College Ruled: A Pathfinding Approach to Generative Storytelling

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***Abstract*—College Ruled is a prototype storytelling system, iterating on past projects in the field, such as Lebowitz's UNIVERSE system and Skorupski's Wide Ruled re-imagination of the author-goal based model of story generation. College Ruled attempts to build on these systems by utilizing story waypoints to help guide plot fragment selection, allowing for authorial influence over how character relationships are shaped, and providing agency over the dramatic arc of a spun tale. College Ruled attempts to provide a framework to be utilized alongside manually authored plot fragments in order to generate these stories within an author's desired story world, with a pathfinding system optimized for a higher degree of non-determinism, in order to provide a wide variety in generated tales from any given set of inputs.**

***Index Terms*—storytelling, story generation, pathfinding**

I. Introduction

Procedural content generation for narrative works and entertainment purposes has been a popular area of study in recent years, because even as storytelling remains an important part of the human experience [1] [2], even modern approaches fall short of manually authored works [3], or require heavy authorial input [4]. Though purely autonomous systems are capable of generating stories, we have not yet boiled down narrative to the point where we can distill it in such a way that "good" story generation can be entirely captured by autonomous systems. Prior mixed authoring or "mixed-initiative" [5] approaches aim to sidestep this problem by still including the author in the story generation process, to allow for the positive influence of insights and ideas that would not be captured by purely autonomous narrative planners.

Though generating static stories from author-supplied plot fragments is an established area of computational storytelling [6] [7] at this point, and so is the concept of drama-management within generated narratives, particularly in interactive formats [8] [2], directing the flow of a story within a static story generation system has not been explored to the same extent..

To this end, we aim to explore this gap with College Ruled, an expanded rational reconstruction of Skorupski's "Wide Ruled 2.0", [7] itself a rational reconstruction of Lebowitz's older UNIVERSE system [6], with alterations that allow for a higher degree of authorial control. College Ruled encodes worldstates as story waypoints, and then uses a pathfinding system to chart a course between desired worldstates. Through authoring a complex story-space with subplots and many potential actions, and the ability to specify desired states for individual characters to achieve, our system is capable of producing multiple unique stories that feature the author's target worldstate(s). By encoding drama levels into the different plot fragments that the system can employ, and by integrating it into our pathfinding heuristic, we also iterate on existing narrative planners by constructing stories engineered to match a traditional tension arc [9]. We hope to examine the effectiveness of bringing more modern approaches to older static-story generation systems.

College Ruled can produce multiple unique stories by utilizing the same base encoded plot fragments, attempting to reach a desired worldstate through different paths. It is also capable of stringing together a series of states to create meaningful narratives, when provided an appropriate library of plot fragments and an authored waypoint list. In this manner, College Ruled is a powerful tool for ideation when it comes to authoring stories, as it allows an author to generate multiple paths through desired narrative waypoints, allowing for experimentation with different ways of constructing a tale around a key set of desired plot points.

II. Related Works

As mentioned previously, the area of procedural story generation and interactive narrative is a dense field, filled with many artifacts that approach these storytelling problems in different ways, ranging from classic AI techniques to machine learning [4], or natural language processing [10]. Those most relevant to our own approach, however, are past static story generation systems, more modern interactive story systems, and narrative planners.

In the early 1970s, developers started producing static storytelling systems like Meehan's TALE-SPIN, a program that writes stories based on character interactions [11]. TALE-SPIN allows an author to initialize a world with characters, locations, and character goals, and then writes an entire narrative arc in which characters either fail or succeed at achieving their goals. Though a notable landmark in the history of computational storytelling, Tale-Spin is ultimately limited by its approach of merely simulating character interactions, rather than orienting itself around creating a world in which specific narrative desires can be achieved.

Lebowitz's UNIVERSE [6] is another story-generator that facilitates the generation of stories with the dramatic arc of soap operas. UNIVERSE allows the author to input key events that they want to take place between characters, and creates conflicts that fit within the author's narrative arc. This system builds upon previous iterations of computational storytelling software, but still seeks merely to select plot options that are available, rather than making intelligent decisions regarding how to arrange provided plot points.

A more recent state of the art story generation system is STellA (Story Telling Algorithm), which explores story space using grounded knowledge representation to create more fine-grained, detailed narratives [12]. STellA has been updated to create non-deterministic stories, where an event can lead to multiple different potential events. Genetic algorithms have also been used to generate data-driven stories based on recorded plots and sets of events. These static story generators all use different approaches to explore potential stories that grow out of a starting point. Once the starting parameters are provided, however, the author has little direct input in how the story progresses or ends, beyond the algorithms that drive the story generators in general. While we believe it to be an interesting artifact in the field of static-story generation systems, we wish to bring a finer level of authorial control to the field with our own system.

Lume [13] is a more modern interactive story generator, aimed to be utilized in the context of video games. Presenting a branching narrative to a player, Lume strings together appropriate story nodes in accordance with the world's state and the player's actions, and utilizes an element of recall in future story nodes, to showcase the consequences of prior actions. It brings a level of believability to the tales it spins. Its advancements in bringing immersive, interesting storytelling to a player in an interactive setting is a hallmark of just how far storytelling technology has come from the days of earlier systems like UNIVERSE and TALE-SPIN. While Lume is an exceptional research artifact in the world of interactive storytelling, it is constrained in its current iteration as an interactive storytelling system that requires continuous input from a player while it spins its narrative. Furthermore, it is a proprietary system, and not currently available for open-source use.

Glaive [14] is one of the most interesting pieces of work in the context of narrative planners in recent years, utilizing a rigorous algorithmic approach to ensure a coherent flow of story from start to finish. It aims to generate a story that meets an author's goals while being composed only of actions taken by characters that are sensible given the motivations of the characters. In doing so, Glaive is able to maintain a sense of believability in their generated stories. However, Glaive is still limited in its scope. It focuses on finding a valid, explainable path between starting and goal states, but may still lack some of the dramatic arc and flair of more finely crafted, human-authored tales.

Ultimately, many advancements have been made in recent years in the field of algorithmic storytelling. We wish to bring such engagement and interest to static story generation systems, breathing new life into the older UNIVERSE-style system, and bringing it in line with more modern storytelling feats, while ensuring our methodology remains accessible. Furthermore, we hope to allow for a higher degree of authorial control over the dramatic arc of generated stories by integrating a drama management system.

III. Technical Description

A. Basic Objects

College Ruled is built out of a few basic objects, which interact with and encapsulate one another to determine what can take place in a story-space, and what should, in order to facilitate the author's goals.

1) Characters: Character objects consist of a number of variables that encode various attributes individual characters can have, from integer ranges of health and happiness levels, to Booleans encoding binary information about specific characters, such as whether or not they are fugitives or are employed, or other identifying information such as their name. Characters also each have a relationship dictionary that contains their unidirectional relationship values to other characters in the worldstate, allowing us to track how characters perceive one another in the story world. This is key, as characters are only willing to undergo certain actions, and therefore partake in certain plot events, if their relationships with other characters meet certain thresholds.

2) Worldstates: Worldstates are objects that contain a list of characters currently in the worldstate, the environments present in the world available for use, a log of what events have taken place in the worldstate historically, and a total drama score. This information helps to encapsulate the story state at a particular point in the narrative. Authors can create initial and desired worldstates that College Ruled will pathfind between, or simply initialize a worldstate and allow College Ruled to continue generating new worldstates without a particular goal in mind. In Fig. 1, you can see the basic structure of a worldstate object and its components.

3) Plot Fragments: Plot Fragments are events that can take place within a story, and each generated tale is provided a library of manually authored plot fragments that can be selected to run at given points in the story. Each has its own prerequisite checking function, so that it can be determined if a given plot fragment can take place given a current worldstate, and which characters and environments can be involved. This is fairly consistent with prior efforts in static story generation [7]. Each plot fragment, when run, manipulates attributes of the worldstate and the characters within, and returns an updated worldstate. Plot fragments each also have an inherent dramatic value, used to increment that of the updated-world state, so that drama levels can be tracked across the duration of a generated story. In this manner, we aim to combine some of the aspects of modern drama management systems [15] into our story generation process.

To clarify how plot fragments operate, consider a potential ”Intentional Murder” plot fragment. A prerequisite checking function for such a plot fragment would ensure that, given a pair of characters, one character has a strong distaste for the other (a motive), a murder weapon in their possession, and is proximate to the other character. The post-conditions of such

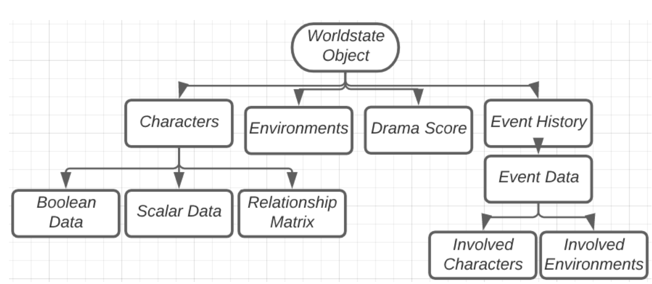

Fig. 1: The structure of a worldstate object

an event might mark the victim as dead, flag the culprit as a murderer, etc.

B. Pathfinding

1) Distance Heuristic: When attempting to determine which plot fragment to select from a given point in a story to run next, our pathfinding algorithm utilizes a distance heuristic in combination with a story waypoint system. College Ruled's distance heuristic evaluates distance by summing the difference in drama level between a desired worldstate and a current or reachable worldstate, as well as summing the difference between the states of individual characters in each. For each parameter associated with a character (be it Boolean, int, or relationships within their relationship matrix), the difference between the two states is found, transformed using a weighting system that allows for different data types to be evaluated on equal grounds as one another, and then summed. This could be described as a weighted Manhattan edit distance between two worldstates. Prior studies indicate Manhattan edit distance, though fairly simplistic, remains a fairly effective dissimilarity metric [16].

Characters produced for a desired waypoint are initialized to have all attributes set to "None" by default. The distance heuristic calculates the distance between any non-null attribute and None to be zero. Thus, it only weights and minimizes the distance between attributes the author is actually interested in changing. Creating waypoints is therefore a simple process for authors. In this way, the difference between two worldstates can be scored, and used to identify worldstates that are closer to a desired target worldstate within a provided waypoint list.

2) Pathfinding Algorithm: In order to drive generated stories toward author-mandated goals, our system treats story generation as a form of pathfinding problem in a graph of possible stories. The graph is relatively easy to characterize: given a starting worldstate node, one can produce a list of all possible variations of events that are permissible to be run, each of which with its own set of postconditions that modify the worldstate. Applying all these postconditions individually to the starting node, we can generate all worldstates reachable within a single plot fragment from the starting worldstate. Without loss of generality, we could continue this recursively on all generated leaf nodes in order to characterize a graph that is composed of all stories possible, given a starting worldstate node. Clearly though, this results in an exponential explosion of nodes, and quickly becomes infeasible to store or traverse.

To get around this, we utilize a greedy algorithm that considers as a frontier those world-state nodes that are immediately proximate to the current node, but for each of those frontier nodes, expands out the search tree in its entirety to an author-specified desired depth.

Following this, we evaluate each reachable leaf node worldstate against the system's current target waypoint using our distance heuristic, and collect a list of all worldstates found to have the same, best, minimum distance. Once this is done, one of these best reachable worldstates is selected at random, and the frontier node at the root of the subtree containing this best reachable worldstate is run. In doing so, the system updates the current worldstate and prints the event's associated text, so that the process can repeat, and pathing can continue towards the next story waypoint.

Though computationally expensive, requiring exponential time in the desired depth of search, the process of expanding our search tree in its entirety allows us to consider less direct paths towards the desired destination, while still ensuring we approach our desired waypoints with our final selection. This is important because using a greedy algorithm approach causes the most direct, "obvious" plot fragments to be selected, often repeatedly, in order to move towards a desired worldstate. In the interest of generating stories that have higher variability and more perceived interest, we opted to avoid this route. It's also worth pointing out that if one is not necessarily interested in producing stories in real-time, the increased time complexity is a trade-off that is reasonable given the other desirable characteristics of stories produced using this methodology. It is also worth noting that a system that examines such a story tree with greater depth, is likely to achieve better results with path selection due to the weighting of Boolean variables. Such variables may only be flipped by the occurrence of certain events, which may have prerequisites that are not necessarily reached by taking a greedy approach toward the desired waypoint. Pathfinding driven by a shallow search is highly subject to encountering dead ends or reaching a worldstate from which a waypoint may never be met.

In Fig. 2, we show how the distance heuristic is used to select the next used plot fragment, and worldstate. As node 4 is the root node of the subtree containing the leaf node with the lowest distance from the desired waypoint, the plot fragment that leads to node 4 is selected to be run, and the pathfinding loop continues. In Fig. 3, an overview of the pathfinding loop as a whole can be viewed.

C. Authorial Input

Authors can determine attributes of a series of worldstates that they want the story College Ruled generates to contain, or approach. These attributes can include changing a character's relationship to other characters, changing their health and happiness, job status, or even removing them from the worldstate.

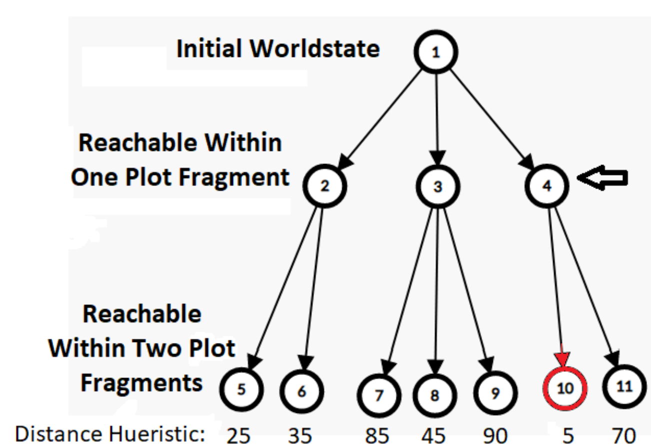

Fig. 2: Heuristic-guided plot fragment selection

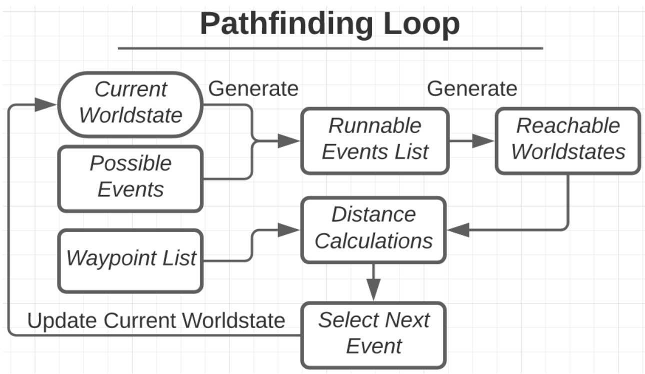

Fig. 3: Pathfinding overview

Authors can also determine desired drama scores for a series of worldstates, or specify a dramatic curve for use in pathfinding, thereby allowing for control over a generated story's dramatic arc, without specifying which events will occur within the narrative. A high desired drama scores within a waypoint will cause the system to prioritize higher drama events, while a low drama score will cause the system to prioritize lower drama events, while still balancing the author's other objectives. In this manner, a high degree of control is offered over the direction a narrative takes.

Waypoints within our system are also given a waypoint radius, a tolerance in distance (as calculated by our metric) to be met before they are considered satisfied. This is necessary, as it may be that a given waypoint may have target values in character attributes that are relatively prime to the values by which they may be manipulated in the library of plot events.

IV. Analysis

A. Example Tale Analysis

College Ruled has to intelligently pathfind between waypoints by prioritizing dramatic value and character attributes, rather than cycle through predetermined combinations of events on an event tree like Wide Ruled does. If authorial input is minimal and proper waypoints are not utilized, stories generated by College Ruled become disconnected and create bizarre narratives, resulting in stories like the following:

> Inara makes a rude 'your mom' joke. Mal doesn't laugh. Mal goes to the hospital to recover their health. Inara hits Mal with their spacecar. As Mal lay there on the spaceway, they stared at the two moons rising over the dusky horizon. Then they closed their eyes for the last time.

In this story, the system unintentionally implies that Inara's joke was so bad it sent Mal to the hospital, and that Inara then decided to murder Mal. In reality, the spacecar accident event occurs randomly, independent of character relationships with one another, more resembling a drunk driving accident than premeditated homicide. Hospital events occur as long as a character's health is below 5, which happened to be Mal's initial health in the worldstate. Because the College Ruled system has more freedom to arrange event ordering than the extremely regimented Wide Ruled system, it may produce unexpected series of events. This same feature is what allows the user to experience many varied produced narratives, but also highlights the importance of using story waypoints to guide the construction of these stories.

To give a demonstration of the drama management present in our system we include examples of two stories that were generated with the same waypoints, but different desired drama scores. In both examples, a story was generated with a series of waypoints that involved the character Mal dating Jess, only to later end up dating Inara, and with a worsened relationship between Jess and both Mal and Inara. This first story was generated with a lower desired drama level:

> Jess and Mal go for drinks at the Leaky Engine and make each other laugh a lot. "We should do this again," Jess says. Jess asks Mal to go on a picnic with them at the Rocket Wreck Hills. Their heart is racing. Mal blushes and says they would love to go on a date with Jess. Inara looks at Mal and realizes their feelings for them have been growing stronger as they have spent time together. They find themselves thinking about Mal more and more. After visiting the open market every day and getting increasingly desperate Mal got a mining job. Inara asks Mal to go on a picnic with them at the Rocket Wreck Hills. Their heart is racing. Mal declines Inara's invitation. Jess looks at Mal and realizes their feelings for them have been growing stronger as they have spent time together. They find themselves thinking about Mal more and more. Mal looks at Jess and realizes their feelings for them have been growing stronger as they have spent time together. They find themselves thinking about Jess more and more. Jess looks at Inara and realizes their feelings for them have been growing stronger as they have spent time together. They find themselves thinking about Inara more and more. Mal asks Inara to go on a picnic with them at the Rocket Wreck Hills. Their heart is racing. Inara blushes and says they would love to go on a date with Mal. Jess finds out what Mal did and is devastated. They break up with Mal.

In contrast, the following story was generated with the same waypoints, but a higher drama requirement:

> Jess and Mal go for drinks at the Leaky Engine and make each other laugh a lot. "We should do this again," Mal says. Mal makes a rude 'your mom' joke. Inara doesn't laugh. Jess asks Mal to go on a picnic with them at the Rocket Wreck Hills. Their heart is racing. Mal blushes and says they would love to go on a date with Jess. Inara looks at Mal and realizes their feelings for them have been growing stronger as they have spent time together. They find themselves thinking about Mal more and more. After visiting the open market every day and getting increasingly desperate Mal got a mining job. Inara asks Mal to go on a picnic with them at the Rocket Wreck Hills. Their heart is racing. Mal declines Inara's invitation. Mal asks Inara to go on a picnic

> with them at the Rocket Wreck Hills. Their heart is racing. Inara blushes and says they would love to go on a date with Mal. Jess finds out what Mal did and is devastated. They break up with Mal. Jess notices Inara forgot to lock up when they left their bunker. Jess breaks in and steals all their valuables. Inara notices Jess forgot to lock up when they left their bunker. Inara breaks in and steals all their valuables. The law finally caught up with Inara. They are in space jail. The Law finally caught up with Jess. They are in space jail. Jess spent months chipping at a crack in the circuit panel. They finally succeed at shutting down space jail long enough to make a break for it. Jess returns to their home planet, Higgins. Inara spent months chipping at a crack in the circuit panel. Just as they are about to escape, Jess sees them and calls the guards!

Although they hit the same beats—two characters initially falling in love, then one cheating and running off with someone else—each plays out differently. The first approaches the same topic in a more reserved manner, focusing on lower drama events such as emotions between different characters intensifying over time, in a sort of love triangle. The second has more dramatic flair. Following a cheating incident, Jess opts to steal from the homewrecker Inara, who retaliates in turn. Both end up jailed for their crimes, and multiple jailbreaks are attempted. One of Inara's attempts is even foiled by the vengeful Jess! In both narratives, the same characters fall in love, and their relationship falls apart due to infidelity. Even though their individual actions and reactions differ, the same worldstates are achieved. This is an example of how indeterminism functions in College Ruled.

B. Graphical Analysis

Though the above sections give some understanding of the types of stories generated by our system, which involves stringing together manually authored plot events and their tagged descriptions in a cohesive manner, below we also demonstrate the effectiveness of our system in meeting our goals numerically. The box and whisker plot in Fig. 4 charts the spread of drama scores from 10 unique stories generated using our system on the same input, plotted against a target drama curve. While the spread of generated drama values does not match 1:1 with the desired target values, it still does a good job of approximating the targets we have requested the system try to match while simultaneously attempting to balance meeting other author-mandated goals as per the waypoints provided to the system.

That stated, it is worth discussing some of the limitations of the system here: We can see that we fall short of precisely meeting our targets. This is because, with any given library of plot fragments, we may not have a sequence of plot fragments that is able to meet all author waypoint goals–it is possible to make requests of the storytelling system that cannot be met. In this particular instance, we have a library of 19 unique plot events that can occur and a cast of three characters. No plot event in this list of legal events is capable of dropping the drama level of a story by more than 10 in a single step, and so the slope of the desired drama curve at times outpaces the capabilities of this set of plot fragments that have been provided for use. This highlights the importance of having a robust library of plot fragments for use with our system. In order to tackle more complex narrative goals, a deep library of plot fragments with a high level of variety may be required. Thus, our system has a degree of overhead cost in terms of generating these manually authored plot fragments in order to function at its peak.

V. Conclusion

College Ruled demonstrates how James Skorupski's Wide Ruled 2.0 system could be augmented to include intelligent pathfinding and to have more flexibility in story generation, while still prioritizing authorial input. College Ruled also allows authors to control the dramatic arc of a story in a way that has not been implemented in current state-of-the-art static story generators. Authors can use this tool to explore how a story can achieve the same beats with different levels of drama and is valuable for ideation for would-be authors.

A. Future Work

The current College Ruled system has room for improvement. Boolean values are the least useful in our distance heuristic calculations because there is no gradation in minimizing the distance to a desired Boolean; either the value is true or false. This limits our pathfinder's ability to incrementally approach worldstates that involve changes in Boolean attributes, as it is unable to measure if it is approaching a worldstate that would permit said Boolean to be manipulated as desired. While our system tries to get around this by allowing for a story tree to be expanded to a desired depth, doing so to a high depth becomes computationally expensive very quickly. Specifically, it takes $O(n * c^d)$ time, where C is the branching factor of our graph construction, heavily related to the number of plot fragments contained within a given library being used, the depth of desired search, d, and the length of a desired generated story, n. This constrains the depth of search that is feasible to use on most systems to relatively shallow depths if one wishes to generate stories in real-time. The time complexity of this system could be alleviated by using an algorithm such as A* to speed up the pathfinding process in future iterations of College Ruled, but we must stress that part of the appeal of the current system is the level of variety it offers. Finding a suitable method to blend efficient deterministic methods with a degree of nondeterministic pathfinding moving forwards may be necessary to maintain variety in generated stories while decreasing computation time.

Within our prototype, College Ruled also has limited opportunities for drama management independent of plot events. A larger library of plot events that allows for changing character attributes identically, but with different dramatic values and narrating the story with different levels of drama would be a great improvement. This would allow the drama of the story to change independently of other attributes, and allow authors to manipulate only the dramatic arc, and not unintentionally

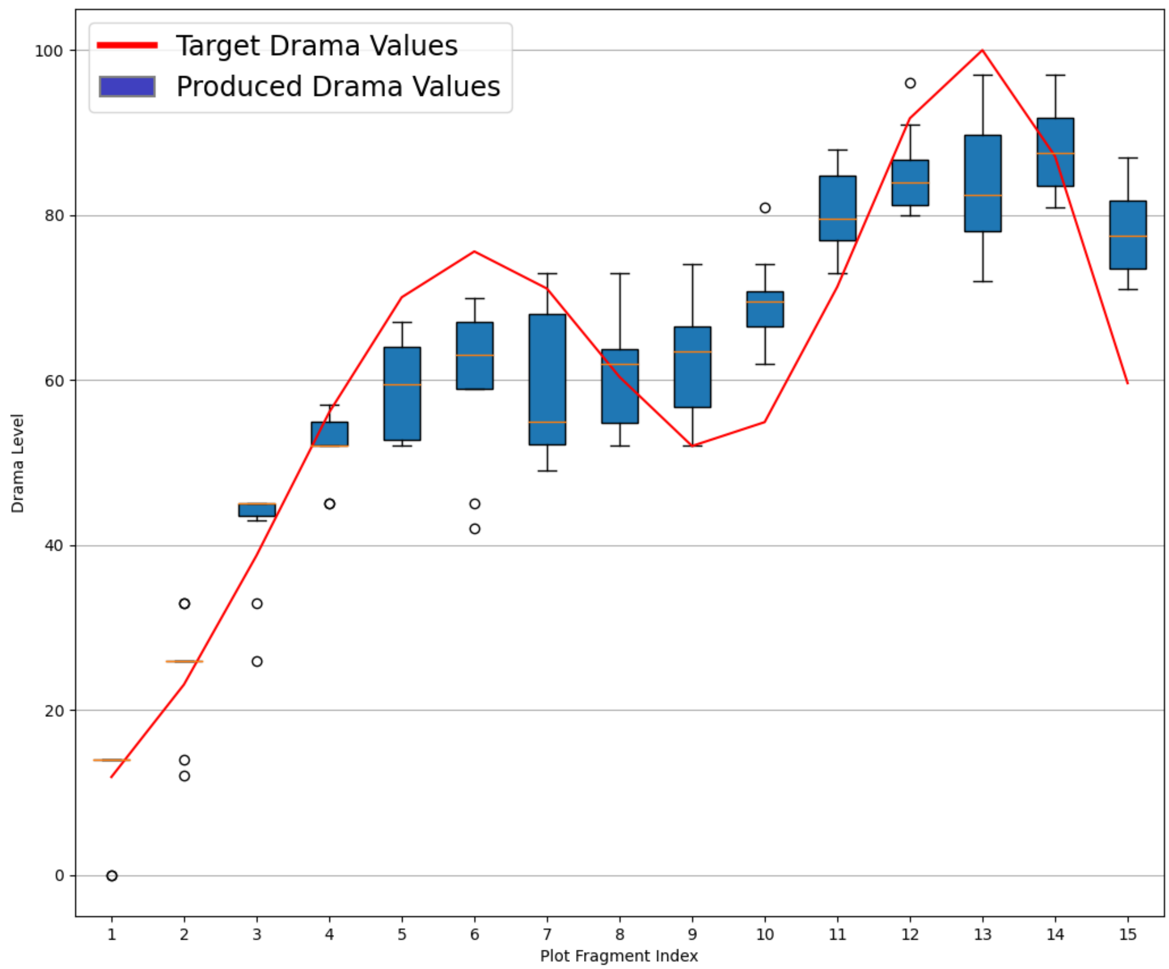

Fig. 4: Target and Desired Drama Scores

cause high drama events that push the system off track to reach desired character states. Additionally, events with a granular impact on character attributes would allow the system to get closer to a desired worldstate, requiring a lower degree of tolerance in the form of tighter waypoint radii.

Finally, there is the prospect of conducting user studies on the quality of story output. While we have included generated example stories to give an idea of the form output from our system takes on, a thorough investigation of how the stories are evaluated by readers would give insight into the quality of produced results. Especially so, if contrasted with manually authored short stories.

All in all, we believe our system to be a fruitful effort in bringing new ideas to older author-goal-based story generation systems, but believe there is plenty of room to expand on our efforts.

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Appendix

Our codebase, and some further example output can be found in the attached files of this submission.