Hypergame Theory for DTGT Agents

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Abstract

In this work, hypergame theory has been extended to record decision theoretic and game theoretic information in a single table, called the hypergame normal form. A two-player, zero-sum, single-stage hypergame has been provided in this paper to describe a decision-making situation. Hypergame expected utility is introduced as an embellished concept of expected utility that provides an estimate of the benefits and risks of this approach. Hypergame expected utility provides a preference criterion for selecting options or plans. This article does not address repeated play and learning, but does provide a new interpretation of the game theoretic concept of the Nash Equilibrium Mixed Strategy, which is often attributed to repeated play situations.

Introduction

Decision theory and game theory are the two primary approaches to selecting alternatives. Unfortunately, they often recommend different solutions to the same decision-making situation. Decision theory is too optimistic, particularly in competitive situations, often ignoring possibly damaging results because of the beliefs of the decision-maker. On the other hand, game theory requires too much information to be shared by opponents in situations where both players should be attempting to mask such information. Game theory does not allow information about the opponent's behavior, doctrine, sensors or training to have any influence on modeling expected behavior. Thus, the game theoretic concept of consistent alignment of beliefs is unlikely to be true in anything but a game. This observation casts serious doubts on reliance of using game theory in relying on so-called mixed strategies as a prescription of my play.

Starting with a descriptive observation of the German General Staff's apparent planning before the French campaign of 1940 and observing how it diverges from game theory, Bennett and Dando (1979) described a new competitive reasoning approach, that they called hypergame theory. They had decoupled the reasoning of the two staffs, allowing the French to ignore the Ardennes forest because it was so detrimental to successful attack. By reasoning about how the French might exclude a serious consideration of the Ardennes, the German Army planned a quickly moving attack, one built on radio and perfected a year earlier in Poland, called Blitzkrieg. By placing field grade officers in the lead armored fighting vehicles, General Guderian was able to see the battlefield better than his telephone-bound adversaries. As a result the attack split the Allied Army and resulted in an incredible victory.

Several years after this original idea at explaining non-game theoretic behavior, Bennett and Huxham (1982), submitted a more formal theory. It was based on two or more completely separate games that were designed to model an opponent's thoughts. It was couched in the language of game theory, but it resulted in recommendations that were quite different from game theory. I believe that they exhibited veryy independent and innovative thought to develop a competing approach to fashionable game theory. Their theory used a subset of the options available to both players to describe an opponent, what is now called subgame reasoning. It does not appear that the intellectual foray was met with much encouragement.

The approach explained in this poster session paper addresses many of the properties of a hypergame both as a problem capturing structure and as a solution to adversarial games. Hypergames have been extended to explicitly include decision theoretic models of opponent behavior as well as subgame reasoning. The problem and proposed solutions have been joined into the hypergame normal form in this work rather than a series of sequential games.

Lastly, an introduction to hypergame expected utility is explained to show that decision theory and game theory can peacefully co-exist in a single representation that highlights the strengths of both.

Hypergame Normal Form

In this section a simple game, called Rock-Scissors and Paper (RSP) will be modeled in the hypergame normal form. It is chosen because of its transparency, not because its model of reality is an interesting domain.

			C_Σ	.866	.067	.067
	.8		Belief 2	1	0	0
		.2	Belief 1	.333	.333	.333
Model Opponent	B 2	NEMS full game		R	S	P
0	-	.333	Rock	0	1	-1
0	-	.333	Scissors	-1	0	1
1	-	.333	Paper	1	-1	0
.8	-	0	EU(*,CS)			
-1	-	0	EU(*, G)			

Figure 1. Rock-Scissors-Paper Hypergame

In figure 1, the payoff matrix for the game is seen in the lower right hand corner of the hypergame. In it, the payoffs for the Row player are placed at the intersection of a row and column. The row represents the Row player's choice and the column represents the choice of the opponent, the Column player. The payoff values range between a win, represented by a one for the Row player and a loss, represented by a negative one. Game theory and hypergame theory share this representation of the upcoming decision.

The total belief picture is captured in the top row of the hypergame normal form, labeled C_Σ, which is a summary of the Row player's beliefs about Column's upcoming play. By convention the game theoretic mixed strategy, which is also called the Nash Equilibrium Mixed Strategy (or NEMS) solution is provided in the first belief context. The second belief context is that of the Row player about the Column player. This is the belief that is based on knowledge, sensing, and reasoning. It may be decision theoretic in nature as shown in this example or based on a subgame (a game which includes a subset of the rows and columns of the full game). The weighting of these contributing probability vectors is placed to the left of each. In the example the Row player thinks that it is .8 likely that the Column player will choose the 'rock' column. More information about this process will be included in the full paper.

Hypergame Expected Utility

Hypergames are solved by evaluating plan selection strategies, called hyperstrategies (Vane 2000). These are placed on the left side of the hypergame normal form. A hyperstrategy is a probability vector over all of the available options. A hyperstrategy can be a game theoretic mixed strategy or a decision theoretic one.

Row's best choice for the beliefs summarized in C_Σ is the row labeled 'Paper.' This approach has been called the 'model opponent' selection strategy, or hyperstrategy. Its expected utility is calculated similar to game theory and represents the utilities weighted by the 'model opponent' probability vector and C_Σ. However 'model opponent' represents a decision theoretic approach to the game, since it is based solely on Column's expected play.

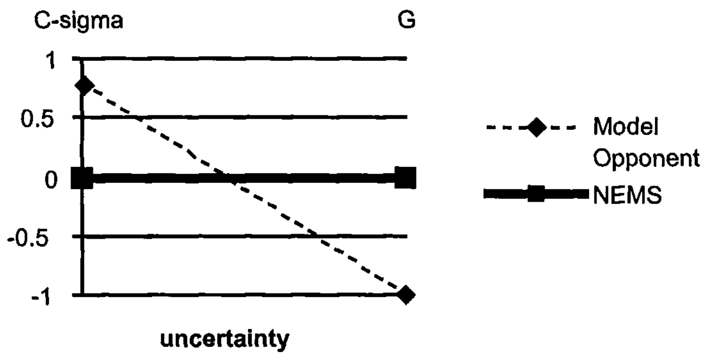

Figure 2. Hypergame Expected Utility

Hypergame Expected Utility (HEU) was created to account for outguessing in a hypergame context. It is based on the observation that to gain an advantage over a game theoretic solution, a risk must be undertaken. HEU encapsulates that risk and is a function of the expected utility of a hyperstrategy against C_Σ combined with the expected utility of that hyperstrategy against its worst-case column, called *G*. These are plotted against uncertainty, represented by *g* in figure 2. The HEU function for any hyperstrategy, *h*, is defined below.

$$HEU(h, g) = (1-g)[EU(h, C_\Sigma)] + g[EU(h, G)]$$

When plotted against the NEMS (figure 2) the relative merits of game theory become evident. Game theory provides the best answer against an unknown opponent who might be very tricky. It is represented by the right side of the figure. Decision theory yields the best answer against a predictable foe. HEU helps the decision-maker determine the desirability of any hyperstrategy based on uncertainty.

Conclusion

Hypergame theory is a new approach to selecting plans under uncertainty that incorporates the decision-maker's best estimate of the situation, C_Σ, with the shape of the utility surface. The full paper discusses other hyper-strategies than 'model opponent' and provides a more detailed example. It also explains an approach to assessing beliefs under uncertainty that incorporates the NEMS.

References

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