A BOARD GAME AND CYBERNETICS

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Abstract

Complex adaptive systems use a great amount of computer simulations to generate data and emphasize patterns in systems. In order to simulate a systems complex behavior in a faster and more pleasant maner we have used a multi-player non-deterministic board game. Our conviction was that games can serve as an interactive education tool and we wanted to help students understand the properties of a complex adaptive systems. As a cybernetic system, the rules of a game define the sensors, comparators, and activators of the game's feedback loops. Within a game, there are many sub-systems that regulate the flow of play, dynamically changing and transforming game elements. Incorporating a game such as The Settlers of Catan into a classroom increased students' engagement and helped them retrieve insight about how feedback loops look like in real life and what's the exemplification of an adaptive behavior. The aim of this article is to share the relevance of the use of SOC for learning about complex adaptive systems.

Keywords: *Board Game, Complex Adaptive System, Learning*

Classification JEL: *C78, M10*

1. INTRODUCTION

The applicability of complex systems concepts and methodologies, to a wide range of natural and social phenomena offers a rich palette for educators to reach students and help them learn important scientific knowledge and skills (Jacobsen, 2000) [5]. A way to explain undesired or unexpected behavior in a real-world system, such as power black outs, economic market crises and social systems, is to consider the system at hand as a complex adaptive system (CAS) (Kauffman, 1993[7]; Gell-Mann [3], 1994; Holland, 1995[4]). Games can simulate a real complex adaptive system and provide conditions for the learning and understanding of their behavior. "Settlers of Catan" was published in Germany in 1995. The gameplay includes a shifting initial setup, strategy, elements of randomness, and asymmetric information. The board game "Settlers of Catan" can be played by three or more people, which make it suitable for investigating multi-player strategic decision making. Research is indicating that SOC has several CAS characteristics which are described in the following subsections.

2. LEARNING ABOUT COMPLEX ADAPTIVE SYSTEMS BY PLAYING CATAN

Adaptive systems are a model for thinking about the world around us. In nearly all situations we can view what is happening in Complex Adaptive Systems and that this opens a variety of new options which gives more alternatives and more freedom. First, we should check if the game has

the properties of complex systems: many elements and variables, nonlinear relations between these elements and variables, uncertainty about the state of elements, the values of variables, and the relations. In SOC players are the subsystems and we can also identify variables, relations, adaptive feedback loops and their uncertainties.

The standard set-up of the SOC consists of plenty of elements: 18 resource terrain tiles and 1 dessert tile, 6 sea frame pieces that together contain 9 ports, 18 number tokens and 1 robber, 95 Resource Cards, 25 Development Cards (14 Knight Cards, 6 Progress Cards and 5 Victory Point Cards), 2 Special Cards: Longest Road and Largest Army, 16 city pieces, 20 settlement pieces, 60 road pieces (Teuber, 2005) [8].

Complexity results from the inter-relationship, interaction and interconnectivity of the elements within a system and between a system and its environment. This implies that a decision or action by one part within a system, will influence all other related parts. This happens in the game when players' choices are influenced by the other players' moves. With co-evolution, elements in a system can change based on their interactions with one another and with the environment. In the game, if Player X changes its strategy, the other players will respond and the landscape will change. CAS are sensitive due to their dependence on initial conditions. There is constant action and reaction to what other players are doing, thus nothing in the environment is essentially fixed. Any coherent behavior in the system game arises from competition and cooperation among the players themselves.

The game contains some negative feedback loops. When a player has a lot of resources and a 7 is rolled, they must discard half of their resources. A positive feedback loop appears because the more settlements a player has, the more resources they are likely to get per turn. A lot of the negative and positive feedback loops are affected by how the players play the game, some players may try to make it harder for the player they perceive to be winning, and others may try to help losing players in exchange for some sort of trade agreement.

Players can choose from a large action-set, and they must balance long and short-term decisions. There is an element of chance for resource production, and interaction with the opponents is required for negotiation. As noted earlier, some degree of nondeterminism is needed for a system to be a complex adaptive one. Based on these observations, we conclude that SOC can be regarded as CAS.

3. UNDERSTANDING COMPLEX ADAPTIVE SYSTEMS BY PLAYING CATAN

Incentives are drawn from a broader belief, that an appreciation and understanding of the world as comprising interlocked complex systems is critical for all citizens in making effective decisions about their lives as both individuals and as community members.

The educational aims that are met in these studies include displayed awareness of the comprehensive nature of the problem and the need to consider each of the different parts, their interactions and interdependence, and their functions in creating the system itself (English, 2007)[2].

Of central importance to education and simulation gaming are the conditions under which learning may occur. It is suggested that students (and many adults) may have difficulty learning about complex systems if the focus is only on the conceptual level. At the same time, an enrichment of the students' conceptual toolkit is suggested to increase students' expertise (Jacobsen, 2006)[6]. Other reports indicate that students were best able to develop a deeper understanding of the observed phenomena when they made connections between the micro and macro- levels of the phenomena, while most school curricula deal with macro and micro

phenomena in separate classes (Wilensky and Resnick, 1999) [10]. The above observations represent necessary conditions that need to be satisfied for learning about CAS to emerge.

The game model is influenced and adapts to the players, while these players are influenced by, react and adapt to the model. Thus, both players and simulation models are adaptive, and together form a CAS. In the above observations, the connecting concepts of CAS introduced earlier – hierarchy (layers), processes, the human agent and adaptation – are found useful. Using these concepts and phenomena for analyzing games, we observe that not all games can be considered as complex.

The game is played in two phases: the initial set-up phase and the game phase. The initial phase comprises of island construction, distribution of pieces and positioning two settlement and road pieces of each player on the board. There are various possibilities for island construction, in fact, a random approach can be followed if desired. In order to win in the board game "The Settlers of Catan" you must be the first player to reach 10 Points. These are gained by building settlements and cities, constructing the longest road, or raising the largest army. This is a challenge to all the players involved because any player could take away the points you achieved for getting one of these feats.

The game board is made up of tiles that produce resources listed in Figure 1. Players begin by placing two settlements at the intersections of these tiles. Throughout the game they collect resources based on the tiles which are adjacent to their settlements. These resources can then be used to build roads, settlements, cities or buy development cards. Each of these items counts for various numbers of points. (Teuber, 2005) [8]

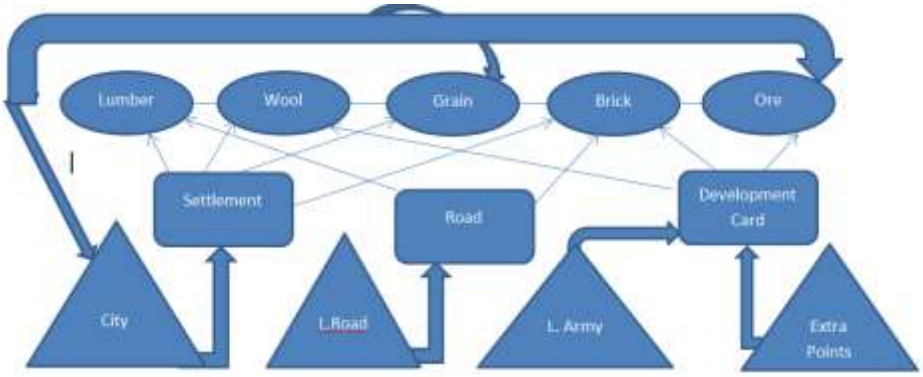

Figure 1: Game rules

A table of the items which can be built, the resources used to build them, and the number of victory points earned is shown in Table 1. All future settlements are worth an additional victory point and must be connected to one of the original settlements by a continuous path of roads. Cities are an upgrade of existing settlements. Players earn a double amount of resources and score two victory points. Development cards contain various one-use bonuses which help players advance the game for free. Settlements can be built at the corner intersections between the hexagon tiles, with the restriction that all settlements must be at least two hexagon sides apart.

Choosing the best initial settlements is a critical part of overall success in the game. Each player who has a settlement on an intersection marked with the number corresponding to the outcome of a dice roll, receives one Resource Card of the tile's type. If the player has two or three settlements bordering the same tile, he/she receives one Resource Card for each settlement. The players receive two Resource Cards of the same type for each city bordering the active tile. If there is not enough Recourse Cards in the main card deck to supply everyone, no one receives any resources that turn. If a player rolls a 7, instead of resource distribution, the following happens before the trading can continue: (a) All players that possess more than seven resources must select half (rounded down) and return it to the supply stack, (b) The player in turn has to move the robber to another terrain tile

to block resource production, (c) The player can choose to steal one Resource Card from any player occupying the selected terrain tile. All players that have settlements or cities positioned around the blocked tile do not get any resources when the production number is rolled. The robber may be moved to the desert tile, where it does not block any production until the next seven is rolled or a Knight Card is played.

Table 1. Items and Resources

Items\Resources	Lumber	Brick	Wool	Grain	Ore	Victory Points
Road	1	1				2 for longest road of total length at least 5
Settlement	1	1	1	1		1
City				2	3	2
Development card			1	1	1	2 for largest army; 1 possible on some cards

After the resource production, each player is allowed to trade freely, using one or both types of trading. In a Domestic Trade, the player in turn can announce what type of resource he wants to trade for what price. Other players can trade only their Resource Cards with the player in turn, while trying to negotiate for the best possible trade. Once the trading has been finished, the player in turn can proceed to build new elements on board to gain Victory Points, expand the territory, improve the resource production and/or buy Development Cards.

With an ever-changing game board layout, it is important to have a strategy for initial settlement placement. Developing such a strategy poses an interesting problem with many possible solutions ranging from very simple to more complex. Many players quickly develop a personal strategy for success in the game based on preference and experience. Some players like to avoid duplicate numbers and would not choose a second settlement on a tile which shares the same number as a tile adjacent to their first settlement. Although game rules are important for the balance and fairness of the game, players can be expected to show strategic behavior, circumvent rules and cheat. Each player not only acts based on what he senses and perceives at the moment, or has experienced in the game session. He also acts, based on a unique history which is largely unknown to us, illustrating path dependency. To conclude this non-exhaustive series of observer handicaps, no exact relations are known between players' unique histories and their current in-game decisions. Although an individual player may have access to his individual information and relations, he is still a handicapped observer of the rest of the group.

To achieve understanding, players must be tempted to look for interdependencies, pay attention to long-term effects, perceive complex cause-effect relations, and identify emergence in the system. By switching roles, players can adapt and learn to understand different perspectives, experience the system from different angles, and learn from these differences (Duke and Geurts, 2004 [1]; Mayer, 2009 [9]). In short, it is found that a complete view, an understanding of different perspectives, an experience of the system from different angles, all support understanding and learning of CAS. Sufficient time ought to be spent on the debriefing of the game. If they are open for it, players of simulation games step into a learning experience.

The elements of the game interact dynamically, and the interactions can be physical in building cities and settlements or they involve the exchange of information and resources. The interactions are non-linear because small changes in inputs can cause large effects or very significant changes in outputs. For example, a surprise card can provide you monopoly on a resource or the 3 missing points that a player needs in order to win the game. Also, any interaction can feed back onto itself directly or after a number of intervening stages. Such feedback can vary in quality. We can take as

an example the fact that 2 players might compete for the longest road card. They keep switching it between each other, after building new rows.

Also on the player group level, the unique history of the game session up to a point in time, influences the decisions for the remaining duration of the game. The results of one round positively and negatively feedback as input to the next round, indicating again path dependency, but now on the game process level. In groups, one may also observe tipping points as for example group opinion sways and suddenly tips over to a favored view, often advocated by an active, extravert or lead personality.

A puzzle, for example, has only one final state, which is independent of the path chosen. Even though it is not possible to model the whole world, managers and students must be supported to try and look at the simulation model (of reality) from a higher level and develop a complete – almost holistic – view. Therefore, the system needs to be modelled (mentally or otherwise) in a dynamic but complete way, focusing on feedbacks, non-linear development, and system behavior on both the short and long term.

4. CONCLUSIONS

The aim of this article was to assess the relevance of the use of SOC for learning about CAS. First, CAS concepts were introduced, which connect the micro level to the macroscopic phenomena. In order to adequately simulate a CAS, a game must be a CAS itself. It immediately followed that the game must consist of numerous different elements, with many relations and multiple possible outcomes. By taking players as interacting subsystems, SOC were established to be CAS themselves. The game can be considered a valuable method for learning and one of the few tools to accomplish this in complex adaptive systems. Considering games as learning systems opens the door to consideration of the system being as sustainable and adaptable as it can. Sustainability, adaptation potential, and engagement levels emerge from the 'game as learning system' discussion in order to provide insight into the functioning of the game. High levels of engagement and sustainability are the presented goals for teachers working from a complexity thinking perspective.

Incorporating a game such as The Settlers of Catan into a classroom has the potential to increase students' engagement and facilitate the use of mathematical concepts in iterative problem solving.

This context allows students to develop a strategy, quantify it mathematically, experiment with it by playing the game according to their proposed strategy, and possibly return to their strategy for revision. In addition to the variety of approaches discussed in this article, students who are more familiar with the game may derive their own strategies, such as assigning value to blocking other players from attractive adjacent locations. Additional strategies could come from aspects of the game not detailed here, including ports, a robber, and rules about trading and placement. The possible connections between "The Settlers of Catan" and cybernetics do not end here. For example, there are applications in graph theory and combinatorics. These many possibilities make The Settlers of Catan an interesting example which can be used to explore many aspects of both entry-level and advanced cybernetics in an innovative and fun way.

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