How Heuristic are Heuristic Decision Rules in a Dynamic Game?

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1. Heuristic decision rules vs. optimization decision rules

Game players must decide what decision rule to use. Traditionally, game theorists assume that game players will use "expected utility maximization rule (EUMR)." It is beyond question that no one will play to harm himself or herself. Most economists admit that EUMR is an optimal decsion rule.

Many decision scientists and cognitive psychologists have pointed out that the optimal decision rule might be sub-optimal with incomplete information and the accompanying costs. They contend that some "heuristic decision rules (HDR)" with less cognitive burdens can provide more benefits to decision makers.

Furthermore, the concept of optimal decision rules cannot be justified in the game situation. In a non-cooperative game, we play to defeat others. If all players use optimization decision rules to defeat others, who will be the winners or loosers? If no one can be defeated by the optimization decision rule, we cannot accept it as optimal any more. In a non-cooperative game, one cannot distinguish an optimal decision rule from inferior decision rules without information about their consequences.

With regard to these disputes, we think, following questions are still unresolved.

1) Can EUMR be the ideal decision criteria in dynamic game situations?

2) How well does HDR play with EUMR in dynamic games?

2. Heuristics decision rules in a dynamic mixed-strategy game

With these questions in mind, we used our system dynamics model of mixed strategy game as an experimental laboratory for testing the performance of HDR and EUMR. The system dynamics model of mixed strategy game consists of two kind of players; policemen and drivers (Kim & Kim 1995). They should use a mixed-strategy for optimizing their expected payoffs.

We choosed three kind of HDRs among fourteen decision rules summarized by Bordley (1985), because other decision rules cannot be applied adequately to our game model. We assumed that policemen will choose EUMR while drivers use various kinds of HDRs. In our study, we experimented with weighted ranking rule (WRR), elimination by aspect rule (EBA) and adjusted random rule (ARR). The performance of drivers in our original model of mixed strategy game was used as a reference performance, because they were modelled as using EUMR in choosing between violation and conformance of a speed limit.

<Table 1> Heuristic decision rules represented in SD model

HDR	Procedure of decision rule	Representation in SD model
Weighted Ranking Rule (WRR)	Assign a weight of m to the most probable event,...,a weight of 1 for the least probable event...*	euv = IF(prob_p<= 0.5) THEN(2) ELSE(1) eunv=IF(prob_p > 0.5) THEN(2) ELSE(1)
Elimination By Aspect (EBA)	Start with the most probable state. Eliminate all decisions which lead to consequences having unacceptable utilities given that state...**	euv = IF(prob_p <= 0.5) THEN(dpvnp) ELSE(0) eunv = IF(prob_p > 0.5) THEN(dpcp) ELSE(0)
Adjusted Random Rule (ARR)	Choose any decision according to random variable. The upper limit of random variable is adjusted between 0.5 and 1 by experience.	euv = IF(random_v >= 0.5) THEN(dpvnp) ELSE(0) eunv = IF(random_v > 0.5) THEN(dpvnp) ELSE(0)

prob_p = probability of patrol of policemen
dpvnp = drivers payoff for violation with no patrol of policemen
dpcp = drivers payoff for conformance with patrol of policemen
*, ** = Bordley (1985)

Table 1 explains how we represented HDRs in the model of mixed strategy game. Figure 1 is an example diagram for the case of ARR. In the model, the probability of patrol of policemen (prob_p) can be interpreted as the probability of states in the frame of decision making. Decision alternatives for drivers consists of violation and conformance of a speed limit. HDRs are represented into variables that calculate the expected value of violation and conformance. This representation scheme of HDRs works well, because it determines what decision alternatives for drivers to consider at subsequent stages in the model.

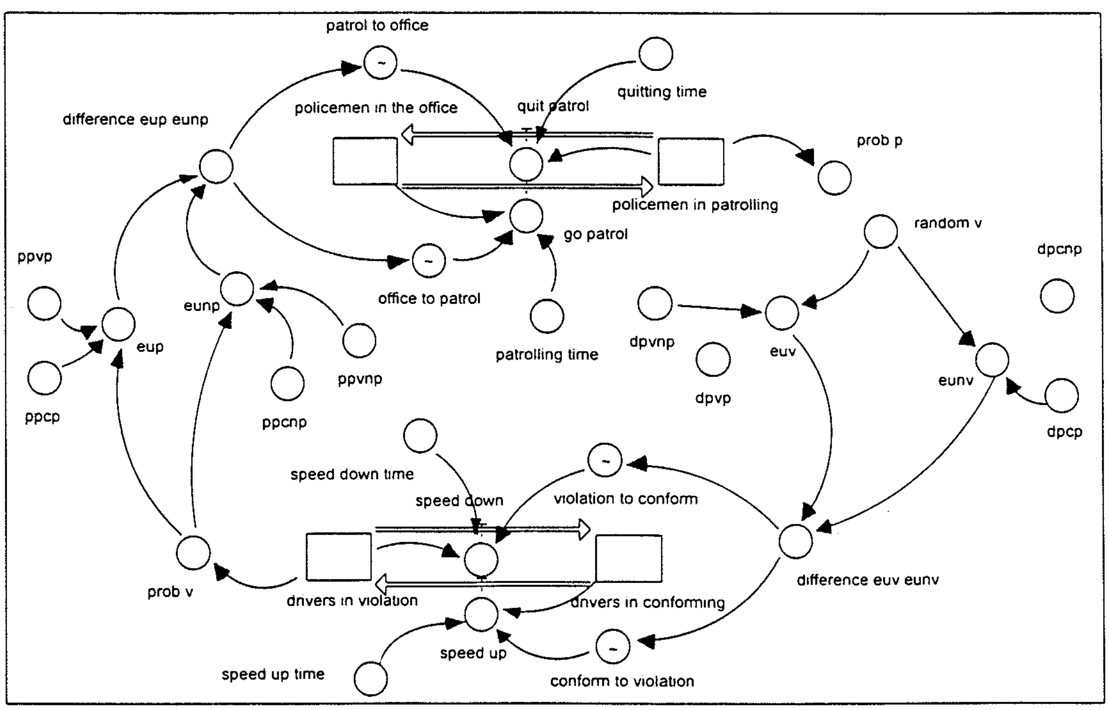

Figure 1. System dynamics model for mixed strategy game with drivers using ARR

3. Simulation results I: HDRs are better than EUMR

For evaluating performances of each decision rules, we inserted into our model a variable that accumulate the expected payoffs for drivers at each simulation time as in figure 1. For comparing heuristic decision rules to optimization decsion rules, we included EUMR. In addition, since EUMR requires more time and efforts than HDRs, we experimented also EUMR with information delay of 10 days.

Table 2 shows performances of decision rules. To our surprise, heuristic decision rules are better than the optimization decision rule. The EBA decision rule performs best. Even the adjusted random decision rule (ARR) performs better than the optimization rule with information delay (EUMR with delay).

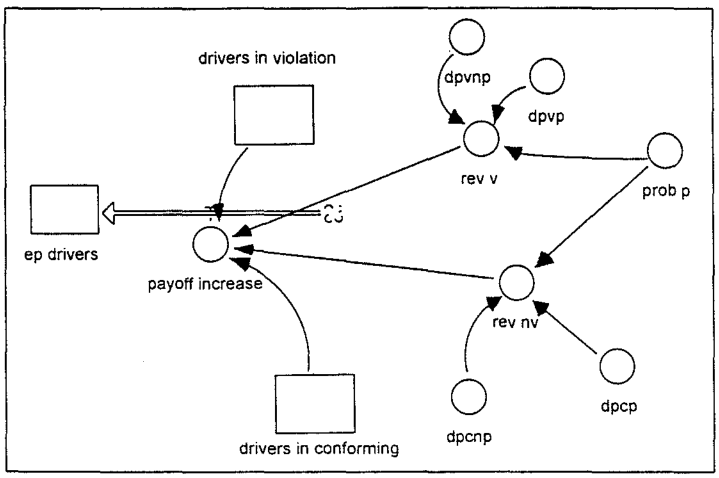

Figure 2. STELLA diagram for acumulating performance of decision rule

Decision Rules	Index of Performance
EBA	2500541
WRR	2499853
EUMR	2498181
ARR	2485430
EUMR (delay)	2472978

<Table 2> Performance of decision rules

4. Simulation results II: HDRs are more sensitive than EUMR

Our second question on the performance of HDRs is how much stable or fluctuating behavior HDRs produce. Figure 3 shows time behavior of different decision rules. One can easily find that EUMR produces most stable behavior of drivers, while ARR produces most fluctuating behavior. WRR shows relatively stable behavior with good performance.

Note that EBA and WRR produce lots of frequencies in their time behavior. It can be interpreted that EBA and WRR respond to the behavior of policemen more sensitively than EUMR and EUMR with information delay. Since drivers using HDRs respond much more sensitively than those using EUMR, they can produce more payoffs.

Unstable behavior of HDRs can be interpreted also as resulting from the lack of behavior adjustment between drivers and policemen who use EUMR. In particular, drivers using EUMR without information delay can adjust their behavior around the probability of 0.25. However, drivers with other decision rules could not adjust their behavior, and their behavior oscillated with that of policemen.

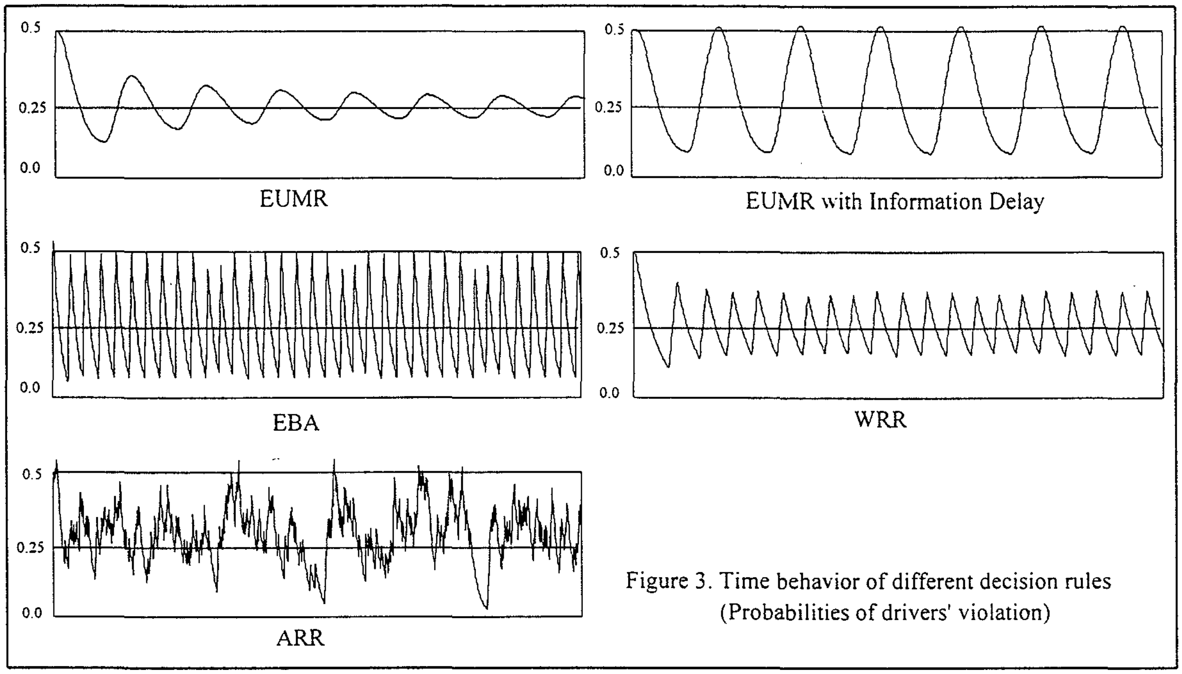

Figure 3. Time behavior of different decision rules
(Probabilities of drivers' violation)

5. Conclusion and Future Research

Our simulation shows that heuristic decision rules perform better than optimization decision rules but produce more fluctuating behavior in a dynamic game.

These results are not hard to believe. In reality, most people do use various kinds of HDRs rather than EUMR. They buy expensive materials such as house or computer without extensive analysis of probabilities for future states and their utiltities of decision alternatives. HDRs are prefered to EUMR, not only because they can save time and efforts but because they perform better than EUMR in real life that is full of dynamic games.

In this paper, we confined our experimentation to the non-cooperative mixed strategy game. We think that following questions will provide challenging research areas as well as practical insights for making a link among decision science, game theory and system dynamics.

How well do HDRs play with other HDRs?

How well do HDRs and EUMR play in cooperative games?

Can HDRs play well in the N-person game where most players use EUMR?

[References]

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