The Exploration of Engineering Hybrid Modeling Strategies Applied to World Cup Soccer

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Abstract

Given the challenges of modeling multi-scale social phenomena, hybrids may hold the key to unlocking social complexity dynamics. We introduce hybrid system modeling from engineering, as a means to capture complex dynamics within interacting, multi-scale, and global social systems. Whereby hybrid modeling is used in industrial processes and automated control systems, this research uses world cup soccer tournament simulations to demonstrate successful applications. Agent-based modeling for soccer games and cellular automatons for crowd and bettor emotional reactions are modeled on each side of a playing field. A predator-prey theoretical approach is applied with self-organizing soccer teams represented as predators and the soccer ball as prey. Simulations of multiple soccer tournaments of thirty-two teams were conducted with pre-game betting and without betting as a pseudo-control measure. Tournaments conducted with pre-game betting resulted in the final tournament games having the wining team demonstrating strong defensive playing styles and scoring by a large margin. Divergence of playing styles did not develop in tournaments without pre-game betting. Hybrids offer a means to explore complexity with evolutionary learning by players, corresponding emotional reactions of spectators, and betting interacting, resulting in patterns of emergent behavior and unique evolutionary behavioral responses to complexity.

Introduction

Hybrid modeling, characterized by discrete and continuous dynamics with interconnected structure for complexity decomposition in engineering and applied mathematics, has proven effective in areas like complex industrial processes and automated control systems (Diepold, Winkler, and Lohmann 2010) (Branicky 1995). However, hybrid system representations also have the unique potential to capture complex dynamics within complex and interconnected social systems like world cup soccer and gambling.

Social life as we perceive it occurs in both physical and geographic space on continuous and discrete time scales. Systems that operate on diverse scales can be evaluated in terms of both physical description and simulation. In order to better understand complex social systems and resulting behavior, agent-based modeling can be effectively used as an illustrative, analytical tool for presenting "what could be" in research analysis, discovering the most likely of unlikely events. Through modeling properties of locality and interactions, local and global levels can be captured through agent-based modeling simulations (Page 2009) (Johnson 2010). Applying this tool to globally escalating sports gambling nested within a global sporting culture can provide a representational model whereby complex global systems are directly represented. There continues to be growing interest in sport cultures but scant research and data on how gambling interacts. So theoretically, how do hybrid complexity strategies contribute to real world networks like cultural systems? Additionally in applying the theoretical, what is the impact of nationally sanctified betting on national team success?

Background

Complexity science research entails tackling some of the most fundamentally challenging phenomena, emergent

organization of interrelating agents of global systems. Complexity science continues to offer new insights and understanding of complex adaptive systems (CAS) we find in the world around us. However, in one entire system the number of subsystems, varying scales, levels and directions of interactions, can be daunting to include in a single agent-based model. In response, the blending of established agent-based modeling techniques can be incorporated into an interacting network to create a hybrid framework to address this. A hybrid framework allows for combining agent-base model types with varying structures, on various scales, and with simultaneous interactions into one model. A hybrid approach additionally, allows for flexibility and provides the capacity to capture multi-level interactions of different complex systems nested within the entire system. Whereby hybrid approaches to complex systems have been successfully used in engineering, there is an opportunity to expand this approach and apply the framework to non-linear, social systems of complexity. Also, a bottom-up approach of agent self-organization can be integrated into a hybrid to better mirror the real world of social phenomena.

Model Description

The agent-based model is an event-driven, bottom-up complex adaptive system (CAS) simulation whereby soccer players, global crowd, and betting agents have an opportunity for interactions in their respective environments in each iteration. The soccer players are endowed with evolutionary learning capacity. Each time a player makes a mistake like allowing a goal, allowing a pass, or causing a turnover, they lose a point. Each time a player makes a good play like steal, block opponent, score goal, or successfully make a pass, they gain a point. Over a number of events some players get replaced. The new player is created from the playing statistics randomly generated on a normal distribution of the means of the average players. The model is scaled on the level of the soccer players and game, stadium with crowds, and global scale of spectators and possible bettors.

The model employs agents that are sorted into two teams and operate on self-organization properties. The crowd agents serve as spectators that can influence the game by emotional responses and in turn the game actions can influence them emotionally.

Methods

The simulation employs a combination of logic (agent-based) modeling, cellular automaton (recurrent fuzzy-based), and differential equations which all interact simultaneously creating the hybrid systems' dynamics. A predator-prey theoretical approach is applied for simulation of the soccer games with 32 teams competing in the tournament. The world cup soccer players and teams are represented as predators, and the soccer ball as prey, impacting local and global interactions by logic-based modeling. Each soccer player has attributes like error rate for goal shot or passes, level of aggressiveness, and self-confidence. These attributes are continuously adapted based on differential equations during each game. The connecting parameter between the players' attributes and the spectators is the game atmosphere inside the stadium, which clearly depends on the players, as well as on the spectators.

The soccer spectators are modeled via recurrent fuzzy-based cellular automaton as follows: emotional states x (e.g. happy, angry, and disappointed) were defined. A rule based interconnection of the actual state of a person x(t), its neighbor's emotional state, and their odds (winning or losing money) lead to their new emotional state x(t + 1). To overcome the disadvantage of a conventional cellular automaton, which just allows staying in a strict defined state, the automaton represented in the model are expressed as a recurrent fuzzy system. This enables a person to be in a state ⌣x(t), which is somewhere in-between all the defined x(t).

The global gambling odds in the world cup soccer simulation are represented by time discrete differential equations iterating from one game to the next. As human behavior is non-deterministic, a Gaussian distribution-based random variance of the above-defined deterministic behaviors is enabled.

Overall Hybrid System

The model is based on three sub-systems comprised of a soccer game, global crowd, and global gambling. The systems are interconnected and loops exist leading to dynamical behavior during one game event. The soccer game agent-base model, crowd cellular automatons, and global gambling as a discrete-event driven system, iterate from one game to the next. Thus the model captures information from one game to the next and information within one game, which results in a multi-time scale expression or a complex hybrid system.

1.Agent-Based Model
Players: attributes *a(t)*, error rate *r(t)*, atmosphere *x(t)*

2.Cellular Automaton
Game-based: crowd emotional responses to game getting close, very close, and goal.
Neighbor-based: Moore Neighborhood.

Gambling-based: sports betting, winning or losing money.

3.Gambling Recurrent Fuzzy Model-Gambling odds $g(t)$, winning team $s(t)$, bookie.

Crowd behavior depending on probability

$$x(t + 1) = f(p, x(t), g(game)$$

Actual betting situation neighbors surrounding each person

$$x(t + 1) = f(p, x(t), x')$$

Soccer game

$$x(t + 1) f)p, x,(t), d(t,a(t)))$$

4.Merging the equations together:

Attributes of the soccer player, which depends on the crowd:

$$x(t + 1) = f(p_x, x(t), d(a(t)), g(game))$$

$$a(t + 1) = f(p, a(t), x(t), r(t), a(t))$$

Evolving gambling iterates from one game to the next:

$$g(game + 1) = f(p_g, g(game), s(a(t))$$

Initial values of the player's attributes and crowd's mood for new game are calculated based on the old game:

$$a_O(game =1) = f(p, a(game))$$

$$x_O(game = 1) = f(p_x, x(game))$$

Results

The results show pre-game betting has a significant impact on the outcome of the final tournament game. Simulations with gambling most notably demonstrate the final game evolving into strategies whereby; one team displays strong defensive characteristics such as man-to-man coverage. In contrast, the opposing teams focus almost entirely on strong offensive characteristics such as effective passing. Further results demonstrate that a more defense-oriented team is almost always the winner of the tournament by a wide margin. Additionally, the divergence of playing styles does not appear to develop and evolve in non-gambling simulations. Further research is needed to support preliminary evidence that betting may contribute to a team's unique style of play and the ultimate creation of vastly superior teams.

Conclusions

The goal of this research is to gain more insight into the complex dynamics of global social cultural systems, which were modeled in the form of world cup soccer. We believe this type of research can be further developed to expand the modeling of gambling behaviors, attitudes, and trends from a global perspective. There is yet to be substantial data on critical areas of concern like portion of global population that gambles on sports legally and in non- government sanctioned gambling countries, along with correlating symptoms of gambling addiction and related personal debt issues. Hybrid modeling strategies can be implemented to further address these concerns.

This research shows hybrid-modeling strategies can be effectively applied to complex social system phenomena. Hybrids can demonstrate the features of complex adaptive systems (CAS) of emergence, unique behavioral responses to complexity, and self-organization descriptions. Hybrid strategies applied to social systems offer great potential modeling interacting systems with limited resources. These represent a wide-range of complex adaptive systems (CAS).

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