Rational Dialog in Interactive Games

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Why Make NPCs Rational?

- Role-Play games & Adventure games
- Rigid and scripted story lines
- Simple NPCs, they always react the same and in a very limited way.

Proof of concept

Research question

Will an NPC interact with a player and other NPCs in a rational and goal driven way, when given a past life and a decision mechanism?

My focus is on interactive dialog and I built an engine that uses:

- Propps Morphology and Bayesian networks to generate a past life and connections with other payers.
- Bayesian networks as a causally connected decision mechanism.
- Game Theory as a means to calculate a rational strategy.
- Tools: GeNIe & SMILE, Java, Intellij.

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Rationality

Definition

Rationality is the choice of actions which best satisfy a person's objectives. These objectives are desires that motivate the individual

Objectives or desires include for instance:

- Satisfying feelings.
- Morals, integrity, being liked.
- Being successful, discovering and advancing in some area.
- Avoiding trouble, hiding uncomfortable truths.

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The Fool's Rationality

- A fool in a marked place is surrounded by a small crowd that repeatedly asks the fool to choose between a pound and a half pound.
- The fool always picks the half pound over a pound.
- "Well, how long would they play this game if I picked the pound?"

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Rationality in Game Theory

Definition

A Nash equilibrium is a profile of strategies such that each player's strategy is an optimal response for each of the other players'strategies.

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- No other strategy profile will yield a higher payoff.
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- The player is not competing against his opponent.
- The players are rational and do not make mistakes.
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Nash Equilibrium

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A *mixed-strategy* profile σ^* is a *Nash equilibrium* if for all players i, and for all strategies $s_i \in S_i$,

$$u_i(\sigma_i^*, \sigma_{-i}^*) \geq u_i(s_i, \sigma_{-i}^*)$$

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Incomplete Information Games

- Nash equilibrium deals with complete information games.
- A dialog is not a complete information game.
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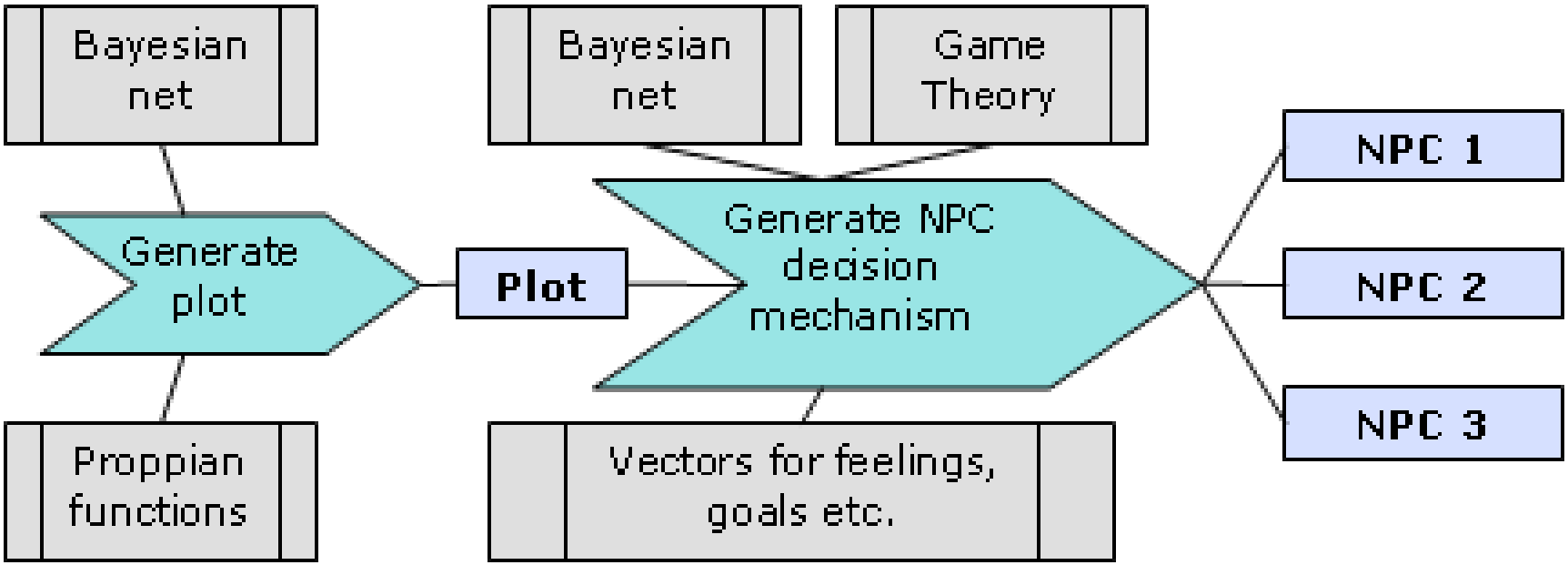
Incomplete Information Games

- The result of Harsanyi work is Bayesian equilibrium.
- Probabilities are used to convert incomplete information into imperfect information.
- I will discuss the Bayesian equilibrium in conjunction with the part of the engine that calculates equilibrium.
- First it is good to understand the basics of the engines setup.

The Big Picture



The Dynamic Plot Generating Engine

- The engine uses a Bayesian network to generate a new murder mystery plot for each new game initialized.
- The resulting plot is a consistent murder mystery that is solvable with logical inference.
- It contains:
  - One and only one murderer and murder weapon.
  - On victim and a murder scene.
  - Other suspects and weapons
  - Possible motives for the murderer and other suspects

Propps Morphology

Vladimir Propp, a Russian structuralist, (St Petersburg, April 29, 1895 - Leningrad August 22, 1970)

1. Functions of characters serve as stable, constant elements in a tale, independent of how and by whom they are fulfilled. They constitute the fundamental components of a tale.
2. The number of functions known to a fairy tale is limited.
3. The sequence of functions is always identical.
4. All fairy tales are of one type in regard to their structure.

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Generating a Plot

1. Read text files that describe the initial net.
2. Draw the initial net based on the settings
3. Initiate a victim
4. Initiate a murderer
5. Initiate a murder weapon
6. Eliminate all other suspects as possible murderers
7. Eliminate all other weapon as possible murder weapons
8. Instantiate the rest of the network

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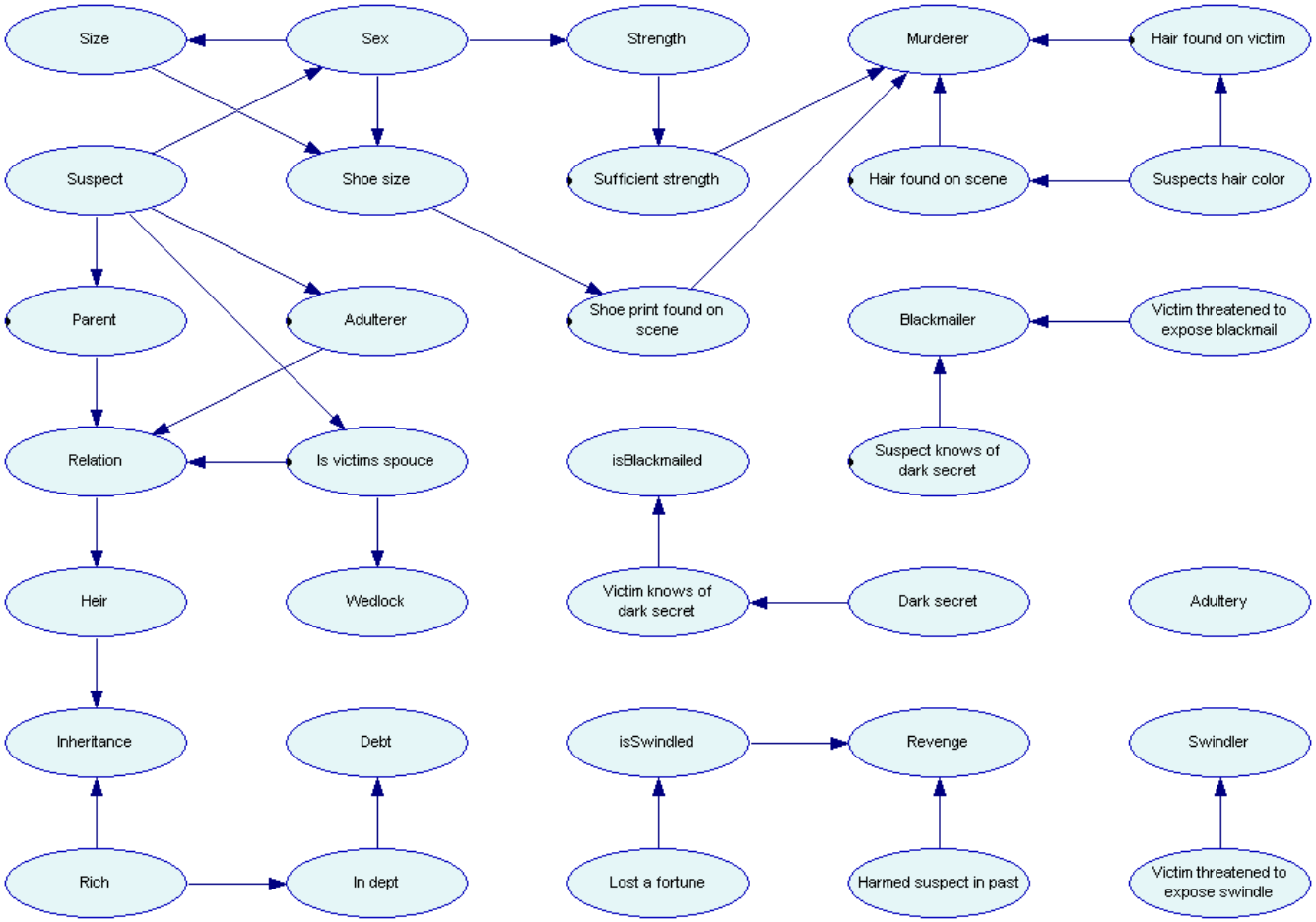
Size
Sex
Strength
Murderer
Hair found on victim
Suspect
Shoe size
Sufficient strength
Hair found on scene
Suspects hair color
Parent
Adulterer
Shoe print found on scene
Blackmailer
Victim threatened to expose blackmail
Relation
Is victims spouce
isBlackmailed
Suspect knows of dark secret
Heir
Wedlock
Victim knows of dark secret
Dark secret
Adultery
Inheritance
Debt
isSwindled
Revenge
Swindler
Rich
In dept
Lost a fortune
Harmed suspect in past
Victim threatened to expose swindle

Motives

- Swindle
- Blackmail
- Wedlock
- Inheritance
- Adultery
- Revenge
- Dept

The NPC

Each NPC is generated from the plot that the DPGE generated. This means each suspect and the murderer are generated as an independent NPC.
Complete with:

- Characteristics.
- Connections between characters.
- Connections between victim and characters.
- Motives and evidence.

The NPC Knowledge Base

Character

Characteristics, crime knowledge, weapon knowledge, scene knowledge

Characters opponent

Characteristics, crime knowledge, weapon knowledge, scene knowledge

Characters opponent opponent

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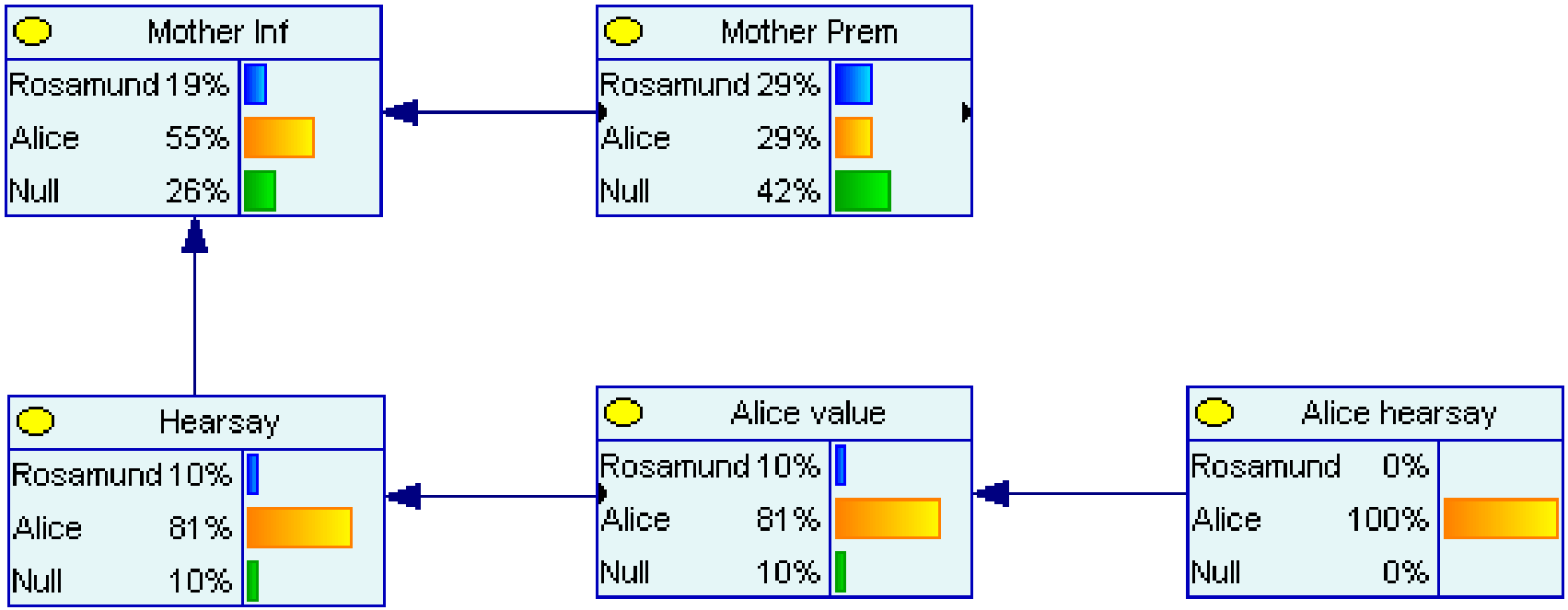
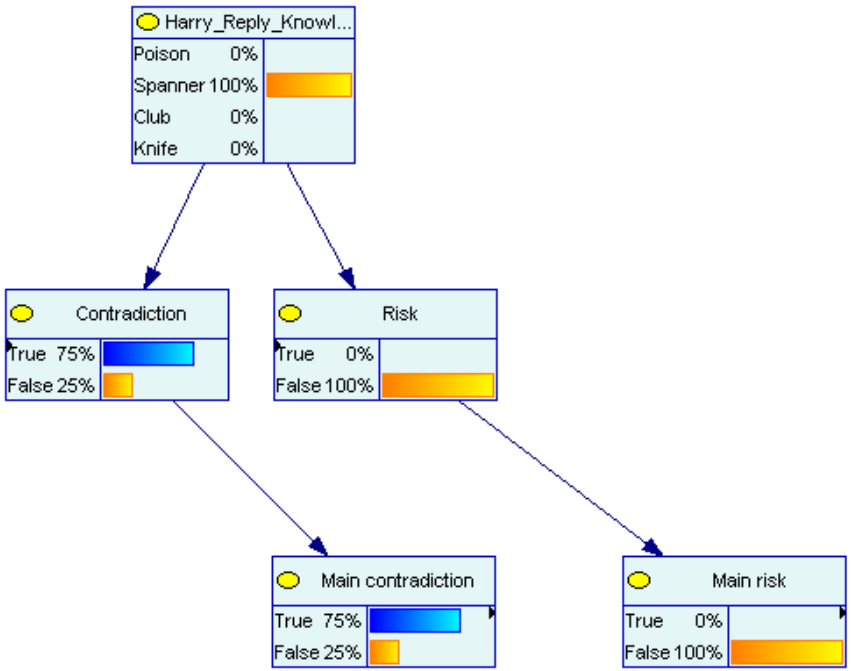
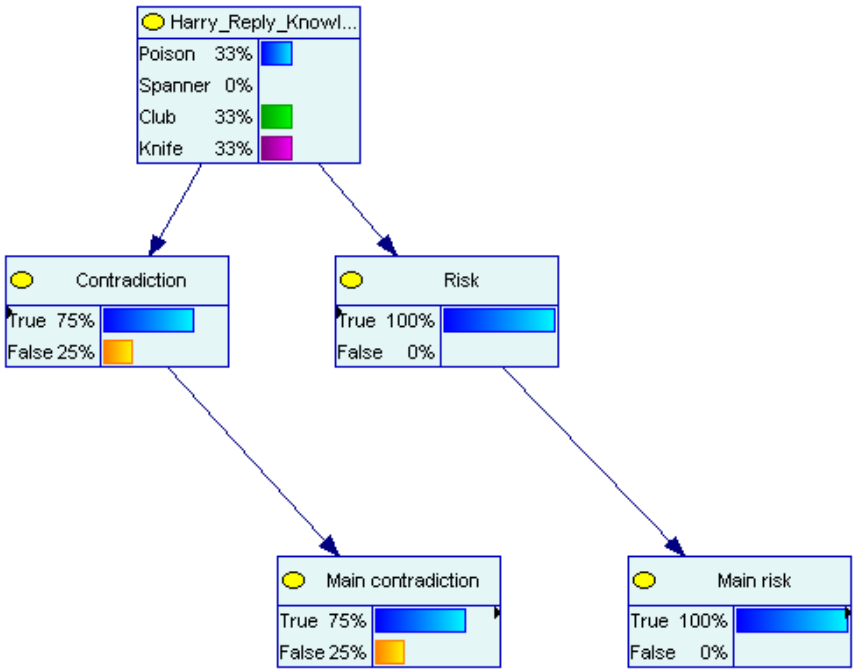


SENTENCE GENERATION

- The sentences are generated from the knowledge variables.
- Each knowledge variable can stated as true or false.
- A sentence is created from one or more knowledges.

GENERATING SENTENCES





FINDING EQUILIBRIUM

- In order to find equilibrium we need a mathematical definition.
- Harsanyi proposed to use types to represent different states that the opponent could be in.
- Types Θ are really all possible positions that the Bayesian net could be in at a given time.
- Essentially a cross product of all the variables in the net.
- Still it is possible to reduce the problem to a finite set of types of a manageable size.

Strategy Profile

Definition

Given a strategy profile $s(\cdot)$, and an $s_i'(\cdot) \in S_i^{\Theta_i}$,
let $(s_i'(\cdot), s_{-i}(\cdot))$ denote the profile where player i plays $s_i'(\cdot)$
and the other players, his opponents, play $s(\cdot)$, we let

$$(s_i'(\theta_i), s_{-i}(\theta_{-i})) =$$

$$(s_1(\theta_1), ..., s_{i-1}(\theta_{i-1}), s_i'(\theta_i), s_{i+1}(\theta_{i+1}), ..., s_i(\theta_i))$$

Bayesian Equilibrium

- The probability of an opponent being of any given type $p_{-i}(\theta_{-i})$ is strictly positive.
- We use prior calculations to find the probability that the opponent is of a given type $p_{-i}(\theta_{-i})$.
- We use prior calculations to find the opponent's strategy for each of his possible types $s_{-i}(\theta_{-i})$.

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We find an equilibrium by maximizing the sum of player i weighted payoff u_i, conditional to his type θ_i, over the opponents' possible types θ_{-i}, for each of his strategies $s'_i \in S_i$ as is shown here

$$s_i(\theta_i) \in \arg\max_{s'_i \in S_i} \sum_{\theta_{-i}} p(\theta_{-i}|\theta_i) u_i(s'_i, s_{-i}(\theta_{-i}), (\theta_i, \theta_{-i}))$$

Bayesian Equilibrium

(Fudenberg & Tirole 1991)

- Since Bayesian equilibrium, like Nash equilibrium, is essentially a consistency check , players' beliefs about opponents' beliefs do not enter the definition.
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Multi-Agent Influence Diagrams

- Koller and Milch, Stanford University, propose a very good way to tackle the same problem as discussed, namely dealing with the incomplete information of every day decision making.
- Their solution is a Multi-Agent Influence Diagram (MAID).
- A MAID is an expanded Bayesian net in order to calculate Nash equilibrium.
- The MAIDs structure divides the decision process up in as many nets as there are decisions to make and then each decision is made in a reverse topological order.

Multi-Agent Influence Diagrams

- In a dialog there are two decisions, the sentence and the reply.
- The next step then is to find all the set of optimal replies for each of the sentences using the Bayesian net.
- There are complexity problems due to too many entries in the decision variables.
- It is not possible to just split the decision variables.
- If there are 9 other variables, each having 10 states, that need to be evaluated, then the strategy function of each decision variable has a complexity of 10^9

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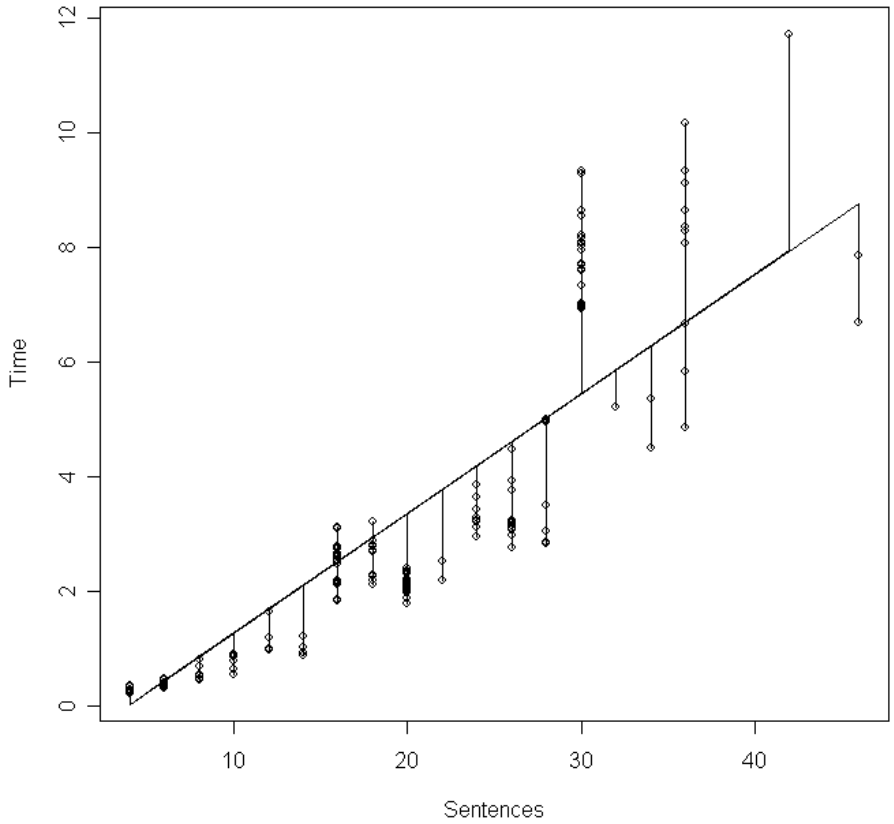
Multi-Agent Influence Diagrams

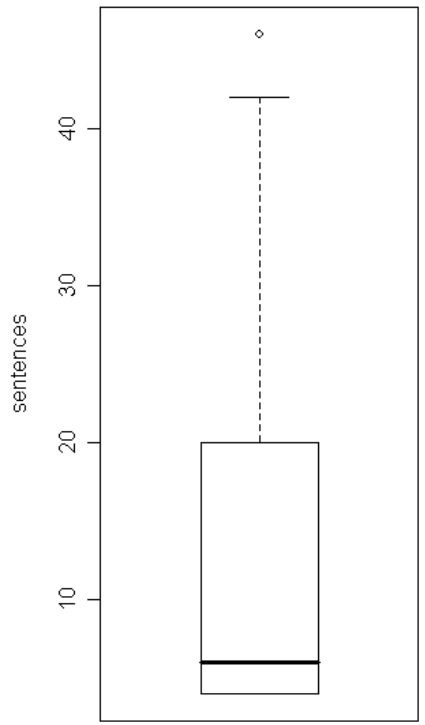
- Each decision variable needs to be calculated separately.
- This means that the sentence and speech part of the net needs to be recreated for each set of sentences and for each set of replies calculated.
- First optimal replies to each of the sentences are found.
- Then a set of optimal sentences is found in respect to the optimal replies.

Rational Dialog

- `Rosamund says:` Horace did not hold me in wedlock.
- `Alice says:` Horace did not hold me in wedlock.
- `Rosamund says:` I'm not Horace's wife.
- `Alice says:` I'm not Horace's wife.
- `Rosamund says:` I'm Horace's parent.
- `Alice says:` Horace did not have an affair with a male.
- `Rosamund says:` I'm Horace´s mother.
- `Alice says:` Horace was having an affair with me.
- `Rosamund can't think of anything to say!`

Results


Time
0
2
4
6
8
10
12
10
20
30
40
Sentences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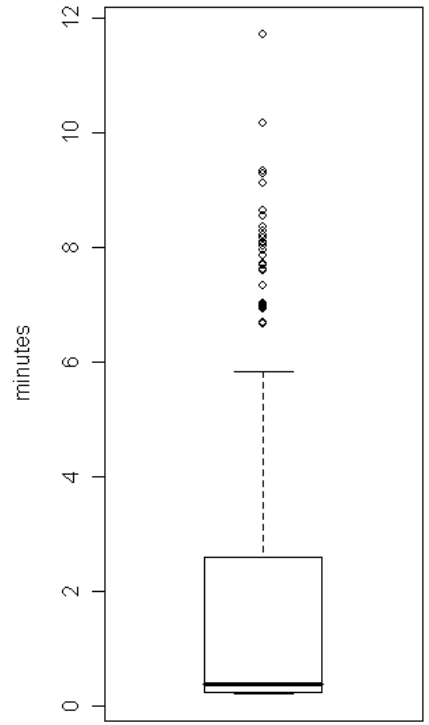
minutes
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2
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Conclusion

- The concept is proved.
- Even without many possible optimizations the time needed to calculate more than 75% of the sentence is within 3 minutes and more than half of the sentences are calculated in less than 1 minute.
- linear growth in respect to number of sentences.
- players are able to adapt to what they hear from their opponents.
- This approach uses calculations and logic to infer what action to choose.

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- Maturing the player's decision mechanism.
- Generating sentences in a more logical and way.
- Optimizing calculations.
- Use Natural Language Processing for a more speech-like sentence generation.
- Courtesy mode.

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