Making a Better Game: The History of Cluster

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Abstract. The authors present a case study of the initial inspiration and design process that led to successfully optimized versions of the game "Cluster". Various aspects of game design are examined in the context of human and computer assisted playtesting.

1 Introduction

Cluster is a two player connection game designed by Philip Shoptaugh in 1972. This article describes the initial inspiration and development of successively optimized versions of the game. In doing so, the primary question addressed by this work is: "How can playtesting be effectively applied to successively improve the design of a game?" Herein, the following aspects of the game's design are addressed:

- Two player games are sometimes produced via the recombination of elements obtained from the domain of existing games [3]. An example is given whereby a novel "hybrid" two-player game is derived from a cross between a two player game and a single player puzzle.
- The optimization of an existing game is demonstrated via applying design heuristics gleaned from insights acquired through playtesting.
- The utilization of computer assisted game design software is examined. Prior work in this area has been primarily directed towards the goal of automatic invention of new games via automated recombination and evaluation of existing two player games [2, 3]. These systems typically employ a generic AI. This work illustrates utilizing a game design system that incorporates a high quality custom AI specifically designed to play variations of a single game. The rule set is fixed, whereas the board topology and initial piece type distribute and initial placement is allowed to vary. This work is aimed at increasing the interaction between the game designer and the game design software by enabling the designer to quickly generate and playtest proposed variations.

The resulting design rules and playtesting techniques, shown to be successful for Cluster, should yield applicability to a larger domain of games. The applicable classes of games include connection and territorial games, where the primary design goal is to optimize the board topology, the distribution of piece types, and the initial piece placements.

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1.1 Rules of Cluster

The Cluster game board consists of a pattern of holes, some which are deep (as identified with a chamfer), and some which are shallow (without the chamfer). Each player, identified as black or white, has two rows of pegs of their respective color inserted into holes. Some pegs are tall and some are short. Based on the combination of peg length and hole depth, three levels are possible, short, medium, and tall which can also be identified numerically by the numbers 1, 2, and 3 respectively (Fig. 1). With white opening, the players take turns moving their pegs until the winning player forms a contiguous group of pegs of their respective color and all pegs of the group are at medium height (level 2). Pegs can move in two ways. They can either step to an adjacent empty hole or they can jump any number of pieces on the lateral or on the diagonal, regardless of ownership or height of the pieces being jumped, then landing in the first vacant hole.

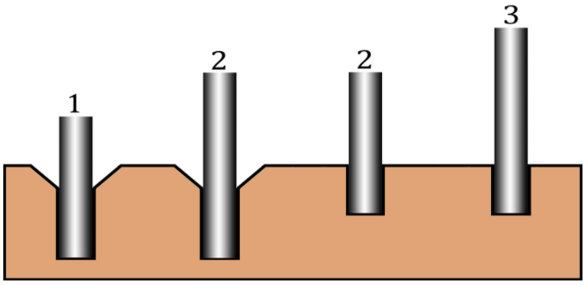

Fig. 1. Peg height as determined by peg size and hole depth.

2 The Genesis of a New Game

Interestingly, the inspiration for Cluster originated from combining elements from two sources, Fig. 2, the "Lines of Action" (LOA) game [1], and Fig. 3, the "Plunging Pegs" (PP) puzzle. In LOA, the goal is to form a connected group of one's own pieces. In PP, the goal is to align pegs of varying lengths into holes of varying depths. This ancestry highlights an important aspect of game design whereby new, "hybrid" games can emerge via recombination of elements from existing games [3], and in this case, includes the puzzle domain. It is a process somewhat akin to that of genetic recombination.

2.1 Cluster's Lineage

During Cluster's inception, Shoptaugh was working with a company named Four Generations in Sebastopol California. One of the products produced was a puzzle called "Plunging Pegs". It is a puzzle made out of a single block of wood with four holes, each at a different depth. It has eight pegs of differing lengths. The object of the puzzle is to stack two pegs into each hole such that the tops of the extending pegs are all at the same level. After playing with the puzzle quite a bit, Shoptaugh thought that it would be fun

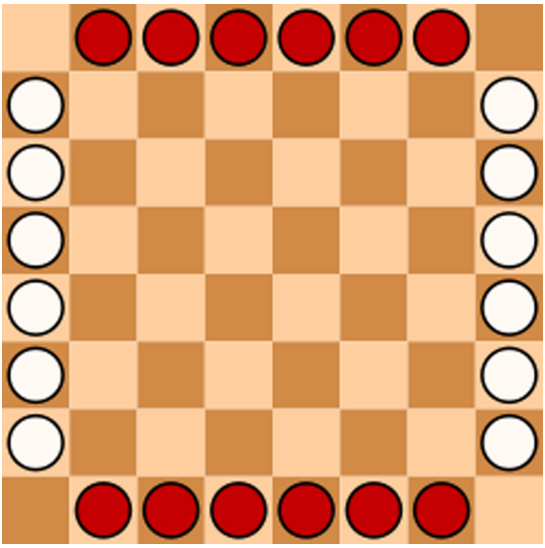

Fig. 2. Lines of Action game starting position.

Fig. 3. Plunging Pegs Puzzle.

to make a two player strategy game using the same "leveling" concept. At the time he had just created a couple of other games for Four Generations, a game called TAU (now called Calypso) and another game called Impasse (now called Shuttles). Shoptaugh also happened to be reading Sid Sackson's newly published book, "A Gamut of Games", and had reviewed Claude Soucie's game "Lines of Action" with its "grouping concept". In a moment of inspiration, Cluster was born as a two player game with two different depths

of holes, and two different lengths of pieces. The object of the game is to arrange all of one's pieces clustered together in any free formed group, all the same level, anywhere on the game board. Shoptaugh later met collectively with Sid Sackson, and Claude Soucie. Cluster met with Soucie's approval as he was complimentary of the game[1].

3 From Concept to Realization

There is no doubt that settling on the general form of the rules is a crucial milestone in a game's development. However, in addition to the rules, one must also consider the actual topology of the board and pieces. For Cluster, this topology is represented both by the number and arrangement of shallow and deep holes, along with the number and initial placement of the black and white pegs. These variables represent degrees of freedom which must ultimately be finalized prior to claiming completion of the game design. In the case of Cluster, handmade wooden prototypes were tediously produced for the purpose of experimenting with various board configurations, various depths of holes, differing initial peg positions, and even alterations to the initially proposed rules.

3.1 Design Considerations

One initial design goal was to require each player to move each one of their pieces at least once during the course of the game. This requirement was met by ensuring that none of the initial peg placements were at level 2 (Fig. 4). Specifically, a player's tall pieces are placed along the furthest row consisting of shallow holes (at opposite sides for each player). The short pieces are placed at the second furthest row of deep holes (and on the opposite side of the board with respect to that player's tall pieces).

This arrangement has the additional advantage of promoting the strategic interaction of both players' pieces during the early phase of the game since there are initially six jump moves available to each player. The remaining holes in the center of the board are spaced so that there would be both shallow and deep holes in the center of the game board, with an equal number of each kind. In order to provide a visual cue of the differing hole depths, a chamfer (i.e. countersink) appears on the top of each deep hole. This distinction reduces the memory burden of the two players allowing increased focus on strategic and tactical concerns thereby enhancing the clarity of the game[2].

Initially, the pegs were allowed to jump over other pegs only if the levels of all the pegs along the line to be jumped over were either less than or equal to the level of the jumping peg. This design proved to be both overly confusing and restrictive and thus was abandoned (Fig. 5). The final rules are both simple and elegant. A player can either step to an adjacent empty hole or jump any number of adjacent pieces on the lateral or on the diagonal, regardless of ownership or height of the pieces being jumped, landing in the first vacant hole. The layout of the shallow and deep holes in the "honeycomb" pattern was inspired by Hex, although maintaining symmetry and equal distribution of the two depths were guiding principles.

[1] Personal communications with Shoptaugh in 2009.

[2] http://www.thegamesjournal.com/articles/DefiningtheAbstract.shtml.

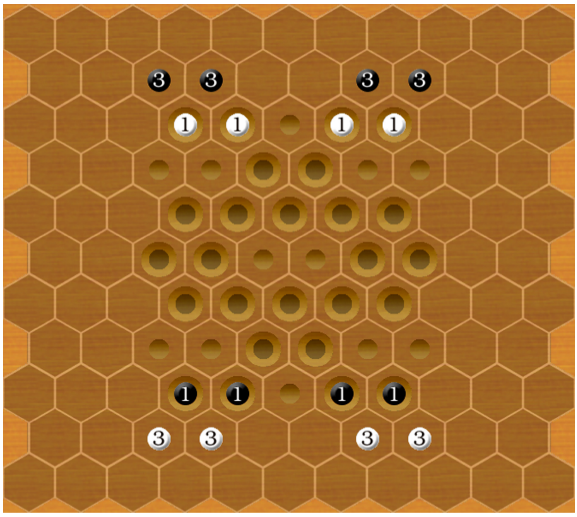

Fig. 4. Starting configuration. All pegs must be moved to win the game since none are initially at level 2.

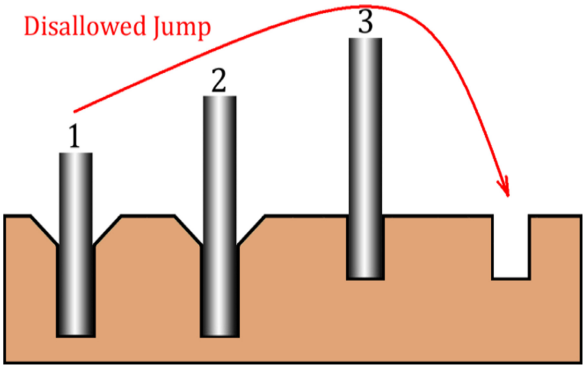

Fig. 5. Initially jumps could only occur over pegs at a less than or equal length of the jumping peg.

During the course of experimenting with the game play, there was a desire to avoid the potential problem of "first player advantage". Fortunately, this was not an issue, because in many cases the second player can jump over the opponent's initially moved piece, thereby advancing further (Fig. 6). Additionally, the layout of the differing hole depths is such that neither player can achieve an insurmountable blocking configuration during the early stages of the game. In order for a player to build a "wall", both tall and short pieces must work in unison to form a string of level 2 pieces. Even if a player creates a wall, the opponent may be able to overcome it by jumping over the wall, and in some cases strategically jump from one end of the game board to the opposite end.

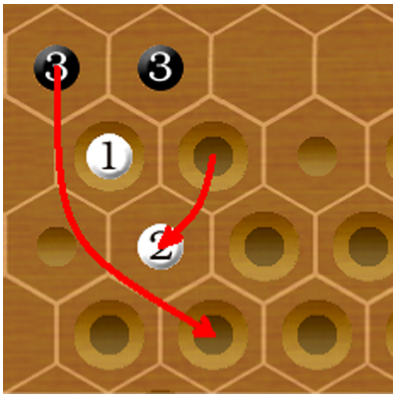

Fig. 6. Following white's initial move, black is able to advance over two pieces.

Two critical elements in winning the game are timing and position. Games between players of similar strength are usually very close with only one or two moves apart from achieving the winning "cluster" formation. As in any good strategy game, it is necessary to think ahead and carefully observe the consequences of the opponent's moves. The rules for Cluster are simple, but players of the game develop complex multi-move strategies that emerge from these simple rules.

3.2 Initial Release

The initial version of the game contained 46 holes (referred to generically as "Cluster-46") with 20 shallow holes and 26 deep holes, and with the initial peg location as shown in Fig. 7. Although two larger prototypes were also proposed, due to cost and manufacturing constraints, the smaller version was selected for production.

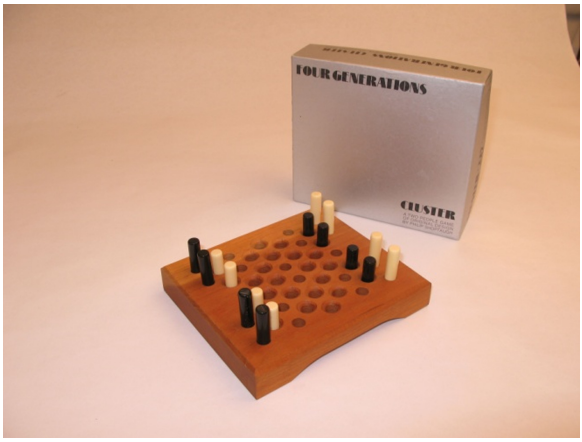

Fig. 7. The original Cluster game with Four Generations packaging, circa 1973.

Four Generations made the Cluster game for several years, circa 1972–1975, before the company went bankrupt. The combination of the peg movement rules and the connection goal along with the additional constraint of leveled pieces make Cluster a novel enough game to warrant a patent. The game was patented in 1974 [4] and the patent lists several variations, including holes which have three depths rather than two.

4 Cluster-64

During 2009, Schmidt corresponded with Shoptaugh to create an Axiom [5] computer version of the original game. At that time, he had expressed belief that the initial design of the game could be improved and wanted to experiment with some ideas. However, testing new variations of the game would require the effort intensive work of creating physical wooden prototypes. Obviously, the number of prototypes created this way is limited by both patience and physical resources.

4.1 Automating the Prototype Generation Process

What if instead of creating a Cluster computer game that was bound to a specific configuration, the designer could instead design their own Cluster game and playtest it? This idea formed the basis of a new program called "Cluster Designer"[3]. When invoked, Cluster Designer initially presents an empty board void of all holes. The game designer can subsequently place holes, both shallow and deep, on the board to create a unique hole pattern. Once the hole pattern is fully specified, an arbitrary number of black and white pegs can then be placed to form the initial placement of pieces. The completed game variation can then be saved to a computer file. The game variant is now ready to be playtested. Prior to playing a game, black and white can be assigned to either a human or an AI player.

A Cluster variation can alter the number, layout, and distribution of shallow and deep holes, as well as the number, initial placement, and distribution of short and tall pegs. Otherwise, all variations share the same rules and end of game condition. Cluster Designer's AI was designed specifically to play these variations generically. For example, the AI examines features which are common to all variations such as encouraging level 2 piece groupings and peg mobility while discouraging other negative features such as isolated pegs.

Cluster Designer was implemented as an Axiom game and presented to Shoptaugh who then began creating experimental variations of Cluster. After playtesting a variety of games ideas, he settled on a 64 hole configuration (Fig. 8), and via additional playtesting, concluded that Cluster-64 is superior to the original Cluster-46. The number of pieces per player was increased from 8 to 12 as it was determined that 12 pieces led to deeper game play with a more satisfying tempo. Having 12 pieces increases the challenge of timing the coordination of moves required to bring all pieces into play. The board size increased as well since increasing the number of pieces naturally led to a corresponding increase in the number of holes, equally split between shallow and deep.

[3] Understandably, due to a desire to prevent the proliferation of endless variations of Cluster, Shoptaugh requested that Cluster Designer not be made publically available.

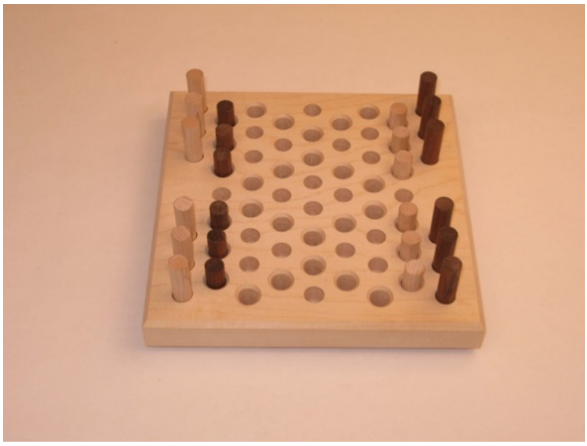

Fig. 8. Cluster-64, a.k.a. “Cluster Tournament”.

The revised game was not marketed although a small number of handmade copies were produced by Shoptaugh in his workshop. However, Cluster-64 was made more widely available via a subsequent Axiom program that includes the new Cluster-64 design along with the original Cluster-46 (a.k.a. “Cluster Classic”) version (Fig. 9). Both stand-alone Axiom PC version[4] and Zillions of Games™[5] versions are available.

Fig. 9. Axiom implementation of Cluster-64.

[4] http://www.boardgamegeek.com/filepage/46261/cluster-axiom-computer-game-pcs
[5] http://www.zillions-of-games.com/cgi-bin/zilligames/submissions.cgi?do=show;id=1760

5 Cluster-58

Fast forwarding to 2015, Shoptaugh discovered a third incarnation of Cluster (Fig. 10), played on a 58 hole board (30 shallow, 28 deep).

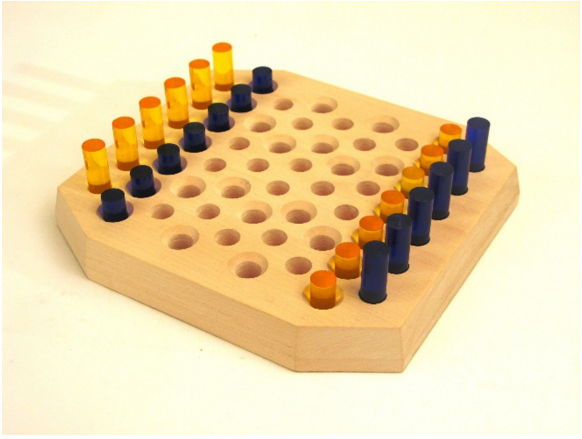

Fig. 10. The new Cluster-58.

Cluster-58 is an improvement over Cluster-64 for the reasons discussed below. Here we will illustrate the transformation of Cluster-64 to Cluster-58 as a series of incrementally improving steps.

5.1 The Refinement Process

First, the blank area gap (no holes) in the two starting rows were eliminated and the remaining six shallow holes were brought together to form a single contiguous row (Fig. 11). By eliminating the gap, players can now jump laterally across the back row. It also has the benefit of increasing clarity by eliminating potential confusion as to whether or not a player is allowed to jump laterally over the gap. Furthermore, it improves the end game play, as a player can now jump a piece laterally across the entire row, unrestricted by the former gap.

Secondly, after observing the use of the side holes during play of many games, it was determined that some of the outside, deep holes, were very infrequently used, so a total of six deep holes were eliminated from both sides of the board thus reducing the number of holes to a total of 58 (Fig. 12). By reducing the number of holes from 64 to 58, and adding one more piece per player (from 12 to 13 for a total of 26 pieces), there is improved interaction and increased competition for critical holes between the two players. However, removing these six deep holes left some undesirable gaps in the middle row.

Thirdly, some of the holes were then rearranged in such a way as to both remove the gaps and to achieve a more even distribution between the two hole types (Fig. 13).

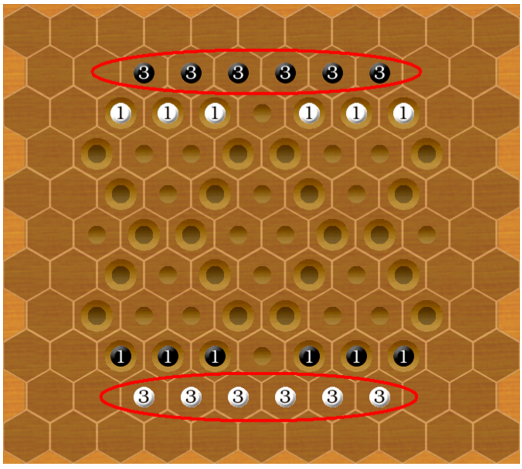

Fig. 11. Cluster-64 with starting row gaps removed.

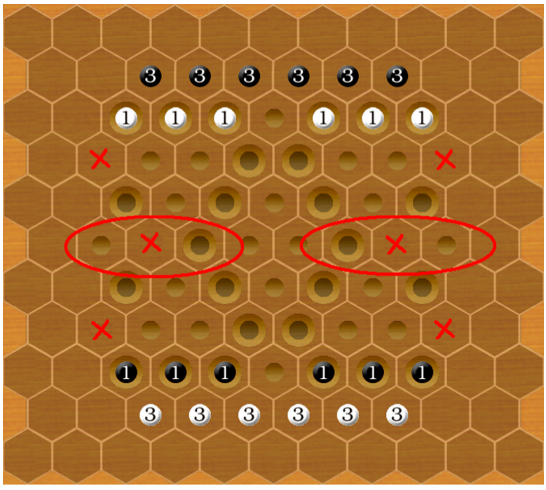

Fig. 12. Revised Cluster game with starting gaps removed and 6 deep holes eliminated.

Finally, since there is no way to divide 58 in half (yielding 29 holes of each depth) while maintaining a symmetrical board, the 2nd and 8th row shallow holes were changed to deep holes resulting in 30 shallow holes and 28 deep holes. Also, an additional piece was added for each player in order to increase the interaction between players (e.g. vying for the same shallow hole at the end of the game) as well as for aesthetic reasons (Fig. 14).

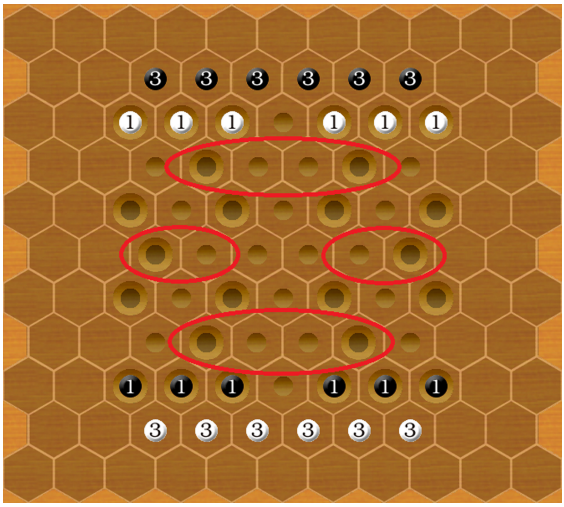

Fig. 13. Revised Cluster game following hole re-arrangement. Note the large number of shallow holes (32 shallow vs. 26 deep).

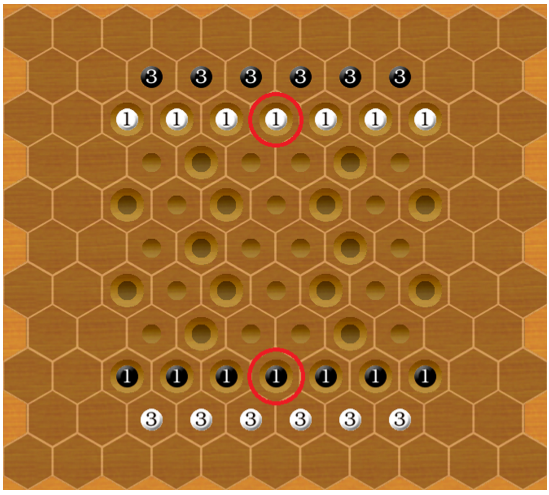

Fig. 14. Final version of Cluster (Cluster-58) now with 28 deep and 30 shallow holes and two additional pieces.

5.2 The Finalized Design

Visually, the new shape with its slightly truncated corners, (due to the gap elimination), is more aesthetically pleasing to the eye.

The revised game board is now slightly longer than it is wide and simply "felt" right to the designer. Most games end with a clear winner and rarely does a situation occur where neither player can force a win thereby ending the game in a draw. Although the

game works in a variety of configurations, it is now finalized in its preferred configuration as Cluster-58.[6]

6 Cluster Strategy

Cluster is a game where "efficiency" is of key importance. Quite frequently the games are won or lost by just a few moves, so players must be careful not to lose tempo by playing subpar moves. Listed here are a few important strategic and tactical concepts which are intrinsic to Cluster game play.

Definitions:

- A "group" is defined as a collection of connected pieces, of uniform color, all at height 2.
- A "cluster" is defined as a group containing all 13 pieces of a single color.
- A "liberty" is defined as an empty hole that is immediately adjacent to (i.e. "touching") one's group.
- A "sentinel" is defined as a piece strategically placed for the purpose of inhibiting the further growth and/or eventual completion of the opponent's cluster.

Strategic and tactical concepts:

1. **Mobility** – Maximizing the number of moves available to one's own pieces while minimizing the number of opponent moves.
2. **Center control** – Frequently, winning clusters occur at the center of the board so it's often advantageous to occupy centrally located spaces.
3. **Advancement** – It is important in advancing one's pieces to desired spaces quickly by leveraging jump moves.
4. **Group size** – In many cases, it is good to favor moves which increase the size of one's largest group.
5. **Wall formation** – A player forms a connected string of pieces, (i.e. a "wall") which splits the opponent's pieces into two groups thereby making it harder for them to unite as a single cluster.
6. **Fork** – Moving a piece to an intermediate location such that in a subsequent move, it can connect to a group in more than one way.
7. **Adequate Liberties** – One must ensure that sufficient liberties exist in order to complete the cluster. Note that this includes taking into consideration the hole depths of these liberties in conjunction with the length of the remaining "stray" pieces such that they will eventually mate at the correct height as they are assimilated into the group.
8. **Offensive moves** – A player can inhibit the formation of the opponent's cluster by deliberately placing a piece in one of the opponent's liberties. By strategically placing a sentinel, it's possible to "starve" the opponent's group thereby thwarting

[6] Cluster-58 will be commercially marketed in late 2016.

its completion. If the sentinel is not already part of the offensive player's group, it must eventually be moved. An expert player using this tactic can sometimes defer movement of their sentinel such that it becomes the final winning move. Note that just as in a "fork", a "block" can prevent multiple pieces from connecting.

9. **Tempo** – It's important not to get too far behind in the game. Although tempo is critical during all phases of the game, an advanced player can obtain a good sense of tempo during the end game by counting the number of moves required for each player to turn their largest group into a cluster.

Figure 15 illustrates a few of these concepts. White's attempt at forming a cluster is inhibited by the fact that it is bounded by the south and east edges of the board. Consequently, white has a limited number of liberties available. Furthermore, black has a sentinel which prevents white's group from becoming a cluster. White's only option is to relocate its group to another place on the board. However, doing so would result in white losing tempo, a serious disadvantage since black requires comparatively few remaining moves to win. This example also highlights the pitfall of increasing one's group size at the expense of sacrificing the liberties required to eventually form a cluster.

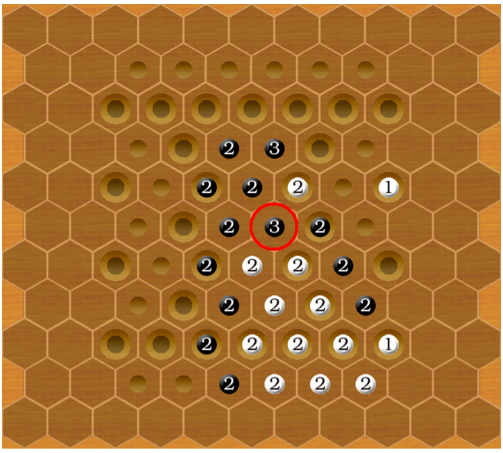

Fig. 15. White's group is lacking liberties. Note black's sentinel.

7 Experimental Game Designs

Included here is a sampling of a few experimental game designs considered, but not adopted since the goal was to converge on a single "best" version of Cluster. Playtesting revealed that although these game variations were both viable and playable, each had its shortcomings. However, if producing a "suite" of Cluster game variations had instead been the goal, then these games might serve as potential candidates.

1. "**Cluster-82**" (Fig. 16) – A large version of the game. It served as a starting point for paring down the size and number of pieces until the "optimal" configuration of the Cluster-58 version was finally settled upon.

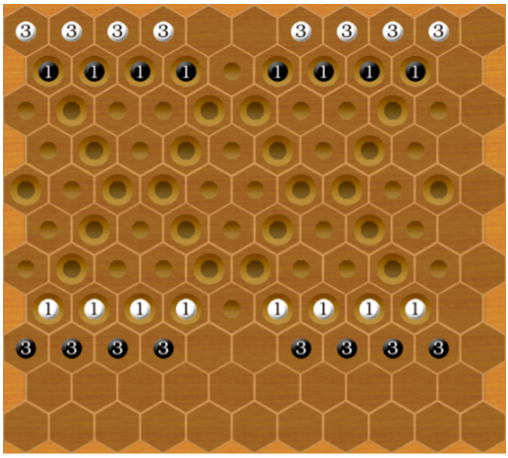

Fig. 16. Cluster-82.

2. "**Cluster-80**" (Fig. 17) – A large version of the game played on a hexagonal board. It was found that A ratio of 80 spaces to 22 pieces does not work well because the players often tend to avoid each other and the game becomes more of a race than a "thought provoking" positional game

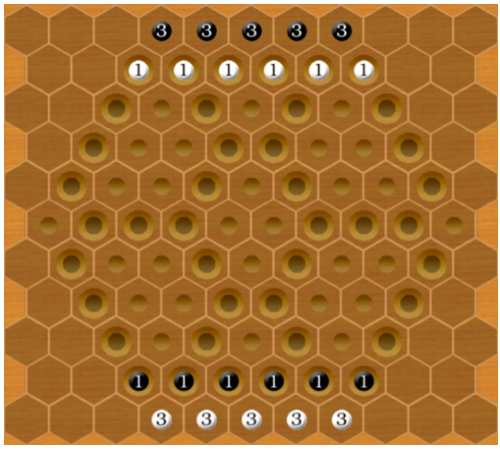

Fig. 17. Cluster-80 featuring a hexagonal hole Pattern.

3. "**Cluster-30**" (Fig. 18) – A "mini" version of the game. Due to the small number of holes, there is much less flexibility to the games.

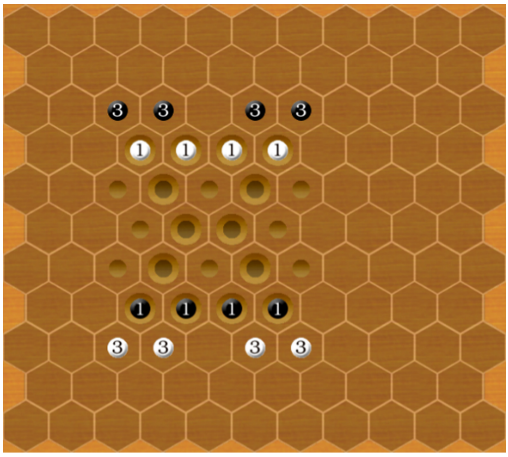

Fig. 18. Cluster-30, an experimental "mini" variation.

8 Piece to Space Ratio

An important discovery is that Cluster works much better and becomes more enjoyable when there is a higher level of interaction between the players' pieces. When there is a higher degree of scarcity of spaces at both hole depths, this results in increased competition between the players and they are required to do more strategic and tactical planning in order to form a cluster. Via extensive playtesting, a 2:1 ratio between game board spaces and total number of pieces appears to work best. The main design challenge was to discover a board topology that approximates this ratio while yielding a symmetrical and elegant aesthetic design. Note that the final Cluster-58 game board has a 2.23:1 ratio of spaces to pieces.

9 Design Heuristic Synopsis

As discussed, there were a number of heuristics that motivated the sequence of the Cluster designs. The most important ones are summarized below:

- **Board topology** – Refers to the overall shape of the board and how it affects game play. It includes effective distribution of the hole depths, consideration of the effect of gaps, and removal of infrequently used spaces.
- **Piece count and initial piece placement** – Refers to the number and initial placement of the pieces. Typically it has the largest effect during the opening phase of the game. However, it can also lead to longer range effects such as requiring all pieces to be moved at least once (as in the case where no initial piece is at level 2).
- **Piece to space ratio** - Affects the level of interaction of the pieces as well as the tempo of the game.
- **Rule simplicity** – The goal is to ensure that the rules are not unnecessarily complex.

- **Minimizing the potential for draws** – Ideally, most if not all games result in a clear winner. The rules, the board topology, and the piece count can have significant impact on this goal.
- **First player advantage** – The goal is to ensure that the second player can make a comparably strong reply to the first player's initial move.
- **Balance** – One player should not be able to easily "tip the scales" too easily such that the other player cannot recover.
- **Aesthetics & symmetry** – A subjective consideration which can often lead to aesthetically pleasing and balanced designs. It can positively affect both game play and player satisfaction.
- **Use of visual cues** – The goal is to reduce the player's mental burden on the game mechanics, thereby allowing greater focus on the game play itself.

Note that the above design heuristics are general enough that, in many cases, they may be applicable to games other than Cluster.

10 Game Design Wisdom

Each game design has its own key core elements that must be discovered and exploited in order to optimize the game play experience. Finding and refining these elements is arguably a blend of art and science. Aesthetics and intuition apply mainly to the "art" aspect, whereas applying one's knowledge base of game design heuristics, coupled with extensive playtesting, apply to the more formal "science" side. In retrospect, the Cluster design experience has revealed the following "wisdom" for approaching game design.

1. Don't quit or finalize your design too soon. In other words, your game may be good, but it might not be in its "preferred form".
2. Be open to making changes. Keep working until it cannot be improved any further. Be obsessed about your project and stay with it until it "feels" right.
3. Simplify the rules, and the format. Strive for elegance and avoid complexities, i.e. "less is more".
4. Be sure to thoroughly playtest your game. If there are any "flaws" either in the rules or in the topology of the game board, then determine and identify the problem and make changes to remove them. Don't "fall in love" with your first creation, as it most likely can be improved.
5. Try to holistically refine your game in order to find the optimum combination of rules, format, materials, sizes, shapes, colors, etc. until you feel that it cannot be improved any more. Clarity and aesthetics do matter here.

11 Conclusion

New game designs often arise by combining existing game concepts, and in the case of Cluster, may involve puzzle concepts as well. Recombination represents a powerful tool for game invention. Once the basis for the new game has been established, further

refinement based on applying a variety of game design heuristics can be considered and then evaluated through playtesting.

In the case of Cluster, the variations are primarily based on the form of the shallow/deep hole configuration along with the initial setup of the pegs. These various setups can only be effectively evaluated via persistent experimentation and extensive playtesting.

The utilization of computer assisted game design software has so far provided two major benefits. Not only has it eliminated the need for physical prototypes, it has also accelerated the playtesting phase of proposed variations thereby promoting the discovery of new candidate variations.

Future work should explore this potential further. For example, through computer self-play that facilitates logging and replay of a series of games, various metrics of a specific game variation can be examined and assessed. For example, these metrics may include the degree of first player advantage and the average number of moves per game. Additionally, observing the automated games in a "replay" fashion may likely yield further strategic insights into effective game play.

As we have witnessed with Cluster, the improvement process may even span decades. As new insights are found, improved variations of the game are discovered constituting a "plateau" or "sub-optima" in the game's fitness landscape (e.g. an extreme example is the evolution of Chess rules over a period of centuries[7]). Finally, this design experience has revealed some general "wisdom", useful for approaching game design. The evolution of Cluster from Cluster-46 to Cluster-64, and ultimately to the current Cluster-58, offers an excellent example of applying these processes and principles.

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[7] See http://www.chess.com/groups/forumview/history-of-chess-rules