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Procedural Generation for Tabletop Games: User Driven Approaches with Restrictions on Computational Resources

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Abstract. Procedural Content Generation has a focus on the development of digital games, this leaves out a number of interesting domains for a generation of wargames and other board game types. These games are based on limited computational resources, using dice for random numbers and creations via tables. This paper presents a historical look at non-digital methods for PCG application and in particular a taxonomy of methods and locations of their use.

Keywords: Procedural Content Generation, Analog Computing, War Games, Taxonomy

1 Introduction

The idea of a configurable board which can be generated predates the computer. The training of Prussian officers included the war game Kriegspiel (formal rules in 1812). The table for this game, presented to King Friedrich Wilhelm III, included such features as movable terrain pieces as board tiles. An even earlier example, created in 1780 by Johann Christian Ludwig Hellwig, boasted a board of 1600 color-coded terrain squares as an expansion on *Königsspiel* developed in 1664, with a relatively small five-hundred squares – though it is not known if these terrain squares were preset or somehow configured [7]. These early Procedural Content Generation (PCG) for games far predate the examples as shown by Smith [10]. These titles represented fields, forests, streams, etc. and would be configured or "rolled up", depending upon the wishes of the commander leading the examination. *Little Wars* [16] would further advise the players to use such terrain as what was available to them, which undoubtedly lead to a number of broken objects being swept up by maids as the Victorian wood dowel firing cannons streaked their ordnance across the gardens and studies of the British stately homes[3].

[3] There is a long historical precedence of wives being upset with their wargaming husbands. Catherine the Great of Russia, born Princess Sophie of Anhalt-Zerbst,

Later board games, both of German and Western designs, such as *Carcassonne* and *Zombies!!!*, utilize a configurable board as part of the core game mechanics of play. Neither of these has a much complex application of resources nor delivers a playing experience which truly meets with the requirements of an actionable field-ready military game, like Kriegspiel. Still, they allow for massive combinations of new outcomes in terms of the space in which the game is fought over.

The randomness of war has been remarked on by great historical generals; Sun Tzu [12] as early as the fifth century refers to the high of generals being able to anticipate the enemies plans and thwart them. He advises that the general should act in accordance with their own forces, and in accordance to terrain, and should embrace intelligence gathering and spies in order to better plan. Moreover, Sun Tzu remarks on the randomness inherent in war, "According as circumstances are favorable, one should modify one's plans." Carl Von Clausewitz [15] would echo this sentiment into the Napoleonic era stating that:

> ... the great uncertainty of all data in War is a peculiar difficulty, because all action must, to a certain extent, be planned in a mere twilight, which in addition not unfrequently [sic] – like the effect of a fog or moonshine – gives to things exaggerated dimensions and an unnatural appearance. What this feeble light leaves indistinct to the sight talent must discover, or must be left to chance. It is therefore again talent, or the favor of fortune, on which reliance must be placed, for want of objective knowledge.

In such plans it is obvious that the commander must deal in vagaries for the opponent is not a known entity, nor should the commander allow others to know plans beforehand.

At this time, generation techniques are mainly focused on PCG for computer games and do not consider the user requirements for board games. Looking at reviews of future directions in PCG [11, 19], there is no mention of non-digital methods. Tools for the generation of computer driven terrain are costly in terms of the required computation and do not meet with the needs of the average wargamer standing at the table making an arrangement for a session. While the work of Ashlock and McGuniness[5], Valtchan and Brown[13], have presented developments which can address the creation of dungeon games such as *D&D* or *Pathfinder*, the aim of this paper is to examine the techniques allowing the layout of such boards which would be within the domain of a board or wargame

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led a coup d'etat brought about by Peter III's neglect. His predilection to to spend his time enjoy wargaming, as opposed to running a nation state. She writes in her autobiography, "the main plaything of the Grand Duke, when in town, was an excessive quantity of small puppets, of soldiers made of wood, lead, starch and wax, which he arrayed on very narrow tables that filled the entire room; one could hardly pass between those tables. He had nailed long strips of brass along the lengths of these tables; these bands had wires attached to them, and when one pulled these, the brass strips made a sound which, according to him, was akin to the rolling fire of muskets." [6]

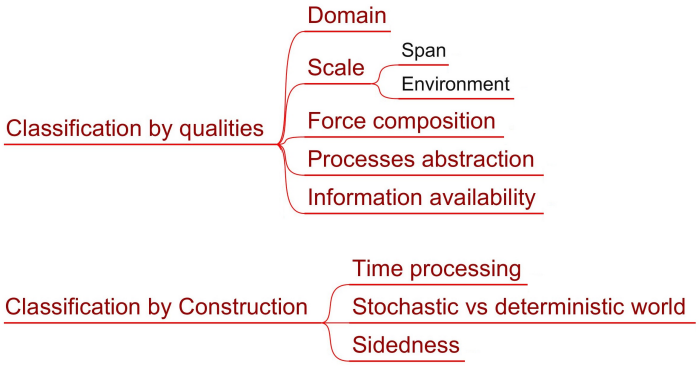

Fig. 1. The proposed taxonomy of Wargames.

played without access or need for digital devices. The tools required should not go beyond the requirement of tables, dice, drawing cards, etc. common to the consumer.

We present a taxonomy of wargames, based on previous research and expanded to include specific characteristics of wargames in Section 2. In Section 3, we present a survey of the main methods for PCG in boardgames, discussing their benefits and shortcomings and providing examples of commercial games that include such features.

2 A Taxonomy of Wargames

Wargames are a subset of games; Van Creveld defines a wargame as a contest of opposing strategies that, while separated from real warfare, simulates some key aspects of real war [14]. Interestingly, in the research related to wargames – especially from the military perspective – there appears to be some disregard for games that simulate non-realistic war, as exemplified by a US army officer's statement: "This is not Dungeons and Dragons we're doing here" (Allen, 1994 [1]). This sentiment is further supported by the Prussian High Command's remarks in 1824 (but only recorded in 1874[4]) that Kreigsspil was "not an ordinary game, but a school of war" [17]. See [18] for a more through review of Kreigsspil development.

In this paper we do argue that according to Van Creveld's definition all kind of games that represent a conflict with some war-like aspect are indeed wargames, *Dungeons & Dragons* included. Sabin [9] agrees with this, in general stating that, "The key characteristic uniting war and games, and which sets them apart from most human activities, is their competitive and agonistic nature. In games, this conflict is mainly artificial, while war is mainly situational, but the

[4] We would like to thank the reviewer to brought this to our attention

effect is the same." All wargames are abstractions, as noted by Nakamura [8], "correct simulation is always dependent on the player's *image* of the subject being simulated" (author's emphasis retained).

While many works have been written on wargames, not a lot of attention has been given to ways to classify wargames as a separate subset of games. A rare example of such a taxonomy can be found in a 1989 workshop report by Anderson *et al.* sponsored by the Military Operations Research Society (MORS) [2, 3]. While Anderson's taxonomy has many interesting qualities, it is based on a definition of wargames that is closer to "military simulations", in fact excluding all wargames that are played outside of a military environment. The following taxonomy aims to allow for categorization of wargames both for personal enjoyment and for more practical uses. The taxonomy is divided into two subclassifications: by the quality and by construction. The classification by qualities focuses on differentiating between games based on the type of conflict that is being represented, while the classification by construction looks at distinctions of game mechanics.

We hope that this taxonomy will help frame the possible aspects that can be procedurally generated, and moreover give a more solid framework on which to analyze wargames.

2.1 Classification by qualities

Domain By domain, we define the type of conflict represented. An incomplete list of examples of domains is land, sea, n-dimensional space, psychological, or economical conflict. *Warhammer* mostly represents land conflict, while *General Quarters* represents sea conflict, and *Crimson skies* air conflict.

Scale We define scale as the size of the described conflict since this can have multiple facets – such as the level of control of the player on the units, or the role of the represented conflict – we further divide this category in *Span* and *Force composition*.

Span While this quality might seem similar to a domain, it serves to express what role does the conflict represented in the game in the bigger context of a war. Possible spans of conflict include global, theater, local, etc.
Of course, a game might represent a single battle of a larger campaign based game - in which a separate set of rules would be adopted in order to represent the campaign level. There are also a number of games with a 'Legacy' effects (*Risk Legacy*), in which the outcome of previous battles impacts on the future set.

Force composition The force composition quality deals with what is represented as a "unit" by the wargame. The typical representations are:
- Division, corps, or in general army-sized units.
- Battalions to divisions.
- Squads, platoons, companies, vehicles.
- Individual soldiers

Note how in many of these, individuals are not directly represented but are an abstract component of the "unit".

Environment In the context of wargames, we define environment as how the playing field is structured. For example is the construction of the playing field achieved through placement of set pieces (terrain reliefs, fortifications, rivers, etc.), or is the terrain divided in tiles that have to be connected, or is there a static predefined map?

Processes abstraction This quality describes the level of abstraction of the actions the units can execute. If we consider the omnipresent "attack" action we could, for example, differentiate between calculating damage shot-by-shot, by average, by damage-per-second (DPS), piece capture, etc.

Information availability With this attribute, we want to differentiate between games that present complete or incomplete information to the players. While partial information, especially through the use of the 'fog of war' is very common in digital games, it has also been previously implemented in board games; an example is *Quebec 1759*.

2.2 Classification by Construction

Time processing Wargames can be differentiated by how they deal with time, the most obvious distinction being if the progress of the game is based on real-time or turns. At the same time, there are more subtle distinctions, such as the time relevance of orders or interrupt actions. Interrupt actions are special actions that can be either triggered manually by the player in some conditions, or automatic actions outside the player's control. An example of automatic actions can be seen in *Warhammer 40000*'s overwatch action: once a unit has overwatch applied to it, it will perform an automatic attack on the first enemy unit to come into range. Variations of interrupts can be seen in both real-time and turn-based wargames.

Stochastic vs deterministic world Some wargames might present a completely deterministic world – empathising player strategy and fairness – while others might include stochastic elements. Randomness can be used to create interesting and surprising situations, and including a more continuous sense of tension since the result of each move is not completely assured a priori. An example of classic wargames that present such opposing approaches are Chess and Risk: given any state of the board, in Chess, each action has only one possible resolution, while Risk requires the players to roll dice to determine the result of an attack.

Sidedness Finally, sidedness differentiates between games depending on where the players stand in the conflict. We differentiate games into three categories:

One player side (multiple players) vs the game: in these games the player(s) all stand on the same side of the conflict, while the game itself provides the enemy. Examples of wargames that fall into this category are *Space Alert* and *Dungeons & Dragons*.

1 vs 1: in these games there are two sides, both manned by a human player. A classical example would be most two-player Chess-like games.

1 vs many: these games present more than two sides to the conflict, which could be controlled by human players or by the game itself. *Risk* would fall into this category, as is usually played by more than 2 players. A game that can also present game-controlled sides is the *Game of Thrones boardgame*, as it has a static number of "houses" that can be more than the players' number.

3 Techniques

This section examines the techniques used in wargames to provide a procedural content. In many of these methods, the provider of randomness is a dice roll or a card draw, we do not see dice or cards themselves as a generator, but instead as the analog randomness tool which a generation method utilizes.

3.1 Lookup Tables

This technique is based on having a table (or something that can be abstracted to a table) of possible outcomes that are selected through a stochastic process. We divide this technique into two categories: where the lookup table is integrated into an analog "random number generator", or where it is external to the object. It is important to note that the use of an integrated lookup table in a game does not preclude the same game from using an external lookup table in a different mechanic. For example, a game may include a deck of cards for selecting and issuing orders (an integrated table) and a dice roll for checking in a rule book the number of casualties if a unit is hit with shot (an external table).

Integrated This category includes techniques in which the consequence of a "roll" is integrated into the physical object used as a source of randomness. An example would be the dice in *Risk*, which, while being six sided, it only has blue/red colors on the faces to indicate a positive/negative result. In this category also fall examples of randomly shuffled decks (see event cards in *Betrayal at the House on the Hill*), in these cases by drawing a card from the deck a procedural element might be introduced where the consequence of the randomness is explicit on the card itself.

External In this category fall all other examples of decision making where an external table (often in the game manual) is used to determine a random numerical value. *Dungeon & Dragons* (and in general most pen and paper games) presents many examples of this approach. In fact, it is not only used to determine how successful attacks are in combat but is also used in dialogue, traversal of levels, character creation, etc. It seems likely to us that such a technique is mainly favored by very open-ended games, such as pen-and-paper role-playing games since, given the extreme range of game mechanics, having specialized artifacts to determine the outcome of all of them would be severely impractical.

3.2 Tiles

A very common technique for generating playing boards consists of delegating the creation to the map to the players themselves through the positioning of resources. We will refer to this resources as *tiles*, since very often they are just that, but could take different shapes than, for example, a square or hexagonal tile. We define *tiles* as a representation of resources, in fact while often directly representing some type of terrain (e.g. *Carcassonne*, *Settlers of Catan*) or dungeon layout (e.g. *Dungeons & Dragons*), it could also represent a resource to place on a predefined map (e.g. *Game of Thrones, the board game*). This approach has many variations, which we have split into two main categories: the ones that encompass the usage of some geometric tile and the ones that use a more free-form representation (and usually placement) of the resources.

Geometric The geometric approach is based on the usage of tiles that present some geometrical shape which allows the players to connect them together to create the playing field. The most common shapes used for these techniques are squares and hexagons since they allow connecting a large number of tiles in a space fitting. One of the common issues with this approach is that the maps might not look very consistent if the rules for placing adjacent tiles are too strict (a well known problem in *Settlers of Catan*). On the other hand, when rules for connecting pieces are quite strict to encourage consistent and pretty boards the risk is that the initial board generation might take the players a long time. An interesting example to create complex, "natural", and fast maps, while using a geometrical tiled approach can be observed in *Victory: The Blocks of War*. In this game, the movement tiles and the board-generating tiles are decoupled (respectively hexagons and rectangles), and each board-tile contains a number of movement tiles. This means that a quite large playing map can be created by connecting just a small amount of tiles.

The most common approach game designers use to solve this dilemma is to make the placement rules an integral part of the gameplay. An example can be seen in *Carcassonne* and similar games (e.g. *Kingdomino*): the placement of the tiles to generate the map becomes part of the core gameplay, with the players drawing and placing a tile each turn to distribute the resources in the most profitable way. This method often leads to "incomplete" maps (with gaps), since

the conflict shifts from a more direct fight to an economic conflict of resource obtainment.

Terrain This approach allows instead for a more fluid placement of resources, that could be represented by non-geometric or irregular shapes. The historical Kriegspiel already presented this approach, as various tiles (or tokens) could be placed on the playing field to represent terrain characteristics such as mountains, trenches, rivers, etc. Most modern miniature wargames (or table-top wargames) present some similar terrain modification mechanism, examples include H.G. Wells' *Little Wars*, the *Warhammer* games, and *Axis & Allies*.

The placement of these tiles can create bonuses (e.g cover or high ground) or penalties (e.g. limited movement or visibility) for the units in the vicinity and can have a great impact on the strategy necessary to achieve victory. It is also interesting to note that, while the game publishers often provide tile sets for the players to buy, it's quite common for a hobbyist to create their own set pieces or use common objects to improvise new tiles.

3.3 Control Structures

Control methods place restrictions on the types of orders which may be given or the order in which units gain the initiative. While the common game method is a *You go - I go* approach to turns, control structures may allow for a random unit to gain the initiative or be played during a turn, either by use of a roll of a die, or a card based system. Games such as *Bolt Action* implements placing an order die for each unit on the table for both sides. A player draws from this pool one at a time and the colour of the selected die allows that army to give an order to one of the units. *Star Wars Legion* has each player take turns pulling unit type counters from a personal bag in order to decide on who is allowed to move in a turn by turn order. Other game effects can interrupt this process allowing a unit to move without being drawn from the bag.

Kingdom Death is a recent and interesting example of the level of the control structure that can be implemented inside of a game only using analog generation. It implements a sophisticated analog AI via a series of cards drawn in sequence from an AI deck with conditions of the actions. This is a similar representation to a Finite State Machine or If-Skip-Action list [4] implemented by cards. The cards might also be self referential to the AI, allowing for a reordering of future actions.

Conditions include targeting the closest threat, visible threat, an enemy unit with an affinity or item, and have a default action when those conditions are not met. These defaults are normally searched actions, attempting to repair damage, or activating buffs (bonuses).

Game	Domain	Span	Force composition	Environment	Process abstraction	Information availability
Warhammer 40000	Land (mostly)	Variable	Individual-platoons	Set pieces placed before the game	Conglomerated damage	Full information
Dungeons & Dragons	Land	Local	Individual	Predefined	Individual	Incomplete
Axis and Allies	Land, air, sea	Global	Army-sized	Predefined	Army damage	Full information
Kingdom Death	Mystical Land	Home Base/Local	Individual	Predefined	Individual	Incomplete
Little Wars	Land	Local	Squad	Set pieces placed before the game	Unit Damage	Full information

Table 1. Taxonomy analysis of war-games **qualities** for the games *Dungeons & Dragons*, *Axis and Allies*, *Kingdom Death*, and *Little Wars*

Game	Time Processing	Stochastic/deterministic world	Sidedness
Warhammer 40000	Turn-based with automatic actions	Stochastic	1 vs many
Dungeons & Dragons	Turn-based with initiative	Stochastic	1 player side vs the game
Axis and Allies	Turn-based	Stochastic	1 vs many
Kingdom Death	Turn-based with interrupts	Stochastic	1 player side vs the game
Little Wars	Turn-based	Deterministic	1 vs 1

Table 2. Taxonomy analysis of war-games **construction** for the games *Dungeons & Dragons*, *Axis and Allies*, *Kingdom Death*, and *Little Wars*

Game	Lookup tables		Tiles		Control structures
	Integrated	External	Geometric	Terrain	
Warhammer 40000	Limited	*		*	
Dungeons & Dragons		*	*	Limited	
Axis and Allies		*			
Kingdom Death	*	*	*		Card Based AI
Little Wars		*		*	

Table 3. Areas in which **PCG techniques** are used by the games: *Warhammer 40000*, *Dungeons & Dragons*, *Axis and Allies*, *Kingdom Death*, and *Little Wars*

4 Conclusions

This paper describes a taxonomy of wargames and a survey of analog procedural content generation methods used by such games/simulations. By providing a taxonomy to break down current games, planners and developers of new games can better transfer both methods and tools to future applications in new domains. Common complaints are applying old methods which work well in one situation into another situation - from both Military and games developers, by better understanding the current sets of games, its highlights were a game is (un)applicable to a situation.

The taxonomy highlights not only the domain of application but the tools available to designers. In future work, an interesting direction would be to apply the taxonomy and look for correlations between the the battle field properties and the mechanisms used in play.

References

1. Thomas B Allen. War games: Inside the secret world of the men who play at world war III, 1994.
2. Lowell B Anderson, John H Cushman, Alan L Gropman, and Vincent P Roske. Simtax: A taxonomy for warfare simulation. *Phalanx*, 20(3):26–28, 1987.
3. Lowell B Anderson, John H Cushman, Alan L Gropman, and Vincent P Roske Jr. Simtax: A taxonomy for warfare simulation (workshop report). Technical report, Military Operations Research Society Alexandria VA, 1989.
4. Daniel Ashlock and Mark Joenks. Isac lists, a different representation for program induction. In John R. Koza, Wolfgang Banzhaf, Kumar Chellapilla, Kalyanmoy Deb, Marco Dorigo, David B. Fogel, Max H. Garzon, David E. Goldberg, Hitoshi Iba, and Rick Riolo, editors, *Genetic Programming 1998: Proceedings of the Third Annual Conference*, pages 3–10, University of Wisconsin, Madison, Wisconsin, USA, 22-25 July 1998. Morgan Kaufmann.
5. Daniel Ashlock, Colin Lee, and Cameron McGuinness. Search-based procedural generation of maze-like levels. *IEEE Transactions on Computational Intelligence and AI in Games*, 3(3):260–273, 2011.

6. Cathrine II. Mémoires de l'impératrice catherine ii, écrits par elle-même, et précédés d'une préface par a. herzen, londres, 1845.
7. George F Dales. Of dice and men. *Journal of the American Oriental Society*, 88(1):14–23, 1968.
8. Tetsuya Nakamura. The fundamental gap between tabletop simulation games and the "truth". In Pat Harrigan and Matthew G. Kirschenbaum, editors, *Zones of Control: Perspectives on Wargaming*. MIT Press, 2016.
9. Philip Sabin. *Simulating war: Studying conflict through simulation games*. A&C Black, 2012.
10. Gillian Smith. An analog history of procedural content generation. In *Proceedings of the 2015 Conference on the Foundations of Digital Games (FDG)*, 2015.
11. Julian Togelius, Alex J. Champandard, Pier Luca Lanzi, Michael Mateas, Ana Paiva, Mike Preuss, and Kenneth O. Stanley. Procedural Content Generation: Goals, Challenges and Actionable Steps. In Simon M. Lucas, Michael Mateas, Mike Preuss, Pieter Spronck, and Julian Togelius, editors, *Artificial and Computational Intelligence in Games*, volume 6 of *Dagstuhl Follow-Ups*, pages 61–75. Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, Dagstuhl, Germany, 2013.
12. Sun Tzu. The art of war. In *Strategic Studies*, pages 63–91. Routledge, 2008.
13. Valtchan Valtchanov and Joseph Alexander Brown. Evolving dungeon crawler levels with relative placement. In B. C. Desai, S. Mudur, and E. Vassev, editors, *C3S2E'12 Fifth International C* Conference on Computer Science & Software Engineering*, pages 27–35, Montreal, 2012. ACM.
14. Martin Van Creveld. *Wargames: From gladiators to gigabytes*. Cambridge University Press, 2013.
15. Carl Von Clausewitz. *On war*. Jazzybee Verlag, 1940.
16. Herbert George Wells. *Little wars*. Read Books Ltd, 2013.
17. Jorit Wintjes. not an ordinary game, but a school of war. *Vulcan*, 4(1):52–75, 2016.
18. Jorit Wintjes. When a spiel is not a game: The prussian kriegsspiel from 1824 to 1871. *Vulcan*, 5(1):5–28, 2017.
19. G.N. Yannakakis and J. Togelius. A panorama of artificial and computational intelligence in games. *IEEE Transactions on Computational Intelligence and AI in Games*, PP(99):1–1, 2014.