# TOWARDS A FRAMEWORK FOR MANAGEMENT OF STRATEGIC INTERACTION

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Abstract: Our research aim is to construct a software framework and associated language for definition, providing and recording of strategic interactions between real-world agents, human and artificial respectively. In this paper we present an example of such interaction, which is used to show designed and partially implemented concepts. We use FIPA based framework for our multi-agent system. The investigated scenario is a repeated two player zero sum symmetric matrix game. We also conducted a study and analyzed the data.

## 1 INTRODUCTION

A strategic interaction (SI) are events, which happen, if participants are interested in achieving something and their success is depending on decisions of other participants. The specialty of SI (called also game) in real-world domain is the partial non-appearance of game theoretical predictions (Tagiew, 2008). Especially in SI of humans, researchers use special heuristics to model this deviation. This heuristics are needed for programing advanced artificial agents, who interact with humans. Our view is to construct a prototype system, which helps to improve and standardize this heuristics from AI point of view. The system is expected to provide and record human-human-interaction through allocation of proxy agents for humans, which communicate over network. The behavior of the system is based on the definition of the interaction rules in special language and it also provides an ability for definition of artificial agents. Artificial agents can be tested against humans or each other. A state-of-art multi-agent architecture is considered for implementation. Assembling of concepts for building such a system on a concrete example is the aim of this paper. Further we assume that the reader is familiar with game theory. After talking about games and related works, we present a concept of using of a multi-agent system (ch. 4) and a concept for defining SI (ch. 5). Then, we present the study.

## 2 GAMES

Our concrete example is using of MSE by humans. For humans, there are two problems to use mixed strategy equilibrium (MSE) in repeated matrix games. They are exact calculation of MSE and production of an identical and independent distributed (iid) sequence (F.Camerer, 2003). Humans use a distribution that is near to MSE and an equal distribution and they avoid repetitions in the sequence. It is also interesting to record human behavior in games with not only one MSE. A set of games similar to Roshambo is chosen, because they are fast to explain for test persons, fast to play and have a simple structure for analyze of basic concepts. These games are symmetric, zero sum, two player, and the entries of the payoff matrix can be only 1(win), 0(draw) and $-1$(loss). The only difference to simple Roshambo is that we use more than three gestures. The payoff matrices of these games can be also seen as adjacency matrices of directed graphs (set $-1$ to 0). There are 7 directed graphs for 3 gestures, 42 for 4, 582 for 5 and so on (Harary, 1957). We proved all graphs for 5 gestures to find variants with only one MSE non-equal distribution. There are 4 such variants (Fig.1). The first variant is an existing American variant of Roshambo with additional gestures fire and water. We merged 3 of these graphs with probabilities $\frac{1}{9}$ and $\frac{1}{7}$ and a 4-nodes cyclic graph to a graph of 9 nodes. Every node became a plausible name and hand gesture. The resulting game framework is shown in Fig.2. The cyclic 4-gesture variant Paper-Mosquito-Hunter-Monkey has as MSE solution all distributions on the line between points $(0, \frac{1}{2}, 0, \frac{1}{2})$ and $(\frac{1}{2}, 0, \frac{1}{2}, 0)$.



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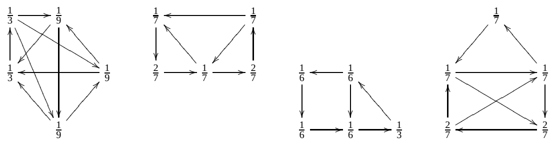

Figure 1: All nontrivial variants for 5 gestures.

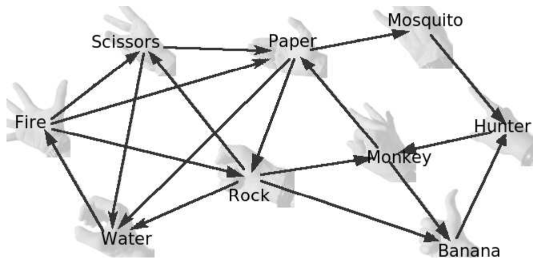


Figure 2: Game framework.

## 3 RELATED WORKS

ACE is a general concept of software architecture for investigation of economic processes(Tesfatsion and Judd, 2006). ACE is a design for a multiagent system consisting of four kinds of agents: worlds, markets, firms and consumers. Worlds and markets manage environmental data like ownership and current prices. GDL is a logic-based language for definition of a server for managing games between multiple programs(Genesereth et al., 2005). Finite games of perfect information are definable in GDL. Then, there is a state-of-art games solving program GAMBIT.

## 4 FRAMASI

JADE (Bellifemine et al., 2001) is used for our framework for management of SI (FRAMASI). Three types of agents are defined: periphery agents, worlds and participants (similar to ACE). A world represents the SI itself. Participants search for worlds and then contract with a world, about how and at which place to participate. After closing contracts worlds supply the associated participants with (partial) information about the state of the interaction. Participants send their actions to the world. Worlds die after fullfilled interaction. A couple of periphery agents add some extended abilities to our system like gesture recognition.

## 5 RUNNING PETRI NET

The idea for a definition language for practical representation of SI in finite and discrete domains is using petri nets (PN). PN are usefull for representing distributed processes (Priese and Wimmel, 2008). A PN is a labelled directed graph, formally represented through tuple:

$$\mathrm{PN} = (P,Q,F,W,M) \tag{1}$$

It consists of places $P$ (circles), which can be filled with a positive amount of tokens (dots), and transitions $Q$ (rectangles), which can be fired with an effect on places. Places and transitions are disjunct $P \cap Q = \emptyset$. Places can not be connected to places and transition not to transitions. Arcs $F \subseteq (P \times Q) \cup (Q \times P)$ are weighted with positive natural numbers $W : F \rightarrow \mathbb{N}_1^+$. A transition can not be fired, when any place of incoming arcs have less tokens than its arc weight. Firing abolishes tokens of every incoming arc and produces tokens for every outgoing arc according to their weights. The fill levels of the places represent the state of the petri net. $M \in \mathbb{N}^{|P|}$ is the current state of PN. To model SI, PN is extended with tuple:

$$\mathrm{SI} = (I,C,N,D,A,O,H,B) \tag{2}$$

$I$ is a set of agents, empty element $\varepsilon$ stands for nature or world accordingly. $C \subseteq Q^*$ is a subset of sequences of transitions, called choice sets. Every transition is a member of only one element of $C$. $N : C \rightarrow \mathbb{N}$ is a numbering function and not injective. $D : \mathbb{N} \rightarrow (\mathbb{R}_0^1)^n$ is a function for firing probability distribution in a choice set, where $\sum(D(\_)) = 1$. $n$ is number of elements of the related choice sets. $O : \mathbb{N} \rightarrow I \cup \varepsilon$ denotes ownership. $A : Q \rightarrow \mathbb{R}^{|I|}$ is the payoff vector of a transition, if it fires. $H : P \rightarrow \{I\}$ provides for every place a subset of agents for which it is hidden. Agents can alter $D$ for own numbers and see all unhidden places. $B : I \rightarrow \mathbb{R}$ is the current account balance of agents.

Fig.3 demonstrates a small application of this formalism for a repeated game "matching pennies". It is representative for our scenario. Dashed diamonds are taken for the gathered payoff of players. Dashed boxes are choice sets. Every transition, which is not in dashed box, is in a single element choice set and has a firing probability of 1. Altering of $D$ must be done at specific time, because it has a default state and the transitions firing algorithm does not wait for agents decisions. The places Ready and Time shows to the participants, if they have or have not to react. The weight 'latency' between Time and Timer represents the time period for simultaneous decisions.

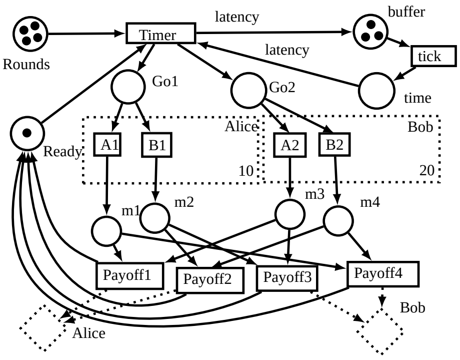


Figure 3: Matrix Game using PNSI.

# 6 CONDUCTED STUDY

The feature of gesture recognition is added to our scenario in sense of making it more situated and similar to real-world physical activities like sport competitions. We used a cyber-glove and a classifier for recognition of gesture (Heumer et al., 2008). The study was conducted on a thread of 200 one-shot games of 7 kinds (41 to 61 tab.1) using our game framework (fig.2). A player had a delay for consideration of 6 sec for every shot. If he did not react, the last or default gesture was chosen. A thread lasted $200*6$ sec $=20$ min and had following structure - 30 times #31, 30x #41, 30x #51, 30x #52, 30x #53, 30x #54 and finally 20x #61. 10 test persons (computer science undergrates in average 22,7 years age and 0.7 male) were recruited, had to play this thread twice against another test person. In this way we gathered 2000 one-shot games or 4000 single human decisions. Every person got €0.02 for a winned one-shot game and €0.01 for a draw. A winned thread given additionally €1 and a drawn €0.5. Summarized, a person could gain between €0 and €10 or in average €5. The persons, who played against each other, sat in two separated rooms. One of the players used the cyber-glove[1] and the another a mouse as input for gestures. The proxy agent for a human player has following features on his gui - own last and actual choice, opponents last choice, graph of actual game, timer and already gained money. According to statements of the persons, they had no problems to understand the game rules and to choose a gesture timely. All winners and 80% of losers attested, that they had fun to play the game.

[1] except of one participant, who had to play both threads with mouse, because of mismatch of cyber-glove size to her hand

Table 1: MSE and observed distributions for all games.

| 31 | Rock | Paper | Scissors |
|---|---|---|---|
| MSE | .3333 | .3333 | .3333 |
| All | .36 | .335 | .305 |
| Glove | .3222 | .3407 | .3370 |
| Mouse | .3909 | .3303 | .2788 |

| 41 | Hunter | Monkey | Paper | Mosquito |
|---|---|---|---|---|
| MSE from | 0 | .5 | 0 | .5 |
| MSE to | .5 | 0 | .5 | 0 |
| All | .2783 | .2533 | .23 | .2383 |
| Glove | .2704 | .2407 | .2444 | .2444 |
| Mouse | .2848 | .2636 | .2182 | .2333 |

| 51 | Rock | Paper | Scissors | Fire | Water |
|---|---|---|---|---|---|
| MSE | .1111 | .1111 | .1111 | .3333 | .3333 |
| All | .1867 | .1533 | .13 | .3267 | .2033 |
| Glove | .2222 | .1555 | .1259 | .3 | .1963 |
| Mouse | .1576 | .1515 | .1333 | .3485 | .2091 |

| 52 | Rock | Paper | Monkey | Fire | Water |
|---|---|---|---|---|---|
| MSE | .1429 | .1429 | .1429 | .2857 | .2857 |
| All | .1783 | .155 | .1767 | .2983 | .1917 |
| Glove | .1593 | .1481 | .2 | .3 | .1926 |
| Mouse | .1939 | .1606 | .1576 | .297 | .1909 |

| 53 | Rock | Banana | Monkey | Paper | Hunter |
|---|---|---|---|---|---|
| MSE | .1429 | .1429 | .1429 | .2857 | .2857 |
| All | .2133 | .1417 | .2433 | .1883 | .2133 |
| Glove | .1704 | .1481 | .2555 | .2074 | .2185 |
| Mouse | .2485 | .1364 | .2333 | .1727 | .2091 |

| 54 | Hunter | Monkey | Paper | Mosq. | Banana |
|---|---|---|---|---|---|
| MSE f. | 0 | .5 | 0 | .5 | 0 |
| MSE t. | .25 | .25 | .25 | .25 | 0 |
| All | .1833 | .3217 | .1583 | .1833 | .1533 |
| Glove | .1704 | .2963 | .1481 | .2148 | .1704 |
| Mouse | .1939 | .3424 | .1667 | .1576 | .1394 |

| 61 | Rock | Paper | Sciss. | Monk. | Fire | Water |
|---|---|---|---|---|---|---|
| f | 0.1111 | .1111 | .1111 | 0 | .3333 | .3333 |
| t | .1429 | .1429 | 0 | .1429 | .2857 | .2857 |
| A | .185 | .0975 | .0925 | .12 | .265 | .24 |
| G | .2222 | .0667 | .0944 | .1056 | .2778 | .2333 |
| M | .1545 | .1227 | .0909 | .1318 | .2545 | .2455 |

# 7 RESULTS OF THE STUDY

Tab.1 presents the tables of theoretical and played distributions for every investigated game. For a game, there are $10*2*30=600$ and $10*2*20=400$ for 61 recorded human decisions. In games 51 till 53, at least one probability deviates with significance far below 1‰ from MSE towards equal distribution. The high probability of fire in 51 can be explained as best response on equal distribution of the opponent. In game 41, people prefer the middle one of extreme solutions. But it can not be cleanly demonstrated on games 54 and 61, because of consequences from thesis 1. Distribution during playing with glove deviates from which with mouse. This thesis can be demon-

Table 2: Patterns probabilities for 31 and 41.

| | 31 | | 41 | | Bridges | | |
|---|---|---|---|---|---|---|---|
| Pattern | The. | Obs. | The. | Obs. | 0 | 1 | 2 |
| ABCD | 0 | 0 | .0938 | .2611 | 0 | 0 | 0 |
| ABCA | .0741 | .15 | .0938 | .1519 | 0 | 0 | 1 |
| ABCB | .0741 | .1315 | .0938 | .0926 | 0 | 1 | 0 |
| ABAC | .0741 | .1278 | .0938 | .0926 | 0 | 1 | 0 |
| ABCC | .0741 | .0667 | .0938 | .087 | 1 | 0 | 0 |
| ABBC | .0741 | .0796 | .0938 | .063 | 1 | 0 | 0 |
| AABC | .0741 | .0685 | .0938 | .0722 | 1 | 0 | 0 |
| ABBA | .0741 | .0611 | .0469 | .037 | 1 | 0 | 1 |
| ABAB | .0741 | .0593 | .0469 | .0333 | 0 | 2 | 0 |
| AABA | .0741 | .063 | .0469 | .0222 | 1 | 1 | 1 |
| ABAA | .0741 | .0574 | .0469 | .0204 | 1 | 1 | 1 |
| AABB | .0741 | .0463 | .0469 | .0222 | 2 | 0 | 0 |
| ABBB | .0741 | .0352 | .0469 | .0204 | 2 | 1 | 0 |
| AAAB | .0741 | .0352 | .0469 | .0185 | 2 | 1 | 0 |
| AAAA | .037 | .0185 | .0156 | .0056 | 3 | 2 | 1 |

strated only in 5 of 7 games, where at least one of probabilities for playing with glove significantly deviates from case, if it is played with mouse. But, there is no plausible explanation for this deviation at time. We counted tuples, which consists of own actual decision plus own three last decisions plus opponents last three decisions. In game 31 for example, we have 4 tuples, each of them is observed 4 times. As example, the tuple $\{$rock, $\{$rock, paper, scissors$\}$, $\{$paper, rock, paper$\}\}$ was observed in threads of four deferent persons. The probability for one tuple in 31 to be observed more than 3 times is about $0.126‰$. Persons play in a rhythm which is far from iid. Further they transform in consequence of this deviation a repeated matrix game to an extensive game, in which one must consider his turns in dependence of own and opponents last turns or in common speech fill the rhythm of the game.

The latter brought us to calculate probabilistic grammatic of human behavior in games 31 and 41. We used methods of (Budescu and Rapoport, 1994). Variables $A,B,C,D,\ldots \in$ gestures have all different values. Patterns are abstract types of sequences and constructed of these variables. For instance, the sequences $\{$paper,rock$\}$ and $\{$fire,water$\}$ are both of pattern $AB$. We used patterns with length 4, because of limited size of our data. We calculated theoretical probabilities of these patterns according to thesis, that humans used equal distributions in games 31 and 41. Per game we can count $(30-3)*2*10 = 540$ sequences and assign them to patterns. Additionally we counted bridges (variable repetition) over $0,1,2$ elements in the patterns for possible explanation of deviation. Tab.2 shows the results.

## 8 CONCLUSIONS

Our paper showed a practical way for construction of a highly scaleable multi-agent system for definition, providing and recording of SI between real-world agents, human and artificial respectively. Especially, we presented a multi-agent system design and a PN based language. It produced data for a concrete scenario - using MSE in zero sum by humans. The recorded data was analyzed and showed results similar to already alluded in literature. Core elements of our system can be downloaded from our home page.

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