended with IDN tools and methods. Such an approach to computational storytelling can be seen in ShowRunner [48]. The authors present a tool that can visualize stories in a cinematic way, within a 3D game environment. As described, ShowRunner gets as an input an abstract of the story, along with some declarative specifications of the story script. It also gets a set of mappings between terms in the story and data elements in the game engine and then executes the story's actions. The overall approach is based on Unity and is available online ³. Similarly, FireBolt [73] is a system for automated low-level cinematic narrative realization, as its title defines. Machinima, a term used in cinematography, is a method of making an animated film using software designed for making video and computer games. FireBolt is suitable for use as a rendering system for

a range of machinima-producing enterprises, from fully generative narrative systems to direct human authorship. Its algorithms handle aspects of cinematography such as camera angle, framing, movements, focal length, aperture, and depth of field. Dowling et al. [74] presented their case study on the VR film *Faoladh* ⁴ (Figure 6). The creators of *Faoladh* describe the film as “a stereoscopic virtual reality film that follows the perilous journey of a 9th-century Irish child whose village is attacked by Viking raiders”. In this paper, the authors researched the way cinematic storytelling has been adapted to VR. They deal with the challenge of making spectators focus on the stage where the plot is evolving and not the environment.



Figure 6. *Faoladh* [74].

In a similar way as above, Vosmeer and Schouten [114], in their research project called Project Orpheus, examined VR as a new way of storytelling in the filmmaking industry. In the same project, they used 3D audio to guide the viewers' attention in VR. Pillai and Verma [115] attempted to illustrate the significance of narrative immersion concerning the 360° medium of storytelling in VR, thus helping filmmakers to create effective narrative experiences. In a video game or a film that uses VR or 360° video, the prominent question is how to make users focus on the place where the narrative really happens. Ko et al. [109] discussed making new narrative structures because of issues such as that.

Kampa [110] studied the complexity of combining IDS components with AR technology, to produce systems for entertainment computing. New forms of media and experiences could arise, but according to the author, no publicly available authoring tool exists for producing such systems; instead, they are made from scratch by programmers and content authors from different fields.

2.6.3. Interactive Documentaries (iDocs)

With the term iDoc, we refer to a kind of documentary in which interaction with the audience is possible. As discussed before, Mu [19] delved into interactive documentary narratives. iDocs narrate real stories (in contrast with IF) and permit the audience to interact with reality. In his survey, he aimed at building a new systematic theory, based on the projects of previous researchers. Basaraba et al. [75] investigated cultural heritage under the iDocs genre with respect to creating a prototype for user testing titled "Sentenced to Transportation: A Virtual Tour of Australia's Convict Past". The authors analyzed perceived agents based on the narrative structure, choices provided in the interface design, and the ability to persuade further user participation and concluded that iDocs holds a high replay value.

Tell a Tail 360° [76] is a project designed for teenagers, that uses 360° video and VR technologies that expose the audience to animal welfare issues (Figure 7). It is an immersive, interactive documentary, designed in Unity for Oculus VR equipment and could be used in the classroom, as part of an educational course.



Figure 7. Tell a Tail 360° [76].

2.6.4. Interactive News

News are actual narratives, presenting nonfictional events. As the era of newspapers seems to have completely passed, we mostly consume news on mobile applications and feeds. They still have the traditional look and feel of a newspaper but can be interactive and combined with technologies such as AR and VR. Svensson et al. [77] created a demo of a VR application to present interactable news of an AR news service. Users can navigate in news via a geographic map on which news have been positioned. They experimented with the demo with young people aged 16–25 as potential users of AR news services.

Stavarakakis [78] created a system that takes RSS feeds from Greek news sites and parses through text to locate places and locations on a map. It presents news pinned on the map in an interactive way and in real-time.

3. Media and Interaction on Related Work

After classifying all the works according to their objectives, we proceed in discussing the employed media and form of interaction (Table 4). In some works, the narration comes in the form of text, while in others, it may be audio, visual, or may take a more specific form. Virtual and Augmented Reality technologies are very often used to enhance the user experience and immersion in virtual worlds. A portion of the projects relies on user interaction to create narratives on real, tangible objects. Even more notably, some projects use robotic mechanisms and narrative systems are embodied.

Table 4. Type of media and interaction used in works.

No	Work Title/Authors	Tangible IDN	Gesture Recognition	Embodied DS	VR/AR/360° Video/Animation	Interaction/UX
1	Koenitz H. et al. [89]	✓				Cards
2	Letters to José [63]	✓				Paper objects
3	Chu J. [102]	✓				Special objects
4	Mapping Place [103]	✓				Embodied replicas
5	Olegoru [64]	✓				Special objects
6	Chu S. et al. [104]	✓				Special objects
7	Vim [65]	✓				Complex construction
8	Brown S. et al. [47]		✓			Hand gestures
9	Liang H. et al. [66]		✓			Hand gestures
10	Wicke P. et al. [67]		✓	✓		Hand gestures
11	Paradedá R. et al. [105]			✓		Robot
12	Paradedá R. et al. [106]			✓		Robot
13	Striepe H. and Lugin B. [107]			✓		Robot
14	Ozaeta L. and Graña M. [108]			✓		Robot
15	Tokunaga et al. [68]			✓		Robot
16	CANVAS [53]				✓	Computer animation and sound
17	Rouse R. [123]				✓	Augmented Reality
18	Revells T. et al. [56]				✓	Virtual Reality
19	Carolyn Miller [4]				✓	AR, VR and mixed reality

Table 4. Cont.

No	Work Title/Authors	Tangible IDN	Gesture Recognition	Embodied DS	VR/AR/360° Video/Animation	Interaction/UX
20	Svensson T. [70]				✓	VR and AR
21	Ko et al. [109]				✓	360° Video and VR
22	Kampa A. [110]				✓	Mobile app with AR
23	Bhide S. et al. [111]				✓	VR and Spatial sound
24	The thousand autumns of Jacob de Zoet [71]				✓	Sound recordings and VR
25	Firebolt [73]				✓	Animation and Video
26	Project Orpheus [114]				✓	360° Video and VR
27	Pillai J. and Verma M. [115]				✓	Cinematic VR
28	Mu C. [19]				✓	Interactive Video
29	Tell a Tail 360° [76]				✓	360° Video
30	Svensson T. et al. [77]				✓	VR and AR

3.1. Tangible Interactive Narratives

Crafting interactive narratives under a tangible method has been under research for decades. For example, Gorbet et al. [127] used plastic triangles to create stories and the popular Rory's Story Cubes was invented in 2004. Nevertheless, research on IN over the years mostly focused on screen-based applications and algorithms. Echeverri et al. [63] contributed to the body of works about tangible storytelling with Letters to José. This is a hybrid system using both digital and tangible artifacts, enabled by multimodal interactions. It is based on the letters written in the period 1948–1957, in Colombia, between two brothers. The authors created cards, as in a cardboard game and a digital system, which combined and led to a narrative system about life in that period. In addition, the authors attempted to create a theoretical basis for tangible narrative (TN) systems by defining associated terms. Prior to this project, Catala et al. [128] organized a workshop in which participant researchers tried to delve into the opportunities and challenges of TN. Chu [102] researched the use of tangible narrative interfaces for learning about and reflecting on cultural practices. The final target of this research is the design of a tangible interface, based on narrative content and supported by meaningful interactions. In a later project [103], she designed a framework for digitally presenting cultural heritage artifacts. Her tangible and embodied narrative framework (TENF) was used on a pilot project called Mapping Place to show that TNs help visitors to create a personal connection with a museum artifact.

Olegoru [64] is a sound composition tool in the form of “magic gloves” and “soul stones” to augment children's storytelling when using physical objects. According to the authors, “children can create contextual and regional sound effects as well as event-based acoustics through speech, non-verbal and gestural interaction, and could potentially enable children to create more immersive story-worlds”. Another work focused on children is the one of Chu et al. [104] to support children's creative self-efficacy and creative thinking in storytelling. The authors proposed a method in which children use real-world objects and act to create animated stories and enhance their creativity. Examples of these stories can be found on YouTube.

Vim [65] is a tangible interactive narrative about energy (Figure 8). According to the authors, “it is designed to illustrate how a story about a public issue could be designed for physical interaction and whether that interaction can encourage participation in that issue”. Vim is a wooden box with buttons and switches that includes a variety of technologies (like a thermal printer and cellular network connection) that print a story for the user according

to his options. The main theme of the story is energy and there is a question for each reader to answer.

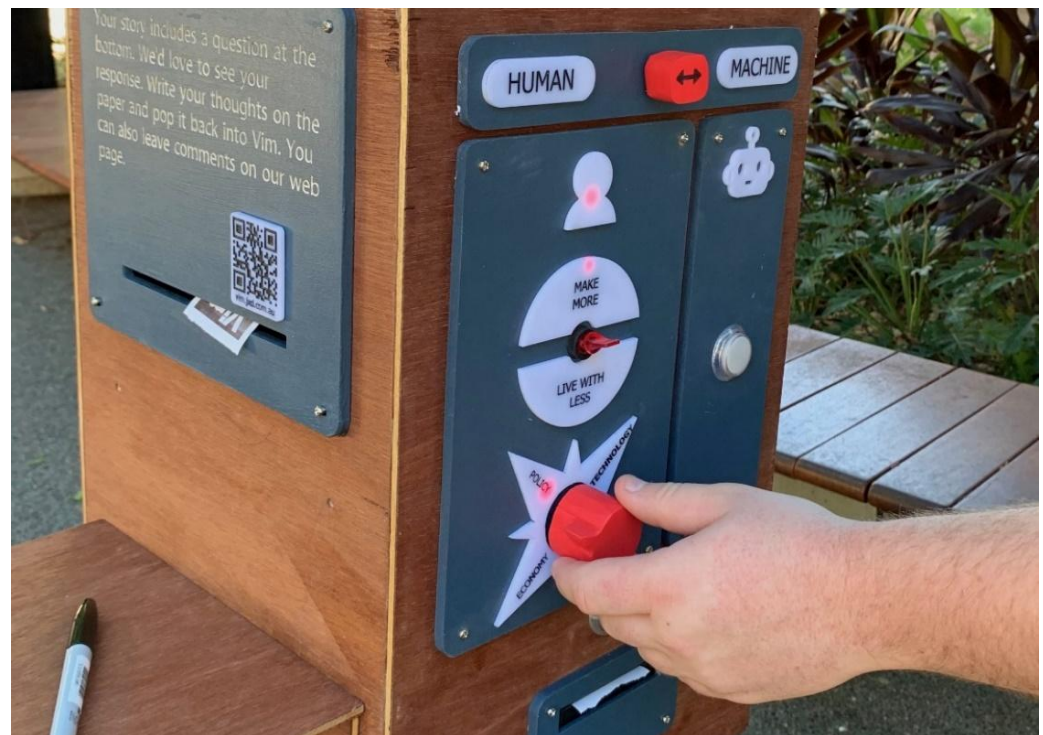


Figure 8. Vim [65].

3.2. Gesture Recognition Narrative Systems

There are systems that create stories upon users' gestures (mainly predefined gestures). Brown et al. [47] attempted to improve the functionality of systems such as by teaching them about design implications from feature analysis of iconic gestures during storytelling, as their title implies. In other words, they recorded gestures from 20 participants over the same stories, and by analyzing them, they produced iconic gestures, that is, representational gestures that provide information about objects such as their shape, location, or movement. Their work is based on that of other researchers in the field of gesture recognition [66,129,130].

3.3. Embodied Storytelling Systems

Embodied storytelling systems are actual hardware systems, usually human-like, but can possibly have any other organic shape and can process narratives. Wicke et al. [131] attempted an approach to the concepts of IDS, where stories become physical movements—gestures in an embodied system (robot) aiming at a direct meaning transmission and communication. The project is based on the previous work of the same researchers [132]. Social robots are often used as companions for the elderly, for educational purposes and during medical rehabilitation [133]. Paradedá et al. [105,134] studied the impact of social robots as storytellers and the way their personality (if existent) affects listeners (Figure 9). In another work by the same authors [106], where autonomous social robots are used as storytellers, research was focused on the power of the machines to convince the audience to follow a specific trajectory of the story. On a similar path, Striepe and Lugin [107] researched how emotional robot storytellers support stories better than neutral social robots. Ozaeta and Graña [108] proposed digital storytelling as a central tool for social robotics and they emphasized the importance of DS in education.

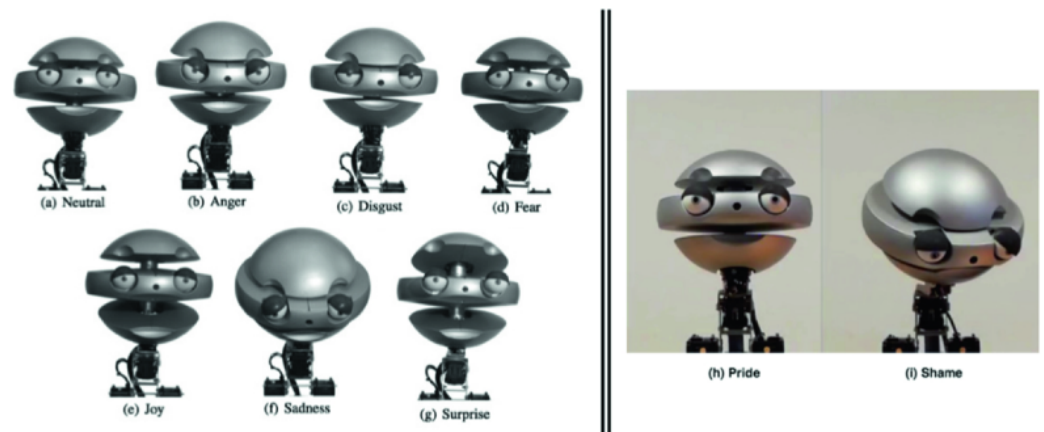


Figure 9. Robots as storytellers [105].

3.4. Mixing AR, VR, 360° Video and Animation Technologies

When mixing technologies, we can benefit from the powerful elements of each one, in the creation and reproduction of stories for any purpose. For example, Svensson [70] used VR as a simulation environment for AR digital storytelling on cultural heritage sites (Figure 10). On the other hand, technologies such as VR and AR can make things more complicated, as they raise new challenges. For example, one challenging objective when creating VR content or a 360° video is how to make spectators focus on a specific part of the visual content. Kampa [110] studied the complexity of combining IDS components with AR technology to produce systems for entertainment computing. New forms of media and experiences could arise, but according to the author, no publicly available authoring tool exists for producing such systems, with the content being made from scratch by programmers and content authors from different fields. Additionally, Bhide et al. [111] combined IDS with VR technology and focused on spatial sound as a storytelling tool in a virtual game environment. Implementing a more complex idea, students in The Thousand Autumns of Jacob de Zoet [71] managed to combine a radio-broadcasted drama novel with virtual reality.



Figure 10. Svensson [70].

4. Discussion

General thoughts: As discussed above, the research field of interactive and computational DS is broad and expanding in several directions. The reason for that is the acceptance of DS as a method, because of the simplicity in its base, the ease of use and understanding, and the fact that, in the end, narrating a story is a simple natural human activity. We tell our stories from the period we start to talk. In addition, humans evolve in storytelling as they get older. We obtain an education, we socialize, we have to deal with everyday demands, and storytelling is interwoven into our life, appearing almost everywhere; at work, in family life, in social life, in education, in entertainment, in relationships, and so forth. As we advanced in the digital era, narratives also took digital forms and started traveling the globe at high speeds. News can travel all over the world almost instantly, films have their “global premiere” across continents (at least before the COVID-19 era), video games are massively sold through web stores, and TV shows are broadcasted through international online TV services and platforms. Literature and books, in general, took a digital form “for the well-being of the environment”, and as a result of all the above, newer generations are being exposed to more narratives than ever before. Young people are “tuned” globally through social media and societies are slowly shifting to a cultural equilibrium where everybody’s personal story can potentially have a global audience and acceptance.

The findings, after analyzing all the aforementioned works, are that the field is active and attracts many researchers, who come from different domains. They create applications and tools able to speed up the writing of new narratives but also manage to enrich these narratives with multiple media, giving them new dimensions. The areas of application of these narratives can be museums and cultural sites, schools, health and entertainment venues, video games, and so forth. Many research projects do not progress to any implementation but provide ideas, reflections, and thoughts for future projects. They result in theoretical frameworks and system designs that can form the basis for a subsequent project. Other projects result in portable applications, capable of creating or managing narratives to serve a specific purpose. Some of the apps that have been built are actually authoring tools that can be used to develop narratives with speed and relevance to a topic. These narratives generally obey rules to serve the purpose for which they are written, without deviating in terms of the impact they can have; they are free from prejudice, discrimination, and offensive or disturbing content. Some other implementations try to avoid the trend of the last decade and stay out of the screen of mobile devices. They result in tangible objects that the user can interact with in order to create a narrative. Selections are made by pressing buttons, pulling levers, dragging faders, flipping switches, turning knobs, gesturing in the air, and speaking. They require the physical participation of the user and the activation of the senses of touch and hearing. Some tangible implementations are autonomous robotic mechanisms that can move, respond to their user’s choices, and create narratives (usually in audio form), giving the feeling of communicating with an intelligent being. These implementations have been used in medical applications, to rehabilitate patients as well as provide care to the elderly. They have also been used in museums around the world. A typical example is the robot Pepper from Softbank Robotics, which is used to welcome people and provide information, in the Smithsonian museum. AR and VR technologies are widely used in storytelling. Despite their disadvantages, such as their cost and consequently low availability to the general public, their bulk, and weight, as well as the nausea they can cause to the user, they remain the most powerful means of user engagement, participation, and immersion in the world of the narrative. They offer a very powerful user experience and therefore cannot be ignored by the creators.

Future trends: In university education, it is expected that programs for the design of interactive narratives are going to appear. In fact, these programs are likely to be found in departments of theoretical as well as technological studies. In school education, technologies associated with storytelling will make it very easy to create interactive narratives in the classroom, even by elementary students.

Social robots will be used more and more. Whether in hospital care or caring for the elderly and disabled at home, they offer valuable companionship and communication. The evolution of speech and conversational algorithms will increase their usability, and ultimately, their demand.

It is expected that narratives created by computational methods, and more specifically by AI systems such as GPT3 [119], will start to be used more and more in everyday applications, such as writing letters and simple emails, professional text, websites, and so forth. However, what is of more interest to the present research is the ability of these systems to produce text in more complex ways, for example in cultural heritage applications to make descriptions of artworks, museum tours, recommendations for sightseeing routes, and so forth. Museums already use storytelling systems that include audio, video, VR and AR, robotic systems, and so forth. Until now, however, all narrations are pre-recorded and pre-planned, specific for each point and exhibit. What will be more interesting to see are emergent storytelling systems, where every tour, description, and recommendation are created instantly, and personalized for each visitor.

The gaming industry has always led technological developments due to its very large appeal to the public. Games are becoming more and more complex in terms of their plot and are converging towards cinema, where complete scenarios are required, with a plot that can deviate according to the user's choices. This has never been easy to implement, but the emergent storytelling methods make it much easier to develop more interesting games, tailored to the player's reactions and character. The same also holds true for the film industry, but even more impressively for live theater performances, where the scenario to be followed is created in real-time, due to the audience reactions in certain ways. Documentaries and news stories are not expected to remain unaffected by all these developments, as any other human activity related to the creation and presentation of text and narratives. ChatGPT has been accepted by the public with enthusiasm and companies are investing huge amounts in the further development of tools that will lead us to a new era of searching for knowledge on the Web.

The AI factor: Creating narratives with computational methods can be seen either as a natural evolution or as an abnormal situation in which we are losing a skill that is purely human. AI can be scary in all its forms and uses, as human activities are being replaced eventually by smart systems and algorithms, but this kind of fear follows our being since the 19th-century industrial revolution. What happened then is that many people lost their jobs as they had been replaced by machines and entire societies had to transform and adapt to new conditions. Tools and methods presented in this paper try to assist and not replace people in the creative process of storytelling. They can be used as tools for organizing fast and massively producing, distributing, enhancing and enriching stories, in a way that is beneficial for all audiences and every kind of use. The questions that follow the analysis of the above works is whether the time will finally arrive when human intervention will not be needed to create narratives and whether we really want that. The GPT system as well as other AI systems in development can create texts and narratives with increasing, to a frightening point, ease and fidelity. The boundaries between human and artificial creativity begin to blur. However, we must not forget that these systems are self-trained through the data they are fed, which might (the data) not always be accurate or complete. They may contain misinterpretations, incorrect conclusions, and ambiguities. So when we have scientific applications where we need to be precise, we certainly cannot trust such a system to build our narratives. In other words, for example, we cannot yet trust a system to be our personal guide in the archaeological Acropolis museum and answer all our questions regarding the exhibits, without falling into errors and contradictions. Furthermore, narratives always contain local cultural elements, as well as personal opinions and perceptions. In order for a system to be able to reliably create a narrative, it must have cultural knowledge and experiences transferred to it (machine enculturation) and, on the other hand, it must have formed its own personal opinions; that is, it must have its own personality.

The technologies that have been developed do not yet allow us to create fully automated narratives and that is probably not the point. They help us in terms of productivity, speed, enrichment, distribution, and availability, but they require human involvement and intervention. To build on the previous example, it is not possible, and perhaps not even desirable, to have an automated tour guide in a museum that knows every detail of the exhibits and can answer every question accurately. However, we can have tools that can make that visit to the museum much more interesting. Especially for the “difficult” ages of children and teenagers, these tools add elements of gamification and simplify the educational process.

Interaction with the narratives and UX: Summarizing Table 4 and in relation to user experience, it appears that all projects that have some kind of implementation can be divided into two broad categories; those that rely exclusively on the existence of a screen (computer, mobile device, VR or AR goggles) and those that either avoid the use of a screen (altogether, or use it in a limited way and in combination with another object). Projects in the former category far outnumber those in the latter. Another general observation is that audio is, in principle, an under-represented medium, despite its well-known importance in storytelling. Creators focus on the methodology for creating stories, their feasibility, distribution methods, modes and degree of interaction, and user interface design, but in the end, it is all too common to put aside issues related to quality, direction, type (binaural vs stereo), ways of integration, and the technical means for audio. In any case, creators try to make the most of all available technologies, old and new, to create the richest and most engaging user experience possible.

Where do these works come from: For those projects of Table 4 that included some form of implementation, an attempt was also made to locate them geographically, that is, to find in which countries and places they were implemented and utilized. This is a type of information that is not always available and so with all due caution, we note the following; of the 30 projects in Table 4, 12 are from the Americas (USA and Canada), 11 are from Europe (from 9 different countries), 7 are from Asia (China, Korea, India, and Japan), and 1 is from Oceania (Australia). Almost all projects have been implemented and tested in universities and research centers. A couple of them have also been tested in schools, with students [93,94]. Those research centers were all pinned on a map as a visual representation⁵. The Emotive project [125] has been implemented in the Hunterian Museum in Glasgow and in the Ancient Agora in Athens, while the CHESS project [124] has been tested in the Acropolis Museum in Athens, with hundreds of visitors from all over the world. Social robots [133] were used in hospitals. Vim [65] was placed on a public road in Brisbane Australia, to be tested by bystanders. *Being there* [6] was tested by 35 people in Edinburgh UK, while Psomadaki et al. [13] performed their tests with 328 people in Thessaloniki, Greece. Some works such as Villanelle [45] and Fadolah [74] were placed online to be tested and reviewed by the public. fanSHEN [112] has been performed for 10 years in theaters in the UK. In conclusion, the examined projects span four continents and have been tested by countless people in a variety of ways.

5. Conclusions and Future Work

Numerous projects are aiming at designing and creating software and hardware tools that assist in the creation of stories. These tools use algorithms for automating procedures, such as the creation of characters, environment and a plot, or can just provide an environment with templates for the faster creation of stories. The stories created are suitable for specific uses, or they could be general-purpose stories that could fit in more applications. In this survey, we have set a taxonomy of works, according to their purpose and scope, and we have analyzed them to discover the emerging trends in the research field. Thus, AI methodologies seem to be gaining ground, in combination with AR and VR technologies. Companies, universities, and researchers invest time and money in the development of AI algorithms and systems that can create multimedia content, but also in the development of virtual and augmented reality technologies and applications, for

everyday and widespread use by larger audiences. The GPT system (GPT3, as of writing) is expanding exponentially and becoming more and more efficient in creating narratives. Based on the latest machine learning methods, these systems learn by themselves by crawling web pages and by collecting crowdsourced data. However, as they proliferate, they also create new technological challenges such as whether the data they collect is correct and accurate, free from bias, whether such a system can distinguish cultural differences between countries, races, and ethnicities and reproduce them when necessary or whether it is possible to manipulate the system to produce a text that follows specific rules, without deviating from a desirable trajectory.

Continuing our research, we will try to train GPT3 models using valid scientific data related to the artifacts of a specific exhibition in the Hunterian Museum in Glasgow, Scotland. The relevant data have been collected by other researchers in the field [125], who also created audio narratives that are broadcasted inside the museum. Next, we plan on instructing the system to create new narratives and answer related questions and report on our results.

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Abbreviations

The following abbreviations are used in this manuscript:

AR	Augmented Reality
DS	Digital Storytelling
IDS	Interactive Digital Storytelling
IDN	Interactive Digital Narrative
GPT	Generative Pre-trained Transformer
DN	Digital Narrative
CDS	Computational Digital Storytelling
CH	Cultural Heritage
EM	Experience Manager
PW	Possible Worlds
MINE	Multiplayer Interactive Narrative Experience
AI	Artificial Intelligence
GPS	Global Positioning System
NPC	Non-Player Character
PCG	Procedural Content Generation
GFI	Goals Feedback Interpretation
API	Application Programming Interface
IF	Interactive Fiction
DGE	Data Generation Engine
CIN	Cinematic Interactive Narrative
iDoc	Interactive Documentary
TN	Tangible Narratives
UX	User Experience
VR	Virtual Reality

Notes

- ¹ http://tecfa-labs.unige.ch/narrativeacts_vis/, accessed on 24 January 2023.
- ² <https://raffba.itch.io/med10>, accessed on 24 January 2023.
- ³ <https://eae-git.eng.utah.edu/01221789/utahpia2>, accessed on 24 January 2023.
- ⁴ Film available on <https://tilefilms.ie/productions/faoladh/>, accessed on 24 January 2023.
- ⁵ <https://www.google.com/maps/d/u/0/edit?mid=1HDbXisLOevXUTHFiHbBXAo7NWVxLIfo&usp=sharing>, accessed on 24 January 2023.

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