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Review on Dynamic Difficulty Adjustment (Dad) In Plat former Games

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Abstract: ***There are many challenges in procedural content generation (PCG), maintaining the quality of content with all the diversity, without any flaws and maintaining the balance in the level of difficulty by dynamic difficulty adjustment (DDA) of the game content in real time based on active inputs are some of the primary issues when concerned with machine generated adaptive content. This subject investigates the efficiency in the use of Procedural content generation by combining the learning based and rule based approach. The research is motivated by the PCG framework based on the learning approach, with the novel approach to address the two primary issues in Super Mario Bros (SMB). To deal with the content quality issue the combination of rule based and learning based techniques is used, which will help to produce the game segments with good quality, also called constructive primitives (CPs) which are all the quality segments in a game level. A DDA algorithm is proposed in the research that will control a CP-based level generator and will adjust the difficulty of levels rapidly based on players' real-time game play experience. The use of model based approach over model free approach will be the main focus of this research where the sampling will be done to minimize content into their respective datasets using the simple random sampling approach without replacement.***

Index Terms: ***Procedural content generation (PCG), Content quality assurance, Constructive primitive, Dynamic difficulty adjustment, Machine Learning & Real-time adaptation, Super Mario Bros.***

I. INTRODUCTION

Procedural content generation is used to generate game content dynamically [1] either fully or partially, could be model based or model free and can be based on online content generation i.e. real-time time content generation or offline content generation i.e. based on more analytical approach based on previous result to generate better result. Super Mario Bros is a 2d platformer game [2], [3] where the player have to run from left to right and reach the final goal point/castle by avoiding traps such as enemies like Tunnel flower, Goomba, Koopa Troopa, Cannons etc. while taking power-ups like mushrooms to increase the mario's size and fire flower for the ability to shoot flames. The Super Mario Bros has been used as a test game for the research which was initially developed by nintendo (released in 1985) while also including some features like animation, background and sprites of Super Mario World was also developed by nintendo (released in 1990) [2]. The main focus of this research is on dynamically generating quality segments of the game also called as Constructive Primitives [6]. There are two approaches possible either model based or model free [12], [13]. In a model-free approach, player model is mainly determined by the players' gameplay data, e.g., controllable parameters and playlog in the game, and the feedback from this control parameters, e.g., state changes the affect the "fun" content of the game, while model based approach have the player model which relies on derived values of psychological emotion theories to mainly balance the game difficulty [14].As far as it is known most of the current implementation on SMB game falls under the model free approach and the model based approach is yet to be explored and not many have efficiently implemented the model based approach. The real-time model based approach for Dynamic Difficulty Adjustment (DDA) within the generation of a level is only implemented in the recent work of P. Shi and K. Chen [5], [6] for SMB level adaptation research to date. Learning-Based Procedural Content Generation (LBPCG) framework [15]is the main motivation in our research. The quality evaluation function of the content of the game will be determined from the levels mentioned by the developers. Generating short game segments of good quality will be determined as constructive primitives (CP)[5], [6] and modified Infinite Mario Bros will be used as a test game [3].

II. RELATED WORK

P. Shi and K. Chen [6] have proposed a system of dynamic difficulty adjustment which uses a combination of rule-based and learning-based methods. Uses model based approach and sampling with replacement as opposed to the proposed approach of sampling without replacement. The sample with replacement technique contains a set of independent elements while sampling without replacement contains a set of dependent elements. However both are suitable for population with indefinite size.N. Shaker,

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G. N. Yannakakis, J. Togelius, M. Nicolau, M. O'Neill [9] have introduced a method for automatic level generation for the platform game Super Mario Bros using grammatical evolution. The proposed system extends this simple approach with active learning approach to balance difficulty level. The active learning approach can be either Type I (false negative) or Type II (false positive), but for the proposed system in our paper we use Type I because of the fact that it will consider even some good set as worst reducing the number to only the best suitable/fit sets for generation. W. M. P. Reis, L. H. S. Lelis, Y. Gal [8] have proposed a system that merges human-annotated game segments to form quality levels. Unlike proposed system in our paper, this system has to make a great deal of effort in obtaining enough annotated segments for level generation and needs to address the controllability issue in addition.

G. Smith, J. Whitehead, M. Mateas, M. Treanor, J. March, M. Cha [10] have proposed a technique where levels are created by generating rhythms & then generates geometry (game level) based on rhythms. Generation is constrained by a set of style parameters can be tweaked by a human designer. The proposed system in our paper uses model based approach which only genrates the content with help of algorithm and player's gameplay pattern without any human designer involved.

Summerville, M. Mateas[11] have used LSTMs (Long Short-Term Memory recurrent neural networks) which uses the path system information of current human generated levels and studied the pattern of those human crafted levels. However, it can be difficult to generate diverse design patterns from a limited number of human authored levels (only 32) and can make the levels of the game more predictive after few gameplay sessions making it boring.

III. PROPOSED SYSTEM

This section, gives overview of the concept and information about the representation of content space. Then, we present our approach to learning constructive primitives (CPs) in SMB.

A. Overview

The focus is to decompose the whole level into smaller segments of a quality to match the human generated levels often referred as constructive primitives this has already appeared in the previous work as in [6], [7], [8], [10]. The existing system SMB used to generate the whole level segments by segments either based on the rhythm of the player interaction [10], with a partial human interaction [7], [8], the other technique is by using evolutionary algorithm where online(during execution or active play sessions) monitoring is done to check the player interaction and the algorithm adaptive to the player's difficulty handling [12], [13] or used the Long Short-Term Memory recurrent neural networks (LSTMs) [11] for the purpose of generating levels trained from *Super Mario Bros.*

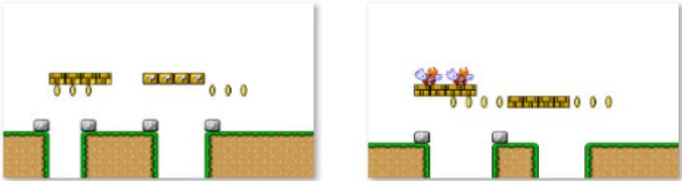

Fig.1. Single segments of level containing different elements.

The quality assurance is the main focus in the content generation, this can be generally categorized into two main techniques in developing such mechanism [1], [6], [15]: deductive and inductive. The problem with using the deductive technique is that the developers will need all perquisites of the whole content space before generation of the segments with proper rule and this becomes especially complicated when the content space is too large such implementation may not be impossible but will not lead to proper rule/training sets and may often create problems in Procedural Content Generation (PCG).

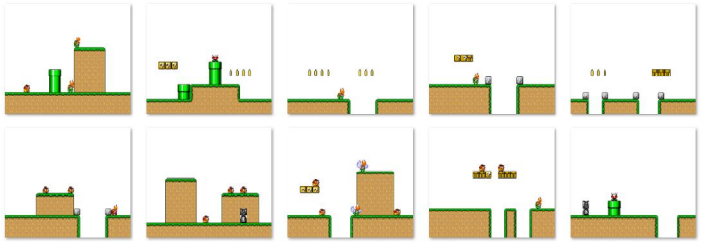

Fig.2. Typical 20 X 15 game segment instances [6].

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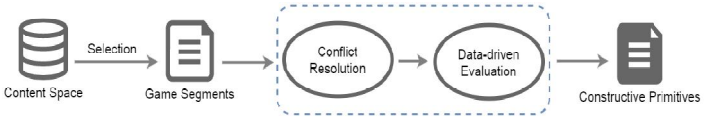

Fig.3. Constructive primitive (CP) generation process for SMB [6].

However, some rules are really easy to identify like for example we can have rule where two enemies do not overlap with each other (see Fig. 2. Left top/bottom) or this will be a glitch. We use the inductive method as proposed in a learning based procedural content generation (LBPCG) [15] which will implement quality rules via learning from datasets. The proposed system will use both simple rule and learning based approach for quality control. Fig.3. illustrates our proposed system which is influenced by P. Shi's and K. Chen's implementation [6] where:

1) Simple Random Sampling (SRS) [4] without replacement where sampled values are not independent will be used as compared to previous work [6] that uses SRS with replacement the values are independent. Practically, this means that what we get for the first one affects what we get for the second one.

2) CURE algorithm [16] will be used for clustering the sampled dataset same as the existing work. Active learning will also be applied in the same way as the previous implementation with Type I (False Negative).

3) An open source infinite Super Mario Bros game engine which is used in existing work will also be used to measure the performance of our implementation vs. others.

TABLE I. TYPES OF SAMPLING

Type	Description	Pros	Cons
Random Sampling	Every member is eligible for selection.	Suitable for very large size population.	Creating list out of large size of population time consuming.
Stratified Sampling	Divide the population to subcategories.	Effort is made to create sample representation of population.	Subcategorizing can be time consuming as groups need to be identified and proportion is to be made.
Volunteer Sampling	Group of population is self chosen.	Convenient and ethical if leads to an informed consent.	Can be full of bias like some of population would never participate.
Oppurtunity Sampling	Simply selects the population that available for selection.	Economical, convenient and quick.	A large number of population will remain unselected.

The sampling technique to be used in the proposed is Simple Random Sampling (SRS) because the population size is not known and simple random sampling does not require grouping and can be suitable for both independent and dependent elements in the set, also it is easy to implement. Previous work [6] has only used Simple Random Sampling with replacement which creates a set of

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independent values while the proposed system will employ sampling without replacement which will generate set of population with dependent elements.

B.Content Representation

A game segment of 20:15 ratio (see Fig. 2.) is sufficient to fit enough amount of unique elements for making a constructive primitive [6], [8]. However the pre-generated segments could be playable and refreshing just for few gameplay but may become redundant in future to avoid redundancy the only way is to add more segments to the content space but is still no solution to the redundancy. We have employed the technique that was used by P. Shi and K. Chen[6] where, instead of the 2D grid representation, they used a list of design elements (see Fig. 3.), which are single unit of assets used to generate a segments of a level, for representing the contents (see TABLE II.).

TABLE II. CONTENT FEATURES[6].

ID	Description
1	height of initial platform
2	number of gaps
3-11	x, width and type of the 1st - 3rd gap
12	number of hills
13-18	x, width and height of the 1st and 2nd hill
19	number of cannons
20-34	x, y, height, wbefore and wafter of the 1st - 3rd cannon
35	number of tubes
36-53	x, y, height, wbefore, wafter and type of the 1st - 3rd tube
54	number of boxes
55-62	x, y, width and type of the 1st and 2nd boxes
63	number of enemies
64-78	x, y and type of the 1st - 5th enemy
79	number of coins
80-85	x, y and width of the 1st and 2nd coins

The proposed system takes representation of the previous work [6], [9] where, *x*, *y*, *width*, *height* and *type* is given for each element; also wbefore and wafter for the width of the platform before or after each cannon or tube.

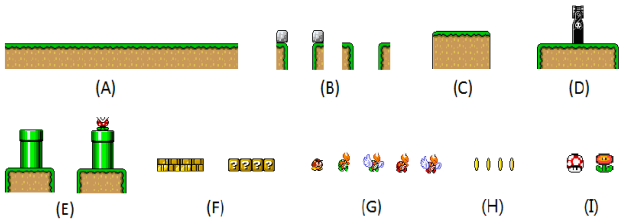

Fig.3. Game design elements. (A) Initial platform. (B) Gaps w or w/o rock decoration. (C) Hill. (D) Cannon. (E) Tubes w or w/o flower enemy. (F) Boxes w or w/o coins/powerup. (G) Enemies. (H) Coins. (I) Mushroom and fire flower.[6]

C.Conflict and Resolution

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The section III-B have mentioned about the different game elements and its parameters now consider an example of a Cannon (6, 0, 5, 4, 2) and Tube (6, 0, 7, 4, 1) where each number represents their respective (x, y, width, height, type) now as we can see that x, y coordinates are same for both Cannon and Tube which may lead to overlapping of the two elements which should not happen during the generation process as it will make the generated segments error prone and unappealing. To tackle this problem as mentioned in previous work [6], [9], simple rules will be employed so that no overlapping takes place for elements likes gaps, cannon ,tubes ,platform etc. This will help to create more refined quality game segments.

IV. CONCLUSION

The human generated levels are always perfect but continuous level generation in real-time is outside the human tendency. It is one of the biggest challenges to generate the human level of perfection with algorithm, but with the combination of rule-based and learning-based approach will help to attend that perfection where it will be possible to create level just as if it was crafted by human algorithmically. The Dynamic Difficulty Adjustment algorithms can be tweaked with better rules for quality control and give the best experience to the player based on his ability to handle the difficulty thus will make game more fun and less predictive.

V. FUTURE SCOPE

It is not possible to assure the content generated dynamically will be as perfect as the ones that is generated by humans and will always remain as a challenge in PCG to attain that level of quality. So we can say that generated levels of a game are not good or even worse when compared to manually generated content.But as seen in the previous work it is possible to make improvements to dynamically generated contents using the model-based dynamic difficulty adjustment with set of rules and learning curves to improve overall content quality and game difficulty by studying the player's gameplay pattern along with content generator patterns. The focus is to minimize the number of datasets by applying rules and improve the machine generated content's quality and improve the time limit by reducing time for overall level genration process and from the previous work showing progressive improvements it is assured that more human level perfectson can be achieved in future.As for our implementation is concerned with improvements to come up, it is planned to be used in even more games not only from the plat formers genre but also for other genres of games as well with progression of the system.

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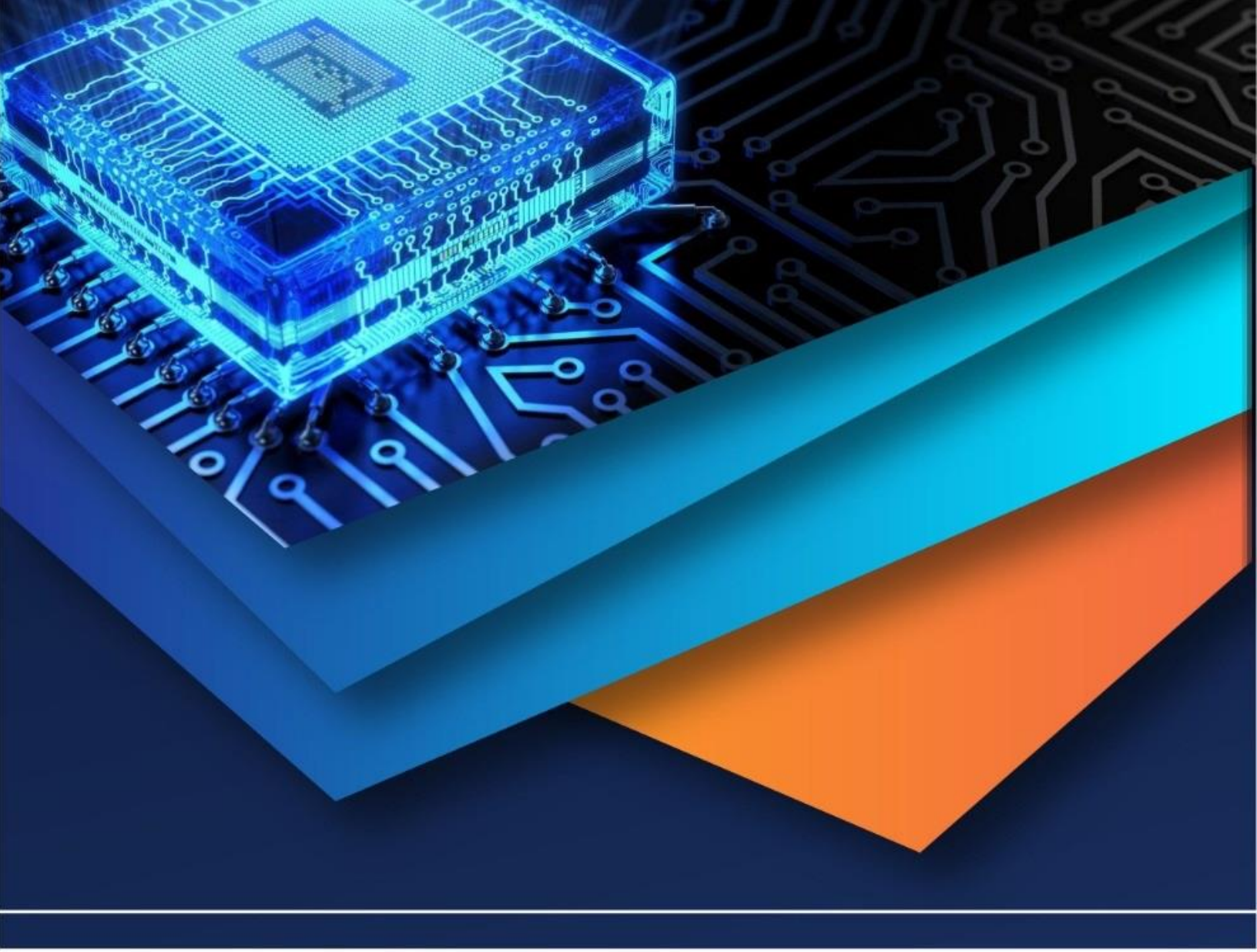

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