

Bayes' rule for Calculating probability of  $P(v_1s_1|v_2s_2)$  Calculating probability of  $P(v_1s_1|v_2s_2)$  2.3.237 Bayes' rule exam.2.3.2

# Tracked changes

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## Abstract

A fully interactive drama, where the player interacts with intelligent Non-Player Characters (NPCs), ~~has the potential of revolutionising~~ can revolutionise entertainment, gaming, education, and therapy. Creating such a genuinely interactive drama that is ~~not only entertaining but also~~ entertaining and gives players a sense of coherency as active participants in the unfolding drama has seen a substantial research effort. ~~A coherent will contain a plot and a tie are in order to structure the into a recognised dramatic form. When authoring theatre or television, the author has the~~ Authors have the power to shape ~~the plot and the course of the dramatised stories for theatre or television~~ at will. ~~This authoring control is not available if the is expected to change and adjust to actions of a~~ Conversely, authors ability to ~~shape~~ interactive drama ~~is limited because the drama emerges from players' and~~ NPCs actions during game-play ~~because the author cannot foresee every possible action that a could take~~, which significantly limits authoring control.

~~One philosophy has been A coherent drama has a recognisable dramatic structure. One philosophy is to use planning algorithms and narrative structures to reduce required authoring. The problem with this approach is that due to the complexity of planning algorithms the games do not scale well because the computation quickly becomes intractable, and indeed infeasible for real-time applications. Additionally, this approach has not managed to reduce However, planning algorithms are intractable for the large state-spaces intrinsic to interactive dramas, and they have not reduced the authoring problem sufficiently.~~

~~A more straightforward and more computationally feasible way is to have the emerge from the actions of the computationally feasible method is emergent interactive drama from players as they interact with the game world, other, and NPCs' actions. The main difficulty with this approach is to maintain maintaining a drama structure and theme, such as a mystery theme or a training scenario, that the player experiences while interacting with the game world. It is, therefore, Therefore, it is necessary to impose some form of structure to guide or direct the unfolding drama.~~

The solution introduced in this thesis is to distribute the computation among autonomous actors that are guided by goals and drama structures ~~that which~~ a centralised autonomous director agent distributes among the actors, ~~and is comprised of which comprises~~ the following four main elements:

~~label=~~

a autonomous rational actor agents ~~that~~ know they are acting and can negotiate dialogues between them to remain realistic while simultaneously progressing the drama, without the ~~player~~ knowing,

- b Bayesian network ~~is used~~ to model the actors reasoning, including beliefs about other actors' mental states
- c an autonomous director agent uses "schemas<sup>2</sup>"<sub>2</sub>, conceptual structures based on motifs, to guide the actors.

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### **Refereed book chapters**

**Actor bots.** Freyr Arinbjarnar and Daniel Kudenko. In *Believable bots*, Philip Hingston editors, Springer 2012.

### **Refereed conference papers**

**Bayesian networks: Real-time applicable decision mechanisms for intelligent agents in interactive drama.** Freyr Arinbjarnar and Daniel Kudenko. In Proceedings of the *IEEE Conference on Computational Intelligence and Games (CIG2010)*, Copenhagen, Denmark, August 2010

**Duality of Actor and Character Goals in Virtual Drama.** Freyr Arinbjarnar and Daniel Kudenko. In Proceedings of the *9th International Conference on Intelligent Virtual Agents*, Amsterdam, Holland, September 2009

**Directed Emergent Drama vs. Pen & Paper Role-Playing Games.** Freyr Arinbjarnar and Daniel Kudenko. In Proceedings of the *AISB'09 Symposium: AI & Games*, Edinburgh, Scotland, April 2009

**A Critical View of Interactive Drama Systems.** Freyr Arinbjarnar, Heather Barber and Daniel Kudenko. In Proceedings of the *AISB'09 Symposium: AI & Games*, Edinburgh, Scotland, April 2009

**Schemas in Directed Emergent Drama.** Freyr Arinbjarnar and Daniel Kudenko. In Proceedings of the *First Joint International Conference on Interactive Digital Storytelling (ICIDS)*, Erfurt, Germany, November 2008

# 1

## Introduction

### 1.1 Motivation

In the last couple of decades, computer technology has evolved sufficiently to create ~~Massively Multiplayer Online Games (MMOG)~~ MMOGs such as Neverwinter [Stu16], World of Warcraft [Ent04][Ent04], Eve Online [Gam03], Runescape [Jag01]. In an ~~MMOG~~, ~~multiple players~~ MMOG, ~~multiple~~ players play simultaneously in the same game world and ~~can~~ interact with each other, collaborate and even fight~~each~~ other. ~~Since the players are in the same game world and interact with each other competitively, collaboratively, and socially, they are also Virtual Reality Society (VRS).~~ ~~Collectively the players create a virtual reality (VR), i.e. virtual worlds were a virtual world where people socialise online, such as~~ ~~The Sims [Art19], VRChat [Inc17], IMVU [Rie04], Second Life [Lab03]~~. These are vibrant VRS that offer high-quality graphics, physics and sound effects and they are so vast that a player can roam around for months and still find new places to explore, and new things to occupy their time.

~~Computer games such as Vampyr [EI19], Assassin's Creed series [Ubi18], Elder Scroll series [LLC18] are good examples of such worlds. There are virtual social environments such as Second Life [Lab03] full of players that are seeking Second Life [Lab03] (SL) are examples of VRs without a game element where players are motivated by:~~

- an alternative lifestyle or just friendship. Some are even running a ~~full-time business,~~
- ~~friendship,~~

- creating virtual goods that they ~~sell to players and then exchange the game world~~ give or sell to other players.
- running a full-time business; they exchange in-game currency for real-world currency on ~~the online shopping and auction website~~ E-Bay.

~~Still lacking in these virtual worlds is a fully where the drama emerges around the actions of human players and actor agents. While adhering to a specific genre and containing a dramatic arc, where the player is the protagonist or at least a critical participant, and the player's actions directly affect the drama and where the player can interact with actors such that the course of the drama changes but still holds to a known genre.~~

~~Creating such a genuinely is a significant challenge that is entirely worthwhile as it has the potential of revolutionising entertainment, gaming, education, therapy and even news coverage. Several single-player games, such as Vampyr [EI19], Assassin's Creed series [Ubi18], Elder Scroll series [LLC18] contain vast game worlds that a player can roam around in for months and still find new places to explore and new activities to occupy their time.~~

*What happens, in reality, is irreversible, while in play, it is possible to start again from scratch. Play is a simulation of reality that, far from making play a frivolous pastime, emphasises the immense importance of all play activity for the well-being and development of man.*

*Children play in order to familiarise themselves with the behaviour patterns which they will have to use and experience in their life, in reality. Young animals play to learn to hunt, to flee, to orientate themselves. All play activity of this kind is inherently dramatic because it consists of mimesis, an imitation of real-life situations and behaviour patterns.*

– [Ess76, p. 19-20]

Imagine an interactive emergent murder mystery where the ~~player~~-player is the lead detective interviewing suspects and examining clues to discover the real perpetrator. ~~Imagine that the puzzle tests player, a mystery that challenges the~~ player's skills and intelligence, ~~where the player interacts with characters that have a full set of characteristics, emotions and life history and respond to player interactions fluently in a believable way according to their distinct personalities. The~~ player ~~interacts with believable characters that respond fluently to dialogue and events.~~

Education can ~~be evolved to accommodate for each student's actual evolve to accommodate students'~~ abilities. The students attend a ~~virtual reality~~-VR classroom where they have unlimited access to teachers guidance, extra help and advanced material ~~all in direct relation related~~ to the student's actual performance, skill set, intelligence, motivation and abilities.

~~To have significantly enhanced Significantly enhance therapy sessions by re-enacting actual social challenges of the patient allowing the therapist to appreciate the patient's difficulties better and give relevant advice to the patient that they can then test and exercise in an under professional guidance patients' social challenges in a VR to improve therapists' assessments and patients' coping skills.~~

~~Envision portraying news coverage in an such that the player can step into the aftermath of the situation, look at events and talk to s real-world simulations where players' can interact with the NPCs that believably represent the individuals included in the news event. The player could even become one of the key figures in extraordinary series of specific people or people similar to specific target groups from real-world events. Players can play significant roles in historical events, such as the process of creating the human rights treaty or the Iraqi war , where people could see the process from both and experience events from all sides.~~

Although some of these visions appear very distant, they all share a distinct common ground, which is the core of this proposal. They all call for interactive drama where a player can actively participate in point to point player actively participates as one of the characters in the drama's action experiencing each event first hand as it transpires and where the player player can affect the scene such as to alter the course of future events.

~~Creating a genuinely that is not only entertaining but also gives the player a sense of coherency and that the player is an active participant in the unfolding drama is a challenge. The response of actors needs to be believable, i.e. it needs to be contextual to what has transpired immediately before and the characters state of mind as well as the unfolding drama as a whole. At the same time, the unfolding drama should follow a dramatic arc with the expected rise and fall in suspense to fully immerse the player in the theatre.~~

~~It is necessary to master two primary areas of successfully. The first is to create characters that respond fluently to interactions from the player so that the player has a feeling of directly influencing the unfolding of the drama and is more likely to become immersed. The second is to have a complete dramatic arc with; exposition, rising action, climax, falling action and Dénouement. Additionally, it should conform to a known drama genre such that a majority of players immediately recognise a distinct drama genre, e.g.~~

#### Definition 1.1.1 (Emergent drama)

*For this thesis, we define that emergent drama is a murder mystery drama that emerges from one or more human actors' and NPCs' interactions, and comprises:*

1. *Interactive drama:* A structured narrative which includes:

- Structuralism, e.g. Freytag's pyramid [Fre63], Proppian uniform structure and adherence to a known genre [Pro68].
- Drama theory e.g. Polti's situations [Pol21], and Improvisation.
- Drama: actions by one or more actors that play a role in front of one or more spectators.

2. *Players' agency:*

- Players' are either protagonists' or play a critical role in the drama.
- Players' actions directly affect the course of the drama as expected within the confines of its genre.

3. *NPCs'*, Autonomous agents that demonstrate of their own volition:

- Timely responses to players' actions.
- responses; respond in context to past and present events, their role, character, and emotional state.
- decisions; they choose actions according to Nash Equilibrium.
- Theory of mind; they base their decisions on an understanding of what other characters think and how they may reply.
- Have personality traits and emotions.

Creating emergent drama, as defined above, is a worthwhile challenge that can revolutionise entertainment, gaming, education, therapy and Defence stabilisation operations.

## 1.2 Background

Related systems adapt either a *story-based* philosophy or an *emergent-based* philosophy. The philosophy emphasises a need to use a pre-authored story as a basis for implementing an interactive narrative rather than an . The player is then playing a pre-authored role through a narrative rather than an actual role where she can shape the character to her liking. The characters in the need to follow the intended narrative and to entice the player to do the same, which means that the structure of the uses either extensive planning or action inhibitors to ensure that the player and characters will play out the intended narrative and to ensure that they do not destroy the plot either purposefully or inadvertently. These systems tend to face

~~well-known tractability and scalability problems, usually due to extensive use of planning or scripting.~~ Emergent drama ~~has two primary challenges; drama management and believable human behaviour representation.~~

~~systems tend to have few actors a short storyline and limited options of interactivity for the player, merely to reduce complexity. It is essential to keep the complexity low, to avoid intractable systems. Moreover, it becomes necessary to have the characters strictly follow the orders of a central manager so as not to deviate from the~~

Drama management depends on the aim of the drama, which includes:

1. Dramatising pre-authored plot. As a result, a primary management unit is required rather than distributing computation amongst multiple agents, further increasing tractability problems. stories where the player can either play the protagonist [YRB<sup>+</sup>04] or observe and influence the main characters [PCLC07].
2. A virtual training environment which ensures that the player encounters specific teaching moments [RS06c].
3. Generating a narrative structure from players' and NPCs' interactions [Szi03].

~~Additionally, these systems face an authoring problem coined the *authoring bottleneck* [MS05b, RY06], for instance, An alternative to drama management is unrestricted emergence with unpredictable results, which is unlikely to meet any of the above goals.~~

~~The main challenge in drama management is the need to author actions and dialogues in sufficient detail for the NPCs to respond correctly to players' interaction; coined as the authoring bottleneck [MS05b, RY06]. For example, it took three person-years to author Façade, it Façade; which contains one scene, two characters and each drama takes approximately 25 minutes [MS05b]. The main reason for this authoring problem is the need to author actions of the characters in sufficient detail so that the characters can both act out the narrative correctly and respond to a fair number of interactions from the player~~

Believable human behaviour representation is whether the NPCs exhibit behaviour similar to humans while maintaining the intended narrative structure.

~~An alternative to the story-based philosophy is to have the emerge from character and player interactions rather than follow a pre-authored tale. Emergence and improvisation, call for more engaged actors that need to be able to both engage the player and to act out a coherent, the should emerge into a specific genre recognisable by the player. Due to the added demands of the actors in an improvisational theatre, the actors need far more sophisticated algorithms that are divided up between them. Distributed~~

~~computing is far more feasible than centralised computing as then each actor is only computing a portion of the overall composition that is relevant to the actor's current status and recent interactions with other actors and the player. Additionally, this enables the actors to respond more fluently to player interactions because they do not need to wait for instructions from a central manager.~~ As we defined in Section 1.1, we consider believable behaviour to be:

1. **Coherent**: The behaviour is consistent with previous behaviour and expectations based on character goals [Szi03, p. 6], and logically inferred [SGRR73] from its knowledge base.
2. **Rational**: As defined in Game Theory; that NPCs choose actions that optimise their utility given their expectation from a theory of mind reasoning.

The main ~~danger in improv is that the does not emerge as intended. Emergent systems such as Gadin [BK07] tackle this by using simple scenes with distinct goals for the characters, using STRIPS planning to plot character actions. The use of planning means that they face the same tractability issues as systems in that the planning algorithms will not scale well.~~

~~There are distinct benefits of emergent ; the action is more responsive to player interactions, as demonstrated in Gadin by creating dilemmas for the player in response to the players' actions and choices. Additionally having s emerge significantly reduces the authoring bottleneck due to a significant reduction in the need for detailed action scripts.~~

~~What remains is to do away with unnecessary planning algorithms and to decentralise the management by making the actors responsible for the emergence of a [ALW11, p.5]. refers to a theatre with all the conventional components; stage, costumes, actors, audience, which requires the use of rational agents that can respond to challenges with creating believable NPCs is the actions of the user logically and in context, specifically in dialogues because they carry the highest complexity complexity of the human mind and how to still manage the drama without compromising believability.~~

~~Our answer~~

**Solution:** Our solution is the Directed Emergent Drama, combining deep autonomous ; to distribute the computation between autonomous and drama aware actor agents with a shallow director agent to create an emergent that follows the dramatic arc and conforms to a known genre emergent drama.

### 1.3 Directed Emergent Drama (DED)

Fast-growing virtual realities and the apparent lack of development in playability in computer games in the last 15 years is the ~~main primary~~ motivation for the DED and its contributions presented in this thesis. The DED has a director agent, actor agents and motif like structures called schemas that guide the emergence of an interactive drama. The drama emerges from the interactions of the actors and a human player. We summarise the DED below and give a detailed description in chapter 4.

**Schemas**, motif like structures similar to G. Polti's situations, that a director uses to inform the actors of where the drama should emerge ~~to follow the drama genre and the structure laid out by an author~~. The schemas do not contain any specific instructions ~~in the form of such as~~ actions, sentences, gesture or behaviours. ~~There can be numerous schemas deployed~~ ~~The director deploys several schemas~~ in parallel. At any given time there are at least two or more schemas deployed, see detailed description in Section 4.3.

**Director**, ~~a shallow agent that matches schemas to actor agents in order to give them guidance on how to progress the to fit a specific genre to guide the emergent interactive drama~~. The director deploys schemas as appropriate for the intended drama genre. The director ~~is not following does not follow~~ a pre-authored script similar to a film script. Instead, the director guides the actors using goals that are pre-assigned by an author, see detailed description in ~~Section 4.4~~ 4.4.

**Actors**, the ~~prima motor of the , they drama's prima motor~~, interact with the player and improvise ~~a for the player an emergent interactive drama~~. The actors are responsible for the ~~drama~~ and will overrule the director's guidance if it interferes with ~~a fluent performance of the character that they are portraying their performance~~. The actors are aware that they are actors in a ~~and that they drama and~~ need to ensure that the ~~drama~~ conforms to the expected genre, see detailed description in Section 4.5.

**Player**, ~~a~~ human player that is ~~at the same time both simultaneously~~ a spectator and an actor in the ~~drama~~, i.e. the protagonist, see detailed description in Section 4.6.

## 1.4 Hypothesis

~~That: That distributing the drama management among rational, autonomous agents, using motif like structures called schemas, applying BNs as the core decision mechanism for the agents, giving the agents drama awareness and making them responsible for the drama emergence, will allow for real-time application of emergent emergent dramas that include several characters, behaviours and scenes, and run for extended periods without more than half an authoring bottleneck hour~~

We now define the terms in the hypothesis as we use them in this thesis:

~~That “...distributing the drama management among rational, autonomous agents...”~~  
~~- (novelty) - decentralising Decentralising, the director of the systems by using [Mat02, p.41]; making the actors take a greater part in managing the interactive drama systems with autonomous actors responsible for managing the drama, i.e. facilitating the expected emergent drama.~~

~~“...using motif like structures called schemas...”~~ - (novelty) - rather than using episodes or plot points that are sequential and linear, or beats (the smallest dramatic structure) we We use motif like structures similar to G. Polti's situations [Pol21], that are non-sequential and non-linear; they are an abstract depiction of a current situation. The schemas have goals that guide the actors in developing the drama, and goals that pertain to their character and cause conflict and tension. In this manner, the schemas generate a situation - evaluated by N. Szilas & Co computational models [SER16].

~~“...applying causally causal structured BNs as the core decision mechanism for the agents...”~~ - (novelty) - using We use rational agents capable of logical reasoning and theory of mind in an interactive drama system, building up on the work of the on our Rational Dialogue Engine (RDE) [Ari07a, Ari07b]  
~~- (evaluation) - Requires:~~

1. ~~that players find them coherent~~
2. ~~that recorded responses are rational BNs~~

~~“...giving the agents' drama awareness and making them responsible for the drama emergence...”~~ - (novelty) - applying Apply duality in the actor's decision mechanism, allowing the actors to be aware that they need to choose actions that are both believable and aid the progression of the . Enabling the drama's progression—enabling the actors to realise if there is a conflict between believability and the requirements of the drama requirements and ask other actors for help when needed.

"...will allow for real-time application..." - (evaluation) - ~~requires the actor agents to react within 1 second so that the player does not need to wait for the response~~ — evaluated by timing the response and via user testing.

Requires:

1. that players find them timely
2. that recorded reaction time is < one second.

"...of emergent emergent dramas..." - (evaluation) - ~~emergent = a A drama emerges from player and actors interaction. = the player, being at the same time a spectator, takes part in a and plays a role in the . players' and actors' interaction.~~ Evaluated by observing the drama structure ~~in complete systems~~ primarily from logs and by user testing.

"...that include several characters, behaviours and scenes - (evaluation) - ~~compare the numbers between systems where this is available~~ The drama content is primarily observed from logs.

"...and run for extended periods..." - (evaluation) - the player can engage in the drama for at least 30 minutes ~~or more as is typical with a episode in the television; similar to a television drama.~~

~~without an authoring bottleneck~~ — (evaluation) — the major drawback of previous systems has been the authoring bottleneck. Minimise the authoring index such that the time of authoring in months yields longer than those of previous systems.

$$\text{Authoring Index} = \frac{\text{Authoring time}_{\text{months}}}{\text{Playing time}_{\text{minutes}}}$$


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We make no promise that the dramas generated will be more aesthetically pleasing, dramatically satisfying, or artistically complete than the output of previous systems. We believe that it is practically impossible to measure these aspects scientifically. It is not the aim of this thesis to attempt to measure such considerations.

apply both computational and user evaluation that are grounded on the established by H. Barber [Bar08].

## 1.5 Thesis outline

Chapter 2. Background, we ~~start the chapter with a discussion on the definitions of narrative versus drama and their compatibility with popular computer gamesgenres.~~

~~discuss relevant definitions and work from Narratology and how it relates to computer games.~~ The DED builds on ~~several~~ existing technologies and former work which we describe in some detail; starting with existing technology, ~~and~~ followed by our former work.

Chapter 3. Related Work, We review ~~existing narrative and drama systems and discuss the division of the field to~~, and systems [Mat02, p.41].

~~We summarise by discussing existing shortcomings related work and discuss existing challenges and how our work is building on lessons from the previous systems~~builds on lessons learnt.

Chapter 4. Directed Emergent Drama (DED), We describe the technical structure of the DED in detail; how the director, schemas, actors and player function within the emergent drama. We use the latest implementation of the DED in a leading MMOG technology, toolset; SpatialOS, as a running example to demonstrate ~~the technology~~our solution.

Followed by a comparison of DED to ~~narrative, drama, , and related systems, in particular related~~related systems.

Chapter 5. Evaluation, We describe ~~the implementations of the DED in virtual reality, in mystery games that we developed and in and several DED applications, discuss their evaluation, and~~ summarise the results.

Chapter ???. Conclusion, We summarise and discuss conclusions, limitations and future work.

# 2

## Background

### 2.1 Introduction

In this Chapter, we introduce and discuss several key definitions, technology and previous work ~~that we rely on~~ for the DED. ~~Therefore~~ We refer back to this Chapter throughout the thesis. ~~The Chapter is structured as follows.~~

~~We start by defining commonly used terms and how we understand them in the context of our work. The as a linear inflexible recount of events, see Section 2.2.1. A brief introduction to structuralism, see Section 2.3 and how we have established our definitions on the work of structuralists including G. Freytag [Fre63] in Section 2.3.1, G. Polti [Pol21] in Section 2.3.2, V. Propp [Pro68] in Section 2.3.3. Additionally S. S. Van Dine [Van92], M. Esslin [Ess76], R. A. Freemann [Fre92], R. A. Knox [Kno92], G. Princee [Pri03], T. Todorov [Tod77] on the structure of the murder mystery, see Section 2.3.4. We define drama and the difference between drama and narrative, in Section 2.2.2, followed by a discussion about modern computer games~~

2.2 Narratology. ~~We define narrative and drama, discuss their structure and how they relate to drama and narrative in Section 2.2.3. We describe the structure of the murder mystery, see Section 2.3.4, which we repeatedly use in our experiments games. We end the section on a summary of the definitions and how they are relevant for the thesis.~~

~~We introduce two distinct technologies, starting with in Section 2.3.1, which we use as the basis for actor agents knowledge base and coherent reasoning. Followed by , in Section 2.3.2, which we use for the actors rational reasoning algorithms that are a powerful tool to create believable characteristic behaviour. The powers of and are then combined in the~~

~~, in Section 2.3.2.4, creating a very precise and accessible means of developing robust and coherent reasoning.~~

2.3 **Computation.** We apply two core technologies in the DED:

We build the

2.3.1 **Bayesian Network (BN)**: causally structured stochastic networks.

2.3.2 **Game Theory (GT)**: rational and coherent reasoning when combined with BNs.

A basic understanding of the underlying technology is imperative to understand our contribution.

2.4 **Former work.** The DED on two former work, the , see Section 2.4.1 which dynamically creates novel mystery plots from static input, and the , see Section 2.4.2, which uses the to create rational agents. extends on our former published work:

2.4.1 Bachelor of Science (BSc) project: Dynamic Plot Generating Engine (DPGE) [Ari06, Ari08].

2.4.2 Master of Science (MSc) thesis: Rational Dialogue Engine (RDE) [Ari07a, Ari07b].

2.5 **Summary.** We finish the Chapter on a summary of its contents and how it leads towards our current work, ~~see Section ??.~~

## 2.2 ~~Narrative~~**Narratology**

We start by defining commonly used terms and how we understand them in the context of our work. A brief introduction to structuralism, and how we have established our definitions on the work of structuralists including: G. Freytag [Fre63] in Section 2.2.1.1 , G. Polti [Pol21] in Section 2.2.1.2, V. Propp [Pro68] in Section 2.2.1.3.

Additionally S. S. Van Dine [Van92], M. Esslin [Ess76], R. A. Fremann [Fre92], R. A. Knox [Kno92], G. Prince [Pri03], T. Todorov [Tod77] on the structure of the murder mystery, see Section 2.2.1.4. We define drama and the difference between drama and narrative, in Section 2.2.2, followed by a discussion about modern computer games and how they relate to drama and narrative in Section 2.2.3. We describe the structure of the murder mystery, see Section 2.2.1.4, which we repeatedly use in our experiments.

### 2.2.1 ~~Narrative~~

~~Most will instinctively feel that they know what a narrative is, i.e. The word narrative derives from the Latin verb narrare, which means "to recount", and,~~

in everyday usage, it is a story or a novel either written or told by a storyteller or a narrator. Essentially, in everyday usage, that is what a narrative is. A narrative is though a much broader More specifically, a narrative presents a sequence of events which do not need to be causally connected [Pri03].

While a narrative tends to account past events rather than present events it is nevertheless a broad term that includes far more than stories and novels. The word narrative derives from the Latin verb narrare, which means "to recount". The narrative is a concept, composed by an author to be delivered in any medium. A narrative describes a sequence of real or unreal events [oed12]. By this definition, a narrative does not refer to an interaction or effect on the narrated events. according to the Oxford English Dictionary:

A narrative tends to account past events rather than present events happening in the here and now. Therefore, a narrative is not an appropriate structure to use in a highly interactive game where the player is to have an active say in how the game and the game's unfolds. The gameplay, however, could be collected into a story of that game instance.

More specifically, a narrative presents a sequence of events which do not need to be causally connected [Pri03].

1. A spoken or written account of connected events; a story.
  - A non-causal narrative: "the king dies, and the queen dies". [1.1] The narrated part of a literary work, as distinct from dialogue.
  - A causal narrative: "the king dies, and the queen dies of grief". [1.2] The practice or art of telling stories.
- 1.3 A representation of a particular situation or process in such a way as to reflect or conform to an overarching set of aims or values.

- [oed12]

An example of a non-causal narrative is Ulysses [Joy22]. Therefore, a narrative can include gameplay which has "an overarching set of aims or values" [oed12].

Some narratives do not have an explicit causal sequence of events, for example, Ulysses [Joy22] where the narrator Leopold Bloom describes a series of mostly unconnected events that he happens upon witnesses while walking through Dublin on an ordinary day.

A story begins at some point in time, which is understood to have a prior narrative, which is frequently implicit and left to. However, unlike Leopold, we have an intrinsic urge to reason about the world around us in narrative terms. To this end, we often imagine a narrative to explain current events, in the imagination of the reader. The mind instantly creates a backstory for all of what it senses; even the most uncomplicated narrative will have a former world state. For example, the three-word narrative : "The stone fell. " The stone must have been somewhere before falling, and it was in an elevated

~~position relative to the place it fell too. The mind will draw a picture of a plausible scenario and a narrative in which the stone fell. Perhaps it pictures a hiker climbing a mountain slope and dislodging the stone.~~

~~The implicit necessity of previous events makes us see a narrative where there is no action; even in absence of actual action. For example, when looking at a static picture, there is the suggested past action of how things arrived at their positions. We ask ourselves why a person in a picture is sad or happy, what they might be thinking and of a stranger, we contemplate several narrative aspects, including:~~

- ~~who they are,~~
- ~~what they are thinking,~~
- ~~what they are feeling,~~
- ~~What they are doing,~~
- ~~what they intend to do,~~
- ~~where they came from, and~~
- ~~where they are going. The narrative is, therefore, an essential part of our cognitive processes, yet it is still and unmoving like a picture, we do not affect it; we only observe it. For movement, we need drama as in theatre, movies, and games.~~

~~We aim to develop algorithms that generate narratives from users' interactions with events and characters in VRs. Algorithms need structure to facilitate meaningful emergence. Structuralism is a field within Narratology dedicated to identifying intrinsic structures within the literature.~~

~~We give a brief introduction to relevant structuralists and their work:~~

1. [G. Freytag](#) [Fre63] in Section 2.2.1.1
2. [G. Polti](#) [Pol21] in Section 2.2.1.2
3. [V. Propp](#) [Pro68] in Section 2.2.1.3
4. [Structuralistic approach to analysing the murder mystery](#).

~~In this Section, we give a brief introduction on relevant structuralists and their work that we build the .~~

### 2.2.1.1 [Freytag's pyramid](#)

In 1863, a German playwright and novelist Gustav Freytag wrote Die Technik des Dramas, a definitive study of the ~~5-act dramatic arc that starts on an introduction to characters and the situation. The dramatic tension then gradually rises until it reaches a climax followed by falling action and a resolution:~~

~~dramatic arc in five acts as follows:~~

1. Exposition (originally called introduction)
2. Rising action (rise)
3. Climax
4. Falling action (return or fall)
5. Denouncement, resolution, revelation, or catastrophe

The pyramid is an excellent baseline to understand the general flow of a drama and the need to build suspense via complex interactions of the characters. It is ~~not necessary~~ unnecessary to stick strictly to G. Freytag's five acts; he would likely have modified his structure if he had been around when television and movies started to be popular. After all, there are multiple acts in a TV series, neither is it always five acts within an episode. In our modern medium, we need to adjust the structuralist theories to the current conditions that the authors could not foresee.

#### 2.2.1.2 Polti's 36 situations

According to G. Polti, there are 36 situations [Pol21] that represent every dramatic situation known in drama, for example, the below list with the numbers from Polti's list:

- (23) Necessity of sacrificing loved ones; a hero wrongs a beloved victim because of the necessity for their Sacrifice.
- (24) Rivalry of superior vs inferior; a superior beat an inferior rival and wins the prise
- (27) ~~Discovery of~~ Discovering the dishonour of a loved one; the discoverer discovers the wrongdoings committed by the Guilty One.
- (30) Ambition; the ambitious person is opposed by an adversary when seeking the coveted thing.
- (33) Erroneous judgment; the mistaken one falls victim to the cause or the author of the mistake and passes judgment against the victim of the mistake when it should be passed against the guilty one instead.
- (34) Remorse; the culprit wrongs the victim or commits the sin, and is at odds with the interrogator who seeks to understand the situation.
- (35) Recovery of a lost one; the seeker finds the one found.
- (36) Loss of loved ones; a kinsman sees their kin slain in front of them.

These situations ~~, also called motifs, are an abstract view~~ are motifs of the conflict between characters ~~that is~~ producing the drama.

### 2.2.1.3 Propp's Morphology

Vladimir Propp [Pro68] a Russian structuralist analysed a subset of Russian folktales, classified by Aarne index 300 to 749 [Aar11].

Arne index is a collection of folktales indexed ~~in order~~ to enable researchers access to preserved copies of original folktales. Propp selected a specific set of the folktales from the index, i.e. tales 300 to 749. These tales were so similar that he could reduce the number of folktales from 449 to a set of 100 distinct tales.

Propp then further analysed these 100 folktales and found that, although names and attributes of the characters change, they all adhered to the same structure which he captured in the following four rules [Pro68]:

1. Functions of characters serve as stable, constant elements in a tale.  
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 regarding their structure.

Propp proved that this is true for the tales in Aarne index 300 to 749 by showing that it holds for every single one of those tales. Propp named and numbered the functions that make up these specific folktales. The result is called Propp's morphology of the Russian folktale. There could exist Russian folktales that are not of this structure simply because they were not in the Aarne index.

Propp further theorised, in line with other structuralists, that there exists a uniform structure for stories, i.e. that all stories, of any genre, will conform to a single distinct structure. Due to the theories of the structuralist of generalised and uniform structure in all things, their work is of significant interest to Computer Scientists when creating algorithms that rely on structure and predictable patterns.

### 2.2.1.4 The murder mystery

A typical murder mystery is in three acts, a prologue, a sizeable middle part and an epilogue [Tod77].

In act I, the prologue, the drama introduces the characters and sets the scene; including any secret drawers, hidden compartments and any readily accessible stacks of poisons or lethal apparatus. Additionally, the detective discovers the body, traditionally in one of the last scenes after the drama introduces the victim.

In act II, the detective ~~, played by the player, interviews all~~ interviews all ~~the~~ suspects and observes all ~~clues, which means that all clues should be revealed to the player~~ relevant clues to deduct who is the murderer. All clues need to be accessible to the detective by the end of act II. ~~The~~ To carry out their role. The game should reveal to the detective all suspects' motives, means ~~and opportunity of all suspects need to be revealed either through dialogue or by~~ and opportunity through either dialogue or physical evidence.

In act III, the epilogue, the murderer is revealed by showing that only the murderer had a motive, means and opportunity. We have identified specific primary goals that should be satisfied ~~in order~~ to progress the drama, from act I to act II and ~~from~~ act II to act III.

The drama has five primary sections that form the dramatic arc: exposition, complication, climax, fall, and closure [Pri03]. In the murder mystery, the exposition or prologue is the first act. It serves ~~the purpose of introducing to introduce~~ characters and scenery and has at its end a murder ~~which that~~ serves as the inciting moment of the drama. The second act contains the ~~complication of the plot~~ plot's complication, where many facts about the characters and their relationship to the murder surface. ~~This happens first Events first occur~~ in a seemingly disparate way, but as act II progresses, the facts become more evident, and gradually reveal the ~~sequence of events that took place events' sequence~~ before the murder. The final act sees the climax of discovering the murderer and the closure of proving that no other could be the murderer. ~~Parts of the murder mystery can get monotonous, for example, act and the player can quickly lose interest and leave. It is necessary to have a continuous engaging unfolding in order to keep the player immersed.~~

The murder mystery genre is a game of *spotting the piece that does not quite fit* [Kno92, ?][Kno92, Tod77]. A good mystery has all clues in the open easily observable but not visible. The detective needs to recognise their significance to the mystery. The clues ~~appear ordinary and~~ blend into the background, ~~and if the detective were not explicitly looking for them, they would not be seen as out of the ordinary at all; the detective needs to discover them via an investigation.~~

It is a game of pretence; characters appear manipulative and devious without the viewer recognising it because they do not see the real motive for the character's behaviour. ~~The viewer Therefore, the viewer frequently sees intelligent devious characters frequently as being as carefree, superficial and rather silly because the characters do not reveal their true motives, and somewhat silly~~ [Van92, Ess76].

There is a pretence of normality in the murder mystery surrounding the ~~abnormal bizarre~~ incident of having someone brutally murdered in ~~your~~

~~midst~~ and ordinary everyday scene. The drama ~~portrays~~ depicts the suspects as good standing citizens that we would typically not consider capable of murder ~~in the first place~~ [Fre92, Van92, Ess76].

When we talk about revealing characteristics of characters, then we refer to this pretence. Namely, characteristics are revealed but not in direct connection to the real motive behind the characters actions. The ~~player~~ detective will need to connect motives with the actions and characteristics of the suspects. The same applies for revealing clues: The clues should be observable, but the ~~player~~ detective needs to understand how they can be a piece in the puzzle and ~~how to~~ put the pieces together to make a whole picture.

### 2.2.2 Drama

~~As we discussed at the start of Section 2.2.1, the narrative recounts past events, the , however, happens in the here and now. In the words of M. Esslin:~~

~~whereas any narrative form of communication will tend to relate to events that have happened in the past and are now finished, the concreteness of is happening in an eternal present tense, not there and then, but here and now.~~

~~In the~~ In the Oxford English Dictionary drama is defined as follows:

*A composition in prose or verse, adapted to be acted on stage, in which a story is related by means of dialogue and action, and is represented, with accompanying gesture, costume and scenery, as in real life; a play.*

– [oed12]

This definition is ~~fine acceptable~~ for drama proper, that is a drama for a theatre stage, but there are many other types of drama, and for those, as M. Esslin says, this is "downright incorrect" [Ess76, p. 9] for the following reasons:

1. "A composition in prose or verse" [oed12]. According to M. Esslin: "seems to imply a text previously composed" [Ess76, p. 9] which would rule out any improvised drama.
2. "adapted to be acted on stage" [oed12]. In M. Esslin's words: "what then about drama in television, radio or the cinema?" [Ess76, p. 9] if drama requires a stage, then none of these would constitute a drama.
3. "in which a story is related by means of dialogue and action" [oed12]. If a dialogue is necessary, then mime cannot constitute drama and neither would many of the old black and white movies that had no sound. ~~We need action, but the action does not need to be physical~~

~~since it rules out radio~~ Neither is a physical action necessary since it rules out radio drama.

4. "and is represented, with accompanying gesture, costume and scenery" [oed12]. M. Esslin says: "I have seen very good drama without costume or indeed scenery" [Ess76, p. 9] and neither costume nor scenery are in radio drama.
5. "as in real life" [oed12]. M. Esslin says: "It seems to assume that all drama must be realistic drama" [Ess76, p. 9], *Waiting for Godot* [Bec53] and *The Merry Widow* [Leh05] are not like real life but are still dramas.

~~Drama~~ According to M. Esslin drama is a broad term ~~and can encompass most of our activistic in one form or another, as M. Esslin that encompasses most of human behaviour, he~~ says: "It is well-nigh impossible to draw the exact dividing line between when one kind of general activity stops and drama proper starts." [Ess76, p. 10]. Therefore, drama includes ~~a great number of activities that include tie elements; ritual, activities such as~~

- ~~ritual,~~
- make-believe play,
- tribal dances,
- religious services,
- great state occasions,
- gladiatorial contests, ~~public executions and all-~~
- ~~public executions, and~~
- spectator sports, ~~even though they are in-~~

~~However, according to~~ M. Esslin's words~~they are~~: "not proper drama such as we see in theatre with the full dramatic structure" [Ess76, p. 10].

For example, a soccer game matches the Oxford English definition of drama. A soccer game has an illuminated and clearly defined stage. The game has spectators that applaud and cheer and boo if the game goes badly. ~~There are, and it has~~ a clear beginning and end; ~~there are, with a~~ rise and fall in suspense. ~~In a soccer game, there~~ There are clearly defined gestures, dialogues, actions, scenery, and costumes –

~~Conversely, in~~ a soccer game~~cannot constitute a narrative because it is not recounting anything; it is happening in the here and now. Many forms of drama, therefore include spectators participation to a greater or lesser extent – for example, religious services where the congregation frequently needs to take part in some of the rituals.~~

Drama is primarily an action, "in Greek the word *drama* simply means *action*. Drama is a mimetic action, action in imitation or representation of

human behaviour"[Ess76, p. 14]. Since drama is at its heart action, then actors are an essential part of the drama, "there is no drama without actors whether they are present in flesh and blood, or projected shadows upon a screen, or puppets"[Ess76, p. 11]. In order for there to be action, there must be an actor to act, we only need one actor; "even the internal monologue, where we follow the thoughts of a single character is drama and is frequently acted, particularly on radio"[Ess76, p. 19].

Drama "puts the spectator into the same situation as the character to whom the words are addressed." [Ess76, p. 18] Effectively for our purpose drama is; action by one or more actors that play a role in front of one or more spectators. In the words of M. Esslin:

*The author and the performers are only one half of the total process: the other half is the audience and its reaction. Without an audience there is no drama. A play which is not performed is merely a literature.*

– [Ess76, p. 23]

~~Indeed without action, actor and spectator there is only a recount of past events and the play that so deeply engages us is missing and with it our involvement and direct contact.~~ We start our lives learning through play, action and interaction. Drama in our digitalised world, a structured play that allows us to learn and grow in a manner that is instinctive from earliest childhood is our new frontier in entertainment, training and therapy. In M. Esslin's words:

*Through the mass media drama has become one of the most powerful means of communication between human beings, far more powerful than the merely printed word which was the basis of the Gutenberg revolution.*

*That is why a knowledge of the nature of drama, an understanding of its fundamental principles and techniques and an ability to think and talk about it critically has become very necessary indeed in our world and that does not only apply to such great works of the human spirit as the plays of Sophocles or Shakespeare, but also to the television situation comedy or, indeed, to that briefest of dramatic forms, the television or radio commercial.*

– [Ess76, p. 12]

#### 2.2.2.1 Improvisation

Improvisation is free form drama that does not have the rigid structure of drama proper; there is no script or pre-authoring, no director that micro-manages every move as K. Johnstone says:

*I'd argue that a director should never demonstrate anything to an actor, that a director should allow the actor to make his own discoveries, that the actor should think he'd done all the work himself. I objected to the idea that the director should work out the moves before the production started. I said that if an actor forgot a move that had been decided on, then the move was probably wrong. Later I argued that moves weren't important, with that only a couple of actors on a stage, why did it matter where they moved anyway? I explained that **Hamlet** in Russian can be just as impressive, so were the words really of first importance? I said that the set was no more important than the apparatus in the circus.*

– (FA: emphasis is in italics in the original text) [Jho79, p. 24]

While improvisation does not always lead to success, it often outshines pre-authored text, as K. Johnstone says: "We learned that things invented on the spur of the moment could be as good or better than the texts we laboured over" [Jho79, p. 26]. It is not necessary to get the authored text correctly for drama is action and not a literary art as K. Johnstone says:

*Many writers of great talent have failed to write successful plays (Blake, Keats Tennyson, among others) because of a failure to understand that drama is not primarily a literary art. Shakespeare is a great writer even in translation; a great production is great even if you don't speak the language. A great play is a virtuoso display of status transactions - **Waiting for Godot**, for example.*

– (FA: emphasis is in italics in the original text) [Jho79, p. 72]

Improvisation is spontaneous, an interaction between actors that collaborate to progress the drama, as in this example given by K. Johnstone:

*If an improviser is stuck on an idea, he shouldn't search for one, he should trigger his partner's ability to give 'unthought' answers. If someone starts a scene by saying 'What are you doing here?' then his partner can instantly say, without thinking, 'I just came down to get the milk, Sir.'*

*'Didn't I tell you what I'd do if I caught you again?'*

*'Oh Sir, don't put me in the refrigerator, Sir.'*

*If you don't know what to do in a scene, just say something like, 'Oh my God! What's that?'*

*This immediately jerks images into your partner's mind 'Mother!' he says, or 'That dog's messed the floor again!', or 'A secret staircase!' or whatever.*

– [Jho79, p. 82]

In this manner, improv actors give each other ideas and seeds to create more drama. They collaborate and play together, passing over to each other suggestions on how the plot can develop while they simultaneously remain in character (IC). Which is called not to block the other actors' suggestions as K. Johnstone describes it:

*There are people who prefer to say 'Yes', and there are people who prefer to say 'No'. Those who say 'Yes' are rewarded by the adventures they have, and those who say 'No' are rewarded by the safety they attain. There are far more 'No' sayers around than 'Yes' sayers, but you can train one type to behave like the other.*

*'Your name Smith?'*

*'No.'*

*'Oh ... are you Brown, then?'*

*'Sorry.'*

*'Well, have you seen either of them?'*

*'I'm afraid not.'*

*Whatever the questioner had in mind has now been demolished and he feels fed up. The actors are in total conflict.*

*Had the answer been 'Yes', then the feeling would have been completely different.*

*'Your name Smith?'*

*'Yes.'*

*'You're the one who's been mucking about with my wife then?'*

*'very probably.'*

*'Take that, you swine.'*

*'Augh!'*

*Fred Karno understood this. When he interviewed aspiring actors he'd poke his pen into an empty inkwell and pretend to flick ink at them. If they mimed being hit in the eye, or whatever, he'd engage them. If they looked baffled, and 'blocked' him, then he wouldn't.*

– [Jho79, p. 92]

To block a suggestion ~~stops~~can stop the plot from developing in a specific direction ~~, or entirely,~~ while accepting an offer opens new paths, new complicationand increased suspension. For this reason, the actors benefit from accepting an offer and use it to develop the plot further as in K. Johnstone's words:

*Bad improvisers block action, often with a high degree of skill.*

*Good improvisers develop action:*

*'Sit down, Smith.'*

*'Thank you, Sir.'*

*'It's about the wife, Smith.'*  
*'She told you about it has she, Sir?'*  
*'Yes, yes, she's made a clean breast of it.'*  
*Neither actor is quite sure what the scene is about but he's willing to play along, and see what emerges.*

– [Jho79, p. 95]

Furthermore, to accept does not mean to mindlessly do what another actor asks but to use the request as a means to build the plot. Similarly to block does not mean to say no or to disobey the other character; instead, it means to refuse to acknowledge and accept the part offered as K. Johnston says:

*I call anything an actor does an 'offer'. Each offer can either be accepted, or blocked. If you yawn, your partner can yawn too, and therefore accept your offer.*

*A block is anything that prevents the action from developing, or that wipes out your partner's premise. If it develops the action it isn't a block. For example:*

*"Your name Smith?"*

*"What if it is, you horrible little man!"*

*This is not a block, even though the answer is antagonistic. Again: "I've had enough of your incompetence, Perkins! Please leave."*

*"No, Sir!"*

*This isn't a block either. The second speaker has accepted that he's a servant, and he accepts the situation, one of annoyance between himself and his employer.*

*If a scene were to start with someone saying "Unhand me, Sir Jasper, let me go", and her partner said "all right, do what you like, then". this is probably a block. It would get a laugh but it would create bad feeling.*

– (FA: emphasis is in italics in the original text) [Jho79, p. 97]

A block or an accept ~~therefore action is, therefore~~, not necessarily visible to the audience unless they understand the structure of improv, and even then; skilful actors mask the interaction with a masterful play of their characters.

### 2.2.2.2 Interactive Drama

In Section 2.2.2 we argued that drama is, in essence, an action, acted by one or more actors in front of an audience [Ess76].

Interactive drama is a drama where ~~the spectator takes one or more spectators from the audience play a~~ part in the drama ~~by taking on a~~

~~character role similar to . Although the as if they were one of the actors, even if their role is nothing more than stating their name, posing or holding something at the request of one of the actors. Although a spectator has taken on a role in the drama, they remain a spectator of the drama because they are only improvising and have no without a script. They do not know how the drama will play out or what the end will be and they are, therefore, unless they have seen it before. Therefore, the participating audience is still spectating the drama as it unfolds, which means that it is still a drama. It remains a drama; it retains all the suspense and tension that drama can have. For an we need action, one or more actors, some of the actors are also spectators of the drama. Taking part in the drama is entertainment for them, a game that they are playing.~~

We must ~~keep in mind~~, not to be too ~~strict rigid~~ in our definitions because that will only restrict the growing field that interactive drama is, as Esslin expertly puts it:

*Definitions—and thinking about definitions—are valuable and essential, but they must never be made into absolutes; if they are, they become obstacles to the organic development of new forms, experiment and invention.*

— [Ess76, p. 11]

Interactive drama is a new form of media, and ~~there has we have~~, to a large extent~~been~~, made the same mistakes as in the first films when they filmed theatre productions without adapting them to the altered viewpoint of the camera lens, which resulted in early films being over-acted, i.e. the actors grossly overdid displays of emotions and character because they needed them to be visual to a theatre audience. The camera lens, on the other hand, is close to the actor's face and catches every tiny facial expression which forced the actors to adopt an entirely new way of displaying emotions that would never work on a stage. In the same manner, we should seize this chance to evolve drama into this new media, creating new genres in drama, education, therapy, entertainment and news coverage.

In ~~its essence~~, an interactive drama is ~~an~~ improv designed to engage the ~~spectators~~audience in the drama.

### 2.2.3 Game

*...the vicarious play activity (which drama is for adults)...*

— [Ess76, p. 21]

Game worlds become increasingly advanced in graphics and sound, and players can spend months both in single-player and online-mode exploring, taking on quests and interacting with NPC (NPCs). There are mainly

three computer game genres that are of interest here; ~~First Person Shooters (FPSs), Adventure games, also known as point & click games and .~~

1. FPSs games are centred on using a gun or any projectile weapon and with it killing a large number of enemies that are bent on killing the player. The games are thus very action-based, and the player needs good coordination and reflexes to master the challenges of the games. There is usually the main storyline that runs through the game and multiple levels that the player needs to complete to progress in the game.
2. Adventure games are quite the opposite of FPSs ~~in that there is minimal ; it is rare that~~ action or speed ~~is~~ required to complete the game. Which is why they are frequently called “point & click” games because for the most part all the player does is to locate items with the mouse and combine items to progress the story or talk to NPCs in the game through drop-down dialogue boxes. They are very puzzle-oriented, and the player frequently needs to solve several puzzles to complete the game. These games tend to be story centred and based on a film or a novel.
3. A game where the players take on a role in a fantasy adventures (RPGs) are a combination of FPS and adventure games and Pen & Paper Role-Playing Games (PP-RPGs) which is the “real-life version” of Computer-Based Role-Playing Games (CB-RPGs). In an RPG the player takes on a role in a rather rich virtual world and through a series of quests will save this world from impending doom or resolve some significant in-game issue. The player will gain experience through solving quests and killing monsters and increase in power (level up) as the game progresses. These quests and levelling up combine elements from FPSs and Adventure games. ~~There is skill needed~~ Players' require skill to kill the monsters encountered, and the player also needs to pick up objects and solve puzzles. RPGs have a significant story element; there is the main plot that needs to be played through to complete the game and multiple short stories in the quests that the player takes on. In PP-RPGs, a group of players are needed to play the game using pens and papers to keep track of their character actions and experience gain. There is also the need for a Game Master (GM) who tells the story of the game, plays the NPCs and in general, takes care of managing the gameplay.

At the dawn of CB-RPGs, there were high hopes for the extension of PP-RPGs into computer games. There were visions of vast worlds with endless possibilities and fruitful interaction with NPCs, possibly meeting favourite heroes from favourite fantasy series. The player would not be limited by the imagination and storytelling skills of the GM or by how successfully a good

group of players can gather. The players could adopt any role they desired, shape the character to their likings and play through virtual reality, receiving a unique play experience for each character that they play. Included in the unique play experience would be a clear sense of a story and purpose for the characters actions just like a quality GM can create in PP-RPGs.

The primary motivation for this vision is that it can be challenging to find a qualified GM that offers sessions in the worlds and playing-style of individual player's likings. It can also be challenging to find a good group that fits the player's playing style. Players are primarily seeking is an RPG tailored to their tastes, competence and play style in the CB-RPGs.

~~Current computer games~~-CB-RPGs often fall short of providing a complete experience for several reasons, the most prominent being that the storylines are pre-authored and do little to accommodate an independent role-playing style. There are also pre-authored stories for offering the interactivity of PP-RPGs, but the GM is free to diverge from them when it suits the game and GMs can also make their own stories either in advance or develop them on the fly during gameplay. Frequently the as G. Gygax says:

*Pen-and-paper role-playing is live theatre and computer games are television.*

– As quoted in [Sch06]

Pre-authoring is named by some as the primary reason, in the words of B. Coffin:

*Sometimes G.M.s will write out an adventure's entire plot, soup to nuts. This is a dangerous thing, because it inherently contradicts one of the fundamentals of role-playing: the players should be allowed to determine the pace and direction of the adventure.*

– [Cof01]

Similarly, many CB-RPGs force railroad the player to violate the characteristic behaviours of the role choose specific actions in order to complete quests and progress in the game's main story. Additionally, and the NPCs' responses are pre-authored, making them very repetitive. The results are rich game worlds that lack replayability due to repetitive storylines and limited NPC interactions.

RPG Neverwinter Nights [Bio02] uses the alignment of the character to determine the available paths through the game. Each player creates a character and determines the initial alignment. The players interact with NPCs and choose between good and evil actions. When players choose evil actions, their alignment shifts to evil, and if they choose the right action, their alignment shifts towards good. Quests that are accepted and completed are also used to adjust players' alignment. Good deeds adjust the players' alignment to good and evil deeds towards evil. The alignment affects the

player's progress in the game by for instance hindering players playing druids in getting full access to their powers and the druid community if the player has not been careful to keep the character alignment as good. It will also affect what sub-quests are available, especially when it comes to quests that are for the advancement of a specific role and need a specific alignment. Still, it does not change the main story or the main story plot; the player will need to finish specific main quests in order to advance and complete the main story. Nothing the player does will affect the pre-authored plots of the game.

Fallout 3 [LLC02] has brought this idea even further; the player's actions significantly affect the character's reputation and opportunities. The availability of quests is dependant on player's actions; how much they explore the world, what they say in conversation, and what skills they pick when levelling up. Still the same can be said for Fallout 3 as with Neverwinter nights: nothing the player does will change the pre-authored plots or the main storyline. The player is always playing along one branch of a multilinear story that mostly follows the same fundamental plot-points each time. Which means that players will not get a novel story experience when replaying the game, which makes it very repetitive and lacking replayability.

In multilinear games, the players can save and reload if they say something to an NPC that has negative results. Equally, if they fail in a battle or a quest, they can reload an earlier save. The game adapts to the players and the players adapt their playstyle to the game. Which is very natural behaviour on for the player, and should be accommodated. Furthermore, some players will systematically try every action and explore every area and put their acquired information on the web where other players can benefit from it if they choose.

~~Incorporating a narrative into a game has several problems that Juul [Juu01] relates well. Narration and interactivity are at odds; the two are a contradiction. To narrate means to recount [oed12], when a player is interacting with a game world, it is at odds to try to tell the player a story of what is happening. On the other hand, the player can easily participate in a Games are intrinsically similar to an interactive drama~~ which at its core is “a play”.

In the words of Gary Gygax:

*Pen-and-paper role-playing is live theatre, and computer games are television.*

– [Sch06]

As we have discussed drama is an integral part of RPGs, perhaps surprisingly drama is also becoming more and more integrated into First-Person Shooter (FPS) games.

FPS games are not very replayable in their basic single-player form. The reason for this is that after the first playthrough then playing it again, reveals nothing new and there is no suspense. There are the same bosses, and there are no significant changes between each gameplay and no new challenges. Multi-player FPS is, on the other hand, highly replayable because then the player is always up against a new challenge. In recent years single-player FPS games have evolved towards having the opponents, the NPCs, more intelligent to provide a more significant challenge for the player. They will simulate the normal behaviour of people in similar situations, including going to sleep, eating and in general going about their daily lives. One of the most recent and hugely popular games in these series is Assassin's Creed II [Ubi09] where the player is an assassin that is assigned several assassination jobs. In Assassin's creed as in many other recent FPS, there is a much greater emphasis on the story and character development than before. The player gets an in-depth character description of the Assassin and why he is in this job. The story progresses gradually through the game with seamless cut scenes. The player is playing the protagonist, and as the story progresses, the protagonist faces many moral dilemmas and challenging revelations that dramatically change his perspectives and shape his character. It is a common theme of other recent games such as Fallout 3 [LLC02] and Heavy rain [Ent09]. Heavy rain carries this character development even further and allows the player to make decisions based on the characters' emotions and thoughts, forcing the player to make challenging moral decisions. There is an evident trend towards making the NPCs more intelligent and more autonomous in order to give the player more fulfilling game experience. An excellent example of this is STALKER [Wor09], there the NPCs actively simulate the behaviours of soldiers or mercenaries that try their best to kill the player in heavily polluted Chernobyl. Their behaviour is very believable, and they provide challenging gameplay, they do not merely continuously walk the same circle. In this respect, there is an apparent disparity between the increased playability of FPS which has every potential of providing rich replayability, as becomes clear when these games offer multi-player mode and the still pre-scripted unchanging storyline that the player is forced to follow.

#### 2.2.4 Summary

We discussed how the combination of narrative and drama theory underlies our work for interactive drama and provides our algorithms' structure. Especially the Structuralists' work that we use to evaluate whether the emergent dramas have the expected structure for their genre:

1. Freytag's pyramid.
2. Polti's 36 situations.

3. Proppp's Morphology.

Moreover, we introduced the template that we use to evaluate whether the murder mystery emergent dramas conform to their genre.

## 2.3 Structuralism Computation

We introduce DED's core technologies, starting with Bayesian Network (BN) in Section 2.3.1, which we use as the basis for actor agents knowledge base and coherent reasoning, followed by Game Theory (GT) in Section 2.3.2, which we use for the actors rational reasoning algorithms that are a powerful tool to create believable characteristic behaviour. BNs' and GT's powers are then combined in the Multi-Agent Influence Diagrams (MAID), in Section 2.3.2.4, creating an exact and accessible means of developing robust and coherent reasoning.

### 2.3.1 Freytag's pyramid Belief Networks

Belief Networks are probabilistic graphs comprised of vertices and directed arcs that indicate conditional dependency. Their purpose is to represent a belief, rather than certainty, about some state or event. For example, to form a belief about what has caused the lawn to get wet; was it the sprinkler or did it rain.

Since Belief Networks use probability distributions, rather than absolute boolean logic, they are especially suitable for incorporating any uncertainty which we commonly find in reasoning about the world. Including challenging psychological elements such as traits and Moreover, they are well suited for challenging psychological models of traits and emotions which are very important for believability [BB00, BH09, GD07, HP99, LWHS07, TG01] when creating characters for drama.

A BN is a type of Belief Network in the form of a directed acyclic graph (DAG); comprised of vertices and arcs that indicate conditional dependency [Jen01].

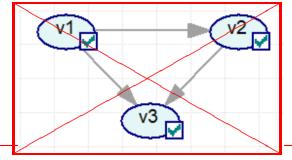
The We use GeNIe an academic modelling environment [DSL07a] for the graphical representation of BN models used in this thesis are created using the an academic modelling environment [DSL07a] and programmed calculations use the, and Smile an academic BN C++ library for calculations [DSL07b].

#### 2.3.1.1 The graph structure

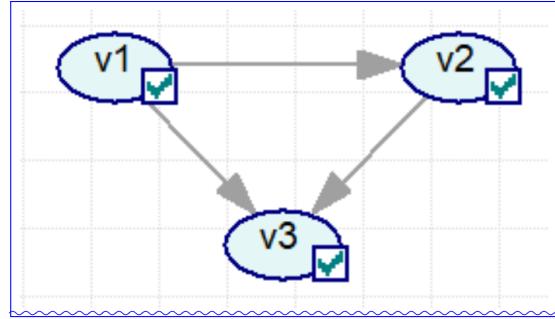
The structure of a BN is as follows:

- A finite set of vertices  $V(DAG) = v_1, \dots, v_n$  where n is the number of vertices.
- A finite set of pairs of vertices called Arcs,  
 $A(DAG) = \{(v_1, v_2), (v_1, v_3), (v_2, v_3)\}$
- Where the directed arcs are considered to start in the former vertex and end in the latter. For example, the arc  $(v_1, v_2)$  starts in  $v_1$  and ends in  $v_2$ . This is represented with an arrow leading from  $v_1$  to  $v_2$ , see Figure 2.3.1 in Figure 2.3.1.

- We call  $v_1$  the parent and  $v_2$  the child in the arc  $(v_1, v_2)$ .
- We call a vertex with no parent a root vertex. In our current example  $v_1$  is the only root vertex.
- There cannot be any path in the graph, if travelling in the direction of the arrow from one vertex to another consecutively, that returns to a vertex that has been previously visited along that path.
- There is only one arc between each pair of vertices.



**Figure 2.3.1** Directed arcs in a BN,  
displayed in the GeNIe UI [DSL07a]

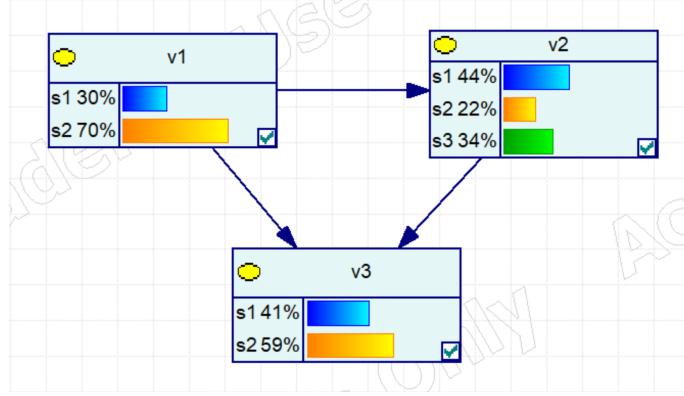


### 2.3.1.2 The vertices structure

Each vertex has a set of states that can be either continuous or discrete. For this thesis, we only require discrete states and will, therefore, not cover continuous states. In the examples below, we have created simple examples with made up values for the introduction of how to evaluate BNs. ~~None of these examples is intended to represent any reality accurately.~~ The states of a vertex are:

- A finite countable set of states for each vertex  $S(v) = s_1, \dots, s_n$  where  $n$  is the number of states for that vertex.
- There are at least 2 states per vertex.
- Each set of states has a marginal probability distribution that in total equals 1 or 100% for any given vertex. For example, if  $v_1s_1 = 0.3$  and  $v_1s_2 = 0.7$  then  $0.3 + 0.7 = 1$  ~~in Figure 2.3.2~~ in Figure 2.3.2.
- If a state's marginal probability has the value of 1 it is considered to be true and if it has the value of 0 it is considered to be false.
- States for a vertex are mutually exclusive, if the marginal probability of  $v_1s_1 = 1$  then  $v_1s_2 = 0$ .

**Figure 2.3.2** A simple BN with 3 vertices and 3 arcs, displayed in the GeNIe UI [DSL07a]



### 2.3.1.3 Assigning conditional probability distribution

Each vertex requires a definition of each of its conditional probabilities in order to evaluate its marginal distribution. We define the conditional probability of a vertex as follows:

- A root vertex has only the assigned marginal distribution since it has no parents, [see the Definition 2.3.1](#) see Table 2.3.1 for  $v_1$ 's values and its visual representation [in Figure 2.3.2](#) in Figure 2.3.2.
- For  $v_1$  we say that the probability ( $P$ ) of either of its state being true is  $P(v_1s_1) = 0.3$  and  $P(v_1s_2) = 0.7$ .
- For vertices  $v_2$  and  $v_3$  we need to define their conditional probability distribution given each of their parent states, [see Definition 2.3.2](#) see Table 2.3.2 for  $v_2$ 's values and [Definition 2.3.3](#) Table 2.3.3 for  $v_3$ 's.
- For vertex  $v_2$  we say that the probability of  $s_1$  being true given its parent  $v_1s_1$  being true is  $P(v_2s_1|v_1s_1) = 0.3$  and similarly the  $P(v_2s_3|v_1s_2) = 0.4$ , [see Definition 2.3.2](#) see Table 2.3.2.
- When there are more than one parent we need to define a conditional probability distribution given every permutation of the parents states.
- For vertex  $v_3$  we say that the probability of  $s_1$  being true given its parents  $v_1s_1 \cap v_2s_1$  being true is  $P(v_3s_1|v_1s_1 \cap v_2s_1) = 0.1$  and similarly the  $P(v_3s_2|v_1s_2 \cap v_2s_3) = 0.6$ , [see Definition 2.3.3](#) see Table 2.3.3.
- The vertices are also called chance vertices because they define the conditional probability distribution.

**Table 2.3.1** Marginal probability distribution for  $v_1$ .

$s_1$	0.3
$s_2$	0.7

**Table 2.3.2** Conditional probability distribution for  $v_2$ .

$v_1$	$s_1$	$s_2$
$s_1$	0.3	0.5
$s_2$	0.5	0.1
$s_3$	0.2	0.4

**Table 2.3.3** Conditional probability distribution for  $v_3$ .

$v_1$	$s_1$			$s_2$		
	$s_1$	$s_2$	$s_3$	$s_1$	$s_2$	$s_3$
$s_1$	0.1	0.2	0.3	0.6	0.5	0.4
$s_2$	0.9	0.8	0.7	0.4	0.5	0.6

#### 2.3.1.4 Marginal distribution

We can now evaluate the marginal probability distribution of  $v_2$  and  $v_3$  by aggregating the conditional probability of each state given the marginal distribution of its parent, see Definition ??

**Definition 2.3.1** (Marginal probability [Jen01])

$$P(A) = \sum_{i=1}^I P(A|x_i)P(x_i)$$

See Definition 2.3.1 where  $P(A)$  is the probability of a given state and  $I$  is the number of permutations of all the parents states and  $X = x_1, \dots, x_I$  is the set of all permutations of parent states. Marginal probability

$$P(A) = \sum_{i=1}^I P(A|x_i)P(x_i)$$

Given We can now evaluate the marginal probability distribution of  $v_1$  and  $v_2$  we can now use it to similarly calculate the by aggregating the conditional probability of each state given the marginal distribution of  $v_3$ , see Example ?? its parent vertices, see Table 2.3.4

Marginal probability for  $P(v_2 s_2)$

Given the marginal probability distribution of  $v_1$  and  $v_2$  we can now use it to similarly calculate the marginal distribution of  $v_3$ , see Table ??

**Table 2.3.4** Marginal probability for  $P(v_2s_2)$ 

$P(v_2s_2)$	=	$P(v_2s_2 v_1s_1)P(v_1s_1)$	+	$P(v_2s_2 v_1s_2)P(v_1s_2)$
$P(v_2s_2)$	=	$0.5 * 0.3$	+	$0.1 * 0.7$
$P(v_2s_2)$	=	$0.22$		

**Table 2.3.5**MarginalProbabilityPV3

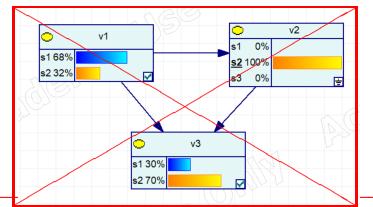
$P(v_3s_1)$	=	$P(v_3s_1 v_1s_1 \cap v_2s_1)P(v_1s_1)P(v_2s_1)$
	+	...
	+	$P(v_3s_1 v_1s_2 \cap v_2s_3)P(v_1s_2)P(v_2s_3)$
$P(v_3s_1)$	=	$0.1 * 0.3 * 0.44$
	+	$0.2 * 0.3 * 0.22$
	+	$0.3 * 0.3 * 0.34$
	+	$0.6 * 0.7 * 0.44$
	+	$0.5 * 0.7 * 0.22$
	+	$0.4 * 0.7 * 0.34$
$P(v_3s_1)$	=	$0.41$

2.3.1.5 Bayes' rule**Definition 2.3.2** (Bayes' rule Jen01)BayesRule

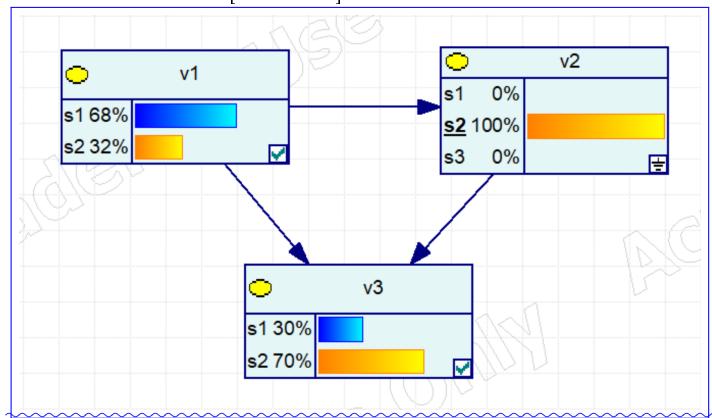
$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

The s are called s because BNs use Bayes' rule, see Definition ??, is used see Definition ?? to evaluate the conditional probability distribution of vertices when the network is updated with evidence as follows:

- We say that a A vertex has been given evidence when evidence when we set one of its states marginal probability is set to 1, also called set to true. to 1.
- The act of setting a state to 1 is called to We call setting evidence to “instantiate the state”.
- An We also say that an instantiated state is also referred to as being true a “true state”.
- The instantiated state  $v_2s_2$ , in Figure 2.3.3 in Figure 2.3.3, affects the conditional probability distribution of its parent and child vertices.



**Figure 2.3.3** A BN with an instantiated state,  $v_2s_2$ , displayed in the GeNIe UI [DSL07a]



We already know how to evaluate the child's marginal distribution using the marginal distribution of the parent vertices, [see Example ??](#) see Example ??

**Example 2.3.1 (Calculating marginal probability for  $P(v_3s_1)$  given evidence to  $v_2s_2$ )**

*Marginal probability for  $P(v_3s_1)$  given evidence to  $v_2s_2$ ) Marginal Probability PV3 after PV2*

$P(v_3s_1)$	=	$0.1 * 0.68 * 0$
	+	$0.2 * 0.68 * 1$
	+	$0.3 * 0.68 * 0$
	+	$0.6 * 0.32 * 0$
	+	$0.5 * 0.32 * 1$
	+	$0.4 * 0.32 * 0$
$P(v_3s_1)$	=	0.30
<i>or simply:</i>		
$P(v_3s_1)$	=	$0.2 * 0.68$
	+	$0.5 * 0.32$
$P(v_3s_1)$	=	0.30

In this manner, we need to evaluate all descendants as long as the parents' marginal probability is affected, and we have not given it evidence.

Updating the parent probability distribution is not as straightforward. Given that we know that  $v_2s_2 = 1$ , we need to evaluate ~~how likely each of the states of the probability of each state of  $v_1$  are. We can therefore~~. ~~We~~ use Bayes' rule for each of the parents' states, i.e.  $P(v_1s_1|v_2s_2)$  and  $P(v_1s_2|v_2s_2)$ , see Example ?? see Example ??.

### Example 2.3.2 ()

<i>Bayesrule PV1</i>	$P(v_1s_1 v_2s_2)$	$=$	$\frac{P(v_2s_2 v_1s_1)P(v_1s_1)}{P(v_2s_2)}$
	$P(v_1s_1 v_2s_2)$	$=$	$\frac{0.5*0.3}{0.5*0.3+0.1*0.7}$
	$P(v_1s_1 v_2s_2)$	$=$	0.68

~~The evidence is propagated using We propagate the evidence with Bayes' Rule to all ancestors from parent to any parent that has and descendant that have no evidence. It is also necessary to update the marginal probability of any children of parents that are updated.~~

This cascading propagation of conditional probabilities can ~~lead to update~~ the whole network ~~needing to be updated~~ when instantiating a single state. Updating the whole network is intractable for large networks with multiple arcs, which is a significant drawback to using BNs. It is therefore essential to limit this cascading propagation as much as possible.

#### 2.3.1.6 Causal networks

So far, we have only discussed the network in terms of vertices, arcs and probability distributions. If we want to use the network to reason about uncertainty, we can structure them ~~so that they to~~ represent a causally connected network where the direction of the arcs indicates the direction of the causal relationship [Jen01]. In the initial network ~~in Figure 2.3.2~~ in Figure 2.3.2, we then say that  $v_1$  causes  $v_2$ , and that  $v_1$  and  $v_2$  cause  $v_3$ .

For example, ~~A man called John has a lawn that needs to be watered John needs to water his lawn~~ with a sprinkler if it has not rained. John has a gardener that checks in the morning if he needs to turn on the sprinkler. ~~If~~

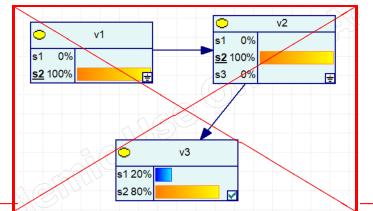
1.  $v_1$  represents whether it rained ~~and~~
2.  $v_2$  whether the sprinkler was ~~turned on then the directed arc on,~~
3.  $(v_1, v_2)$  ~~represents that whether it rains will cause the sprinkler to be either turned on or off.~~
- ~~If the causal effects of rain on the sprinkler's state.~~
4.  $v_3$  represents whether the lawn is wet, ~~then the~~
5. arcs  $(v_1, v_3)$  and  $(v_2, v_3)$  ~~indicate that if it rains or the sprinkler is on it will cause the lawnto be wet. show the causal effect on the lawn.~~

### 2.3.1.7 Evidence propagation via serial connection

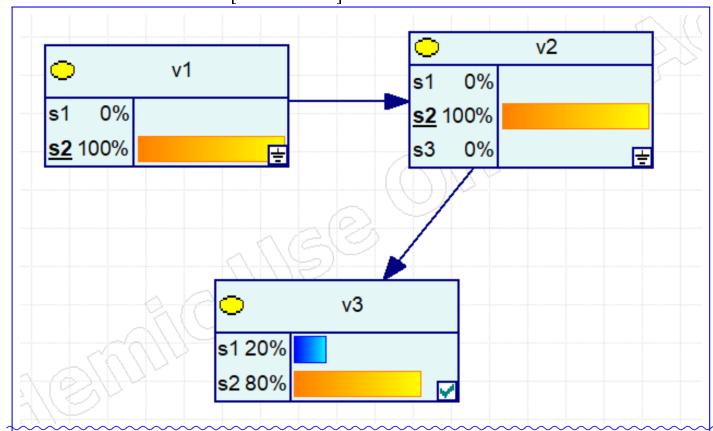
Vertices that are all consecutively connected along the same directed path are said to be serially connected, see Figure 2.3.4 see Figure 2.3.4. We have removed the arc  $(v_1, v_3)$ , see Definition 2.3.6 for  $v_3$ 's values. Giving evidence to  $v_1$  or and  $v_3$  will cause the effects of the evidence to be propagated to evidence affect the other two unless unless we instantiate  $v_2$  has been instantiated. Instantiating a , in a . In a serial connection, blocks any propagation of probabilities through that from parent to child and from child to parent an instantiated vertex blocks propagation through that vertex, see Figure 2.3.4. Although  $v_1$  has evidence, it does not affect  $v_3$  because  $v_3$  is only affected by the evidence in  $v_2$ . Additionally,  $v_2$  has evidence and is also not affected.

**Table 2.3.6** The conditional distribution defined for  $v_3$  after the arc between  $v_1$  and  $v_3$  has been removed

$v_2$	$s_1$	$s_2$	$s_3$
$s_1$	0.1	0.2	0.3
$s_2$	0.9	0.8	0.7



**Figure 2.3.4** A BN with an instantiated state,  $v_2s_2$ , displayed in the GeNIe UI [DSL07a]



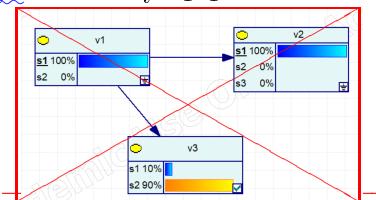
For example, John walks out onto his lawn in the morning in his slippers. If it has rained ( $v_1$ ) during the night, the lawn will be wet ( $v_2$ ), and John will get his slippers wet ( $v_3$ ). Therefore if John's slippers become wet, he will reason that the lawn is wet and subsequently, given that the lawn is likely wet that it likely rained during the night. Conversely, if John knows

that it rained during the night, he will expect the lawn to be wet and that if he walks on it in his slippers, then his slippers will become wet.

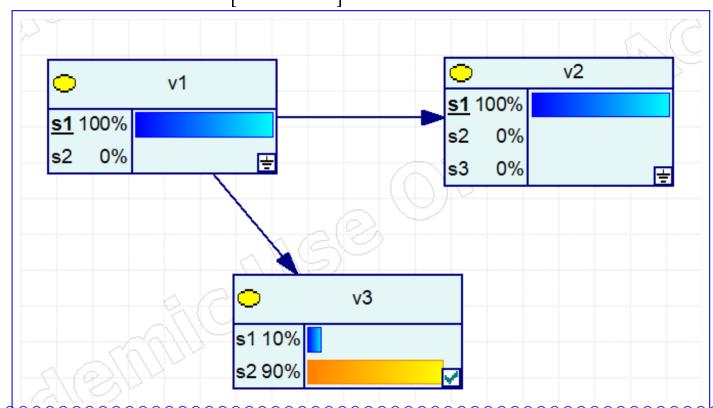
Conversely, if John knows that the lawn is wet, then information about whether it rained during the night will not affect his belief of whether his slippers ~~will become wet by get wet from~~ walking on the lawn. Similarly, knowing that the lawn is wet, if his slippers become wet, it will not affect his belief of whether it rained during the night.

### 2.3.1.8 Evidence propagation via divergent connection

A divergent connection is ~~when between sibling vertices are connected as children of the same parent, see Figure 2.3.5 where the arc  $(v_2, v_3)$  has been removed~~, see Figure 2.3.5 where  $v_2$  and  $v_3$  is, see Definition ???. Giving evidence to  $v_2$  or  $v_3$  will see that evidence propagated through  $v_1$  unless  $v_1$  has been instantiated are siblings, see Example 2.3.3. Evidence to one sibling affects the other sibling via their parent  $v_1$  unless the parent has evidence. Instantiating the parent in a diverging connection ~~will block any evidence from being propagated from one child to any other children~~. In Figure 2.3.5 blocks inference between siblings. In Figure 2.3.5 both  $v_1s_1$  and  $v_2s_1$  have ~~both been instantiated which results in evidence; however,  $v_3$  to only be is only affected by  $v_1s_1$~~ .



**Figure 2.3.5** A BN with an instantiated state,  $v_2s_2$ , displayed in the GeNIe UI [DSL07a]



**Example 2.3.3** (The conditional distribution for  $v_3$  after the arc between  $v_2$  and  $v_3$  has been removed)

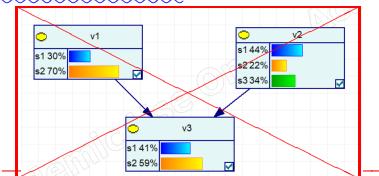
$v_1$	$s_1$	$s_2$
$s_1$	0.1	0.6
$s_2$	0.9	0.4

For example, if John intends to mow the lawn ( $v_3$ ), then it matters to him whether it is wet ( $v_1$ ) since it is not good to mow the lawn if it is wet. If John walks out onto the lawn and his slippers get wet ( $v_2$ ), ~~then~~, that will inform him that the lawn is wet ~~which in turn will make~~, ~~making~~ it less likely that he will mow the lawn.

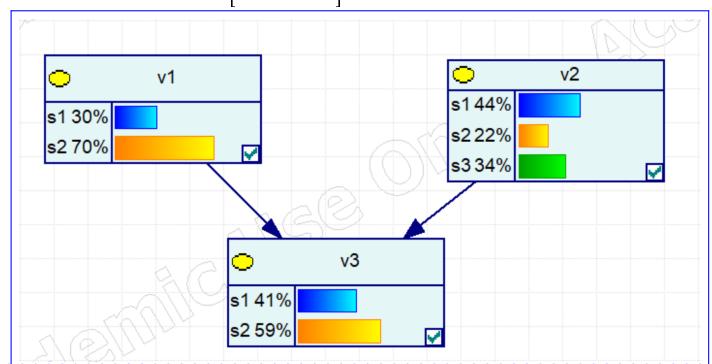
Conversely, if John already knows that the lawn is wet, then getting his slippers wet will no longer inform him of whether to mow the lawn or not. Similarly, if John already knows that the lawn is wet, then finding it not in good condition to be mowed will not inform him of whether his slippers get wet from walking on it.

### 2.3.1.9 Evidence propagation via convergent connection

A convergent connection is ~~when are connected as parents of the same child, see Figure 2.3.6 where the are ( $v_1, v_2$ ) has been removed, and we use the original marginal distribution to define  $v_2$  a connection between the parents of a child, see Figure 2.3.6. Evidence is not propagated through a convergent connection unless the child or the child's descendants have received its descendants have evidence.~~

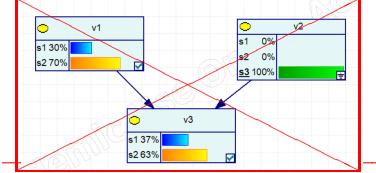


**Figure 2.3.6** Convergent connection, displayed in the GeNIe UI [DSL07a]

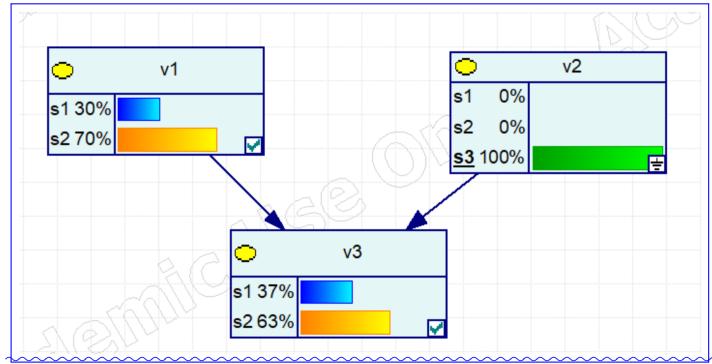


If we give evidence to either ~~parent~~  $v_1$  or  $v_2$ , it will not ~~propagate to each other~~, see Figure 2.3.7 where we have instantiated ~~affect the other~~

parent, see Figure 2.3.7 evidence in  $v_2s_3$  which affects  $v_3$  but not  $v_1$ . The evidence in  $v_2$  informs the belief about the child but not about the child's parent because we have no information about  $v_3$  that will affect our belief about  $v_1$ .



**Figure 2.3.7 ,**  
displayed in the GeNIE UI [DSL07a]



The marginal probability of  $v_1s_1$  remains the same because the conditional dependency has not been altered as we can show using Bayes' Rule and weighing the result with  $v_3$ 's see Example ?? is the same, see Table 2.3.7.

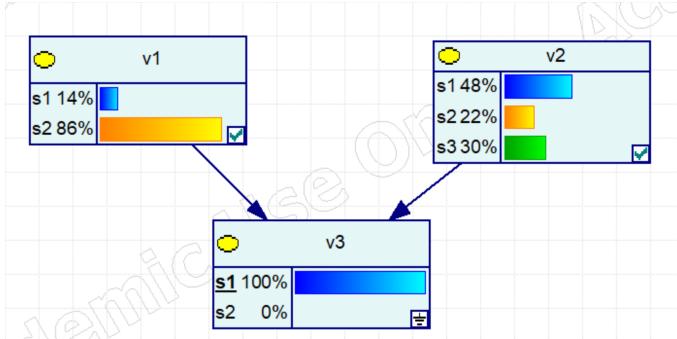
The marginal probability of  $v_1s_1$

**Table 2.3.7** The marginal probability of  $v_1s_1$

$P(v_1s_1)$	=	$P(v_1s_1 v_3s_1)P(v_3s_1)$
	+	$P(v_1s_1 v_3s_2)P(v_3s_2)$
$P(v_1s_1 v_3s_1)$	=	$\frac{0.1*0.3}{0.1*0.3+0.6*0.7}$
$P(v_1s_1 v_3s_1)$	=	0.24
$P(v_1s_1 v_3s_2)$	=	$\frac{0.9*0.3}{0.9*0.3+0.4*0.7}$
$P(v_1s_1 v_3s_2)$	=	0.33
$P(v_1s_1)$	=	$0.24 * 0.37$
	+	$0.33 * 0.63$
$P(v_1s_1)$	=	0.3

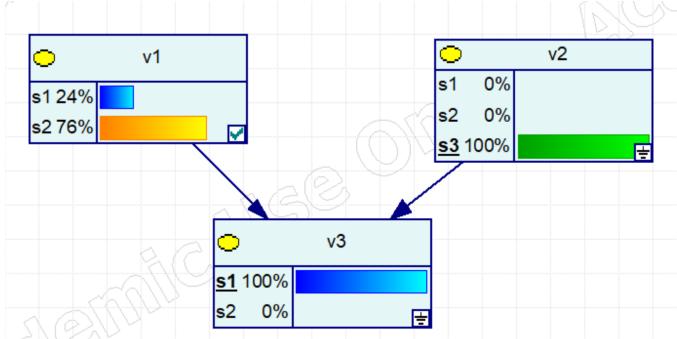
If we have given However, if we give evidence to a joint descendant of the parents however then the parents are affected by other parents receiving evidence because this will change the conditional dependency between the parents and the child each other, see instantiated  $v_3s_1$  in Figure 2.3.8 in Figure 2.3.8.

**Figure 2.3.8** where  $v_3 s_1$  has been instantiated, displayed in the GeNIe UI [DSL07a].



We now need ~~to take into account~~ the marginal probability of  $v_2$  when evaluating  $v_1$  because there is an altered conditional dependency between the two. Furthermore if  $v_2$  ~~is given evidence has evidence~~, it will now affect the conditional probability of  $v_1$  as seen ~~in Figure 2.3.9~~ in Figure 2.3.9, where  $v_3 s_1$  and  $v_2 s_3$  have ~~been instantiated~~ ~~evidence~~.

**Figure 2.3.9** where  $v_3 s_1$  and  $v_2 s_3$  have been instantiated, displayed in the GeNIe UI [DSL07a]



**Table 2.3.8** The conditional distribution for  $v_3$ , where  $v_3 s_1$  and  $v_2 s_3$  have been instantiated

$v_1$	$s_1$	$s_2$
$v_2$	$s_3$	$s_3$
$s_1$	0.3	0.4

In order to know  $P(v_1s_1)$  we now need to take into account the changed conditional dependency, i.e.  $v_1$  is now only dependant on the probability of  $v_3s_1$  which is dependant on  $v_2s_3$ , see Example ?? see Example 2.3.4

**Example 2.3.4 (Calculating  $P(v_1s_1|v_3s_1)$ .)**

$P(v_1s_1)$	=	$P(v_1s_1 v_3s_1)$
$P(v_1s_1 v_3s_1)$	=	$\frac{P(v_3s_1 v_1s_1)P(v_1s_1)}{P(v_3s_1)}$
$P(v_3s_1)$	=	$0.3*0.3+0.4*0.7$
$P(v_3s_1)$	=	$0.37$
$P(v_3s_1 v_1s_1)$	=	$0.3$
$P(v_1s_1)$	=	$0.3$
$P(v_1s_1)$	=	$\frac{0.3*0.3}{0.37}$
$P(v_1s_1)$	=	$0.24$

To understand this with the same example as before of John's wet lawn. The lawn could be wet ( $v_3$ ) because it rained ( $v_1$ ) or because the sprinkler went off ( $v_2$ ). If John does not know whether the lawn is wet, then knowing whether it rained ~~is not going to~~ ~~will not~~ change his belief of whether the sprinkler went off, but it will affect his belief of whether the lawn is wet.

Conversely, if John knows that the lawn is wet, either directly or because his slippers got wet, then he will find it more likely that it either rained or that the sprinkler went off. If he then gets information that it did rain, then he may find it less likely that the sprinkler went off given that the lawn is wet.

### 2.3.1.10 D-separation

~~When evidence is not able to propagate between, as described above, it is called and when it can propagate it is called D-Connection. According to [Jen01], two-~~

**Definition 2.3.3 ( [Jen01])**

Two distinct vertices  $v_1$  and  $v_2$  in a causal BN are D-Separated if for all paths between  $v_1$  and  $v_2$  there is an intermediate vertex  $v_3$  (distinct from  $v_1$  and  $v_2$ ) such that either:

- the connection is serial or divergent, and  $v_3$  ~~is instantiated~~ ~~has evidence~~, or
- the connection is convergent, and neither  $v_3$  nor any of  $v_3$ 's descendants ~~is instantiated~~ ~~have evidence~~.

~~can be used to identify the part of the network to update after giving evidence to a.~~ In Figure 2.3.10, we can see a more extensive example of how ~~can be used to identify the part of the network that we need to evaluate.~~ When evidence cannot propagate between vertices, see Definition 2.3.3, it is called ~~, and when it can propagate, it is called D-Connection.~~

~~In the network in Figure 2.3.10, if we give evidence to A it can travel to D, H, K, and M but not to I via K. It can also travel from D to B, E, I, and L, but not from L to J. From E it can travel to C, F, and J but it cannot travel to G.~~

~~If we give evidence to B, then giving evidence to A will no longer affect B or any of the paths via B, so it will only travel to D, H, K, and M.~~

~~If we also give evidence to M, then it can travel on from K to I and from there to the rest of the network as before, except G, although it will neither affect B or M.~~

### 2.3.1.11 Relevance Reasoning

~~Using , it is possible is used to identify the part of the network that needs to be updated when to update after giving evidence to a vertex —see Figure 2.3.10~~

#### Example 2.3.5 (Relevance Reasoning)

*If we give evidence to A, it can travel to D, H, K, and M but not to I via K. It can also travel from D to B, E, I, and L, but not from L to J. From E it can travel to C, F, and J but it cannot travel to G.*

*If we give evidence to B, then giving evidence to A will no longer affect B or any of the paths via B, it will only travel to D, H, K, and M.*

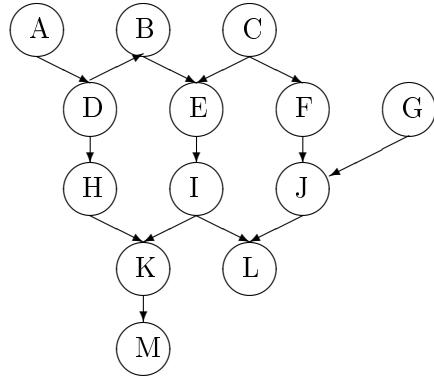
*If we also give evidence to M, then it can travel on from K to I and from there to the rest of the network as before, except G, although it will neither affect B or M.*

*Furthermore, if it is the case that we only need to know how a single or a few vertices, called target vertices, are affected by giving evidence to other vertices, that are distinct from the target vertices, then we can use to identify applicable paths. Using and target vertices in this manner is called Relevance Reasoning [LD97].*

*For example, in the network in Figure 2.3.10 in Figure 2.3.10, if we have instantiated B and M as before, but not subsequently evaluated the graph, and want to know what the value of H will*

be after instantiating  $A$ , then we need to update  $D, E, H, I$  and  $K$ .

**Figure 2.3.10** A BN to demonstrate from [Jen01]



### 2.3.1.12 Object-Oriented Bayesian Networks (OOBNs)

BNs can quickly grow in size to become ~~to too~~ large both in terms of space and computation. The conditional definition of each vertex grows exponentially with the number of its parents ~~see Definition 2.3.4~~ see Definition 2.3.4.

**Definition 2.3.4 (The size of a vertex's conditional probability table (CPT))**

*Is the product of the number of its states  $N(s)$  and all parent states  $N(ps)$*

$$\text{CTCPT}(v_i) = N(v_i s) \prod_{p \in P} N(ps)$$

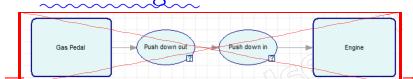
~~This means that a vertex cannot have with too many parents or it will fill the computers can fill the computer's memory.~~

Moreover, the greater the coupling is between vertices the greater number of updates are required for any given evidence. ~~For this reason, we can be structured in the form of [KP97] which is a method of We can use object-oriented architecture for BNs [KP97] by dividing the network up into manageable pieces in order to construct a much larger network through the reuse of the individual into reusable objects. OOBNs are useful for large networks where we can reuse objects.~~

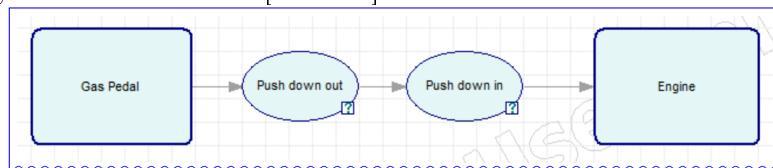
This process can be automated using ~~;~~; it can also follow logical reasoning. For example, ~~see Figure 2.3.11~~ see Figure 2.3.11, a car can be defined

into well structured logical parts that can be divided further into sub-parts, ~~the a~~ car engine has breaks, fuel consumption, steering, drive. The car body has doors, seats, and steering tools. ~~All of these are for For~~ the most part, ~~all of these are~~ independent of each other except for a few ~~well-defined functions~~. ~~Pushing well-defined functions. Stepping on~~ the gas pedal ~~affects increases~~ the fuel intake ~~of the engine but does not affect its breaks or steering. It is therefore only required but has no effects on the breaks or the steering. We only need to update the engines~~ fuel intake when ~~the gas pedal is pushed. Subsequently stepping on the gas. Subsequently~~, increased fuel will speed up the engine, which in turn will cause other parts to be affected.

~~This interaction is modelled into independent sWe model each part into object BNs, called submodels, with defined in and out in- and out-vertices. In our example, the gas pedal increases the value of it's fuel out fuel percentage of the out-vertex state, and the engine has a corresponding in- 's in- vertex ; identical to the pedals out that is given evidence feeds the effects from the pedal to the engine.~~



**Figure 2.3.11** An example of a pedal and engine using OOBN, displayed in the GeNIE UI [DSL07a].



The two submodels ~~in Figure 2.3.11~~ in Figure 2.3.11 are connected, but that is not necessary, they can be independent BNs and only loaded and updated on demand.

### 2.3.1.13 Decision Networks

We use BNs as decision networks and extend them with utility and decision vertices. Utility vertices are:

- Define the utility of potential outcomes.
- Denoted as Utility  $U = u_1, \dots, u_N$  where  $N$  is the total number of utility vertices.
- Are blue diamonds in the GeNIe UI [DSL07a].
- Can have decision and chance vertices as parents.
- Cannot be parent vertices.

A decision vertex is:

- Can have a list of actions, decisions or goals for evaluation.
- We call the states, of the decision vertex, strategies  $= (\sigma_1, \dots, \sigma_I)$  where  $I$  is the number of strategies in a decision vertex.
- Are green rectangles in the GeNIe UI [DSL07a].
- Can be a parent of both utility and chance vertices.
- Cannot have parent vertices.

#### Definition 2.3.5 (Expected utility [Jen01])

*EU  $EU(\sigma_i)$  for  $i \in I$  and for each utility  $u_n \in N$  of a chance vertex  $v \in V$  and its conditional probability given the evidence,*

$$EU(\sigma_i) = \sum_{n=1}^N \sum_{v \in V} u_n(v) P(v|\sigma_i, e)$$

A combination of decision vertex and utility vertices is used to calculate the expected utility (EU) can calculate the expected utility (EU), see Definition 2.3.5 for how to calculate EU:

- If a decision vertex is a parent of a chance vertex, then the chance vertex defines the probability of the strategies' probability.
- If a decision vertex is a parent of a utility then the utility defines the cost of a given strategy  $\sigma$ .
- A utility defines the cost of parent strategies.
- If a utility vertex has chance vertices as parents, then the utility defines a value for each state of the chance vertex.

- A utility calculates the ~~EU~~ EU, given the strategies and the probability of those strategies being true.

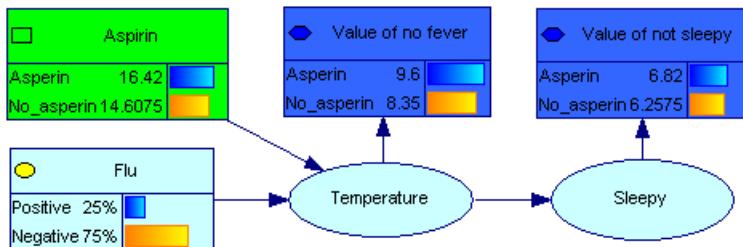
We calculate the expected utility  $EU(\sigma_i)$  for  $i \in I$  and for each utility  $u_n \in N$  of a chance  $v \in V$  and its conditional probability given the evidence, see Definition ??

~~Expected utility~~

$$EU(\sigma_i) = \sum_{n=1}^N \sum_{v \in V} u_n(v) P(v|\sigma_i, e)$$

The following example shows how to use decision BNs. We assume that in Iceland, the general population has the flu about one quarter of the year. The flu increases the probability of fever, and having a fever increases the probability of being sleepy. Moreover taking Aspirin is very likely to reduce the fever to ~~normal-average~~ temperature,  $37^\circ\text{C}$ . The Icelandic government has taken the initiative to distribute free Aspirin to every Icelandic home ~~in order~~ to increase the ~~productivity of the small population~~ ~~small population's productivity~~ and that taking Aspirin has no side effects.

**Figure 2.3.12** The Flu example of a Decision Network, displayed in the GeNIe UI [DSL07a]



In Figure 2.3.12 In Figure 2.3.12 is the Bayesian net showing the causal connections from flu to fever to sleepy,

The Aspirin decision vertex has two strategies:

- {Aspirin = to take Aspirin}
- {No\_Aspirin = not to take Aspirin}

The flu chance vertex has two states: {Positive} with a probability of 0.25 and {Negative} with a probability of 0.75.

~~See Definition 2.3.9~~ See Table 2.3.9 for the temperature vertex. The Temperature chance vertex has two states:

- {Normal, the temperature =  $37^\circ\text{C}$ },
- {Elevated, the temperature >  $37^\circ\text{C}$ }

**Table 2.3.9** The Temperature chance vertex for the Flu example

Aspirin		Aspirin		No Aspirin	
Flu		Positive	Negative	Positive	Negative
Normal	0.9	0.98	0.4	0.98	
Elevated	0.1	0.02	0.6	0.02	

**Table 2.3.10** The Sleepy chance vertex for the Flu example

Temperature	Normal	Elevated
Yes	0.3	0.75
No	0.7	0.25

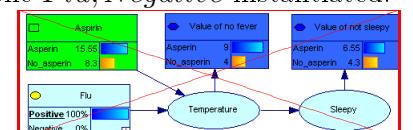
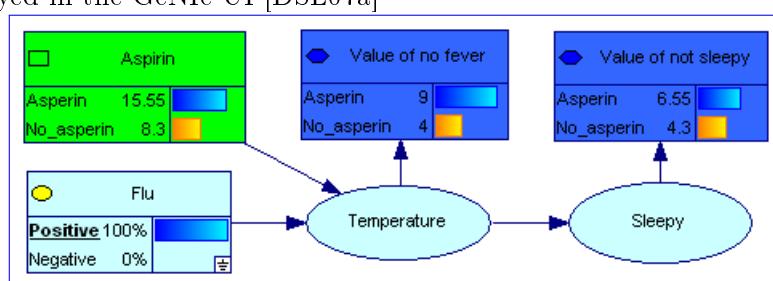
~~See Definition 2.3.10~~ See Table 2.3.10 for the sleepy chance vertex. In [Figure 2.3.12](#) In Figure 2.3.12, we can see from the two utility vertices that the value of taking Aspirin to reduce fever is 9.6, and the value of taking Aspirin to reduce sleepiness is 6.82.

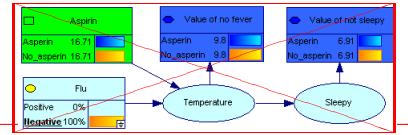
**Table 2.3.11** Utility vertices for the Flu example

Value of no fever			Value of not sleepy		
Temperature	Elevated	Normal	Sleepy	yes	no
value	0	10	value	0	10

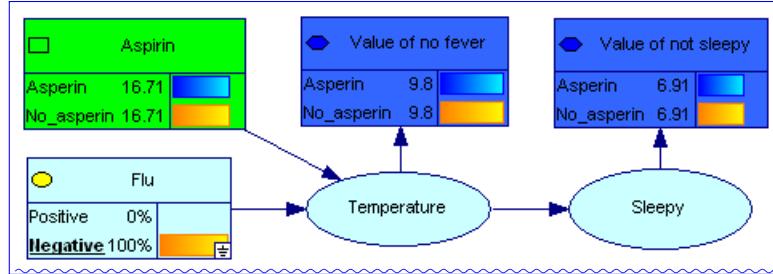
~~See Definition 2.3.11 for both utilities values. The~~ See Table 2.3.11 for both utility values. Therefore, the strategy to take Aspirin, ~~therefore~~, carries a gain of  $9.6 + 6.82 = 16.42$ , and to not take Aspirin carries the gain of  $8.35 + 6.2575 = 14.6075$ .

In [Figure 2.3.13](#) In Figure 2.3.13, the Flu vertex has the *Flu, Positive* instantiated. In [Figure 2.3.14](#) In Figure 2.3.14 the Flu vertex has the value of the *Flu, Negative* instantiated.

**Figure 2.3.13** In the Flu example *Flu, Positive* is instantiated, displayed in the GeNIe UI [DSL07a]



**Figure 2.3.14** In the Flu example *Flu*, *Negative* is instantiated, displayed in the GeNIe UI [DSL07a]



It is useful to instantiate vertices ~~in this way~~ to understand the values that would cause such extreme and how it would affect other vertices and ~~the overall evaluation of the strategies. In Figure 2.3.13 evaluate the strategies.~~ In Figure 2.3.14, the assumption is that the individual does not have any flu, and then there is no higher gain in taking Aspirin than not taking Aspirin. Therefore, in this example, the expected utility indicates a gain of taking Aspirin than not taking it.

### 2.3.2 ~~Polti's 36 situations~~ Game Theory

This Section describes the essentials of GT that are necessary to understand the problem domains tackled by this thesis and the solution proposed. GT is ~~where a game is created to reason mathematically about what would be an optional strategy in interacting with others~~ a mathematical definition of rationality.

#### 2.3.2.1 Terminology

A game in GT:

- Has ~~a~~ set of two or more players,  $(p_1, \dots, p_{\mathcal{I}}$  where  $\mathcal{I}$  is the number of players.
- A set of strategies  $s_k, \dots, s_{\mathcal{K}}$  where  $\mathcal{K}$  is the number of strategies per player.
- A set of strategies for a player is called the player's strategy profile.
- A strategy profile ~~is donated with~~  $\sigma_j, \dots, \sigma_{\mathcal{J}}$  where  $\mathcal{J}$  is the number of strategy profiles.

- A distinct strategy played with the probability of 1 is called a pure strategy.
- A mixed strategy is a strategy of two or more distinct strategies that are all played depending on a probability distribution. For example  $(s_1 = 0.5, s_2 = 0.5)$  means that  $s_1$  is played half the time and  $s_2$  the other half.
- A  $\sigma_j$  can contain both pure and mixed strategies.
- Each player has a utility function  $U$  for each of the strategy profiles that he can play.

We introduce how a game in GT works in ~~the~~ Aumann's example [FT91], see ~~??~~. Aumann's example [FT91] [FT91], see Example 2.3.6.

### Example 2.3.6 (Aumann's example [FT91])

*Player 1 and 2 want to find an optimal strategy in a game where they both have equal expected utility.*

		$p_2$	
		$s_1$	$s_2$
		$s_1$	$5, 1$
$p_1$	$s_1$	$5, 1$	$0, 0$
	$s_2$	$4, 4$	$1, 5$

~~In Example ??~~ In Example 2.3.6 there are two players ( $p_1, p_2$ ) and two strategy profiles each with two strategies:  $p_1, S = (s_1, s_2)$  and  $p_2, S = (s_1, s_2)$ .

If  $p_1$  plays  $s_1$  and  $p_2$  plays  $s_1$  then  $p_1$ 's  $U$  is 5, denoted  $U(p_1(s_1, s_1)) = 5$ , and  $p_2$ 's  $U$  of 1, denoted  $U(p_2(s_1, s_1)) = 1$ . We calculate the ~~expected utility (EU)~~ EU for a strategy profile  $\sigma_i$  by aggregating the utility of each strategy weighted by the probability distribution of the ~~player's~~ ~~players~~ and opponents  $\sigma_i$ , ~~see Definition ?? where~~ see Definition 2.3.6 ~~and~~ see Example 2.3.7.

### Definition 2.3.6 (EU for a player's strategy profile [FT91])

$\sigma_j, \dots, \sigma_J$  are all the strategy profiles.

~~Expected Utility for a player's strategy profile~~

$$EU(\sigma_i) = \sum_{s \in S} \left( \prod_{j=1}^J \sigma_j(s) \right) U_i(s) \text{equation} \quad (2.1)$$

For example, in a mixed strategy, the  $\text{U-EU}$  is dependent on the probability distribution of  $S$  for both player and opponent. ~~For example in ??~~ In Example 2.3.6, if the players play mixed strategies with each strategy being played with 0.5 probability,  $P(s_i) = 0.5$ , the  $\text{U is } \text{EU is } 2.5$ , see Example 2.3.7.

### ~~Calculating EU for the game in Example ??~~

#### Example 2.3.7 (Calculating EU for the game in Example 2.3.6)

$EU$ for $p_1$					
$EU(p_1s_1)$	=	$0.5 * 0.5 * p_2s_1$	+	$0.5 * 0.5 * p_2s_2$	
$EU(p_1s_1)$	=	$0.5 * 0.5 * 5$	+	$0.5 * 0.5 * 0$	= 1.25
$EU(p_1s_2)$	=	$0.5 * 0.5 * p_2s_1$	+	$0.5 * 0.5 * p_2s_2$	
$EU(p_1s_2)$	=	$0.5 * 0.5 * 4$	+	$0.5 * 0.5 * 1$	= 1.25
$EU(p_1S)$	=	1.25	+	1.25	
$EU(p_1S)$	=	2.5			

$EU$ for $p_2$					
$EU(p_2s_1)$	=	$0.5 * 0.5 * p_1s_1$	+	$0.5 * 0.5 * p_1s_2$	
$EU(p_2s_1)$	=	$0.5 * 0.5 * 1$	+	$0.5 * 0.5 * 4$	= 1.25
$EU(p_2s_2)$	=	$0.5 * 0.5 * p_1s_1$	+	$0.5 * 0.5 * p_1s_2$	
$EU(p_2s_2)$	=	$0.5 * 0.5 * 0$	+	$0.5 * 0.5 * 5$	= 1.25
$EU(p_2S)$	=	1.25	+	1.25	
$EU(p_2S)$	=	2.5			

Each game has an ~~equilibrium which, for all players, is~~ see Definition 2.3.7.

#### Definition 2.3.7 (Equilibrium [FT91])

~~is the strategy that has equal or higher EU to any other EU in the game~~ ~~We find an for all players~~

~~We find~~ equilibrium by evaluating the strategies and their probability distribution.

An *opponent* in GT is:

- A common denominator for other players.
- Does not indicate competition or a competitor.
- Is any other player that is not the player.
- Can be cooperative or non-cooperative.
- Is denoted with  $-i \in \mathcal{I}$  where  $-i \neq i$ .

~~Rationality in is when a player chooses-~~

### Definition 2.3.8 ( [FT91] )

~~is choosing the strategy that will give them the optimal maximum EU no matter what their the opponents play, given their current information. Every player is considered to be rational and, therefore, to always choose the optimal EU~~

Every player that plays rationally, see Definition 2.3.8, always chooses the equilibrium strategy. If the player does not act rationally, then they are considered to be making a mistake. For example, if they push a wrong button because their hands are trembling.

There are various levels of information that a player can have in-game:

- A *completely informed* player is someone who knows all the possible utility functions, and strategy profiles and everyone knows that he is completely informed and he knows that everyone knows that he is completely informed, and so on.
- A game is ~~eonsidered~~ a *completely informed game* if all the players are completely informed.
- ~~A~~ An *incompletely informed* player lacks information about their opponents' utility functions and strategy profiles.
- An *imperfectly informed* player is an incompletely informed player that can, by calculation, estimate the strategy profiles and EUs of opponents.
- To reason under uncertainty is when a player estimates the strategy profiles and EUs of opponents.

A *non-cooperative* game is when the players have no prior binding agreements. In most realistic scenarios, the players do not have prior signed contracts with their opponents. ~~There is rarely organised cooperation even though some opponents may value co-operation.~~

#### 2.3.2.2 Nash equilibrium

A Nash equilibrium, see Definition 2.3.9 is a profile of strategies such that each player's strategy is an optimal response to each of the other players strategies, ~~e.g. i.e.~~ there is no incentive to deviate.

~~Nash Equilibrium [FT91].~~

### Definition 2.3.9 (Nash Equilibrium [FT91])

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

$$EU(\sigma_i^*, \sigma_{-i}^*) \geq EU(s_i, \sigma_{-i}^*) \quad (2.2)$$

Nash equilibrium holds for the *extended game*, i.e. when playing repeatedly against the same set of players, as proven by J. Nash [Nas51]. There are three Nash equilibria in Example 2.3.6. Two pure strategies  $(p_1 s_1, p_2 s_1)$  and  $(p_1 s_2, p_2 s_2)$  and one mixed strategy  $((0.5 * p_1 s_1, 0.5 * p_1 s_2), (0.5 * p_2 s_1, 0.5 * p_2 s_2))$ . In Example 2.3.8 we find the first equilibrium.

#### Finding Nash Equilibrium

##### Example 2.3.8 (Finding Nash Equilibrium)

When finding Nash Equilibrium we can try every strategy until we find the set with maximum value. In this example we will find the pure strategy equilibrium  $(U, L)$ .

1.  $p_1$  plays  $s_1$  and can see that  $p_2$ 's optimal response is  $s_1$  since  $U(p_2 s_1) > U(p_2 s_2)$ ,  $1 > 0$ .
2.  $p_1$ 's  $U(p_1 s_1, p_2 s_1) = 5$  and is  $p_1$ 's current max.
3.  $p_1$  plays  $s_2$  and can see that  $p_2$ 's optimal response is  $s_2$  since  $U(p_2 s_2) > U(p_2 s_1)$ ,  $5 > 4$ .
4.  $p_1$ 's  $U(p_1 s_2, p_2 s_2) = 1$  and  $1 < 5$  so  $p_1$ 's optimal strategy and Nash equilibrium is  $s_1$ .

##### 2.3.2.3 Bayesian equilibrium

Harsanyi proposes Bayesian equilibrium as a way of calculating proposed Bayesian equilibrium to calculate Nash equilibrium for incomplete information games, where players lack complete information about the game world [Har95], [Har95], [FT91].

In J. C. Harsanyi's words:

In our own view it has been a major analytical deficiency of existing GT that it has been almost completely restricted to complete information games, in spite of the fact that in many real-life economic, political, military, and other social situations the participants often lack full information about some important aspects of the "game" they are playing [Har67] p:163:.

An incomplete information game is where some players lack full information about the game. We assume that each player knows their utility function and strategy profiles.

For example, two warring factions; that know their state but not the complete state of their opponent. They will have some intelligence of their ~~opponent's state, and they opponents' states and~~ can reason about ~~the opponent's states them~~.

We can assume that there are finitely many states for the opponent to be ~~in that are~~ relevant to the player. For example, ~~that~~ the opponent has a secret weapon, ~~has~~ depleted their food or resources, or has powerful tanks.

The players do not know their opponents' current utility function but know all utility functions that the opponents could be using, which is exogenous data because it is:

- Not derived from the opponents' status.
- Is a factor in the equilibrium-calculations. For example, strategic places, pay off functions, and physics.
- Is considered common knowledge among the players.
- Stands outside the influence of equilibrium calculations.
- Is constant throughout the game.

~~Player-centered~~ Player-centred Bayesian equilibrium In a ~~player-centered~~ player-centred Bayesian equilibrium the player reasons about what the opponent's utilities functions are and what the opponent could do in response to their actions, which leads to an infinite recursion as follows:

- A player's first order expectations  $P_i^1$  is a subjective probability distribution,  $P_i^1(U_{-i})$ , over all possible opponent utilities,  $U_{-i}$ .
- A player's second-order expectations is a subjective  $P_i^2(P_{-i}^1)$ .
- A player's  $k$ th-order expectations is a subjective  $P_i^k(P_{-i}^{k-1})$

~~The~~ Therefore, the player-centred game ~~, therefore,~~ contains infinite recursion that requires a fixed point configuration ~~in order~~ to calculate equilibria [Har67].

~~Type-centered~~ Type-centred Bayesian equilibrium An alternative to player-centred Bayesian equilibrium is an equivalent ~~type-centered~~ type-centred Bayesian equilibrium, that does not lead to infinite recursion, and is structured as follows:

- A player has a finite set of possible types  $\theta_i \in \Theta$  that represent every possible makeup of the player.

- $\theta_{-i} = (\theta_1, \dots, \theta_{i-1}, \theta_{i+1}, \dots, \theta_I)$ . is the opponents type.
- A  $\theta_i$  can represent the players character, beliefs of other player's strategy profiles, and utility functions.
- A  $\theta_i$  is any prior information that is not common knowledge and that may affect the  $U_{-i}$ , their decision making and their belief about  $\theta_{-i}$ .
- Some players may be better informed than others about their  $\theta_{-i}$ .
- The exogenous data of the game is all  $\theta \in \Theta$ .

Rather than reason about all possible utility functions and all possible ~~strategies of the opponent, the types can be used~~ opponents' possible strategies, we can use the types to find a Bayesian equilibrium [Har67, Har68a, Har68b]. If the player does not know the  $\theta_{-i}$ , it can find the probability distribution of the  $\theta_{-i} \in \Theta$ .

- A  $\theta_i \in \Theta$  has an objective prior probability distribution  $P(\theta_i)$ .
- $P(\theta_{-i}|\theta_i)$  is the conditional probability of the  $\theta_{-i}$  given the  $\theta_i$ .
- A player can use Bayes' rule in ex-ante calculations to evaluate the  $P(\theta_{-i}|\theta_i) \in \Theta$ , hence the name Bayesian equilibrium.

When a player knows the probability distribution over all  $\theta_{-i} \in \Theta$ , they can use this to evaluate the EU of the opponent given  $\theta_i$ .

- $\sigma_i(\theta_i)$  is the player's strategy profile which is dependant on its  $\theta_i$ , ~~see Definition ??~~ see Definition 2.3.12.
- Given the  $\sigma_i(\theta_i)$ , player can know the set of opponent's strategies  $s_{-i}\sigma_{-i}$ .
- A player can calculate the  $\text{EU}(\sigma_{-i}(\theta_{-i})) P(\theta_{-i}|\theta_i)$  if the player knows  $s_{-i}\sigma_{-i}$ .

~~Type-centric strategy profile~~ [FT91]

**Definition 2.3.10** (Type-centric strategy profile [FT91])

*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*

$$(s'_i(\theta_i), s_{-i}(\theta_{-i})) = (s_1(\theta_1), \dots, s_{i-1}(\theta_{i-1}), s'_i(\theta_i), s_{i+1}(\theta_{i+1}), \dots, s_i(\theta_i))$$

We can find Bayesian Equilibrium based on ex ante calculation of  $P(\theta_{-i}|\theta_i)$  and exogeneous knowledge of the  $s_{-i}\sigma_{-i}\theta_{-i}$ , see Definition ??—see Definition 2.3.13

**Bayesian Equilibrium using player types [FT91]**

**Definition 2.3.11 (Bayesian Equilibrium using player types [FT91])**

*We find an equilibrium by maximizing the sum of player i's  $P(\theta_{-i}|\theta_i)EU(s'_i)$  for each of its strategies  $s'_i \in S_i$ .*

$$s_i(\theta_i) \in \arg \max_{s'_i \in S_i} \sum_{\theta_{-i}} P(\theta_{-i}|\theta_i) EU(s'_i, s_{-i}(\theta_{-i}), (\theta_i, \theta_{-i})) \quad (2.3)$$

#### 2.3.2.4 Multi-Agent Influence Diagrams (MAIDs)

Harsanyi proposes Bayesian equilibrium as a way of calculating proposed Bayesian equilibrium to calculate Nash equilibrium for incomplete information games, where players lack complete information about the game world [Har95], [Har95], [FT91].

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For example, two warring factions; that know their state but not the complete state of their opponent. They will have some intelligence of their opponent's state, and they opponents' states and can reason about the opponent's states them.

We can assume that there are finitely many states for the opponent to be in—that are relevant to the player. For example, that the opponent has a secret weapon, has depleted their food or resources, or has powerful tanks.

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~~Type-centered~~ Type-centred Bayesian equilibrium An alternative to player-centred Bayesian equilibrium is an equivalent ~~type-centered~~ type-centred Bayesian equilibrium, that does not lead to infinite recursion, and is structured as follows:

- A player has a finite set of possible types  $\theta_i \in \Theta$  that represent every possible makeup of the player.
- $\theta_{-i} = (\theta_1, \dots, \theta_{i-1}, \theta_{i+1}, \dots, \theta_I)$  is the opponents type.
- A  $\theta_i$  can represent the players character, beliefs of other player's strategy profiles, and utility functions.
- A  $\theta_i$  is any prior information that is not common knowledge and that may affect the  $U_{-i}$ , their decision making and their belief about  $\theta_{-i}$ .
- Some players may be better informed than others about their  $\theta_{-i}$ .
- The exogenous data of the game is all  $\theta \in \Theta$ .

Rather than reason about all possible utility functions and all possible ~~strategies of the opponent, the types can be used~~ opponents' possible strategies, we can use the types to find a Bayesian equilibrium [Har67, Har68a, Har68b]. If the player does not know the  $\theta_{-i}$ , it can find the probability distribution of the  $\theta_{-i} \in \Theta$ .

- A  $\theta_i \in \Theta$  has an objective prior probability distribution  $P(\theta_i)$ .
- $P(\theta_{-i}|\theta_i)$  is the conditional probability of the  $\theta_{-i}$  given the  $\theta_i$ .
- A player can use Bayes' rule in ex-ante calculations to evaluate the  $P(\theta_{-i}|\theta_i) \in \Theta$ , hence the name Bayesian equilibrium.

When a player knows the probability distribution over all  $\theta_{-i} \in \Theta$ , they can use this to evaluate the EU of the opponent given  $\theta_i$ .

- $\sigma_i(\theta_i)$  is the player's strategy profile which is dependant on its  $\theta_i$ , see [Definition ??](#) see Definition 2.3.12.
- Given the  $\sigma_i(\theta_i)$ , player can know the set of opponent's strategies  $s_{-i}\sigma_{-i}$ .
- A player can calculate the  $\text{EU}(\sigma_{-i}(\theta_{-i})) P(\theta_{-i}|\theta_i)$  if the player knows  $s_{-i}\sigma_{-i}$ .

[Type-centric strategy profile \[FT91\]](#)

**Definition 2.3.12** (Type-centric strategy profile [FT91])

*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*

$$(s'_i(\theta_i), s_{-i}(\theta_{-i})) = (s_1(\theta_1), \dots, s_{i-1}(\theta_{i-1}), s'_i(\theta_i), s_{i+1}(\theta_{i+1}), \dots, s_n(\theta_n))$$

We can find Bayesian Equilibrium based on ex ante calculation of  $P(\theta_{-i}|\theta_i)$  and exogeneous knowledge of the  $s_{-i}\sigma_{-i}$ , see [Definition ??](#) see Definition 2.3.13

[Bayesian Equilibrium using player types \[FT91\]](#)

**Definition 2.3.13** (Bayesian Equilibrium using player types [FT91])

*We find an equilibrium by maximizing the sum of player  $i$ 's  $P(\theta_{-i}|\theta_i)\text{EU}(s'_i)$  for each of its strategies  $s'_i \in S_i$ .*

$$s_i(\theta_i) \in \arg \max_{s'_i \in S_i} \sum_{\theta_{-i}} P(\theta_{-i}|\theta_i) \text{EU}(s'_i, s_{-i}(\theta_{-i}), (\theta_i, \theta_{-i})) \quad (2.4)$$

### 2.3.3 ~~Propp's Morphology~~ Summary

### 2.3.4 ~~The murder mystery~~

We introduced the computational techniques that we use for DED

1. Bayesian Network (BN)'s:
  - (a) Causal network structure BNs which we use for coherent agent reasoning
  - (b) OOBN architecture, which we use to manage DED agents' knowledge bases
  - (c) , which we use to optimise computation for the agents to respond within one second.
2. Game Theory (GT):
  - (a) To have a mathematical definition of rationality.
  - (b) Introduce Bayesian Equilibrium for rationality under uncertainty.
  - (c) MAIDs to combine causally structured OOBN with GT

The MAIDs are at the core of our contribution to more believable characters in terms of fluid, coherent and rational responses.

## 2.4 DramaFormer work

We build the DED on two former work, the Dynamic Plot Generating Engine (DPGE), see Section 2.4.1 which dynamically creates novel mystery plots from static input, and the RDE, see Section 2.4.2, which uses the MAIDs to create rational agents.

### 2.4.1 Improvisation Dynamic Plot Generating Engine

The Dynamic Plot Generating Engine is F. Arinbjarnar's BSc final project, in 2004, at Reykjavik University (RU), Iceland.

It was a solo research project, in part guided by a visiting professor Dr Finn Verner Jensen from Aalborg University, Denmark. Dr Jensen had worked on a similar project, *Non-Linear Interactive Storytelling Using Object-Oriented BNs (Nolist)* [BJJ<sup>+</sup>04].

The DPGE is a combination of structuralism in narratives, in particular, uses Propp's Morphology, previously introduced in Section 2.3.3 in Section 2.2.1.3, and causally structured BNs, previously introduced in Section 2.3.1 in Section 2.3.1, to generate a nearly endless supply of plots to use in mystery based computer games.

The is published in a BSc report [Ari06] and in a symposium article, *In proceedings of the Workshop on Integrating Technologies for Interactive Stories, 2008* [Ari08].

#### 2.4.1.1 The plot

A story begins at some point in time, which is understood to have a prior narrative, which is frequently implicit and left to the imagination of the reader. The mind instantly creates a backstory for all of what it senses; even the most uncomplicated narrative will have a former world state. For example, the three-word narrative: "The stone fell." The stone must have been somewhere before falling, and it was in an elevated position relative to the place it fell too. The mind will draw a picture of a plausible scenario and a narrative in which the stone fell. Perhaps it pictures a hiker climbing a mountain slope and dislodging the stone.

The implicit necessity of previous events makes us see a narrative where there is no action; even in a static picture there:

...is a shadowy sense of time preceding it, and specifically of narrative time - that is, time comprised of necessary events that lead up to and accounts for, what we see .

– [Abb02, p. 6]

In murder mysteries, this previous state, the past, is the sequence of events that lead up to and cause the murder, i.e. the murder plot. Con-

versely, the mystery proper is the narrative of the sleuth's murder investigation. There are, therefore, two distinct plots in a Murder Mystery [Tod77]:

1. The murder plot that has occurred before the mystery proper starts.
2. Present, the narrative of the sleuth uncovering the murder plot.

The DPGE generates the first plot, the murder plot, at the ~~start of the mystery~~mystery's start to provide auto-generated mystery plots for murder mystery games.

Conversely, in Nolist [BJJ<sup>+</sup>04], the engine creates the murder plot ~~in during the player~~during the player during the player's investigation. Nolist will create the murder plot depending on how the player plays the game, such that, if the player finds a body and a gun nearby, the probability that the murder victim was shot with a gun increases if the player finds a gun nearby. ~~Conversely~~Similarly, the probability ~~that the victim was stabbed with a knife~~knife stabbing increases if the player finds a knife before finding the gun.

Dr Jensen was aware of the two plots, and we discussed why he chose this approach [Jen04]. He feared that smart players would find it too easy to solve the mystery plots, quickly identify the murderer and subsequently miss out on the intended drama. Conversely, that the difficulty of solving the mystery would confound other, not as sharp, players. In both cases, this could lead to boredom, and players would miss out on the drama. For this reason, the engine would adjust the murder plot to ensure that the player needed to explore the world and interact with the characters to a certain degree to ~~be able to~~ solve the mystery. Similar to a teacher giving more capable students more challenging work.

It is imperative to address the challenges of combining game mechanics and the narrative; however, there are alternative methods to control the difficulty levels of games; additionally, it is difficult to conjecture how much this particular element will affect the ~~quality of the drama's quality~~. It is essential to consider the ~~agency of the player~~player's agency and how much control we give to the player. It is, arguably, a design decision whether to block smart players from finishing quickly.

#### 2.4.1.2 The structure

The DPGE combines BNs and Propp's formalism, introduced ~~in Section 2.3.3~~ in Section 2.2.1.3, to generate the plots. Propp defined four rules; the DPGE generates plots that satisfy them as follows:

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" [Pro68].  
The mystery morphology has a finite set of character functions for

motive, means, opportunity and murder; for the three character types: victim, murderer and suspect.

2. "The number of functions known to a fairy tale is limited"[Pro68].  
The mystery morphology has a finite set of 4 functions listed in #1.
3. "The sequence of functions is always identical"[Pro68].  
We create the mystery in a causally structured BN; the causal structure implies a consistent sequence.
4. "All fairy tales are of one type in regard to their structure"[Pro68].  
We generate all mysteries with the same algorithm, and they are all of the same structure.

As an example of how the BN is defined here are some of the motive functions:

1. **Swindle.** Either the murderer is swindling the victim, and the victim threatens to tell, or the victim was swindling the murderer, and the murderer wanted revenge. Either way, the swindler should be rich.
2. **Blackmail.** Either the murderer was blackmailing the victim and feared that the victim would reveal it or the victim was blackmailing the murderer. In either case, it is necessary that the blackmailed character has some dark secret to blackmail.
3. **Wedlock.** In Agatha Christie's time, it could sometimes be difficult or bad publicity to get a divorce and found it justifiable to murder their partner instead. Wedlock can apply today if people do not wish to go through the divorce process and lose half their belongings and possibly custody of their children. The constraint in the net for wedlock is that the murderer is the victim's partner.
4. **Inheritance.** is self-explanatory; the victim must be rich, and the murderer must be their heir.
5. **Adultery.** The victim was having an affair with the murderer's spouse, and the murderer kills because of pure jealousy.
6. **Revenge.** The murderer believes that they have cause for revenge. The victim must have harmed the murderer in some sense in the past.
7. **Debt.** The murderer owed the victim lots of money and could not pay, i.e. the murderer is poor.

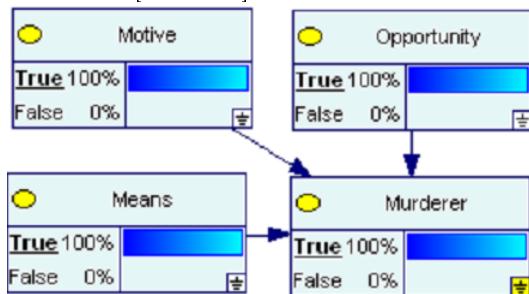
#### 2.4.1.3 Dynamically generated plots

The DPGE generates the plots *dynamically* using an abstract representation of the game world in the form of a causally ~~stuctured~~structured BN that is read in at the start and creates a novel plot by randomly instantiating the BN's chance vertices~~of the~~. For this reason, it is useful for generating a constant stream of novel plots for games.

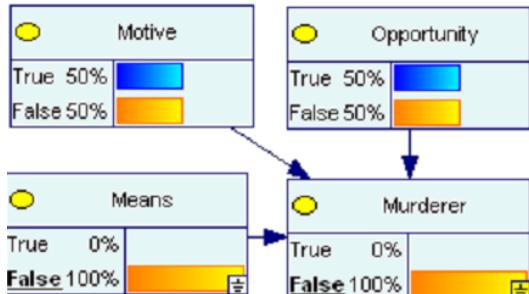
**Step 1, Reading data,** the engine reads in a text file that details all possible names of persons ~~that can be~~ used by the engine. Next, the engine then reads a text file that details all variable types ~~that should be~~ in the net and their connection to other variables.

**Step 2, Drawing the net,** each variable in the BN is programmatically added; using the C++ library Smile. [DSL07b].

**Figure 2.4.1** Instantiating a murderer in the BN,  
displayed in the GeNIe UI [DSL07a]



**Figure 2.4.2** Instantiating a suspect,  
displayed in the GeNIe UI [DSL07a]



**Step 3, Instantiating specific variables,** the next step is to decide on a murderer by randomly choosing one character. A murderer needs to have a motive, means and opportunity so these variables, in the murderer ~~sue~~subset, need to be instantiated to true, ~~see Figure 2.4.1~~ see Figure 2.4.1.

Similarly, to eliminate a suspect as a possible murderer, the suspect can not have all three: motive, means and opportunity. We, therefore, instantiate one of them, randomly, to false for each of the suspects. For example, ~~in~~ **Figure 2.4.2** see Figure 2.4.2, the variable means has been instantiated to false.

**Step 4, Instantiating the plot,** finally, we instantiate all remaining variables by generating a random number between 0 and 1 and select the state that

corresponds to its value.

This dynamic process creates novel plots regardless of whether the input is static. For example;

1. **Static input**, when a player starts a new game, a new plot is generated for the player using the DPGE. This new plot will be significantly different from previous plots.
2. **Semi-static input**, at the start of the game ~~the~~ the player can choose some of the ~~states of the game world~~~~game world's states~~. For example, their background and role. These user choices ~~are used to~~ instantiate corresponding nodes in the BN to reflect the bespoke requests of the player.
3. **Dynamic input**, the DPGE can further be used after the player has solved one mystery to create new mysteries from the updated state of the BN; as a result of the player's gameplay.

~~The engine is easily connected to other applications and has been tested in various contexts diverse setups and requirements.~~

~~The first test of the applicability of the engine was to create a simple mystery game that used plots generated by .~~

~~The mystery game provided the player with predefined logical conclusions based on the plot and showed that each plot was consistent and that the murderer and the murder weapon was deducible. The game demonstrated that each new plot generated was distinct and complete.~~

~~The engine was also connected to the Hexia dialogue control system 13. Hexia provided means to interact with the engine through MSN Messenger. This provided an interactive mystery where the player could talk with a named Theresa and ask her to perform actions on scene such as “open drawer”, “read letter” and “look at desk”. At the beginning of each game Theresa greeted the player and described the scene. The player then needed to tell Theresa what to do next and she then told the player the results of her actions.~~

~~As an example the player could have asked Theresa to look at a desk and Theresa then informs the player that there is a drawer in the desk. The player can then ask Theresa to open the drawer. The player does not need to indicate which drawer as the Hexia dialogue control system is contextual, it is able to preserve context in a dialogue. Theresa will then attempt to open the drawer and if she is successful then she will describe the content of the drawer, otherwise she will describe the problem, e.g. “the drawer is locked!” At any given time the player could frame a suspect and get informed by the engine whether she was correct or not. The player can only frame suspects that she has become aware of in the game.~~

~~This implementation of the engine was demonstrated at the Reykjavik Artificial Intelligence festival (2006). Those who tried it were successful in~~

~~playing the game and deducing who the murderer was after a few attempts.  
It should be stated that no formal tests were done that would prove this.~~

~~Authoring the dialogue for Theresa took less than three 40 hour work weeks.~~

#### 2.4.1.4 Tests

The engine is easily connected to other applications and ~~has been tested in various contexts~~ tested in diverse setups and requirements.

The first test of the ~~applicability of the engine~~ engine's applicability was to create a simple mystery game that used plots generated by DPGE.

The mystery game provided the player with predefined logical conclusions based on the plot and showed that each plot was consistent and that the murderer and the murder weapon was deducible. The game demonstrated that each new plot generated was distinct and complete.

~~The engine was also connected~~ We connected the engine to the Hexia dialogue control system [13]. Hexia provided means to interact with the engine through MSN Messenger. This setup provided an interactive mystery where the player could talk with ~~a~~ an NPC named Theresa and ask her to perform actions on the scene such as “open drawer”, “read letter” and “look at desk”. At the beginning of each game, Theresa greeted the player and described the scene. The player then needed to tell Theresa what to do next, and she then told the player the results of her actions.

~~As an example~~ For example, the player could have asked Theresa to look at a desk, and Theresa then informs the player that there is a drawer in the desk. The player can then ask Theresa to open the drawer. The player does not need to indicate which drawer as the Hexia dialogue control system is contextual, ~~it is able to~~ : it can preserve context in a dialogue. Theresa will then attempt to open the drawer, and if she is successful then she will describe the content of the drawer, ~~otherwise~~ : otherwise, she will describe the problem, e.g. “the drawer is locked!” At any given time the player could frame a suspect and get informed by the engine whether she was correct or not. The player can only frame suspects that she has become aware of in the game.

~~This~~ We demonstrated this implementation of the engine ~~was demonstrated~~ at the Reykjavik Artificial Intelligence festival (2006). Those who tried it were successful in playing the game and deducing who the murderer was after a few attempts. It should be stated that no formal tests were done that would prove this. We did no formal tests to prove this.

Authoring the dialogue for NPC Theresa took less than three 40 hour work weeks.

### 2.4.2 ~~Interactive Drama~~Rational Dialogue Engine

The RDE creates and runs a set of actors that are rational in Game-Theoretic terms, i.e. choose their optimal strategy, i.e. the strategy that has the highest value as explained ~~in Section 2.3.2~~ in Section 2.3.2, that can engage in a dialogue with each other and the player, and. The RDE was developed as part of F. Arinbjarnar's MSc thesis [Ari07a] and published in *AAAI Fall Symposium On Intelligent Narrative Technologies* [Ari07b].

In RDE, a rational actor plays a character that interacts with other characters in a computer game ~~that are played either~~played by human players or other actors. We define the actor's rationality as the choice of actions which best satisfy the character's objectives and desires. We base the character's objectives on what would typically motivate a person [HHL<sup>+</sup>92], i.e. ~~what is thought to be~~ believable goals. For example, in a murder investigation, the detective has the objective to find the murderer, while other characters have the objective not to reveal a motive, means or anything else that could make them a likely murderer.

**Rational actors** We structure the rational actor in RDE with three distinct parts:

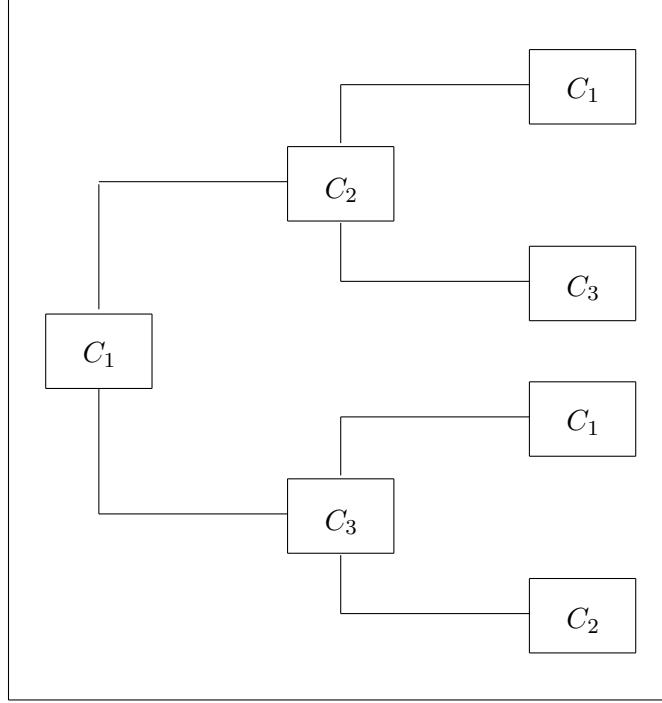
1. A past life for the character to build a knowledge base that contains information of their present state and their knowledge of other characters in the game. Essentially, the DPGE introduced in Section 2.4.1 creates a plot by instantiating a causally structured BN, see Section 2.3.1 for an introduction to BNs.
2. Each actor has a knowledge base structure by their past life, i.e. the plot generated by the DPGE. ~~Their~~Therefore, their knowledge base is ~~, therefore,~~ a causally structured BNs that contains the character's knowledge in the form of instantiated chance ~~es~~in ~~their~~ vertices in ~~their~~ BNs. This knowledge base is updated as the character gains new knowledge.
3. A reasoning algorithm that can find a game-theoretic equilibrium as explained in Section 2.3.2, and uses the ~~s~~ BNs from their knowledge base to reason about the current state of the game world.

#### 2.4.2.1 Character's knowledge base

The actor has a set of knowledge subnets where it maps everything its character knows. When the actor is reasoning about how to respond in a dialogue, ~~with a game-theoretic game~~, it requires a mental image of its opponent's knowledge ~~with a game-theoretic game~~.

We consider the actor to be the acting agent, i.e. the actor reasons and acts ~~in a manner that it has calculated that~~to calculate that the character

**Figure 2.4.3** The character knowledge base structure

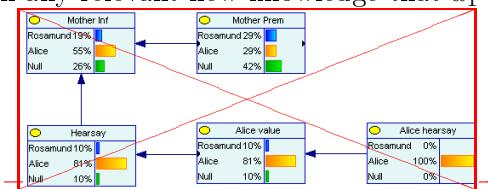


it is playing would do.

We define three characters  $c_1, c_2, c_3$  and an actor  $a_1$  that plays  $c_1$ .  $c_1$  has two opponents  $c_2$  and  $c_3$ , and has a knowledge base for each of  $c_1$ 's opponents identical to  $a_1$ 's knowledge base in form, i.e. it is a causally structured BN based on the plot that DPGE generated, [see Figure 2.4.3](#) see Figure 2.4.3.  $a_1$  has instantiated  $c_1$ 's opponents' knowledge base with what  $a_1$  reasons that  $c_2$  and  $c_3$  would know.

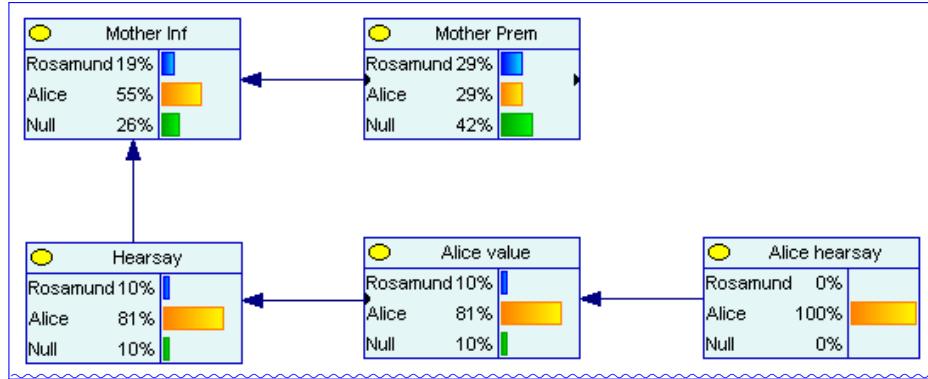
Furthermore,  $a_1$  also requires a mental image of what  $a_1$  reasons that  $c_2$  and  $c_3$  would think that  $c_2$  and  $c_3$ 's opponents would know. Therefore,  $a_1$  has BNs based on the plot and instantiated with what  $a_1$  reasons that  $c_2$  thinks that  $c_1$  and  $c_3$  thinks. Similarly,  $a_1$  has BNs based on the plot and instantiated with what  $a_1$  reasons that  $c_3$  thinks that  $c_1$  and  $c_2$  thinks.

Therefore,  $a_1$  has 7 BNs based on the initial plot and  $a_1$  updates all 7 with any relevant new knowledge that  $a_1$  learns.



We divide each of  $a_1$  BNs into smaller subnets that contain two or more vertices describing the state of the distinct item of knowledge. For example, [in Figure 2.4.4 is a subnet that](#) in Figure 2.4.4, [a subnet](#) contains the state

**Figure 2.4.4** Actor's knowledge subnet, displayed in the GeNIe UI [DSL07a]



of knowing who is the mother of another character. Each of the vertices has three states, two possible female names of other characters in this game, and null. The null represents the possibility that none of the other characters is the victim's mother.

The top right vertex, called "Mother prem<sup>ll</sup>" is connected to other vertices that have "prem<sup>ll</sup>" postfix in the net. Each of these knowledge piece subnets has precisely one such vertex that corresponds to the DPGE plot generated at the start. Some ~~of these~~ premise vertices are instantiated at the start of the game to represent what each actor knows from the DPGE generated plot.

The top left vertex "Mother inf" vertex is an inference of known facts from the "mother prem" vertex and inferred knowledge based on what other characters have told  $c_1$ . This vertex represents the inferred knowledge of both actual data from the premise vertex and information that  $a_1$  has been told by an opponent, in this case,  $c_2$  whom's character name is Alice.

The ~~"Alice hearsay"~~ top left vertex "Mother inf" vertex is an inference of known facts from the "mother prem" vertex and inferred knowledge based on what other characters have told  $c_1$ . This vertex represents the inferred knowledge of both actual data from the premise vertex and information that  $a_1$  has been told by an opponent, in this case,  $c_2$ , who's character name is Alice.

The "Alice hearsay" vertex shows what  $c_2$  claimed to be the mother. The "Alice value<sup>ll</sup>" vertex shows how much value  $c_1$  places on Alice's claims. The "value<sup>ll</sup>" vertices are influenced by the  $c_1$ 's gullibility and by how reliable  $c_1$  believes  $c_1$ 's opponent is. ~~If Similarly, we add if~~  $c_1$  talks to other characters and ~~these characters also give gives~~ information on who the mother is, ~~then that is added similarly~~. Thus  $c_1$  can receive conflicting evidence from other characters and ~~needs to~~ evaluate each hearsay given the opponent's reliability. The hearsay vertex aggregates all hearsay, and the inference vertex aggregates the premises and hearsay vertex. If the actor ~~would receive~~

~~eoncrete evidence then, and only then, will receives concrete evidence, then the “Mother prem” vertex will be instantiated to reflect that.~~

#### 2.4.2.2 Generating sentences and replies

~~The sentences are generated~~ We generate the sentences from the knowledge vertices. ~~The process is started by an arbitrary seed. This seed could come~~ We use seed from another actor or from a player or from some player, event or interaction in the game. First, we find a knowledge vertex matching the seed ~~is found~~. For instance, the Mother Prem vertex in Figure 2.4.4 in Figure 2.4.4 would match the seed mother. Then all the parents and children of the mother prem vertex are retrieved. ~~These are premises that are connected in the Bayesian net to the mother prem. All of these~~ The premises connect to the mother prem vertex. These vertices can be considered are “relevant” because they either match the seed or have causal relations to a vertex that matches the seed.

Each state in a relevant knowledge vertex is used to create two sentences, one for the affirmative and one in denial. For example the Mother Prem vertex in Figure 2.4.4 would generate 6 possible sentences, namely: “Rosamund is the victim’s mother”, “Rosamund is not the victim’s mother”, “Alice is the victim’s mother”, “Alice is not the victim’s mother”, “none of the suspects is the victim’s mother” and finally “one of the suspects is the victim’s mother”. Knowledge vertices are also combined to create sentences ~~that are based on~~ from more than one knowledge vertex. For example, the following sentence contains three knowledge vertices: “Rosamund is a tall, blond female”.

~~The expected replies are generated~~ We generate the replies in the same way as the sentences except that now each of the knowledge vertices used to generate sentences is ~~used as~~ a seed for generating replies.

When an actor wants to say something she will:

1. Generate possible sentences and possible replies.
2. Calculate the optimal reply that she expects for each of her sentences.
3. Calculate her set of optimal sentences given the set of optimal replies.
4. Pick one sentence in the set of optimal sentences to speak.
5. Update her knowledge base with ~~respect to~~ what she decided to say.  
If the opponent is ~~a~~ an actor then the opponent will also update its knowledge base.

#### 2.4.2.3 RDE

The RDE is the decision mechanism of the actor ~~. It is created from the plot that the generated. For example in a murder mystery this means that the murderer and each of the suspects are created as independent actors, fully~~

equipped with a knowledge base describing their world with respect to the plot. The actor uses the engine to calculate to find a rational sentence to speak in terms of.

In game theoretic terms the actor that is about to speak is the *player*  $i$  and the actor or human that the player is speaking to is the *opponent*  $-i$ . When mapping a dialogue into a “Bayesian game” then one game is one actor finding one sentence from a set of sentences to speak against one opponent. When the opponent replies then we have another Bayesian game. This means in game theoretic terms that we have a two-player, non-cooperative, sequential game. There is We have a two-player, non-cooperative, sequential game in game-theoretic terms—one player against one opponent where the player has some  $n$  can choose from  $n$  sentences (decisions) to choose from. The player knows his type  $\theta_i$ , but not her, but not its opponents type  $\theta_{-i}$ . According to the definition of exogenous data then From exogenous data, the player knows all the possible types that the opponent could be of and for each of those types the player will know opponent’s possible types and all payoff functions contingent to each type. This means that the The player knows all the possible sets of replies that the opponent could have and that for each of those sets the player knows what the opponent would gain by each reply. The player also has some estimate of how probable the opponent is to be of any given type. possible replies the opponent can say, the opponent’s payoff function, and an estimate of the opponent’s type.

The game is sequential which means that the player will speak and then the opponent will reply; the player speaks, and the opponent replies.

The type does not refer to character types such as suspect or murderer, instead. Instead, it refers to the status of the actor’s knowledge base. This means that an actor that has not been told An actor does not know of an affair is of one type, but when the same actor is told learns about an affair then he becomes another type. This also means that in In the worst case in a brute force algorithm then, all possible types of a player would mean a crossproduct cross-product of all the states of the in the Bayesian net of the actor vertices’ states in the actor’s Bayesian net.

This is where the Multi-Agent Influence Diagrams (MAIDs) [KM03] come to the rescue. A MAIDA MAID [KM03], introduced in Section 2.3.2.4 is an extended Bayesian net for finding equilibrium in agents for the agents’ decision problems. It is important to note that the game theoretic game just described is what Koller and Milch refer to our problem domain as a “single agent single-agent decision problem” [KM03]. This means that there is only one agent that needs to make a decision in each game. The agent is the player in game theoretic terms. The opponent does not make her decision until after the current player has acted. [KM03], and the players take turns.

For each run of the engine, it needs to set up the Bayesian game. First, it generates sentences and all possible replies to each of the sentences from the

knowledge base. ~~The knowledge base is described~~ We describe the knowledge base in the next ~~Section~~ section, followed by a ~~Section~~ that describes how section describing how to generate the sentences and replies ~~are generated~~.

~~When a Bayesian game has been set up~~ The engine finds an equilibrium, a set of optimal sentences using MAIDs, and ~~then the actor can pick one of these optimal sentences and speak~~. This is described in Section 2.4.2.5. ~~the actor picks one to say~~, see Section ??~. The engine also adds any knowledge gained to the knowledge base.

~~The method described above is developed using Multi Agent Influence Diagrams (MAIDs) [KM03]~~. MAIDs are extended Bayesian nets specifically designed to find Nash equilibria for incomplete data, which is exactly the problem that the actors face.

~~The result is a rationally interactive actor that is able to participate in a dialogue, calculating an optimal sentence to speak based on her knowledge base and what has transpired previously in the dialogue. The actor is able to receive~~ actor receives information from other actors and players, evaluate it and, ~~if she finds it sound, add it to her~~ its knowledge base. ~~Thus allowing for~~ It allows unstructured emergent behaviour from the interactions between the player and actors.

The actors make no distinction between another actor and a human player, so if a human player takes the part of a suspect or murderer defined by the plot engine~~then~~~ the actors will interact with the human player just as if the human player were another actor.

The outcomes of the RDE are measured in ~~terms of and not by Game-Theoretic terms, not~~ whether the dialogues appear natural to humans. ~~This is because no structure is~~ There is no structure applied to the engine itself to present it as, for example, lines in a drama or a fluent conversation with humans. ~~In order to~~ To structure the rational dialogue output ~~for it is necessary to apply a separate~~, we need another engine such as the DED.

#### 2.4.2.4 Sentences and replies

Each time the actor wants to say something, it needs to generate a set of possible sentences. ~~The sentences need to be based on some prior knowledge that the actor has and on her intended purpose for speaking~~ We generate sentences from the actors' prior knowledge and their goals. It is also necessary to generate all the possible replies of the opponent so that she can evaluate the affect opponents' possible replies to evaluate the effect of her intended sentence. ~~This is discussed in more detail in Section ?? and see details in Section ??~~

The sentence and reply subnets contain the sentences that the active character could say and the replies she would expect from her opponent respective.

It is necessary to calculate the levels of contradiction and risk for each

sentence and reply to get an evaluation of the over all risk of each sentence. First it is good to get a detailed description of what the contradiction and risk vertices measure and then it is possible to put it in a more general context by an example.

~~Contradiction is obtained when the knowledge that a sentence or a reply is based on is at odds with the assumed knowledge~~

- ~~contradiction is the degree of difference between the character's statements and its theory of the opponent's mind. For example, if John thinks that Linda knows that he broke a vase, John will measure a high contradiction when considering an opposing statement.~~

To calculate the contradiction vertex of a sentence or reply it is necessary to compare the knowledge  $k^{s,r}$  associated with each sentence  $s$  or reply  $r$  with each of the respective opponent's knowledge denoted  $k^o$ . Such that  $k_1^{s,r}$  is compared to opponent's  $k_1^o$ .

Contradiction is caused by inequalities between the values of  $k_1^{s,r}$  and  $k_1^o$

$$k_1^o = \text{True} \neq \text{False} = k_1^{s,r}$$

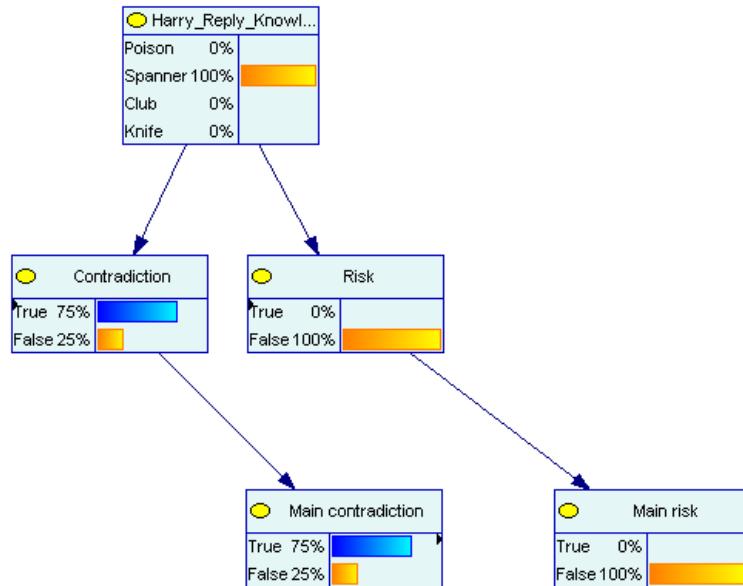
~~It may be We argue that there is only a degree of contradiction since it is a measure of the character's belief of its opponents' state of mind, i.e. the character is reasoning under uncertainty. Moreover, it is reasonable to assume that there are degrees of contradiction due to other factors such as type of knowledge . As an example: knowledge type. For example, if someone tells us he arrived at three o'clock, but we know in fact that he arrived 15 minutes earlier, we do not necessarily consider it a contradiction, or at least less of a contradiction than if the same person claimed that he never arrived. Such affects effects would influence the contradiction vertex.~~

- ~~Risk is when the knowledge that a sentence or a reply is based on contradicts the knowledge of the actor. The level of estimated risk of a sentence is estimated following the same lines outlined above for the level of contradiction follows the same process as the contradiction.~~

~~The main contradiction and main risk central contradiction and risk vertices aggregate values from all the their parent contradiction and risk vertices respectively in the same subnet. Having the main Having primary contradiction and risk vertices as intermediate steps is necessary to simplify the calculations in the speech subnet see Section ??.~~

~~As an example look at Figures 2.4.5 and 2.4.6 For example, see Figure 2.4.5 and Figure 2.4.6 that show two possible replies: reply A “the murder weapon is spanner” and reply B “the murder weapon is not spanner”. In this example, Harry is evaluating what the opponent is likely to~~

**Figure 2.4.5** Reasoning; is spanner true, displayed in the GeNIe UI [DSL07a]

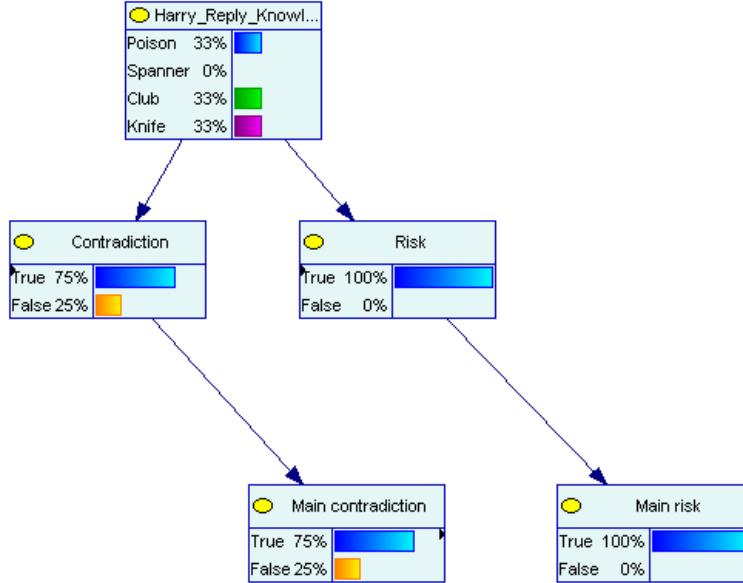


reply. Harry believes that his opponent is ~~absolutely~~ sure that the murder weapon is ~~a~~ spanner and that the opponent believes that Harry is clueless about what the murder weapon is such that Harry has an equal value set on all states in his respective knowledge subnet.

The top vertex ~~in Figure 2.4.5~~ in Figure 2.4.5 has its probability for state spanner set to 1. and all other states set to 0. Since Harry believes that his opponent believes that Harry is clueless, ~~;~~ Harry will assume that the opponent realizes that claiming that the murder weapon is spanner will contradict Harry's knowledge by 75% ~~but will be identical to 25% of Harry's knowledge~~. On the other hand, Harry assumes that the opponent assumes ~~that there is~~ no risk involved in claiming that the murder weapon is a spanner because the opponent is ~~absolutely~~ sure that the murder weapon is ~~spanner~~ ~~a~~ spanner.

~~In Figure 2.4.6~~ In Figure 2.4.6 Harry evaluates possible replies to the effect that the murder weapon is not a spanner; so the probability of spanner is set to 0 ~~but~~, ~~albeit~~, all other states have equal probabilities. Just as ~~in Figure 2.4.5~~ in Figure 2.4.5 the contradiction is 0.75 because there is a contradiction of 75% essentially. ~~But now the~~ ~~The~~ risk is very high because Harry assumes that the opponent will think that he, the opponent, is lying and will find it ~~a very risky business~~ ~~highly risky~~.

**Figure 2.4.6** Reasoning; is spanner false, displayed in the GeNIe UI [DSL07a]



#### 2.4.2.5 Finding equilibrium

The actors want to find an equilibrium to determine a set of optimal sentences from those generated from the seed. It is important to realise that the game theoretic “game” that the actors face is sequential, e.g. the actor makes a move and then his opponent makes a move. They do not make their moves in parallel which simplifies the computation of equilibrium significantly.

First the engine sets up a game theoretic game using Multi Agent Influence Diagrams (MAIDs) [KM03].

The MAIDs offer an algorithm to find equilibrium in incomplete information games for single agent decision problems in linear time. The MAIDs map the decision vertices of the Bayesian net with a “relevance graph” to discover in what order the decisions should be evaluated. There are two decisions that need to be evaluated by the actor: The assumed reply of the opponent and the sentence that the actor should speak with respect to the assumed reply.

Since the set of optimal sentences is dependent on their replies the first step is to calculate the set of optimal replies to each of the sentences. The second step is to determine the set of optimal sentences with respect to the replies that each of them is liable to receive.

This means that the engine generates all the possible strategies (sentences) that the actor can play,  $s'_i(\theta_i)$ , and all the strategies (replies) that the opponent can play contingent on each of their possible types  $s_{-i}(\theta_{-i})$ . This is done by generating the sentences and replies as previously described.

What the actor will say is dependent upon what he expects as a reply. So we have two decision variables in a MAID. One for the optimal sentences  $D_s$  and another for the optimal replies  $D_r$ . Decision variable  $D_s$  is dependent on decision variable  $D_r$ . This means that we can draw a relevance graph such that  $D_s \rightarrow D_r$ . This means that there is need for two MAIDs to find an equilibrium. One induced by the replies  $\mathcal{M}_{[\sigma_{D_r}]}$  and the other induced by the sentences  $\mathcal{M}_{[\sigma_{D_s}]}$ . There are then two MAIDs:  $\mathcal{M}_{[\sigma_{D_r}]}$  where  $D_r$  is a chance variable and  $\mathcal{M}_{[\sigma_{D_s}]}$  where  $D_s$  is a chance variable. When these two MAIDs have been constructed the algorithm evaluates the two MAIDs by iterating through them in reverse order. This means that  $\mathcal{M}_{[\sigma_{D_r}]}$  is calculated first and  $\mathcal{M}_{[\sigma_{D_s}]}$  second induced with the results from  $D_r$ . The decision reached in  $\mathcal{M}_{[\sigma_{D_s}]}$  is then an optimal decision. This is equivalent to finding a Nash equilibrium.

These strategies are then used to find the weighted payoff as detailed for the Bayesian equilibrium [FT91],

$$p(\theta_{-i}|\theta_i)u_i(s'_i, s_{-i}(\theta_{-i}), (\theta_i, \theta_{-i}))$$

Next the engine sums up the payoff for each of the player's strategies and from the sum collects the set of strategies that carries the maximum value.

Finally the actor can simply pick some random sentence from the set of optimal sentences to speak. The engine adds any knowledge gained to the actor's knowledge base as described [in Section 2.4.2.1](#) in Section ??.

In order to better clarify how the engine evaluates sentences I will take as an example an actor named Horace that is talking to an opponent named Linda. Horace has just been asked whether he owed the victim money. First the engine generates a set of possible sentences for Horace to speak. Horace could both say "I'm in debt" or "I'm not in debt" and he could also say "I'm rich" or "I'm poor" since that has a logical connection to whether someone is indebted or not. There could of course be other options but these will do as an example. The engine also creates all possible replies to each of the possible sentences.

If Horace was indebted to the victim then he may want to lie as admitting to having a motive will place him under suspicion. Now lying has risks; if Linda catches Horace in a lie then Horace will appear to be even more suspicious than if he tells the truth. Horace may also have high moral standards and not care to lie.

Let us say that Horace was indebted to the victim, then admitting to it will carry a penalty due to increased suspicion. Denying it will carry a penalty due to risk of being caught lying and possibly because of moral standards. This would mean that admitting to being indebted is likely to get a higher payoff, especially if the engine calculates that the optimal response to denying the debt would indicate that Linda knows that Horace is lying. Horace can also state that he is poor. That may have the highest payoff.

Being poor is not a motive for murder, it is not contradicting what Horace knows is true and unless he believes that Linda may claim that he is lying then claiming to be poor is likely to carry the highest payoff in this example. If Horace is not indebted to the victim then either claiming to be rich or denying the debt is likely to carry the highest payoff.

When Horace has chosen a sentence to speak then his opponent's knowledge base is updated with what Horace just said as described ~~in Section 2.4.2.1~~ in Section ?? . Horace's knowledge base is also updated so that Horace will remember what he told Linda.

If Linda is an actor then Linda's engine would start by adding the knowledge acquired from Horace's sentence to Linda's knowledge base. Then from the newly updated knowledge base the engine will generate all possible sentences for Linda to speak using Horace's sentence as a seed. Then Linda's engine draws up a new game theoretic game and the engine finds an equilibrium for Linda just as Horace's engine found an equilibrium for him. It is important to understand from this example that:

1. Finding one sentence to speak is one game theoretic game.
2. The goals of the actors are subjective such as not to lie or become suspicious.
3. There are no explicit goals, such as solve the mystery.
4. Characteristics, feelings, knowledge, beliefs about the opponent's reactions etc. influence the actor payoff.
5. The actors add to their knowledge base and the next game theoretic game reads from an updated knowledge base.
6. The actor does not care whether he is talking to a human or another actor, it is not a factor in the engine's calculations.

#### 2.4.2.6 Output of the RDE

The actors are able to calculate an optimal sentence using GT and they are able to participate in a dialogue, ~~(see Example ??)~~, see Example 2.4.1.

#### **Example 2.4.1 (Calculating optimal sentence)**

*Rosamund and Alice are talking together and Rosamund got the seed wedlock which is a possible motive for murder. The conversation drifts into stating their actual relations with the victim and ends when Rosamund has nothing to add to the conversation.*

1. Rosamund says: *Horace did not hold me in wedlock.*
2. Alice says: *Horace did not hold me in wedlock.*
3. Rosamund says: *I'm not Horace's wife.*

- 
4. Alice says: I'm not Horace's wife.
  5. Rosamund says: I'm Horace's parent.
  6. Alice says: Horace did not have an affair with a male.
  7. Rosamund says: I'm Horace's mother.
  8. Alice says: Horace was having an affair with me.
  9. Rosamund can't think of anything to say!

## 2.5 Game Summary

In the ~~first half of this Chapter, Narratology~~ Section 2.2 we introduced the work and theories of several structuralists and experts in drama-theory and narratology. We discussed how narrative ~~is non-interactive while drama is essentially a play, happening in the here and now and is by nature an interactive form of entertainment and education, which we enjoy from early childhood play. It is, therefore, also an and drama are an~~ integral part of games and PP-RPG are effectively real-life play ~~, and~~ improvisation, which has been difficult to transfer into CB-RPG and retain the ~~free nature of the former~~<sup>former's free nature</sup>.

In the latter half, we introduced complex technology, BNs, GT and the combination of the two into the MAIDs. We described the DPGE, ~~which is~~ based on causally structured BNs and generates plots dynamically from static input. Followed by our RDE that uses the MAIDs. The RDE calculates a rational sentence for an actor to speak. It uses a knowledge base, of causally structured BNs, to generate sentences and replies and calculates an equilibrium according to GT. The actors evaluate the set of possible sentences by what they think and ~~by~~ what they expect their opponents ~~may~~ ~~to~~ think and reply.

Moreover, the actors can adapt to what they hear from their opponents. They do this by adding the hearsay nodes to their opponent's last spoken sentence. As ~~can be seen from Example ??shown~~ in Example 2.4.1, the sentences generated are far from what humans would expect in a dialogue. The RDE does not generate sentences that humans would find 'interesting', 'natural' and 'fully coherent' as we see it.

Initially, the engine was too slow to respond ~~to players in an~~ about 50% took more than 1 minute to compute. It helped that most of the time, there were not that many sentences generated. In the worst case, belief updating algorithms for ~~s~~-BNs are NP-hard [Coo90]. There are several approximation algorithms available, ~~see Table 2.5.1~~ see Table 2.5.1. All of these algorithms have ~~also been shown to be an~~ NP-hard ~~for the~~ worst-case [DL93]. ~~The worst case is when all of the needs to be updated, or the network has many~~

~~connections between various nodes.~~ BNs' complexity grows with the number of vertices and connections between vertices.

The network used for the ~~current implementation of the actors~~ actors' current implementation has over 3000 vertices, which is not a very big network for an intelligent virtual agent. An average agent in an interactive drama could easily have a few hundreds of thousand vertices.

However, even this small BN takes several seconds to update with basic BN reasoning algorithms ~~[?, 2]~~ [Ari07a, Ari07b], which is not sufficiently fast for real-time applications where the player expects an answer from the NPC in about one or two seconds. Not only is it not fast enough, but it also leaves no room for all the other processes, such as graphics and animation that are highly demanding on resources in any high graphics computer game. All the algorithms available in the Smile library[DSL07b] are shown ~~in Table 2.5.1~~ in Table 2.5.1. We tried them all, but none of them reduced the computation time significantly. All the algorithms ~~in Table 2.5.1~~ in Table 2.5.1 are attempting to update the whole network.

**Table 2.5.1** The algorithms available to compute the values of a BN

LAURITZEN	Probability Propagation [HD96]
HENRION	Probabilistic Logic Sampling [Hen88]
PEARL	Fusion, Propagation, and Structuring [Pea86]
LSAMPLING	Simulation with likelihood weighting [SP90]
SELFIMPORTANCE	Simulation with self importance [SP90]
BACKSAMPLING	Backward Simulation [FF94]
AISSAMPLING	Adaptive Importance Sampling Algorithm [CD00]
EPISSAMPLING	Evidence Pre-propagation Importance Sampling Algorithm [YD03]

~~algorithms available to compute the values of a~~

The DED that we introduce in this thesis resolves some of these issues. First, it addresses the previous problems of lack of coherent behaviour by using goal-driven behaviour and developing algorithms that utilise the causal structure of the actors' knowledge base. It adds generic methods ~~that select actions by whether they to select actions that~~ increase the characters' position and ~~by~~ whether they are causally related to specific character goals and drama goals. We define these goals in schemas, which are motif like structures similar to G. Polti's situations [Pol21]. We also apply a more sophisticated evaluation of knowledge that the actor receives before adding it to their knowledge base. We address the performance issues by applying Relevance Reasoning [LD97] and OOBNs[KP97].



## 2.6 Belief Networks

- 2.6.1 The graph structure
- 2.6.2 The structure
- 2.6.3 Assigning conditional probability distribution
- 2.6.4 Marginal distribution
- 2.6.5 Bayes' rule
- 2.6.6 Causal networks
- 2.6.7 Evidence propagation via serial connection
- 2.6.8 Evidence propagation via divergent connection
- 2.6.9 Evidence propagation via convergent connection
- 2.6.10 D-separation
- 2.6.11 Relevance Reasoning
- 2.6.12 Object-Oriented Bayesian Networks (OOBNs)
- 2.6.13 Decision Networks

## 2.7 Game Theory

- 2.7.1 Terminology
- 2.7.2 Nash equilibrium
- 2.7.3 Bayesian equilibrium

## 2.8 Multi-Agent Influence Diagram

## 2.9 Dynamic Plot Generating Engine

- 2.9.1 The plot
- 2.9.2 The structure
- 2.9.3 Dynamically generated plots
- 2.9.4 Tests
- 2.9.5 Summary

## 2.10 Rational Dialogue Engine

- 2.10.1 Character's knowledge base
- 2.10.2 Generating sentences and replies
- 2.10.3 Sentences and replies
- 2.10.4 RDE
- 2.10.5 Finding equilibrium
- 2.10.6 Output of the RDE

# 3

## Related work

### 3.1 Introduction

First, we establish drama metrics for empirical evaluation of related systems; to effectively compare them to the DED, see Section 3.2.

As we discussed in chapter 2, then narrative and story are restrictive and essentially an account of previous events and are therefore not interactive. Drama, on the other hand, is a play enacted in the here and now and can be highly participatory.

Similarly, games are highly participatory, and the player plays a character that is acting in the here and now. is, therefore, more readily compatible with games than narrative is. An interactive narrative can be useful to convey a specific story or experience but will never merge with games completely since it is entirely of an opposite form.

There are many existing systemsthat have been developed to provide some form of either interactive narrative or . These systems are frequently focusing on a specific element or problem of the field and none of them has been shown to be intergratable with modern fast paced computer games. There is a divide between the two opposing positions, in 2002, Mateas explained this divide in his doctoral thesis: [Mat02, p.41]One can imagine a spectrum of character autonomy, ranging from an extreme at which the characters maintain strong autonomy (call this the *strong autonomy* position), with only occasional guidance from the manager, to an extreme at which the manager continuously intervenes in every character decision. Mateas further discusses the constraints of a position that quickly becomes intractable for the author and the dangers of too strong autonomy where we lose the sense of a coherent story int the autonomous agents' emphasis on being believable.

Many others have agreed with this division of the field including Aylett in 2012, (co-authored with Weallans and Louchart): There are, broadly speaking, two approaches to Interactive Digital Storytelling. One approach is the plot-centric (also called top-down, plot-centric, or author-centric) approach, while the other is the emergent (also called bottom-up, or character-centric) approach.

There R. Aylett agrees with Mateas regarding this primary division of the existing systems. Some of the systems are near the extreme ends of these designs. While other systems are near the middle and contain elements from both sides, it is, therefore, difficult to firmly define every system as either a or an emergent system. Still, this division is essential to provide the field with clear distinctions to work by and to form an academic discourse. In Section 3.3 we review related systems and measure them against the drama metrics.

We have chosen to call the former faction systems, in line with Mateas, and the latter "emergent" systems, in line with Aylett.

systems are discussed in Section 3.2, and emergent systems are discussed in Section 3.3. Both of these factions have similar goals but view those goals through a different perspective, as discussed in Section 3.4. Where we also build up the motivation for our approach. Finally, we present and discuss the result of our measurements, see Section 3.4.

## 3.2 Strong story Drama metrics

We build our Definition 1.1.1 of emergent drama on:

1. Our published *Critical Review of Interactive Drama Systems* [ABK09]
2. H. Barber's Compellingness criteria is defined to include all required features of an interactive narrative. [Bar08]
3. Our requirements for believable NPCs

Compellingness, H. Barber says:

*is defined to include all required features of an interactive narrative. The compellingness criteria must be satisfied by an interactive narrative system. ... interestingness, immersion, scalability, domain independence, agency and replayability. ... An interactive narrative is a game world in which the user-controlled character(s) can physically and mentally interact with ideally perceived total freedom while experiencing a dramatically interesting story which is fundamentally different on nearly every play - dependent on the user's actions.*

- [Bar08, p. 19]

Our review's related systems have their definitions of interactive drama, agency, believability, ideal narrative structure; their goals often differ from our goals and require different emphasise.

From H. Barber's definition, we can define metrics to quantify how well a system supports interactive drama. We assign an inverse numerical value to a subjective categorisation of how well the system supports a feature to avoid inflating the values, see Definition 3.2.1. A 3D game environment or VR accommodates the highest degree of freedom versus simple or text-based environments. We measure separately whether the systems offer means of interacting with objects and NPCs.

### Definition 3.2.1 (Drama systems' metrics)

<i>level</i>	<i>(GT) Graphics' Type</i>	<i>(OI) Objects' interaction</i>	<i>(SI) Social interaction</i>
<i>1</i>	<i>3D game environment or VR</i>	<i>Yes</i>	<i>Yes</i>
<i>2</i>	<i>Simple graphics</i>	<i>Some</i>	<i>Some</i>
<i>3</i>	<i>Text-based</i>	<i>No</i>	<i>No</i>
<i>4</i>	<i>None</i>	<i>N/A</i>	<i>N/A</i>

In Definition 3.2.2 we define a measure for how many fundamentally different narrative variations the system generates from a single setup. This doubles as a measurement of how interesting and replayable a system is since players will generally not replay a game that they find uninteresting or that does not offer any variation on subsequent plays.

### Definition 3.2.2 ((FD) Fundamental difference levels by order of magnitude)

<i>level</i>	<i>O()</i>	<i>Descript.</i>	<i>Explanation</i>
<i>1</i>	<i>O(<math>\infty</math>)</i>	<i>Infinite</i>	<i>Intractable; theoretically impossible to author all variations</i>
<i>2</i>	<i>O(10)</i>	$\geq 10$	<i>Challenging; theoretically possible to author all variation</i>
<i>3</i>	<i>O(1)</i>	$\leq 10$	<i>Feasible</i>

Our narrative metrics, see Definition 3.2.3, measure:

- The use of Narratology to structure the interactive drama.
- Agency of the players and their influence on the plot.
- Autonomy, drama awareness and influence of the NPCs on the narrative.

### Definition 3.2.3 (Narrative metrics )

	<i>Category</i>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
<u>(PS)</u>	<u>Plot structure</u>	<u>Abstract</u>	<u>Stochastic</u>	<u>Discrete</u>	<u>linear or None</u>
<u>(ST)</u>	<u>Structuralism</u>	<u>Yes</u>	<u>Some</u>	<u>Minimal</u>	<u>None</u>
<u>(DT)</u>	<u>Drama theory</u>	<u>Yes</u>	<u>Some</u>	<u>Minimal</u>	<u>None</u>
<u>(PR)</u>	<u>Player role</u>	<u>Protagonist</u>	<u>Secondary</u>	<u>Minimal</u>	<u>None</u>
<u>(PI)</u>	<u>Player influence</u>	<u>Significant</u>	<u>Some</u>	<u>Minimal</u>	<u>None</u>
<u>(AN)</u>	<u>Autonomous NPCs</u>	<u>Yes</u>	<u>Some</u>	<u>Minimal</u>	<u>None</u>
<u>(NI)</u>	<u>NPCs influence</u>	<u>Yes</u>	<u>Some</u>	<u>Minimal</u>	<u>None</u>

In Definition 3.2.4 we define metrics that measure the believability of NPCs.

### Definition 3.2.4 (Agent metrics )

---

	<i>Category</i>	<i>1</i>	<i>2</i>
<i>(LR)</i>	<i>Logical reasoning</i>	<i>Yes</i>	<i>No</i>
<i>(SI)</i>	<i>Stochastic inference</i>	<i>Yes</i>	<i>No</i>
<i>(Ra)</i>	<i>Rational, GT</i>	<i>Yes</i>	<i>No</i>
<i>(TM)</i>	<i>Theory of Mind</i>	<i>Yes</i>	<i>No</i>
<i>(Em)</i>	<i>Emotions</i>	<i>Yes</i>	<i>No</i>
<i>(CT)</i>	<i>Character traits</i>	<i>Yes</i>	<i>No</i>
<i>(DA)</i>	<i>Drama awareness</i>	<i>Yes</i>	<i>No</i>
<i>(Du)</i>	<i>Duality</i>	<i>Yes</i>	<i>No</i>
<i>(KB)</i>	<i>Knowledge base</i>	<i>Yes</i>	<i>No</i>
<i>(TE)</i>	<i>Truth evaluation</i>	<i>Yes</i>	<i>No</i>
<i>(Le)</i>	<i>Learn</i>	<i>Yes</i>	<i>No</i>

In Section 3.3 we add a table by each system with its values across all the metrics. These figures are overestimates of the potential, as exact numbers are not known.

### 3.3 EmergentRelated system

systems have a pre-authored story. They frequently use planners and divide the story into more manageable sections. Most of them have a central manager that commands agents either directly or through structures and this manager can take complete control over the agents. The agents are sometimes equipped with shallow AI to be able to walk around and occupy themselves when the manager is not giving them orders. The systems covered in this Section are in alphabetical order: BARDS, Façade, IDA, IDtension Mimesis, and U-Director.

#### **BARDs** 3.3.1 BARDS [PCLC07, PC07]

Has a Heuristic Search Planner (HSP) with RTA\* as its underlying search algorithm to plan emotional development in the characters rather than actions [PCLC07, PC07]. A user can interact with the story by natural language ~~in such a way so~~ that user comments can cause an emotional reaction with the characters. For example, to remind an adulterous woman of her children to induce guilt.

The emotional plan, actions and feelings are developed according to what the character is feeling and alters the storyline.

The interaction has the feel of movie theatre audience shouting at their hero: "beware behind you" when the hero is in danger. ~~The player is not playing~~ ~~They emphasise believability through emotions displayed by their characters depending on the backstory of the characters. However, their player does not play~~ a character in the story.

**Table 3.3.1** BARDS metrics

Drama	GT	QI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	1	3	2	2	3	1	1	3	3	3	3
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	1	1	2	2	2	2	2

~~The Mimesis system~~ [YR03, RSY03, YRB<sup>+04</sup>]

#### 3.3.2 The Mimesis system [YR03, RSY03, YRB<sup>+04</sup>]

~~The Mimesis system~~ uses planning to reconstruct a pre-authored narrative where the player plays the protagonist. ~~The system is designed~~ ~~They designed the system~~ to allow the player to choose from a wide range of actions, but at the same time, the system goes to great lengths to hinder the player ~~in actually from~~ affecting the intended narration. ~~In order to ensure~~

~~that the player plays the protagonist as the author intended, the~~ The system can use the following story mediations:

1. Accommodation, the system re-plans to allow for this action.
2. Intervention, an action by the player is unsuccessful, such as shooting a character misses or ~~the gun is jammed~~ jamming the gun.

The system first tries to accommodate the action by re-planning based on changes resulting from the action. When the system receives a plan request, it draws a DAG of the ~~actions needed for the intended narrative~~ intended narrative's actions to play out correctly. Generating a DAG in this way is feasible for short stories or a limited range of actions. It is though infeasible for larger stories due to the state explosion of planning in general. For this solution to work, it is imperative to keep the action plans small. It can help to divide the plans into smaller problems or hierarchical structure.

An unforeseen action that would disrupt the ~~pre-authored story~~ intended narrative is intervened by, for example, the player missing or the gun jamming when trying to shoot the main character. The system does not allow any fundamentally different stories to emerge; ~~these mediations are specifically designed~~ they design the mediations to block any diversion.

**Table 3.3.2** Mimesis metrics

Drama	GT	QI	SI	FD	PS	ST	DT	PR	PI	AN	NI
<u>≡</u>	<u>2</u>	<u>1</u>	<u>3</u>	<u>3</u>	<u>3</u>	<u>1</u>	<u>3</u>	<u>1</u>	<u>4</u>	<u>4</u>	<u>4</u>
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
<u>≡</u>	<u>2</u>										

### ~~IN-TALE~~ [RS06a, RS06b, RS06c]

IN-TALE is the same viewpoint ~~to mimesis~~. ~~There is a pre-authored story that the player is expected to follow and the use of planning with plot points as mimesis. They use plot points and planning, and their aim is for the user to fallow a specific narrative path.~~

The player finds himself in a marketplace where a merchant called Mohammed plants a bomb in a stall owned by merchant Saleh. ~~This is a training scenario for soldiers in leadership.~~ When the bomb goes off the player needs to apply their leadership skills ~~in getting to get~~ the marketplace back in order and hopefully ~~charging charge~~ the correct merchant.

The main emphasis of IN-TALE is around the planting of the bomb. ~~It is possible for the player to~~ The player can stop the bomb from going off in the first instance. If the player is successful in stopping the bomb, the

chaos does not ensue. The leadership training is the purpose of the game and, therefore, the bomb must go off.

For this purpose, they developed Narrative Directive Behaviours (NDB). The director can send the actors NDBs which make the actors drop their current goal gently and believably and start to follow the NDB goal, which alters the drama so that the bomb goes off. For example, the merchant may rearm a disarmed bomb.

**Table 3.3.3 IN-TALE metrics**

Drama	GT	QI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	1	1	2	2	3	1	1	1	3	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

### Interactive Drama Architecture (IDA)    3.3.4 Interactive Drama Architecture (IDA) [MLA<sup>+</sup>04, ML04, Mag05, Mag06]

The IDA system has an author, director agent, synthetic characters and a player [Mag06, MLA<sup>+</sup>04, ML04, Mag05]. They built their testbed, Haunt 2, in Unreal Tournament where the player as a ghost needs to find his murderer and manipulate other characters to find the body and the murderer. Having the player be a ghost explains the players' lack of freedom and significantly reducing the complexity of the system and significantly reduces the system's complexity. IDA is in collaboration with the Soar Games Group and draws strongly on lessons from Mimesis.

An author or a group of authors are required to author the story. The authoring includes any domain-dependent functions of the director, the environment and art content, as well as all characters and all characters' behaviours. The characters are semi-autonomous in that they can occupy themselves when they have no instructions from the director. They, for example, light a fire and eat, drink and chat. The agents mainly take commands from the director. The director commands take priority over all other goals. The commands can be high level such as "explore" and also precise: "perform dialogue #131 with John in the library and then run away to another room." [Mag06]

The story itself is drawn up as plot points in a partially ordered graph using STRIPS with pre and postconditions. It faces the same difficulty with intractability as the story grows and has more characters and actions.

IDA also uses story modifiers as Mimesis to correct the plot if the player does not play as intended maintain the narrative. IDA philosophy is slightly different as they recognise that too much direct interaction compromises

believability; for this reason, they introduce director actions that shift or modify the plot to accommodate player actions.

- Deniers, permanently or temporarily make certain plot points inaccessible.
- Causers, the system initiates a plot point.
- Creations, new things appear in-game to replace destroyed items.
- Shifters, plot points are moved around to aid the player.
- Hints, some noise from a room or an NPC says something.

**Table 3.3.4** IDA metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	3	2	3	3	2	1	1	4	3	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

~~Thespian [?, SMP05b, SMP06b, SMP06a, SMP, SMP08c, SMP08a, SMP08b, SMP09a, SMP09b, SMP09c, SMP09d, SMP09e, SMP09f, SMP09g, SMP09h, SMP09i, SMP09j, SMP09k, SMP09l, SMP09m, SMP09n, SMP09o, SMP09p, SMP09q, SMP09r, SMP09s, SMP09t, SMP09u, SMP09v, SMP09w, SMP09x, SMP09y, SMP09z, SMP10, SM10]~~

### 3.3.5 Thespian [SMP05a, SMP05b, SMP06b, SMP06a, SMP07, SMP08c, SMP08a, SMP08b, SMP09a, SMP09b, SMP10, SM10]

The Thespian system aims to create Interactive Pedagogical Dramas (IPD) based on authored scripts. The aim is for the agents to play out the script when they have the opportunity to do so. The agents are given the key points of the script as character goals. ~~The agents in Thespian~~ Thespian agents try to satisfy their goals, and if the player plays it right ~~then~~ the player can experience the complete intended drama. Thespian is by this realising Pedagogical goals by forcing the player by trial and error to learn the correct way through the drama.

~~Thespians~~ Thespian's example domain is to teach users a foreign language and cultural awareness. The user takes on the role of a male army sergeant ~~who is~~ assigned to conduct a civil affairs mission in a foreign (e.g., Lebanese, Iraqi) town. The user navigates in a virtual world and interacts with virtual characters using spoken Arabic and gestures. Thespian agents have a look-ahead search in a decision-theoretic framework to determine how best to achieve their goals. The look-ahead search is when the agents speculate based on their belief of ~~the world~~ how other agents and the player ~~reacts~~ react to their actions. Their goals become a critical determinant of their behaviour, and the agents try to respond to unexpected user interaction in ways consistent with their motivations.

While Thespian has goal-oriented agents and these agents are autonomous to some degree; it is essentially following a script, and the aim is to get the player to learn the correct behaviour to realise the scripted drama. The purpose is to have the player go through the ~~educational lessons in the game~~<sup>game's educational lessons</sup>, i.e. Arabic manners. ~~Thespian is, therefore, essentially not an emergent system but is instead in line with IDA and Mimesis, and is a system.~~

**Table 3.3.5** Thespian metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	1	3	1	3	2	1	3	1	4	2	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	1	2	1	1	1	2	2	1	2	2

~~IDtension [Szi01, Szi02, SMR03, Szi03, Szi04, SR04, SM05, Szi05, Szi07a, Szi07b, Szi08, Szi10, SRP12, SAR12]~~  
~~it's~~

**3.3.6 IDtension** [Szi01, Szi02, SMR03, Szi03, Szi04, SR04, SM05, Szi05, Szi07a, Szi07b, Szi08, Szi10, SRP12, SAR12]

~~IDtension bases its~~ approach on Narratology such as Propp's functions, Bremond's process, Greimas actant's model and Todorov's transformations on which they design their ~~own~~-theory: "we explicitly design our own theory of narrative and drama, both influenced by existing theories and the specific needs of a computer simulation." [Szi03, p. 2].

They divide their interactive narrative into three layers:

1. The discourse, layer which carries the message or theme of the story.
2. The story, layer which is a succession of events and character actions, based on several structuralistic rules and narrative sequences.
3. ~~pereception~~<sup>Perception</sup>, a discourse on how to perceive the narrative during reading/viewing/listening.

The IDtension system is authored by defining and scripting a set of causally ordered tasks to complete a specific goal. There are several such causal pathways to complete each goal. ~~Similar to event-based books that ask the reader a question. Depending on how the reader responds, they are directed to other pages to follow a specific storyline. For example, there is a question to the reader whether they want to open a door, if yes, go to page 10, if no, go to page 35.~~

~~Similarly, as an author envisions a certain type of reader when writing a novel, then~~ IDtension models the narrative by a user model that uses the following criteria as seen in [Szi03, p. 6]:

- Ethical consistency: The action is consistent with ~~previous actions of~~ the same character, ~~'s previous actions~~ concerning the system of values.
- Motivational consistency: The action is consistent with the goals of the character.
- Relevance: The action is relevant to player actions.
- Cognitive load: The action opens or closes a narrative process, depending on the current number of opened processes and the desired number of opened processes (high at the beginning, null at the end).
- Characterization: The action helps the user to understand the characters' features.
- Conflict: The action either exhibits some conflict directly. For example, an incentive that conflicts with the inciting character's values, or the action pushes the user towards a conflicting task. For example, ~~by blocking block~~ a non-conflicting task, if a conflicting task exists.

The idea has an absolute novelty in CS, ~~in~~ offering a range of actions that lead rather than block. It has though a considerable authoring ~~bottleneck~~ ~~bottle-neck~~ as the author needs to design all the possible tasks, and the author is unlikely to anticipate all the ~~expectations of the player~~ ~~player's expectations~~. The author cannot possibly fathom which tasks to include. An author ~~that who~~ attempted to author a story for IDtension experienced ~~problems in authoring~~ ~~authoring problems~~ due to a high degree of abstraction used ~~which alienates~~, ~~alienating~~ the author from ~~being able to author the characters~~ ~~properly authoring the character's personality~~. This method also poses the same intractable planning problems as in Mimesis and IDA if the intention is to have predefined goals reached with each story.

**Table 3.3.6** IDtension metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
<del>≡</del>	<u>3</u>	<u>3</u>	<u>3</u>	<u>2</u>	<u>2</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>4</u>	<u>4</u>
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
<del>≡</del>	<u>2</u>										

### Façade 3.3.7 Façade [Mat02, MS05a]

The player finds herself in a dreadful situation where her old friends Trip and Grace ~~who have~~, ~~who has~~ just invited her over, are clearly on the brink of a marital breakdown [Mat02, MS05a].

The player can move around the scene and point to things, and the characters react. If a player points at an object, the engine instructs the

characters how to react. In the words of M. Mateas, the instructions are beats, which are:

*In the Façade architecture, the unit of plot/character integration is the dramatic beat. In the theory of dramatic writing, beats are the smallest unit of dramatic action, consisting of a short dialogue exchange or small amount of physical action.*

– [Mat02, p. ii]

The player can also talk to Trip and Grace via natural language processing. Trip and Grace do not understand what the player says, according to M. Mateas & A. Stern:

*Grace and Trip interpret all of the player's discourse acts in terms of a zero-sum affinity game that determines whose side Trip and Grace currently believe the player to be on.*

– [MS05a, p. 4]

Trip and Grace are shallow agents that are incapable of any awareness of the unfolding drama. If the player does nothing, ~~then~~–Trip and Grace talk to each other, going through one beat after another.

As the drama progresses, Trip and Grace start to argue and eventually split up if the player does not talk them out of it. There is a lack of an inciting event in the drama. Nothing happens at the start of the drama to get the player interested in the ~~outcome of the marital dispute~~ marital dispute ~~outcome~~. The player is left guessing what their role is.

They say that Façade is the first wholly implemented interactive drama, which is valid for the academic field of interactive drama. Many commercial RPGs, where the player can bargain, attack, kill, steal, flirt, manipulate, form friendships, accept/reject quests offer a more significant amount of interactivity than Façade. For example, Deus Ex [Inc00] (released in June 2000) and RPG Morrowind, (released ~~on~~ in May 2002) and ~~they also~~ have multiple possible endings. These games are certainly dramas and are considerably longer and more intensive than Façade. ~~It does, therefore~~ Therefore, ~~it does~~ not hold in a commercial sense that Façade is the first wholly implemented interactive drama.

Façade has a Drama Manager, beats, characters, story values, actions and natural language processing.

The beats are pre-authored with explicit actions for all roles that are strictly coordinated to allow for multi-agent coordination, in M. Mateas words.

*Roughly, a beat consists of an action/reaction pair between characters. For example, in the case where action is being carried by*

*dialog, a beat could simply consist of one character speaking a line of dialog, and another character reacting. Generally speaking, in the interest of maintaining economy and intensity, a beat should not last longer than a few actions or lines of dialog.*

– [Mat02, p.45]

Additionally, all higher-level goals and behaviours that drive a character are in the beats rather than the character. The character retains some autonomy when it comes to base level goals and actions such as facial expressions or personality moves, as M. Mateas says:

*As architectural entities, beats organize both the procedural knowledge to accomplish the beat's dramatic action, and the declarative knowledge to sequence the beat in an evolving plot. Instead of conceiving of the characters as strongly autonomous entities that coordinate to accomplish dramatic action through purely local decision-making, characters are instead weakly autonomous.*

– [Mat02, p. ii]

~~The approach required significant authoring, in the words of According to~~ M. Mateas & A. Stern:

*Façade required 3 person years of just authoring ... only 27 beats were created in the end.*

– [MS05a, p. 6]

The result is a 20-25 minute long interactive drama that you can play through 3-4 times and get some novelty.

~~Façade is one of the last projects from the OZ group, and interestingly does not build on earlier OZ group findings, in fact, it goes to the other side. M. Mateas, in his thesis on Façade, ranks the earlier OZ project work around 30, on a scale of 0 to 100 where 0 is emergent, and 100 is a and Façade around 70, in his words:~~

~~Comparing this approach with earlier Oz Project work, if the strong autonomy end of the spectrum is labeled 0, and the end of the spectrum is labeled 100, then the Façade architecture falls around 70, while earlier Oz project work falls around 30.~~

~~Façade~~ has an algorithm constantly selecting which beat to perform next based on the level of tension and affinity as M. Mateas says:

*Move Wedding Picture (artist/ advertising). Tension 2, Trip Affinity. At this point, two tension 1 story topic beats have completed, so tension 2 beats become sequenceable (except for Decorating and Ask About Drinks, which have already been performed*

at tension 1). At eight beats into tension 1, the desired tension, as specified by the tension arc, is 2. Tension 2 beats get a higher score against the story arc, and thus have a higher probability of being selected. (though the probability of selecting a tension 1 beat is not zero). Additionally, because the player has maintained affinity with Trip for three beats in a row, the singlet Move Wedding Picture becomes sequenceable, and is in a higher-priority tier (equivalent to a discourse act reference to the beat topic) because of its static priority. Since this is the only beat in the higher-priority tier, the beat manager sequences it. The player takes Grace's side, causing the affinity to switch to Grace. This beat also causes the tension to move to 2.

– [Mat02, p.171]

**Table 3.3.7** Façade metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	2	2	2	3	1	4	3	1	3	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

### U-Director 3.3.8 U-Director [ML06]

U-Director uses HTN planning and dynamic decision networks to implement a medical mystery story ~~that takes place in on~~ a secluded island [ML06]. The story is pre-authored and follows a strict plot. The idea is very similar to IDA except that they use a Bayesian inference mechanism instead of planning when deciding how to manipulate the player into following the plot.

The director agent is constantly evaluating user actions and comparing them with the plot. The director attempts to engage the player in the plot by giving hints that steer the player in the right direction. If the hints are insufficient, the director uses more force. For example, have a character take the initiative rather than wait for the player to ask. The director uses extended s-BNs to evaluate what directive action to take based on maximising expected narrative utility. The director primarily progresses the narrative and tries to involve the player.

### 3.3.9 FAtiMA [PDS<sup>+04</sup>, PDS<sup>+05</sup>, AFL<sup>+06b</sup>, AFL<sup>+06a</sup>, LADP05, FDA<sup>+07</sup>, VSPA07, LAD<sup>+07b</sup>, LAD07a, FPA07, ALT<sup>+08</sup>, FBAP08, LDAP08, LDAP09]

**Table 3.3.8** U-Director metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	2	2	3	3	1	4	1	4	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

Emergent systems do not have a pre-authored story or scripts. Instead, they emerge by the actions of the characters and players in the drama, in the words of R. Aylett & Co: “Emergent narrative requires that a story be dynamically generated by the interactions between different characters and the causal relationships between its different elements” [AFL<sup>+</sup>06a, p. 3].

According to U. Spierling: in emergence there is “implicit creation” where “actions, events and states result from automatic generation during narration” [Spi07, p.11].

These systems frequently have goal-driven agents that use either planning or belief systems to determine how to interact with the environment. Some of these systems have some central manager, that typically does not give direct orders, instead, it manages the environment or initiates scenes or plot points that then are developed by autonomous characters and the player.

The main danger in an emergent is that it does not emerge as intended. The benefits of emergent drama are increased responsivity to player interactions as is clearly shown in Gadin by creating dilemmas for the player in response to the player’s actions and choices [BK07], as measured with the compellingness criteria [Bar08, p. 18–23]. Additionally having dramas emerge, rather than authored can reduce the authoring bottleneck if all character actions do not need authoring to the same detail as in the methodology.

We can remove planning algorithms and decentralise drama management by making the actors be aware that they are actors in a drama and be responsible for the emergence of a [AK08] [ALW11, p.5]. We need to develop deep artificial intelligence agents that act rationally and can understand the actions of the user and respond in context, specifically in dialogues, because dialogues have the highest complexity of human interaction, in the words of R. Aylett & Co:

The bottom-up approach starts with autonomous character action selection with an emphasis on acting believably according to their beliefs, desires and intentions, their emotional state, and their situational context. However in a pure in-role simulation approach, characters will favour the most realistic actions, and these may not be dramatically interesting [?, SKT08]. Even if a character does perform one dramatically interesting action, it is less likely that it will perform a sequence of dramatically interesting actions constituting a dramatically recognisable story, and less likely still that all characters will do so.

This is because characters have no dramatic intelligence: they do not "know" they are trying to tell a story; all they "know" is that they are trying to simulate a human role. In essence, such an agent's action-selection mechanism works entirely on the in-character (IC) level, while the notion of drama is an out-of-character (OOC) concern: the characters themselves are not concerned about the drama and do not take on dramatic responsibilities. They participate in the cycle of Figure 1 but do not model it.

One can contrast here the role of actors in improvisational drama, where the concept of an "offer"—actions giving scope for mutual dramatic development—is a basic one [Rie10]. Current approaches to incorporating dramatic intelligence into characters' action selection are based on generating a range of possible actions rather than just one at each time step and using a metric for selecting between them that involves dramatic responsibility.... However this neglects the requirement for pacing in the dramatic trajectory of an and more recent work seeks to distribute dramatic responsibility into a multi-agent architecture.

The systems covered in this Section are: FearNot!, Gadin, Nolist, OPIATE, PPA, Seenejo, TEATRIX, The virtual storyteller, and The virtual theatre project.

**FearNot!**, [PDS<sup>+04</sup>, PDS<sup>+05</sup>, AFL<sup>+06b</sup>, AFL<sup>+06a</sup>, LADP05, FDA<sup>+07</sup>, VSPA07, LAD<sup>+07b</sup>, LAD0

An anti-bullying interactive drama where the player, plays a~~the~~ same age confidant for a child experiencing bullying. The drama starts by introducing introduces the school, the children in the school and any other characters to provide a starting context. There are four roles in bullying situations the bully, the victim, the bully-victim, a child that is sometimes the victim and sometimes the bully, and the bystander. [PDS<sup>+05</sup>, p. 241] The player witnesses a bullying incident after ~~which they meet~~ meeting the victim in the library. The victim seeks advice from the player in how to deal with the bullying. The player is asked a few questions in dialogue form, as R. Aylett & Co says: "John can you think of a solution for Luke to stop bullying me?"[AFL<sup>+06a</sup>, p. 3]. They have a free-form text interface where the player can type what she wants. Behind the scenes is a drop-down dialogue template based map, in R. Aylett & Co words:

*the agent receives the utterance and converts it to a language action - one of the coping responses using a template-based language system*

– [LADP05, p. 48]

When the player has chosen a coping choice, the victim decides whether to go through with it. The victim does this according to its characteristics and emotions. For example, a timid victim will perhaps not choose to go through with an aggressive recommendation. The victim chooses an action

based on the recommendation ~~, and another possible bullying scene is played out and faces another bullying scene.~~ If the recommendation was excellent, and the victim ~~was successful in carrying it out~~<sup>successfully carried it out</sup>, then the bullying is resolved, if not then ~~victim and player find themselves again in the library where the player is asked to give another advice, the above sequence repeats~~ until the bullying is resolved [PDS<sup>+</sup>05, LADP05, p. 242, p. 44]. In the end, there is some educational message and in some cases, a questioner.

When the characters react, they use a set of emotional reaction rules based on appraisal values ~~such as~~, including desirability and ~~desirability for other~~<sup>desirability for others</sup>, praiseworthiness. Preconditions match the rules with the current situation. The characters are also deliberate or goal-driven for which they use STRIPS-based partial-order, continuous planner. They evaluate the probability of success and the importance of the actions ~~, whether the actions are expected to and whether they~~ generate hope or fear. The action likely to generate the most potent emotion is chosen [AFL<sup>+</sup>06a, p. 4-5]. This architecture is called FearNot! Affective Mind Architecture (FAtiMA).

FAtiMA also applies ~~a theory of mind [LA07, AL08], first it does a double appraisal in that when~~.

1. ~~Double appraisal: When~~ the agent has chosen the action that would cause the strongest emotion, ~~she-it~~ feeds all the actions generated back into ~~her-its~~ appraisal system to determine which ~~of the actions evokes actions evoke~~ the most vigorous emotional response ~~from her~~. ~~Additionally, the agent does a re-appraisal by feeding the actions into the emotional systems of all other characters in the scenario~~.
2. ~~Re-appraisal: feeds the actions into all the scenario characters' emotional systems~~ to determine which action causes ~~the-others'~~ strongest emotional reaction ~~in others~~.

A Story Facilitator(SF) sequences the episodes of the drama. The SF's episode plan is like a state machine, as R. Aylett & Co says:

*For an episode to be selected by the SF, it must have at least one of its preconditions satisfied. A precondition represents a set of tests on events, that when true indicate that this episode fits into the developing story.*

– [AFL<sup>+</sup>06a, p. 8]

The episodes are structured as follows [FDA<sup>+</sup>07, p. 5] and [ALT<sup>+</sup>08, p. 5]:

- Name~~;~~: a unique name for the episode.

- Set, the set is the location in the virtual environment where the events of this episode will take place.
- Characters, the characters of the story, defined through a set of properties like their name, position on the set.
- Preconditions, a set of conditions that specify when is the episode eligible for selection.
- Goals, character goals for the agents.
- Triggers, a condition that executes a set of narrative actions.
- Finish Conditions, conditions: a set of conditions similar to the pre-conditions to complete the game.
- Introduction, a set of narrative actions introducing the episode and characters, some introductory text.

Finally, **FAtiMA** is the only [interactive drama](#) system that we know of, which has gone through proper evaluation ~~on whether it is affective in reducing of whether it effectively reduces~~ bullying. The results ~~where promising were promising~~, although more trials and development would be needed to evaluate long term affects and overall prevalence, in the words of M. Sapouna & Co:

*The close-response relationship within the intervention group indicates that those more actively engaged with the characters, rather than those who passively watched a greater number of episodes, were more likely to escape victimization, supporting our interpretation. We speculate that the interaction with FearNot!, at least temporarily, boosted victimized children's self-confidence in their ability to deal with bullying as they vicariously experienced successfully responding to bullying in the virtual world.*

– [SWV<sup>+</sup>09, p. 7]

**Table 3.3.9** FAtiMA metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	3	1	2	2	1	1	1	1	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	1	1	1	2	2	2	2	2

### Gadin 3.3.10 Gadin [BK07, Bar08]

Gadin is an emergent system for creating clichéd dramas as are commonly found in soaps [BK07]. The system ~~uses STRIPS planning to generate~~

~~actions for characters in the game world for the initially used STRIPS action planning for characters to generate dilemmas according to the characters personality and current interests.~~ A drug addict will want to drug and may find ~~herself itself~~ in prison while a non-drug addict is far less likely to have such bleak prospects.

~~The system~~ However, they found that the additional complexity of planning the dilemmas was an unnecessary overhead. Instead Gadin will periodically generate dilemmas to create conflicts in the unfolding drama. The possible types of dilemmas are:

- Betrayal, ~~to~~: To betray their partner or close friend.
- Sacrifice, ~~to~~: take damage for the good of a friend or partner.
- Greater Good, ~~to~~: Do something good for many, including the players enemy.
- Take Down, ~~Damage your self~~: ~~Damage itself~~, but also damage ~~your its~~ enemy even more.
- Favour, ~~to~~: choose which friend or close partner is favoured.

The engine matches dilemmas to player actions and the current ~~storyline story-line~~ in order to maintain a coherent story. It presents the characters with dilemmas according to their actions and place in the current drama for a realistic character-based decision. Gadin is an ingenious and genuinely novel approach to interactive drama. It has no pre-written script and creates near-endless soaps. ~~Still, it is a generative system rather than an emergent because it uses planning to match dilemmas.~~

#### NOLIST [BJJ<sup>+</sup>04]

**Table 3.3.10** GADIN metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
<del>≡</del>	<del>3</del>	<del>2</del>	<del>1</del>								
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
<del>≡</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>1</del>	<del>1</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>2</del>	<del>2</del>

#### 3.3.11 NOLIST [BJJ<sup>+</sup>04]

In the non-linear interactive storytelling game engine (NOLIST) they utilise a BN to determine the culprit of a murder mystery; the BN is dynamically changing in response to ~~the player's~~ actions and observations ~~made by the player~~. It is not preset but instead ~~it~~ uses the player's moves and the logical inference of the net to determine the culprit. For example, finding a gun beside a body increases the probability that a gun is the murder weapon. The aim is to create a dynamic emergent storyline from player

actions and choices. The engine creates the plot in the course of the game. Thus NOLIST creates the past in reaction to player interaction.

Their engine plots the progression of a player through a murder mystery. The game engine was not ready when the article was published, and there were no follow up publications.

*... we envision a game engine that, whenever it has to choose an action, ensures that the game generated will have an ending, regardless of the players actions. It furthermore has to ensure that the possible continuations of the game will be interesting, and that two games will not be identical even if the player always performs the same actions.*

– [BJJ<sup>+</sup>04, p. 7]

**Table 3.3.11** NOLIST metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	1	2	1	1	3	2	1	1	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

**Open-Ended Proppian Interactive Adaptive Tale Engine (OPIATE)**, [FC03, FC04, Fai04]

### 3.3.12 Open Ended Proppian Interactive Adaptive Tale Engine (OPIATE) [FC03, FC04, Fai04]

The engine creates emergent interactive drama and is in large part based on Propp's Morphology [Pro68]. The game engine uses a story director that guides a set of who guides actors by giving them goals relevant to events in the story world's events. The drama emerges both from character interactions and by events initiated by a director. The story director uses Proppian functions to generate an open-ended story world and chooses functions based on ease-based planning that uses the current state of the story world to find the most suitable reasonable goals to advance the story.

- Social simulation - the actors have an impressive gossiping system that indexes gossip by events and persons and ranks the gossip to have a structure-on structure what is select to gossip.
- Idle behaviours - patrolling or following others when they do not have a goal to chase.

- Targeted behaviour - the director ~~assigns the simple~~ assigns actors goals. The actors commit to one goal at a time. Goals are, for example, an object. The object can have a behaviour that the actor then executes, i.e. (goal = sword), the actor finds the sword picks it up and uses it to slash someone if that is the ~~action of the goal~~ goal's action.
- Attitudes - actors develop attitudes about other actors and the player, both through direct contact and via the gossiping system.

The testbed for OPIATE is limited with pre-scripted puzzles; it is thus unknown how it would scale both to the complexity of planning used and whether the characters would ~~be able to~~ keep functioning as expected from the goals that the story director hands them.

**Table 3.3.12** OPIATE metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	1	2	2	1	1	1	1	1	2	3
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	1	2	2	2	1	2	1

### ~~Proactive Persistent Agent Architecture (PPA)~~ [MDC03, MC03, Mac04]

#### **3.3.13 Proactive Persistent Agent Architecture (PPA)** [MDC03, MC03, Mac04]

PPA is an architecture to simulate human-like behaviour for virtual agents. Their aim is that the agents can pursue their goals regardless of the actions of human users. They use architecture to control the agents comprised of three parts; the Schedule Unit, the Role-Passing Unit and the  $\mu$ -SIC System (or Social Unit). Using a shared knowledge base, the agents and the components have an awareness of the immediate surroundings and objects and persons ~~in it~~.

In the words of B. MacNamee, the general idea is that the human user should be able to: “observe a single character as, for example, she begins her day at home, goes to work, visits a bar and, finally, returns home again” [MDC03, p. 2]. ~~In order to To~~ accomplish this, they pass the agents’ roles that inform the agents what they should be doing because expected actions change during the day, according to a scheduled. ~~An~~ According to its schedule, an agent moves from one scene to another ~~according to its schedule~~, e.g. leaves home and goes to work. The agent has an appropriate role, e.g. the “at work role” when ~~according to schedule~~ it is at work according to schedule.

**Scenejo** [SWM06, Spi09]

**Table 3.3.13** PPA metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	1	3	1	3	4	4	3	4	4	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	1	2	2

### 3.3.14 Scenejo [SWM06, Spi07, SS09, SH10, Spi09]

**Scenejo** uses a chatbot technology A.L.I.C.E. [ALI06] to create conversational games.

A Youtube example of an interactive drama, the office brawl, generated by Scenejo can be seen by following this link <http://youtu.be/cIf86hmsz4E>. [Scenejo](http://youtu.be/cIf86hmsz4E) generates the actions and responses of characters that a player can talk to using a free-text interface. The actors also initiate dialogues and events.

In the office brawl, there are all the essential elements that one expects in a drama. There are actors, a spectator; there is enactment, an imitation of human behaviour, mimesis [Ess76]. There is an inciting event, i.e. being told that there is an argument and the player needs to help calm their colleagues down. There is a complication as the argument heats up, and the characters start to be more aggressive. There is some climax when both of them start to recognise that they need to be more civil and listen to each other and then finally a breakdown when Ben gives up and refuses to continue working in the group. This form of drama is called a tragedy. The tension is due to the plot graph that Scenejo has.

The authors can directly author the plotline or leave it to Scenejo to generate it. They can use either AIML: Artificial Intelligence Markup Language [ALI06] as the bots dialogue base or author it themselves. Scenejo uses scenes to structure the drama; the scenes are sequential; they occur one after another. The scenes compete with each other. Sometimes many scenes are applicable, and then one needs to be chosen over the others, producing varied outcomes and increases replayability.

Stimulus-Response Element (SRE) in Scenejo allows the author to plan dialogue lines by an intermediate abstract structure. An editor allows the authors to design the SREs.

Each actor gets their dialogue graphs for each scene and the dialogue in AIML, this combined makes up the knowledge base of the actors.

This architecture requires considerable authoring; authoring every SRE in the SRE editor that is unintuitive for authors. It is also intractable for long dramas and is why the authors aim at making it more abstract and reusable [Spi07, SS09, SH10, Spi09]. [Spi07, SS09, SH10, Spi09].

**Table 3.3.14** Scenejo metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	3	1	2	1	1	3	2	1	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	1	2	2	2	1	2	2

**TEATRIX** **3.3.15 TEATRIX** [MPG00, MPP00, PMP00, PMP01b, MPB01, MPP01, PMP01a, PPMG02, PPM<sup>+04</sup>]

In the words of I. Machado & Co:

*children create the stories using a set of pre-defined scenarios and a set of pre-defined characters. These characters may act on behalf of the children or autonomously.*

– [MPP00, p. 1]

An agent ~~s~~ has five components according to I. Machado & Co [MPP00, p. 5]:

- Perception Filter - determines the relevance of an agents perception and stores relevant information.
- World Model Update - stores any change in the world module.
- Emotional Reaction - to any emotional influencing event.
- Goal Update - events and emotions influence goals.
- Action Planning - plans actions that fulfil current goals taking into account all relevant detail.

When the child controls the agent, then the mind is mostly inactive, although if the child makes the agent do something that goes against the character that the agent is playing, ~~then~~ the character will be upset. When the child is not playing the character, then the agent takes over.

There is a director that directs the agents, ~~he~~ even takes them over and controls them sometimes, although only when a child is not playing the agent.

According to R. Prada: “TEATRIX have six different roles for the characters: villain, hero, helper, magician, beloved one and beloved relatives” [PMP00, p. 3]. Based on roles from Propp’s Morphology of the Russian Folk-Tale [Pro68].

In the words of I. Machado & Co: “Each one of these roles has a set of Propp’s functions associated with it, and those functions create goals, behaviours and actions. For example, a villain must perform villainy.” [MPP01, p. 3].

According to A. Paiva & Co, the details of the roles are [PMP01a, p. 4]:

- **Villain** villainy – to disrupt peace and cause harm, specifically against the hero.
- **Hero/Heroine** seeking ,love, fortune or revenge on the villain.
- **Helper** is there to help the hero.
- **Beloved one and Family** frequently the victim of the villain or someone the hero is trying to please.
- **Donor or the provider** the character that gives the hero the magic sword or secret info – that allows the hero victory over the villain.

TEATRIX became E-TEATRIX [ZPTP03, ZPPZ04], they describe autonomous and goal-driven agents that are perceptive to their perceptive to the environment with scarce technical details. The information that can be gleaned from the publications on TEATRIX, (including, [MPP00, MPG00, PMP00, MPB01, MPP01, indicates that actually the actor agents are not autonomous as such but instead, as quoted above, actor agents apply Propp's functions defined in Propp's Morphology for the Russian folktales [Pro68]. The agents' act in a sequential rather than autonomous manner. They decide their next action based on Propp's scripts. They use a planning algorithm for the scripts, in the words of A. Paiva:

The planner uses a partial order planning algorithm together with a set of pre-defined plans associated with each role and function of the personae.[PMP01b, p. 6]

**Table 3.3.15** TEATRIX metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	1	1	1	3	1	1	1	1	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

The Virtual Storyteller [SV07, SVB07]

### 3.3.16 The Virtual Storyteller [SV07, SVB07]

The Virtual Storyteller creates emergent stories from character interactions with an emphasis on emphasising emergent improvisational theatre that is told by a narrative agent tells.

There is a plot agent to ensure proper plot development. Autonomous character agents that have individual emotions and beliefs inhabit the story world, and by their interactions, a story emerges. The characters use techniques from the improvisational theatre, and a world agent keeps track of the current world state. They use natural language processing of the story

and create a synthesis. ~~Special rules have been developed~~ They developed ~~rules~~ to transform the synthesised speech into storyteller speech, e.g. with the expected emphasis that a storyteller will use to provoke suspense ~~, and~~ excitement.

**Table 3.3.16** The Virtual Storyteller metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	2	3	3	2	1	1	1	4	4	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	1	2	2	2	2	2	2

### ~~The Virtual Theatre Project~~ 3.3.17 The Virtual Theatre Project [HRSB<sup>+94</sup>, RHR96, RHR97, RHR98]

~~The Virtual Theatre Project~~ use what they call directed improvisation, meaning that improvisational actors receive directions or constraints that they use to centre their improvisation on. For example, an actor can be told to walk to a table but not how to do it. The actor can rush to the table when playing an energetic character and shuffle when portraying laziness. They tried it in Computer Animated Improvisational Theatre (CAIT) which aimed at children between 9 - 12 [HRSB<sup>+94</sup>]. In Cybercafé [RHR96, RHR97, RHR98] Which has two or more players as customers in a café interacting with an autonomous waiter. ~~Also in In~~ a Master-Servant scenario ~~where~~ servant Gregor through a series of postures ~~s~~ switches places with his master Otto and becomes master himself [HRvGH97].

**Table 3.3.17** The Virtual Theatre Project metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	2	1	3	1	4	1	1	1	1	1
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

### ~~Ermatron~~, [Cra03, Cra04] Is-

#### 3.3.18 Ermatron [Cra03, Cra04]

~~Ermatron~~ is a story scripting system to script actions as 'verbs' and connect them in a sequence to account for any eventuality. There is an apparent unsolved intractability in scripting for every eventuality, and the work has yet to prove successful — current text-based stories generated last less than a minute.

**Table 3.3.18** Erasmatron metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	3	1	2	4	3	4	1	2	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

### 3.4 Related Technology

MARGIE, [SGRR73, SGIR75, SA77, SLB80, SK87, SBB<sup>+</sup>90, SKe<sup>+</sup>94] the-

#### 3.3.1 MARGIE [SGRR73, SGIR75, SA77, SLB80, SK87, SBB<sup>+</sup>90, SKe<sup>+</sup>94]

The Memory, Analysis, Response Generation, and Inference in English is a set of programmes and algorithms, in the words of R. C. Schank:

*analyse natural language sentences into an underlying language-free conceptual representation; stores this representation in memory, establishes references and makes inferences encodes the conceptual representation into an English syntactic representation; and then encodes the syntactic representation into an English string*

– [SGRR73, p. 255]

Inference means that the program can draw logical inferences from natural language (NL), see Example 3.3.1:

**Example 3.3.1** *Inference mode: [SGRR73, p. 255], [SGIR75, p. 310]*

- INPUT: *John told Mary that Bill wants a book.*
- OUTPUT1: *A book about what?*
- OUTPUT2: *Mary knows that bill wants a book.*
- OUTPUT3: *Bill wants to come to have a book.*
- OUTPUT4: *Bill wants someone to cease to have a book.*
- OUTPUT5: *Bill wants to read a book.*

MARGIE can also paraphrase NL as seen in Example 3.3.2:

**Example 3.3.2** *Paraphrase mode: [SGRR73, p. 255], [SGIR75, p. 311]*

- INPUT: *John killed Mary by choking Mary*
- OUTPUT1: *John Strangled Mary.*

- *OUTPUT2: John Choked Mary and she died because she not could breathe.*
- *OUTPUT3: Mary dies because she was unable to inhale some air and she was unable to inhale some air because John grabbed her neck.*

Schank's programme is a Natural Language processor, ~~for example;~~ for example, the sentence "John told Mary that Bill wants a book" when the programme considers "told" it infers the following:

*TOLD: The analyzer uses verbs to make most of the important predictions upon which analysis proceeds. 'Told' maps into MTRANS conceptually. MTRANS makes conceptual predictions about what kind of objects are likely to follow it. For example, MTRANS predicts that there will be a human actor, some information as object, and a recipient that is a part of the mental apparatus of some other human. The tense of 'told' tells us the MTRANSing took place before the time of speaking. 'Told' also indicates that the subject of the verb is the actor of the action and that the information that was 'told' was originally in the active part of the actor's mind, which we have labelled the Conscious Processor (CP). We know also that if a human follows 'told' then that person's CP is the conceptual recipient of the MTRANS. 'Told' predicts that the information needed as the object of the MTRANS will follow the human who is the syntactic object.*

– [SGIR75, p. 315]

The 'MTRANS' seen in the above quote is one of MARGIE's primitive acts. The MARGIE analyser parses each sentence into a contextual dependency representation rather than a syntactic one. As a result, MARGIE can have a conceptual understanding of NL. The analyser has a knowledge base that is built conceptually from the NL that they receive as input.

The problem with MARGIE and similar systems is that parsing sentences in this manner is time-consuming, even in small systems, and as the input and system grow, it becomes intractable, so Schank introduced scripts.

~~Schank's scripts are means of~~ Schank's scripts are abstracting conceptual information from blocks of text rather than parsing it word for word. For example, the following passage from the New York Times:

*An Arabic speaking gunman shot his way into the Iraqi Embassy here (Paris) yesterday morning, held hostages through most of the day before surrendering to French policemen and then was shot by Iraqi security officials as he was led away by the French officers.*

– [SLB80, p. 80]

In this passage, the word 'gunman' immediately initiates three possible scripts; \$ROBBERY, \$TERRORISM and \$KIDNAP. The program starts to fill in the scripts to see which matches the text, and the word 'hostages' narrows it down to \$TERRORISM. Now the program can match actors, goals and actions from the text to the script. The scripts speed up the natural language process and additionally enables object-oriented mapping of inference rules and predicates in Schank's programs. There is no narrative structure inherent in MARGIE; hence those metrics are all at 4 in Table 3.3.1.

**Table 3.3.1** MARGIE metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	3	2	2	4	4	4	4	4	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

### Tale-Spin [Mee81]

#### 3.3.2 Tale-Spin [Mee81]

Tale-spin applies first-order logic to generate tales. It uses Schank's scripts and primitives to create event plans in the narratives generated. Tale-spin creates stories from what they call rationally behaving characters. The characters are rational in that they follow first-order logic to reach goals. They use a problem solver that creates subgoals from main goals to solve the main goal by first satisfying the subgoals. The problem with this type of methodology is the intractability of creating the vast logical knowledge bases needed to generate sizeable output. They created several small tales, for example "The fox and the crow". The fox, using flattery, tricks a crow into letting go of a cheese it is holding in its beak by getting the crow to sing. Even in such a small tale, they had considerable problems with the errors created if the knowledge base created unwanted knowledge. For example, if the crow ate the cheese before the fox came ~~because it realised that~~, it realised it was holding a cheese in its beak.

**Table 3.3.2** Tale-Spin metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	3	2	2	4	4	4	4	4	1	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	1	2	2	2	2	2	2	2	1	2	2

**SAM** [Cul77b, Cul77a]

### 3.3.3 SAM [Cul77b, Cul77a]

An experiment in using Schank's scripts to reads a newspaper and then be asked about what it said, Example 3.3.3:

**Example 3.3.3 Question-Answering :**

- *Q1 : Who went to China?*
- *Al : NADIA AND ENVER HOXHA WENT TO COMMUNIST CHINA.*
- *Q2: How did Enver Hoxha and Mrs Hoxha get to China ?*
- *A2 : THEY FLEW TO IT .*
- *Q3: Why did they go to China?*
- *A3 : ENVER HOXHA AND HUA KUO-FENG WANTED TO DISCUSS CHINA ALBANIA ECONOMIC AFFAIRS.*

**Table 3.3.3 SAM metrics**

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	3	3	2	3	4	4	4	4	4	4	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	2	2	2	2	2	2	2	2	2	2	2

**Belief-Desire-Intention (BDI)** BDI uses folk-psychological

### 3.3.4 Belief-Desire-Intention (BDI) [Bra87]

BDI uses psychological views on how humans perform practical reasoning[Bra87]. The BDI describes a rational agency [CL90, RG91] ~~were it is assumed~~ [CL90, RG91] which assumes that humans strive to fulfil specific rational desires as long as they are attainable. If the desired element becomes inactive or unattainable, then the agent stops pursuing that goal.

Work on formalising BDI in the '90s has given rise to several BDI-Based programming languages such as 2APL [Das08], Jack, Jadex and Jason [BDDF05]. Examples of implementations in agents include; encoding a goal-risk framework into the Jadex platform so that ~~the deliberation process of an agent takes into account~~ an agent's deliberation process considers risks and associated costs [AGZ07], and BDI based virtual agents with a theory of mind [SDM09].

**Table 3.3.4** BDI metrics

Drama	GT	OI	SI	FD	PS	ST	DT	PR	PI	AN	NI
≡	1	1	1	1	4	4	4	4	4	1	4
Agent	LR	SI	Ra	TM	Em	CT	DA	Du	KB	TE	Le
≡	1	2	1	1	1	1	2	2	1	2	1

### 3.4 Goals Summary

We show the average score for drama and agent metrics in Table 3.4.1.

The goals of related systems are many and diverse; this Section briefly discusses ~~these our~~ goals and to what degree they are ~~relevant to computer games and~~. We start from the perspective and discuss their emphasis on a complete story and artistic control over to the emergent emphasis on distributed intelligent agents working collaboratively to create a drama reflected by other systems in the field.

~~Artistically complete and finished story~~ This is the idea that if there is an artistically complete story initially, then it should be possible to transfer it into an equally artistically complete game. Compellingness; H. Barber says:

*is defined to include all required features of an interactive narrative. The compellingness criteria must be satisfied by an interactive narrative system.*

- [Bar08, p. 19]

~~The game should aim to preserve the aesthetics of the original story. This is what many story-based systems aim to do, for example, BARDs, see Section 3.2. It is also a common theme in adventure games such as Agatha Christie's *And then there were none* [Com05] and *Murder on the Oriental express* [Com06]. Adventure games restrict the players' ability to affect the story and instead offer puzzle-based paths for the player to progress the plot. The interactivity is, therefore, not affecting the narrative and rather in finding the correct path or one of the multiple correct paths.~~

~~Adventure games are often entertaining and can offer a different perspective on stories. They do take longer to make and are usually only played through once rather than multiple times or for an extended time.~~

~~Another similar view is that a story should be authored for each game rather than an existing novel. The difference is that the story is specifically authored for the game rather than for a novel.~~

~~Replayability: if a game that can be played often yields greater value for the player who can enjoy it for longer. A common goal is that the players should experience a novel plot each time. Therefore, emergent systems rarely have~~

**Table 3.4.1** Player's experience evaluation

<u>System</u>	<u>Drama avg.</u>	<u>Agent avg.</u>
3.3.1 <u>BARDs</u>	<u>2.27</u>	<u>1.82</u>
3.3.2 <u>Mimesis</u>	<u>2.64</u>	<u>2.0</u>
3.3.3 <u>IN-TALE</u>	<u>2.09</u>	<u>2.0</u>
3.3.4 <u>IDA</u>	<u>2.55</u>	<u>2.0</u>
3.3.5 <u>Thespian</u>	<u>2.27</u>	<u>1.55</u>
3.3.6 <u>IDtension</u>	<u>2.27</u>	<u>2.0</u>
3.3.7 <u>Façade</u>	<u>2.45</u>	<u>2.0</u>
3.3.8 <u>U-DIRECTOR</u>	<u>2.73</u>	<u>2.0</u>
3.3.9 <u>FAtiMA</u>	<u>1.45</u>	<u>1.73</u>
3.3.10 <u>GADIN</u>	<u>1.27</u>	<u>1.82</u>
3.3.11 <u>NOLIST</u>	<u>2.09</u>	<u>2.0</u>
3.3.12 <u>OPIATE</u>	<u>1.55</u>	<u>1.73</u>
3.3.13 <u>PPA</u>	<u>2.64</u>	<u>1.91</u>
3.3.14 <u>Scenejo</u>	<u>1.64</u>	<u>1.82</u>
3.3.15 <u>TEATRIX</u>	<u>1.27</u>	<u>2.0</u>
3.3.16 <u>V-Storyteller</u>	<u>2.09</u>	<u>1.91</u>
3.3.17 <u>V-Theatre</u>	<u>1.73</u>	<u>2.0</u>
3.3.18 <u>Erasmatron</u>	<u>2.82</u>	<u>2.0</u>
3.3.1 <u>MARGIE</u>	<u>3.45</u>	<u>2.0</u>
3.3.2 <u>talespin</u>	<u>3.18</u>	<u>1.82</u>
3.3.3 <u>SAM</u>	<u>3.55</u>	<u>2.0</u>
3.3.4 <u>BDI</u>	<u>2.64</u>	<u>1.36</u>

~~the exact same plot for two individual runs and offer greater replay-ability and variety. The author is then mindful of creating an interactive story from the outset. Façade, IDA, IDtension Mimesis, and U-Director are examples of these, see Section 3.2.~~

~~This is quite frequent in , for instance *Morrowind* [LLC02a] and *Baldurs Gate* [Bio98] and in adventure games for instance *Monkey Island* [Gam90] or *Gabriel Knight* [?]. This is where the weakness lies in emergent systems; not only is the ending unknown, but it can also be indeterminable. It can be difficult to keep the emergent story on track to create a structured story.~~

~~As with any design, there is no guarantee that the player will find the interactive narrative as engaging and artistically complete as intended, in fact, there will it can be guaranteed that a certain percentage of players will not find the to be artistically complete, engaging or even interesting. They may even find it to be irritatingly ill-structured, while others may find the same interactive narrative thrilling. This is because of peoples taste, culture and prior exposure to literature, theatre and arts, in general, varies a great deal.~~

~~There is no empirical way of evaluating what is artistically complete, the term means different things to different people. Neither is there any evidence that a pre-authored story will transfer into a good computer game even when that story is authored specifically for that computer game by an experienced game developer.~~

~~systems often have branching story that has multiple endings similar to many commercial computer games, for example, Deus Ex and Baldurs Gate.~~

**Lacks replay-ability** A high emphasis is frequently set on high interactivity that the player should be able to significantly influence the story or characters in the story or at least have the perception that they are.

~~A common goal is that the players should be able to play the game a few times and experience a novel plot each time, which requires sufficient variety in branching storylines and in interaction with characters and environment. In systems, each alternative branch needs to be authored. The characters often start doing something unexpected or inappropriate that does not conform to the expectations of the players. This is, for instance, a worry of the Virtual Storyteller. Emergent systems, therefore, use narrative functions to control how the drama emerges.~~

**Computationally intractable Divide and conquer:** Many systems apply some form of dividing the story into many small parts or tasks and use planning algorithms to plot the story ahead of the player in line with the intended storylines. This carries with it a computational problem because the planning algorithms frequently used, for example, STRIPS are PSPACE-complete

[Byl94] to plot the story ahead of the player [Bar08].

~~Authoring bottleneck~~ The necessary pre-authoring, for systems, carries with it a significant authoring bottleneck which greatly limits the sizes of systems that can be created in this way [MS05a]. Extensive work has been carried out by U. Spierling & N. Szilas in determining the “general authoring problems” [SS09, p. 52]. They found that one of the problems lies in the attempt to describe a highly technical academic tool or system to a genuine author. An author that is not familiar with the technology or even the concepts behind it. Even after spending considerable time explaining the system the authors went away and produced something that was either way off the mark or somewhat close to it but needed to be mended and the author wanted the scientists to do that.

They also found that authors had considerable difficulty authoring at such an abstract level. Possibly more surprisingly that computer science students had no advantage over the authors and that even the authors of the systems had trouble with the abstract authoring.

The systems face four main challenges:

Unrealistic goals, The notion of artistic completeness is not supported with evidence and appears at odds with providing interactivity. Neither is this a prominent request from players. Lacks replayability, It restricts or greatly reduces potential variety within the game and subsequently reduces replayability. Computationally intractable, they require planning algorithms that are an ill fit with modern online games that run vast game worlds on large distributed systems. Authoring bottleneck, there is extensive authoring involved by authors that are able to understand the technology sufficiently. The greater the branching factor, the greater the authoring complexity.

In emergent systems do not use authored stories; instead, they Emergent systems rely on interaction for the drama to unfold, see Section 3.3 see Section 3.3. FearNot!, Gadin, Nolist, OPIATE, PPA, Scenejo, TEATRIX, The virtual storyteller, and The virtual theatre project are examples of emergent systems. Not all emergent systems have players; for instance, the Virtual Story Teller relies on the interaction and emotional models of its sNPCs.

Emergent systems rarely have the exact same plot for two individual runs and, therefore, offer greater replayability in terms of experiencing variety. This is where the weakness lies in emergent systems because not only is the ending unknown, but it can also be indeterminable. It can be difficult to keep the emergent story on track to create a structured story. The characters often start doing something unexpected or inappropriate that does not conform to the expectations of the players. This is, for instance, a worry of the Virtual Storyteller. Emergent systems, therefore, use narrative functions to control how the drama emerges.

**Protagonist, Embodiment:** A prominent design goal is that the player becomes so immersed in the drama that she emphasises with the character that she is playing and consciously or subconsciously becomes embodied in the character. For instance, a player playing a ranger in an RPG senses herself as being that ranger and thus has the ranger behaving as she would behave if she was the ranger. It is even better if the player becomes the protagonist of the story identifying with the role such that she really feels that she accomplished to resolve the complication of the drama and that the drama was centred around her character. Preferably this happens when the player is pursuing her own goals.

**Immersion & Believability:** Most games aim for high levels of immersion, so that the player spends a large amount of time playing it, and becomes emotionally affected.

According to E. Brown and P. Cairns, there are three levels of Immersion [CCB<sup>+06</sup>]:

1. Engagement, the player is willing to play the game, learn the controls and such, and is willing to invest time in the game to advance towards the end or goal of the game.
2. Engrossment, when the player is not only engaged but is also emotionally affected by the game.
3. Total immersion, when the player becomes one with the game, completely losing awareness of their immediate surroundings.

A significant part of immersion is believability in the characters and the game world, and an empathy with the dilemmas they face. In the words of A Paiva & Co:

*In particular, the expression of emotions makes these characters more human-like and believable. ... there are three important points when expressing emotions:*

1. *the emotional state of the character must be clearly defined, in such a way that is undoubtedly perceived by the viewer;*
  2. *the emotional state affects the reasoning process, and consequences must be perceptively reflected in the actions of the characters; and*
  3. *emotions can be accentuated or exaggerated, to clearly communicate the viewer the emotional state of the character.*
- Another element is personality. A coherent character, that acts according to its personality*

*will be more believable than a character that has no long term coherence in its behaviour. Thus it is not so much one property or*

*another that matters but the combination of all these factors, that together providing ingredients for the building of the Believability believability in a synthetic character.*

– [PDS<sup>+</sup>04, p. 2], [PDS<sup>+</sup>05, p. 237]

**Figure 3.4.1** believability, the X axis is believability, and the Y axis is complexity



We can plot Believability believability on a two-dimensional scale as seen in ~~Figure 3.4.1~~ in Figure 3.4.1 where the Y-axis is the level of complexity, and the X-axis is the level of believability.

In the Figure, the (C) is where both believability and complexity is so high that it is indistinguishable from a human player.

Current computer games have virtual agents that aim for high believability and low complexity, see (A), in order to optimise available resources.

We aim to increase complexity at the cost of believability, see (B). Future research could optimise on this research to incorporate greater believability while retaining complexity. The increase in complexity is to create actors that play complex characters with advanced levels of emotional reactions, influenced by traits that affect the characters core responses.

**Drama awareness** We are, therefore introducing rational actor agents that manage the drama similar to improvisational theatre. For this, the agents need to be aware of the drama progress and have a complex reasoning process to be able to collaborate and respond rationally.

**Decentralised management** In order for this to be applicable to modern, fast-paced computer games that run on the large distributed systems, we introduce our decentralised drama management.

# 4

## Directed Emergent Drama (DED)

### 4.1 Introduction

The Directed Emergent Drama (DED) is a decentralised drama management engine for interactive emergent dramas in computer games. The engine's architecture includes a director agent, actor agents and schemas that guide the emergence of an interactive drama. The drama emerges from the interactions of actors and players. We have 6 publications of this work:

1. Schemas in directed emergent drama, in *proceedings of the 1<sup>st</sup> Joint International Conference on Interactive Digital Storytelling ICIDS08*, Erfurt, Germany, 2008. [AK08]
2. Directed emergent drama vs. Pen & Paper Role-Playing Games, *AISB'09 Symposium: AI & Games*, Edinburgh, UK, 2009 [AK09a].
3. Duality of actor and character goals in virtual drama, *9<sup>th</sup> International Conference on Intelligent Virtual Agents*, Amsterdam, Holland, 2009 [AK09b].
4. A critical review of interactive drama systems, in *AISB'09 Symposium: AI & Games*, Edinburgh, UK, 2009 [ABK09].
5. BNs: real-time applicable decision mechanisms for intelligent agents in interactive drama, *proceedings of the IEEE Conference on Computational Intelligence and Games (CIG2010)*, Copenhagen, Denmark, 2010 [AK10].
6. Believable Bots, in book *Actor Bots*, P. Hingston, 2012 [AK12].

In this chapter, we describe the DED in detail and its implementation, followed by a discussion of how it compares to related work.

The extends former work and uses other complex technology that is introduced in chapter 2. For ease, here is a list of the techniques and direct reference to their sections. In Chapter 2 we introduced constructs and technology that our work builds on in Sections:

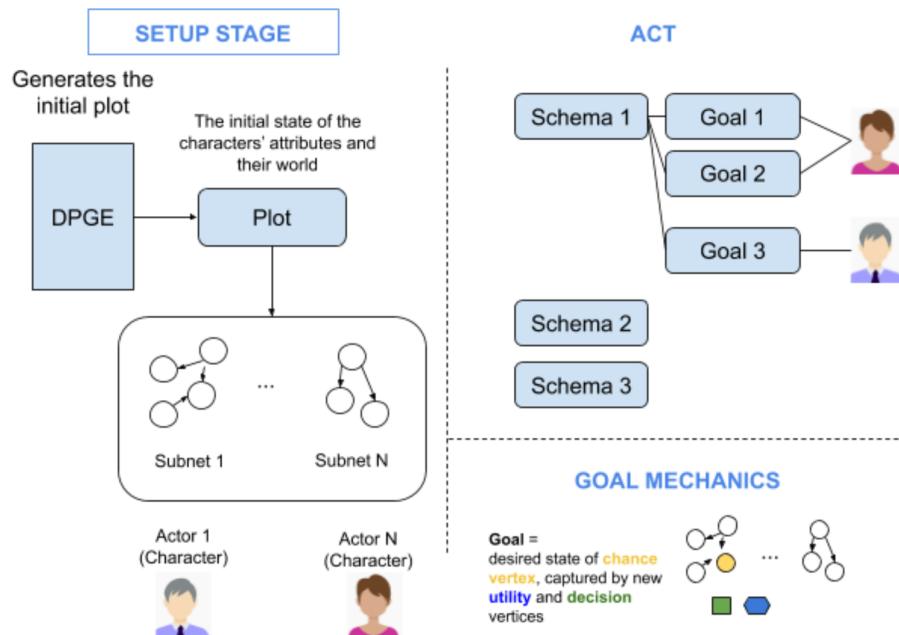
- 2.3.1. [2.2] Narratology; Structuralism and Drama theory
- [2.3] Computation; BNs and GT, 2.3.2., 2.3.2.4 and how the two are combined in the MAIDs to calculate a Bayesian equilibrium. that the NPCs use for rational reasoning.
- The authors published project, 2.4.1. The authors published project, 2.4.2. [2.4] Former work; published in the articles listed above.

We collaborated with Improbable's Enterprise department and connected the DED to their proprietary multiserver platform Spatial OS. Improbable describes Spatial OS, on their web, as “*a cloud platform that provides hosting, online services, tools and a multiserver networking stack for developing and operating multiplayer games*” [Imp19].

*a cloud platform that provides hosting, online services, tools and a multiserver networking stack for developing and operating multiplayer games*” [Imp19].

– [Imp21a]

**Figure 4.1.1**  $a_1$  is evaluating how  $c_1$  expects that  $c_2$  will react to  $5_0$ , displayed in the GeNIe UI [DSL07a].



The DED may be relevant to the enterprise departments Improbable Defence current product, which is a synthetic training environment for defence.

We implemented an academic scenario that is unrelated to current affairs, but that can demonstrate drama emergence and the game-theoretic decision technology. We use a the Single Synthetic Environment for Defence. In this Chapter we use two scenarios to explain the technology:

1. The murder mystery introduced in Section 2.2.1.4
2. An academic scenario of an aid mission in Afghanistan throughout this chapter to explain how the works. The scenario is called the Afghan poppy scenario and is about an officer deciding whether to give aid to an Afghan farmer depending on whether he is growing poppies or not, the farmer is, or intends to, grow poppies, see Section 4.2.

Both of these scenarios are implemented and the code for them is available in our GITHUBLINK.

We now give a high-level view of the information flow underlying the engine. We regularly how the DED drama process is initiated, and we refer to Figure 4.1.1 below for visual guidance. We start with a setup stage, during which a plot is generated using

1. We start by generating a plot with the DPGE, introduced in Section 2.4.1. The DPGE instantiated every vertex in an to randomly selected states instantiates every vertex to a randomly selected state in an Object-Oriented Bayesian Networks (OOBN), introduced in Section ???. These instantiated states represent the generated plot that defines the attributes of the characters and the initial state of their world. characters' attributes and their world's initial state.
2. Knowledge base: The OOBN contains several subnets, including specific subnets that define the specific personal knowledge of each character. Each actor also has a copy of the entire uninstantiated OOBN as a blueprint. The blueprint of the environment's causal structure, which corresponds to Harsanyi's exogenous data of the game, see Section 2.3.2.3introduced in Section ???. The actor uses the blueprint when reasoning about their world. The actors also receive the knowledge specific to them as a list of vertices and their states. For example, a farmer receives the knowledge specific to his person and his farming, which may include including the state that he is growing poppies on one or more farms. The farmer's knowledge is, for the most part, only known to him, unless it has a causal connection to other character subnets. For example, if the farmer is growing poppies, then it is likely that the army has destroyed his crops and so would also know knows about his poppy farming. The causal structure of the OOBN facilitates this inference. For example, if the DPGE sets the chance vertex for the destroyed crop to true during plot creation, then that evidence is propagated to the farmer's chance vertex for the destroyed crop by

updating the BN OOBN. Therefore, the characters start with a knowledge base that is specific to them and any knowledge that they can infer by instantiating their OOBN blueprint and updating it. Once the plot and actors are set up ready, the drama can start.

3. The drama is in several acts; each act has several schemas, see Figure 4.1.1. A schema has a collection of goals, attached to one or more character roles, for example, a farmer or an officer. There are two types of goals;
  - (a) Drama goals that ensure the requirements of the dramatic arc, and character goals, dramatic arc requirements.
  - (b) Character goals that ensure that the character remains IC.

The director uses the drama goals to maintain the dramatic arc and will only move the drama to a new act when all drama goals for the previous act are satisfied. This duality is specifically designed The purpose of this goal duality is to cause tension and conflict in the drama. The actors know that they are playing characters in a drama and are responsible for satisfying drama goals. They do this by requesting aid from other actors, without the player knowledge, and pass the drama goal over to the other actor.

A goal in itself is a simple object that can have massive emergent consequences by leveraging the structure and game-theoretic reasoning of the MAIDs. A goal has references a subnet, vertex and a state or no state as appropriate. A goal has the following attributes:

- The goal always has references a subnet and a vertex.
- The goal may have a specific state, for example, when giving information such as "destroyed crop" = "true". Alternatively, no state, for example when asking a question: "are you growing poppies?" has the state none since it is not known.
- Identity made of *subnet\_vertex\_(state|none)*.
- It has a type for the actor to know how to reason about it.
- It has a set of roles that it pertains to, i.e. goal for the functional roles, e.g. a goal for an officer or Officer Commanding (OC).
- It has an aim role, i.e. ask a farmer.
- The director can assign it as part of a schema.
- It can be created by the actor The actor can create it as part of its reasoning process, for example, if they have the goal of gaining information before making a decision based on that information. They will generate their own question goals based on vertices connected to the decision chance vertex.
- It can be passed to the actor from another actor when requesting aid due to drama and character goal conflict.

- The actor creates decision and utility vertices on-the-fly when creating a MAID to evaluate an optimal action.

Once the goals are distributed, and the BNs of each character updated accordingly, the drama can start. We implemented ~~#the murder mystery~~ both as a turn-based game and as a real-time asynchronous game. ~~The running example used to explain the in this chapter uses However, the poppy scenario only has an asynchronous implementation.~~

~~We start the chapter by introducing the~~ This chapter is organised in the following sections:

- 4.2 ~~Poppy Scenario: The Afghan poppy scenario, see Section 4.2. We then introduce the by describing the architecture of the engine, starting with the~~
- 4.3 ~~Schemas: The schemas that are used to structure the emergence into a of the drama with a rise and fall in conflict and suspense, see Section 4.3. Followed by how the director uses~~
- 4.4 ~~Director: The director which uses the schemas to guide rather than direct the drama, see Section 4.4.~~  
~~We then explain how the drama emerges from the actors' actions based on complex Artificial Intelligence (AI) that uses causally structured s and to reason about the game world and update the actors' knowledge baseas the characters gain knowledge, see Section 4.5. Followed with a discussion of how the players interact with the~~
- 4.5 ~~Actors: The actors, their architecture, knowledge base, and rational reasoning.~~
- 4.6 ~~Players: The player's role and interaction with the game and benefit from the AI, see Section 4.6.~~  
~~In Section 4.7, we summarise how the drama emerges from actor and player interaction. We describe how a drama in is created or designedin Section 4.8. We compare the drama with the structure of narratives in Section ??, and the structure of drama in Section ??, and to games in Section ??, and former work in Section ??, and related workin Section ??.~~
- 4.8 ~~Creating a new drama: The drama design and authoring process.~~
- 4.9 ~~Comparison to background and related work: The work in this chapter compared to the work introduced in Chapters 2 and 3.~~
- 4.10 ~~Summary.~~

## 4.2 Implemented in SpatiaOS

We have implemented an academic scenario using Improbable's ~~We worked in collaboration with Improbable's enterprise department, which is SpatialOS. We collaborated with Improbable Defence, currently developing a synthetic training system for defence~~ Single Synthetic Environment (SSE) for Defence. We are looking at the ~~compatibility of the and the synthetic training scenario DED and the SSE training scenario's compatibility~~ and have implemented an Afghan poppy scenario, an entirely academically sourced motif, to do initial testing. The scenario does not represent current product work at Improbable.

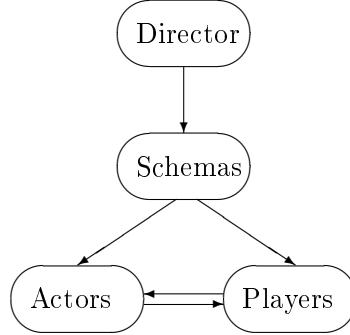
Head of Enterprise research, Christoforos Anagnostopoulos has supervised this effort.

The drama is divided into as many acts as is required to pace the emergence. For example, in the Afghan Poppy scenario where the officer is the player, we designed the following five acts:

1. The officer receives orders and information from the OC regarding an Afghan farmer. The information is any relevant intelligence that the OC knows. The orders are to investigate whether the farmer is ~~growing poppies and if he is growing poppies whether he intends to continue, or intends to grow poppies~~.
2. The officer meets the farmer and starts to ask the farmer about his farms and whether he grows Poppy. The farmer wants aid from the UK forces and has a goal to conceal his farming of Poppy; believing that it lessens his chance of receiving aid.
3. Officer feeds back to the OC what he learnt from the farmer and from anyone else he spoke to that revealed relevant information. The OC again gives the officer any relevant intelligence and orders him to speak to the farmer and offer aid if possible, i.e. if the farmer either is not growing poppies or intends to stop growing poppies.
4. The officer meets with the farmer, and using his judgment, based on his interactions with the farmer, will either offer aid or decide against it.
5. In the final act, the officer relates his decision to the OC, which gives his view of whether he thought the officer made ~~a good the right~~ call or not.

### 4.3 Schemas

**Figure 4.3.1** The DED architecture



The DED engine has a director agent, actor agents and schemas that guide the emergence of an interactive drama. The drama emerges from the interactions of actors and a player, see Figure ??4.3.1.

Schemas contain all information from the director to the actors. The director uses the schemas to direct the emergent drama, and the actors use schemas to orient themselves to where the drama should emerge.

The director agent sends schemas to the actor agents and players. The schemas are motif like structures that a director uses to inform the actors of where to aim the drama emergence. Motifs are generic structures that do not have a narrated list of events. They are situations in the words of N. Szilas:

*In theatre and drama, the concept of situation is a key dimension in the analysis of a given piece. A situation is understood here as a set of characters and their relationships that makes the drama interesting. Examples of dramatic situations include the ‘love triangle’ —two characters love a third one—, forbidden love between siblings (who may ignore their family ties), love between different social classes, and others just to mention the romantic domain as example*

– [SER16]

In conflict areas like Afghanistan, it is easy to see how the above list is relevant, repeated wrongs by far superior force, lost their kin to the cause and even seen them brutally slain before them by ambitious rivals that covet an elusive prize. People make mistaken judgments or lose their honour in the heat of the moment.

The schemas function is to assign goals to the actors that create this type of conflict. For example: In Section 2.2.1.2 we introduced a list of G. Polti's [Pol21] situations which the numbers below refer to, an Afghan

farmer ~~who~~ has been growing poppies ~~, which is against their~~ ~~against his~~ religion (27, 33, 34), and he does not want the UK forces to know. He may have lost a loved one or hopes to get the UK forces to help find them (35,36). Perhaps his brother or son have gone to war, and ~~perhaps~~ ~~maybe~~ he had a part in encouraging them (23, 33, 34). There may be a smuggler or an Al Qaeda agent present ~~that are~~ competing with the UK forces for the farmer's alliance (24, 30).

~~The goals that the schemas have~~ The schemas' goals can be specific down to particular knowledge gain, for example, finding out if the farmer is growing poppies. They are also more general; for example, the farmer seeks aid from the UK forces. The schemas do not contain any instructions on how to accomplish the goals.

A schema has three components:

1. *Acts*, a list of applicable acts for the schema.
2. *Roles*, a list of applicable roles for deploying the schema.
3. *Goals*, a list of drama and character goals for the actors and players.

#### 4.3.1 Acts

Pace the drama: Schemas that have goals relevant to a specific act have the number of that act in their list of acts so that the director can quickly find relevant schemas. ~~Assigning schemas to specific acts helps to pace the drama and retain a drama structure, for example, that the officer first receives orders before speaking to the farmer~~

For example, schemas for the five acts in the Poppie scenario are:

1. Act: Orders and information.
2. Act: Question farmer.
3. Act: Feedback and orders.
4. Act: Aid.
5. Act: Review.

The actors only have goals active for the current act's schemas. For example, the OC and officer initially receive the OC orders and OC information. When the OC gives the officer orders, he gives the orders as a schema assigned to act II.

The aim is to build tension, suspense, and reach a climax with a resolution at the end, as in officer receives the schema and the goal to question the farmer. However, it is not a current act schema. Therefore, the schema's goals do not become active for the officer, and he doesn't act on them until the director signals act II.

Otherwise, the officer could run off and question the farmer without receiving all of his orders and information from the OC.

The resulting structured pace of the drama is evident in the 4 years of available logs that we have uploaded to the departments GitHub repository.<sup>1</sup>

Dramatic arc In Section 2.2.1.1, we introduced Freytag’s pyramid, introduced in Section 2.3.1 [Fre63]. In Section 2.2.1.3, we introduced Propp’s theory of a uniform structure and predictable patterns [Pro68]. In Section 2.2.1.4, we combined Freytag’s and Propp’s structuralism with the work of [Tod77, Pri03, Kno92] on the structure of the murder mystery and the narrative.

We implemented the three-act murder mystery structure in Section 2.2.1.4, and the intended pyramid structure is evident in the logs.

The drama, therefore, starts Similarly, we designed schemas for the Poppy scenario to start on a non-conflicting and straightforward act of giving information and orders. The introduction act is followed by rising tension when the officer tries to understand whether the farmer is growing poppies and whether they can offer him aid and gain an ally. The farmer is initially unwilling to reveal his Poppy farming tension builds because the officer doesn’t know if the farmer is telling the truth. In some cases the farmer is farming Poppy and sometimes not. The officer may need to do some investigative work to learn the truth.

The climax is when the player must decide whether to aid the farmer or not, followed by resolution with out having complete information and must make an educated guess. The resolution is a debrief with the OC. This structure can be seen from the logs in the Departments GitHub repository.<sup>2</sup> This is a scene that we found thrilling due to the multiple parties that we could introduce and the complex political and cultural situation involved.

#### 4.3.2 Roles

The drama has primary roles assigned to the plot and actors are allocated these at the start. In the Afghan Poppy scenario, these roles include:

- Officer, the protagonist, played by the player.
- The OC that incentivises the officer, similar to a quest giver in computer games.
- A farmer that is growing poppies but wants aid from the UK forces.
- A travelling merchant that is selling things near the farm.
- An Al-Qaeda relative of the farmer that is affecting the farmer’s decisions.

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<sup>1</sup><https://github.com/uoy-research/DED/tree/main/SecondLife/logs>

<sup>2</sup><https://github.com/uoy-research/DED/commit/ee8f41b719e8b40744d9fae4b880505ca77e2e15>

~~Each of these~~ These roles can have several secondary ~~roles~~functions, including parent, partner, sibling, a believer in a cause or religion, victim, hero, rival, or lover. The secondary roles introduce conflict and are determined by the DPGE when creating the plot for the drama.

For example, the farmer can be a husband, a father and a brother and hope to find a lost ~~kinsman~~relative, as in Polti's situation number 35.

Additionally, events can lead to characters adopting new roles; for example, the farmer may ~~be asked to pass judgment in a dispute in his family. He adopts the role of a judge~~assume a judge's role and possibly passes a hasty judgment, as in Polti's situation number 33.

The roles are there for the director to understand which schemas the director can deploy and to which characters. For example, the officer has several giving and receiving orders goals, and the farmer has a receiving aid goal.

There are no specific actions or dialogue that comes with the character roles; the actors do not use the roles or the roles of others in their reasoning. For example, when judging if someone is trustworthy, they must use their current knowledge base and judge trustworthiness from experience.

On the other hand, ~~the knowledge base is initially created~~we create the initial knowledge based on their roles, i.e. the farmer knows what a farmer would know, and they are assigned goals based on their roles.

Their goals also tell them which role to address to fulfil the goals. For example, the OC has the goal of informing the officer.

#### 4.3.3 Goals

The goals are pivotal in the DED; everything that actors and players do is dependent on what goals they have.

Each goal has the following parameters:

~~Owner~~: indicates~~Indicates~~ whether the goal is for the character or the drama. Drama goals are goals that are necessary for the drama, while character goals guide the actor in how to stay in character. For example, the drama is about the officer, played by the player, discovering that the farmer is growing poppies and ~~then to decide~~deciding whether to give him aid regardless. Conversely, the farmer's character goal is to hide his Poppy farming from the officer to maximise his chance of receiving aid.

The aim of having these conflicting goals is to introduce conflict and deception to the drama. The player must resolve the goals for the drama to progress. We require conflict and for the player, as the protagonist, to overcome challenges for the drama to reach a climax. ~~In~~There is conflict and disruption of status-quo in Polti's situations and Propp's morphology, ~~there is conflict and disruption of status-quo~~ to build suspense.

**role; Role:** indicates-Indicates which role to assign the goal. There are generic goals that apply to multiple roles, and there are goals for specific roles.

**"Applies to":** the The applicable role for the goal. For example, the OC's has a goal of giving orders to 'officer' for him to give orders to his officer. Similarly, the officer has a goal of gaining information regarding Poppy farming from the role 'farmer'.

**Aim:** indicates-Indicates a vertex  $v_i$  and a state  $v_i$  that is in the actor's BN. For example, the farmer's goal to hide his Poppy farming is  $v_{grows\_poppy} = false$ .

**Importance:** goals Goals are ranked by importance. It is, for example, more important to answer the telephone than to play the next card in a bridge game.

**Satisfied:** indicates-Indicates whether the goal has been satisfied.

### Examples of goals:

- Murder mystery:
  1. Drama goal: Reveal motive.
    - Role: suspect
    - Applies to: detective
    - Aim: Motive = True
    - Importance: High
    - Satisfied: False
  2. Character goal: Hide motive.
    - Role: suspect
    - Applies to: detective
    - Aim: Motive = False
    - Importance: High
    - Satisfied: False
- Poppie farming
  1. Drama goal: Reveal Poppie farm.
    - Role: farmer
    - Applies to: officer
    - Aim: Farming Poppie = True
    - Importance: High
    - Satisfied: False
  2. Character goal: Hide Poppie farm.

- Role: farmer
- Applies to: officer
- Aim: Farming Poppie = False
- Importance: High
- Satisfied: False

#### 4.3.4 Summary

The schemas are motif like abstract structures similar to Polti's 36 situations [Pol21], that guide the actors with goals that the actor aims to fulfil in the course of the drama. The goals are matched to the actors by the role of the actor. They introduce conflict between character and drama goals and introduce tension and suspense.

The schemas have two types of goals; character goals for the actor to stay in character, and drama goals to structure the drama.

There are no explicit instructions in the form of dialogues, gestures, actions or sequencing in the schemas they are assigned to specific acts for the director to pace the drama.

#### 4.4 Director

The director is a shallow autonomous agent that is giving general directions in the form of schemas ~~that~~. The schemas guide the actors in developing the drama and engage the player in directed emergence ~~, by matching schemas to actor agents in order to give them guidance on how to progress to align the drama to fit a specific drama genre. The director deploys the schemas introduced in Section ?? in Section 4.3, to guide the drama, depending on the stage of the drama~~drama's state, and keeps track of the state of the schema goals to read how the drama ~~is progressing progresses~~ and when to switch between acts and deploy new schemas. The director has no script and does not know what the actors are doing. ~~All he can see of the interaction is the state of the drama goals.~~

The director's view is, therefore, limited to an abstract understanding of the drama situation, and it cannot see the actions of the actors or the players, it sees:

- current act
- drama goal status
- character goal status
- actors are in the player's current location
- goals the actors and player have

~~The director is not in a position to make decisions about direct interactions with the player, because the director would need to be constantly aware of everything that takes place ( including the internal state of every character in the drama). In vast multiplayer online games, Our target platform is MMOGs and huge simulations; Improbable developed SpatialOS specifically to facilitate vast game worlds by distributing the computation across multiple servers, see Figure 4.4.1, as they say in their documentation:~~

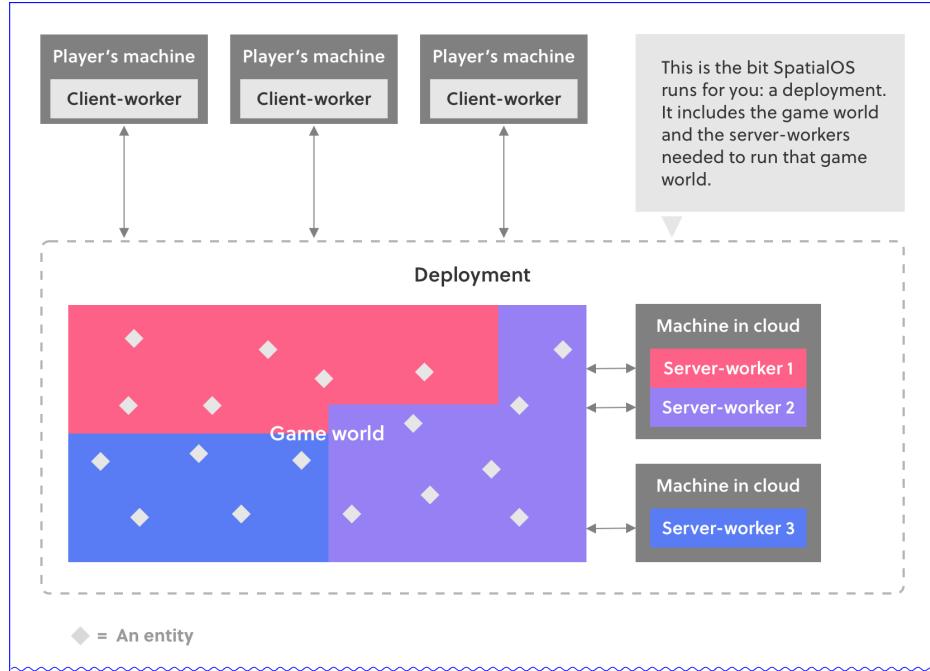
*it brings together many servers so they're working as one. But it does this in a way that makes a single world which looks seamless to players.*

– [Imp21b]

In MMOG, where the computation is distributed across multiple servers, having the director make all the decisions for each actor for all interactions that the actor has would it would rapidly escalate into an intractable computation problem~~— if for no other reason than the enormous amount of messages, as A. S. Tanenbaum et al. says:~~

*Even if we have virtually unlimited processing and storage capacity, communication with that server will eventually prohibit further growth.*

**Figure 4.4.1** SpatialOS distributes computation across multiple servers to run MMOGs that are too large for a single server [Imp21b]



– [TS04, p. 10]

As discussed in Section ?? in Section 4.3, the schemas have two types of goals; character and drama goals, but no scripting, actions or direct instructions:

- Character goals for actors' to stay in character and to aim for role relevant objectives.
- Drama goals are for the director to evaluate the drama situation computationally.

The director deploys schemas with drama and character goals as required to keep up the level of complexity for each act.

The actors use their knowledge base and Game Theoretic reasoning to control the drama, based on guidance from the director in the form of goals. The director:

- detects when the final act is complete and finishes the drama.
- moves the drama between acts when all the drama goals from the former act have been are satisfied.
- evaluates whether a schema is needed depending on the act and the state of the currently deployed goals.

- When a schema is needed the director picks a schema based on which drama goals are still left to fulfil and which schemas fit the current cast

Acts divide the drama up into small, manageable parts with few distinct drama goals. When all the drama goals of an act are satisfied, the director moves over to the next consecutive act. The character goals are less dependant on acts and schemas~~, linked to the characters and their roles.~~ The character goals create conflict with the drama goals to create tension and suspense. Initially, the goals are simple but become more conflicting and challenging as the drama progresses.

In our Afghan Poppy scenario, the farmer wants aid from the UK and can have several other character goals. For example, he is resentful of foreigners invading his land and is making a profit from growing poppies.

The ~~aim of the player~~player's aim in a training scenario as an officer is to determine whether the UK should give him aid depending on whether he grows Poppy or not. The UK is willing to give aid to build an economy that is not dependent on opium production.

There is, therefore, a conflict between the farmer's goal of getting aid and the fact that he is growing poppies. The player's drama goal is to learn if the farmer is growing poppies and if he intends to do so in the future. There is, therefore, a conflict between these primary goals from the start. The farmer should reveal his Poppy growing for the plot progress while simultaneously ~~, he should keep it hidden in order keeping it hidden~~ to receive aid.

Character goals are either deployed at the start as a crucial part of the main plot~~, for example, the farmer wanting aid.~~ Additionally, they are in schemas as a counter to the ~~drama goals of the schemas~~schemas' drama goals to create conflict and variation. For example, ~~there can be a brother that a brother~~ is part of the Taliban~~, and the farmer wants to stop growing poppies but is afraid to admit it in front of his threatening brother.~~ Alternatively, he may have lost his brother in the war and not know whether he is alive or dead and be resentful toward the UK and foreigners believing that they killed him with their invasion. Perhaps he wants to find his brother and ~~would~~ become an ally if he learnt that his brother was alive.

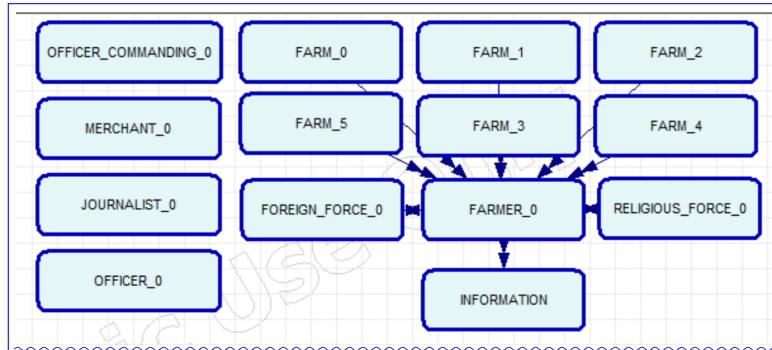
The director will deploy drama goal-related schemas at the start fo each act and then watch for them to be satisfied. He will also deploy schemas with new character goals if they fall below a minimum for that act. For example, at the start of the second act, the director deploys a schema ~~that has goals relevant to the drama goal of asking the~~with goals to ask the farmer about his Poppy growing. If the farmer has no character goal to complicate this, then the scene will become rather dull. Therefore, the director will select schemas ~~that have with~~ some character goals ~~in them in order~~ to increase the current drama score. When the director sees the number of character goals fall below a minimum for that act, it finds and deploys another schema.

#### 4.4.1 Generating actor agents

The director also manages the start of the drama by calling the DPGE. The plot that the DPGE creates is a complete description of everything ~~that is~~ needed to create a knowledge base for each character.

First, the director assigns ~~to~~ each actor a drama role and then an initial knowledge base and a set of traits. It is not dependent on the plot, whether a character is gullible or honest. The traits are defined separately along with the initial character view of the scenario.

**Figure 4.4.2** An example of the Afghan poppy scenario knowledge base and its OOBNs, displayed in the GeNIE UI [DSL07a]



#### We use Object-Oriented s (OOBs)

We use OOBNs, introduced in Section ??, to generate a knowledge base with minimal manual input, introduced in Section 2.3.1.12, see Figure 4.4.2.

For example, in Figure 4.4.2, the OOBNs for an Afghan farmer with six farms or fields. Each farm is an object in the farmer's OOBN that is an instantiation of the same farm BN; see Figure 4.4.3. The only difference between the farms is the instantiation of the vertices, which means that from authoring one farm BN the DED can randomly instantiate any variation of that BN; see Figure 4.4.4 the instantiated farm BN as having a destroyed Saffran crop due to drought. This means that we only design one farm and that one design is used for all similar farms, the values are randomly instantiated by the DPGE at the start.

The director assigns the parts of the plot that are relevant to each actor depending on their role. Each character in the plot is, therefore, created with the knowledge specified for their role. For example, the farmer knows everything in submodels

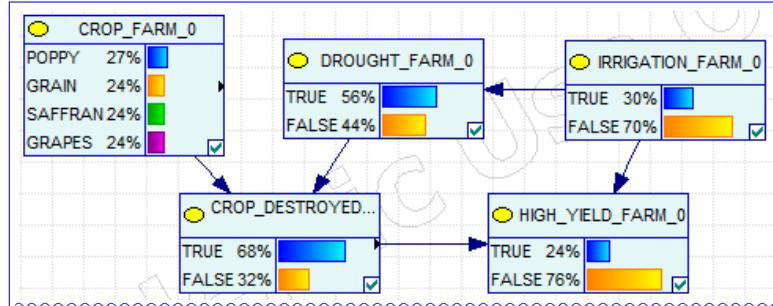
(FARMER<sub>0</sub>, FARM<sub>0</sub>, FARM<sub>1</sub>, FARM<sub>2</sub>, vFARM<sub>3</sub>, FARM<sub>4</sub>, FARM<sub>5</sub>),

and the OC knows everything in the

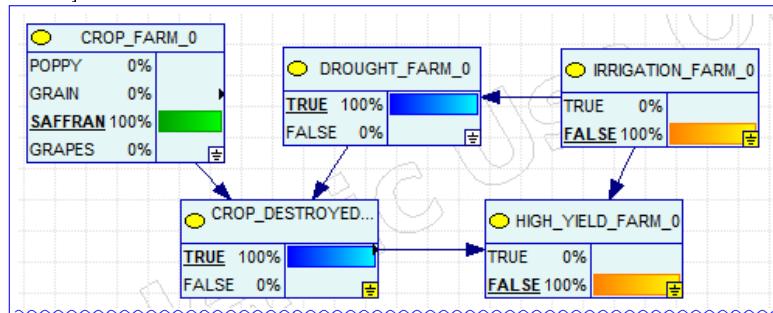
(OFFICER\_COMMANDING<sub>0</sub>, FOREIGN\_FORCE<sub>0</sub>) submodels.

When the actors receive their knowledge base, they instantiate the ~~corresponding states listed in their s~~ states in their OOBN according to their characters part

**Figure 4.4.3** A farm BN in an OOBN, displayed in the GeNIe UI [DSL07a]



**Figure 4.4.4** An instantiated farm BN in an OOBN, displayed in the GeNIe UI [DSL07a]



in the plot received from the director.

## 4.5 Actors

The actors are the prima motor of the emergent drama; they improvise a drama for the player based on guidance from the director.

**Decentralised drama management** The drama management is decentralised and distributed between the actors. The actors are responsible for the drama and will overrule ~~director's guidance that the director's guidance if it~~ is out of character (OOC) for their role. The actors work collaboratively, without the players' knowledge, to manage the ~~drama~~-drama when there are conflicts between ~~requirements of the drama the~~ drama's requirements and the characters ~~that~~ they are playing. The director has no part in ~~helping to resolve such conflicts~~resolving such disputes; the director is not aware of them.

**Drama awareness** The actors are aware that they are actors in a drama and ~~that they~~ need to ensure that the ~~drama~~ conforms to the expected genre. We introduce the ~~econcept of duality between and duality concept between drama goals and character goals~~ and how the actors collaborate to resolve this conflict while staying IC. For example, in the Afghan scenario, the farmer has a character goal of getting aid from the UK officer, ~~but~~. ~~Still~~, he has been growing poppies, which will decrease the chance of the UK officer offering aid. ~~The support. The player~~'s aim is to discover that the farmer is growing poppies and, therefore, the actor's drama goal is to reveal this.

When an actor makes an action that blocks a drama goal that the actor has, the actor will request aid from another actor to realise the drama goal without going OOC.

**Rational agents** The actors ~~have are rational in~~ Game Theoretic reasoning, introduced in Section 2.3.2, where rationality is defined as always choosing the optimal action terms, see Definition 2.3.8, introduced in Section 2.3.2. We use causally structured BNs, introduced in Section 2.3.1.6 in Section ?? and MAIDs, introduced in Section 2.3.2.4 in Section 2.3.2.4 to reason about uncertainty, and find a MAIDs equilibrium ~~which is equivalent to equivalent to Nash Equilibrium~~ in an imperfectly informed game [KM03].

**Compatible with leading online game technology** We ~~have~~ tested the DED with leading MMOG technology stack SpatialOS [Imp19] which coordinates [Imp21a], coordinating agents in a single seamless game world across multiple servers. The rational, autonomous actors respond ~~in ??ms,~~ within a second, to player actions, and the DED is fully integrable with leading MMOG technology.

The structure of this section We start by introducing the ~~structure of the character traits that affect the reasoning, and are based on the big five personality dimensions, see Section ??~~<sup>actors' reasoning;</sup> see Section 4.5.1. Followed by ~~an introduction of introducing~~ the structure of the <sup>actors'</sup> knowledge base, and how it is populated, ~~see Section ??~~ see Section 4.5.2.

We describe the <sup>actors'</sup> reasoning, starting with a simple ~~tasks~~<sup>task</sup> of creating and filtering ~~applicable appropriate~~ actions to choose from, ~~see Section ??~~ see Section 4.5.3. Followed by the act of informing another trusted character and using MAIDs, ~~see Section ??~~ see Section 4.5.4, and responding to possible deception by challenge, threat or intimidation, ~~see Section ??~~ see Section 4.5.4.2. We then describe how they can request from other actors and offer them aid, ~~see Section ??~~ see Section 4.5.4.5, which facilitates actors' collaboration when their drama goals ~~conflicts~~<sup>conflict</sup> with their character goals.

#### 4.5.1 Traits

~~The actors need to show specific characteristics to be believable. The actors also need to choose from applicable sentences that are descriptive of the character they portray. There are many psychological theories and classifications of traits, and it is beyond the scope of this dissertation to discuss their relative merits and disadvantages. Our sole purpose here is to pick one such theory as an example and show how to map it to a BN to demonstrate how efficient the BNs are in handling such transient states' effects as mood and situation on the agents' decision making.~~

~~We experimented with two theories:~~

1. Cattell's 16 traits, see Section 4.5.1.1
2. Big five personality dimensions, see Section 4.5.1.2

##### 4.5.1.1 Cattell's traits

Cattell's 16 traits [Cat46] see Table 4.5.1

~~Cattell selected these 16 traits after careful empirical research and he further spent a large part of his life developing examinations for these traits and the effect they have on behaviour (see for instance [Cat65]). Cattell also discusses how mood and situation can affect behaviour and his work plays a part in developing the big Five Factors of personality [Gol93] which are very broad definitions of personality that are thought to contain or represent the basic structure of all known personality traits. The big five factors are very well respected but as they are very broad we prefer Cattell's more narrowly defined traits as suitable examples. The big Five Factor personality model is of course the most well recognised and widely used personality model used today and DED would work equally well with it.~~

**Table 4.5.1** Cattell's 16 traits

<u>Low range</u>	<u>High range</u>
<u>reserved</u>	<u>warm</u>
<u>concrete reasoning</u>	<u>abstract reasoning</u>
<u>reactive</u>	<u>emotionally stable</u>
<u>deferential</u>	<u>dominant</u>
<u>serious</u>	<u>lively</u>
<u>expedient</u>	<u>rule-conscious</u>
<u>shy</u>	<u>socially bold</u>
<u>utilitarian</u>	<u>sensitive</u>
<u>trusting</u>	<u>vigilant</u>
<u>practical</u>	<u>imaginative</u>
<u>forthright</u>	<u>private</u>
<u>self-assured</u>	<u>apprehensive</u>
<u>traditional</u>	<u>open-to-change</u>
<u>group-oriented</u>	<u>self-reliant</u>
<u>tolerates disorder</u>	<u>perfectionist</u>
<u>relaxed</u>	<u>tense</u>

#### 4.5.1.2 Big five personality dimensions

The characters have traits based on the big five personality dimensions [RC03] that the actors use when reasoning. The traits are measured in terms of percentage value from low to high and represented as states in the BNs:

- *COMPLETE* 100%
- *HIGH*  $\geq 75\%$
- *MEDIUM*  $< 75\%$  and  $> 25\%$
- *LOW*  $< 25\%$
- *NONE* 0%

For example, the officer and OC have complete trust in each other.

We start by introducing the big five traits, and how some roles are likely measured high or low on the traits scale. When we say ‘high’, it means that this role would have a value of *HIGH* to *COMPLETE*, and ‘low’ means state *LOW* or *NONE*. If we do not specify a role as high or low for a trait, it means that it will fall in the midrange. Each trait affects specific parts of the actors’ reasoning, which we discuss below and will go into greater detail later in the Section when describing individual reasoning elements.

#### 4.5.1.3 Neuroticism

*A general tendency to experience negative affects such as fear, sadness, embarrassment, anger, guilt and disgust. High scorers may be at risk of some kinds of psychiatric problems. A high Neuroticism score indicates that a person is prone to having irrational ideas, being less able to control impulses, and coping poorly with stress.*

– [RC03, p. 69]

Religious people, terrorists, smuggler, and people negatively affected by the conflict will have high Neuroticism. Neuroticism affects the characters level of trust in others; they will have low trust and more likely to lie for no apparent reason because of excessive mistrust. Those high in Neuroticism are difficult to gain reliable information from, and they show a more significant response to force threats and intimidation.

In the reasoning algorithm, they have lower initial trust in others. They will have higher rewards for yielding to threats and intimidation, and it will affect their truth evaluation when stressed.

*A low Neuroticism score is indicative of emotional stability. These people are usually calm, even-tempered, relaxed and able to face stressful situations without becoming upset.*

– [RC03, p. 69]

Officers, journalist, and the merchant would be low in neuroticism.

#### 4.5.1.4 Extraversion

*Includes traits such as sociability, assertiveness, activity and talkativeness. Extraverts are energetic and optimistic. ... It was found that Extraversion is a valid predictor of performance in jobs characterised by social interaction, such as sales personnel and managers ... found a positive relationship between Extraversion and job performance of police personnel, and explained this relationship in terms of the high level of interaction in the police service. ... Extraversion is characterised by positive feelings and experiences and is therefore seen as a positive affect.*

– [RC03, p. 69]

Officers, journalist, and merchant are high in extroversion, it is a strong quality to have in a profession that requires a high level of interaction with people. High levels of extraversion will cause the character to say more, and be more trusting initially. They will ask about the person more than others.

*Introverts are reserved rather than unfriendly, independent rather than followers, even-paced rather than sluggish.*

– [RC03, p. 69]

Farmer, smuggler and terrorist are likely characters for introversion.

#### 4.5.1.5 Openness

*Openness to Experience includes active imagination, aesthetic sensitivity, attentiveness to inner feelings, a preference for variety, intellectual curiosity and independence of judgement.*

*People scoring high on Openness tend to be unconventional, willing to question authority and prepared to entertain new ethical, social and political ideas. Open individuals are curious about both inner and outer worlds, and their lives are experientially richer. They are willing to entertain novel ideas and unconventional values, and they experience both positive and negative emotions more keenly than do closed individuals.*

– [RC03, p. 69]

The journalist and merchant are likely candidates for openness since they both rely on this trait in their professions in order to seek out deals, stories and opportunities that others miss. The openness trait affects the characters inquisitiveness, they will ask more and about things that are outside the current conversation and they will be less strictly goal oriented. These characters are useful when engaging the player and guiding the drama towards the drama goals since they are less rigidly adherent to specific character goals.

*People scoring low on Openness tend to be conventional in behaviour and conservative in outlook. They prefer the familiar to the novel, and their emotional responses are somewhat muted.*

– [RC03, p. 69]

Officers, farmers and religious extremists are low in openness. Officers because their success in the profession is directly correlated with their ability to follow orders and fall in line. Farmers need to be dependable and reliable all year round to tend the farm and manage the family. Religious extremists that blindly follow preachers and old doctrine that cannot be questioned are the very definition of a closed mind. Although, unlike officers and farmers they are likely emotionally unstable.

#### 4.5.1.6 Agreeableness

*An agreeable person is fundamentally altruistic, sympathetic to others and eager to help them, and in return believes that others will be equally helpful. ... found that Agreeableness is related to training success. The co-operative nature of agreeable individuals may lead to success in occupations where teamwork and customer service are relevant*

– [RC03, p. 69]

The merchant and journalist are agreeable or else they would not be competent in their profession, which relies on getting along with people. Officers are certainly not disagreeable but more to the middle since they rely on teamwork but are also prepared to fight and will not give in easily.

*The disagreeable/antagonistic person is egocentric, sceptical of others' intentions, and competitive rather than co-operative.*

– [RC03, p. 69]

The smuggler and terrorist are low in agreeableness, which affects how trusting and willing to cooperate the characters are, and how quickly they become threatening. Agreeable people are unlikely to oppose society as strongly as a smuggler, and a terrorist.

#### 4.5.1.7 Conscientiousness

*Conscientiousness refers to self-control and the active process of planning, organising and carrying out tasks . The conscientious person is purposeful, strong-willed and determined. Conscientiousness is manifested in achievement orientation (hardworking and persistent), dependability (responsible and careful) and orderliness (planful and organised).*

*On the negative side, high Conscientiousness may lead to annoying fastidiousness, compulsive neatness or workaholic behaviour.*

*... conceptual relationship between Conscientiousness and integrity. Furthermore, autonomy and goal setting influence the relationship between Conscientiousness and job performance*

– [RC03, p. 69]

Officers are high in conscientiousness, a necessary quality for an army career, and farmers that are continually working and managing to provide for their families. Merchants are also high in conscientiousness in order to manage their finance that can be a balancing act, and they require a certain degree of trust from their customers. The customer needs to believe that

they will not short-change them or sell them a false product or they will not come back again.

They will have higher rewards for truthfulness and trustworthiness when reasoning.

*Low scorers may not necessarily lack moral principles, but they are less exacting in applying them.*

– [RC03, p. 69]

The unscrupulous journalist that is willing to do almost anything for a good story could be here, and a smuggler and a terrorist are lacking in conscientiousness, or they would not be able to carry out their intentions.

#### 4.5.2 Knowledge base

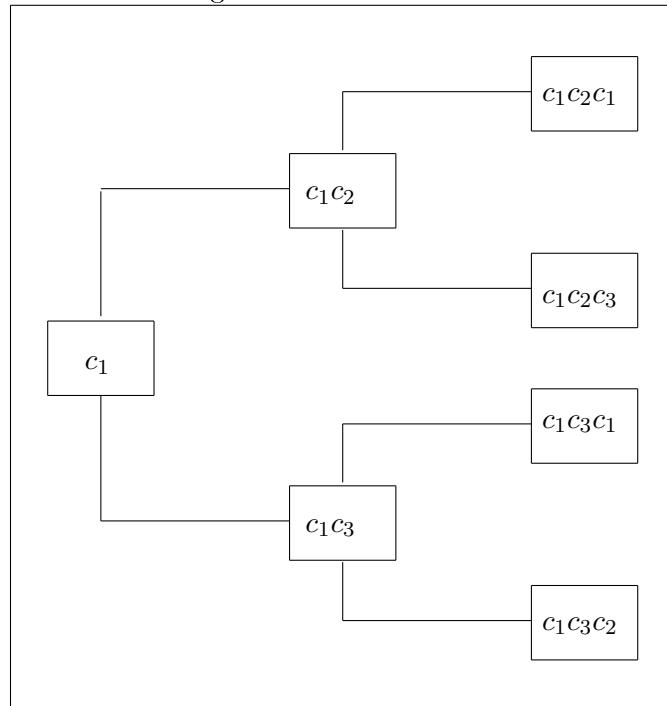
When the director assigns roles to actors, it also sends the actors their initial knowledge base in ~~the form of~~ a list of vertices and their evidence.

The characters will get at least the information in their submodels, i.e. the officer gets all the ~~knowledge in the officer submodel~~, see ~~Figure 4.4.2~~ ~~officer submodel knowledge~~; see Figure 4.4.2. They will also get information relevant to their profession; for example, the farmer gets all the ~~knowledge about the farms~~ ~~farms' knowledge~~.

##### 4.5.2.1 Structure

~~The~~ We introduced the knowledge base structure ~~is introduced~~ as part of the RDE ~~in Section 2.4.2~~ in Section 2.4.2. We described it ~~there~~ with a diagram of the knowledge base structure ~~that is~~ necessary for the ~~calculation~~, we ~~display the diagram~~ ~~GT calculation~~; we ~~display it~~ here again for ease, see ~~Figure 4.5.1~~ see Figure 4.5.1.

**Figure 4.5.1** The knowledge base structure



As seen in Figure 4.5.1 in Figure 4.5.1, the character has three views:

1.  $c_1$ , their character view is what they know, and they will only enter confirmed data there that comes from someone they trust or has evidence. For example, the officer trusts the OC, and stores all information from the OC in the first view.
2.  $c_1c_2$ , the second view, their view of other characters, they store information that they find believable. The traits come into this decision; ~~more trusting~~; more trusting characters, for example, characters high in agreeableness, will more readily store information here than others. Next ~~come those who are high in~~ comes high openness, followed by extroverts, but neurotic individuals will be very resistant to ~~store keeping~~ the information in this layer.
3.  $c_1c_2c_1$ , the third view is what the character believes that the opponent believes about the character. Anything that the opponent tells the character and the character does not refuse, or challenge is stored here. Information in the third layer is also easily replaced if something new comes up. This layer is effectively a memory of what the opponent has said in the past.

#### 4.5.2.2 Technical considerations

In our Afghan Poppy example, we ~~are using SpatialOS technology~~ [Imp19], ~~which is use SpatialOS technology~~ [Imp21a], a highly optimised distributed system for MMOGs. In SpatialOS, as in most online distributed systems, the processes run fast iterations over several agents. In SpatialOS the processes are called workers, and in our default proof of concept, we have the following worker setup:

- Director worker that runs the director tasks.
- Plot worker for the DPGE.
- A NPC worker that runs all the actors per iteration cycle.
- A player worker that ~~suns~~ runs the player tasks.

Games are run by constantly iterating over all agents that need to react or move as part of the game. The SpatialOS workers ~~that who~~ run the agents are stateless; each worker iterates over multiple agents ~~as is~~, common in distributed systems ~~and the workers are not designed to keep the state of individual components. Therefore~~. ~~The workers are stateless; therefore~~, everything needs to be read fresh from a persistent database and inserted or updated at the end of the iteration. In SpatialOS, this database is object-oriented and in the form of entities that the workers communicate ~~with~~ via messages. For every iteration, the actors read all data they require from the database and send it back at the end as a list of [submodel, vertex, state].

When they reason about the world, they instantiate the BNs that they have for the relevant character. Since the workers are stateless, the cost of reading and writing back, all relevant information is added to the time it takes to decide since it is an effective factor in replying sufficiently fast to a player.

#### 4.5.2.3 Initially populate the database

When the actors receive their initial knowledge, they ~~start by entering enter~~ all the evidence into their own confirmed knowledge base, ~~the~~. ~~The BN that~~ represents their character's view of the world; ~~the~~ the leftmost  $c_1$  vertex ~~in Figure 4.5.1~~ in Figure 4.5.1. Next, they update the network and read any additional propagated evidence.

They require an understanding of what  $c_1$  believes that the other characters think for the MAIDs. The actors can reason about it by looking at any instantiated vertices that are in role subnets of other characters. For example, if the UK destroyed the farmer's crop, then the vertex for the farmer's crop destroyed has propagated evidence. The actors, as seen ~~in Figure 4.5.1~~ in Figure 4.5.1 ~~replicates this evidence to~~:

They require an understanding of what  $c_1$  believes that the other characters think for the MAIDs. The actors can reason about it by looking at any instantiated vertices in the role subnets of other characters. For example, if the UK destroyed the farmer's crop, then the vertex for the farmer's crop destroyed has propagated evidence. The actors, as seen in Figure 4.5.1, replicates this evidence to:

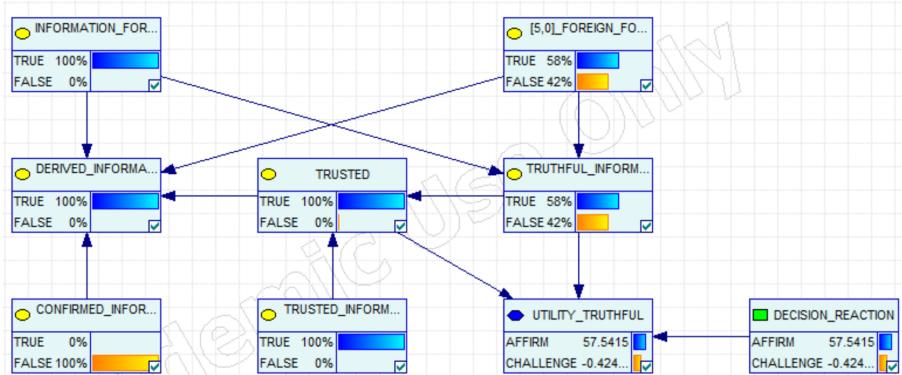
1.  $c_1 c_2$  their character's view of the opponent, what the officer thinks that the farmer knows.
2.  $c_1 c_2 c_1$ , the third view, what the officer thinks believes that the farmer thinks believes that the officer knows.

#### 4.5.2.4 Verifying information

Before adding information to their database, the actors  $a_1$  must evaluate how believable their character  $c_2$  would think thinks it is. Their reasoning uses a small BN with relevant information extracted from the other BNs<sup>3</sup>.

**Example 4.5.1** The OC says to the officer that the farmer is growing poppies. The incoming information is vertex growing poppies, state true, 5<sub>0</sub> see Figure 4.5.2 see Figure 4.5.2

**Figure 4.5.2**  $a_1$  is evaluating how  $c_1$  expects that  $c_2$  will react to 5<sub>0</sub>, displayed in the GeNIE UI [DSL07a].



First we define the conditional probability for the vertices in Figure 4.5.2 in Figure 4.5.2, and then we explain how to evaluate incoming data.

The *TRUTHFUL* vertex has the conditional probability defined in 4.5.2 in Table 4.5.2, it essentially informs how much the existing and incoming information matches.

<sup>3</sup> See Appendix ?? for the code in C++

**Table 4.5.2** Conditional probability of the *TRUTHFUL* vertex in Figure 4.5.2. TRUE(T), FALSE(F)

<i>INFORM</i>	<i>T</i>		<i>F</i>	
<i>EXISTING</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>
<i>TRUE</i>	1	0	0	1
<i>FALSE</i>	0	1	1	0

The *TRUSTED\_DERIVED* table, see Definition 4.5.3 see Table 4.5.3, aggregates how truthful and trusted the information is, to decide which information to trust.

**Table 4.5.3** Conditional probability of the *TRUSTED\_DERIVED* vertex in Figure 4.5.2. TRUE(T), FALSE(F)

<i>TRUTHFUL</i>	<i>T</i>		<i>F</i>	
<i>TRUSTED</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>
<i>TRUE</i>	1	1	0.99	0
<i>FALSE</i>	0	0	0.01	1

**Table 4.5.4** Conditional probability of the *DERIVED* vertex, in Figure 4.5.2, the table is divided in half to fit it on the page.

The first half

<i>TRUSTED</i>	<i>T</i>							
<i>INFORM</i>	<i>T</i>				<i>F</i>			
<i>EXISTS</i>	<i>T</i>		<i>F</i>		<i>T</i>		<i>F</i>	
<i>CONFIRM</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>
<i>TRUE</i>	1	1	1	1	0	0	0	0
<i>FALSE</i>	0	0	0	0	1	1	1	1

The second half

<i>TRUSTED</i>	<i>F</i>							
<i>INFORM</i>	<i>T</i>				<i>F</i>			
<i>EXISTS</i>	<i>T</i>		<i>F</i>		<i>T</i>		<i>F</i>	
<i>CONFIRM</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>	<i>T</i>	<i>F</i>
<i>TRUE</i>	1	1	0	1	1	0	0	0
<i>FALSE</i>	0	0	1	0	0	1	1	1

The *DERIVED* table aggregates all of this; see Definition 4.5.4; see Table 4.5.4.  $c_1$  believes information that comes from a trusted source or is truthful. The confirmed information ensures that the incoming data will result if there is no prior confirmed information, the incoming information will be the resultverified information. If there is prior confirmed information, then the prior information preceding statement is returned.

The utility has both truthful and trusted as parents in order to be able to to give utility value to each independently. For example, a neurotic character is less trusting and can have distorted views. While At the same time, an agreeable individual may be more willing to accept unreliable data than a disagreeable person. This is reflected in the utility values, see Definition 4.5.5; see Table 4.5.5. The utility rewards likely information and a trusted source but punishes untrusted source or unlikely information.

**Table 4.5.5** The initial value of the utility vertex in Figure 4.5.2.

AFFIRM(A), CHALLENGE(C), TRUE(T), FALSE(F)

TRUTHFUL	T		F		F	
TRUSTED	T	F	T	F		
DECISION	A	C	A	C	A	C
Value	100	0	0	0	0	-100

1. We enter existing data into the top-right top-right vertex, which is named by the vertex id and state index  $5_0$ .
2. New information is entered into the top-left top-left vertex *INFORMATION\_*.
3. The bottom left *CONFIRMED\_INFO* vertex is whether the existing information was confirmed. In this example, it is FALSE because the officer has no prior knowledge, so its FALSE.
4. We populate *TRUSTED\_INFORM* vertex with the characters trust in the opponent, in our example, the officer trusts the OC.

#### 4.5.3 Selecting actions

When an actor has a goal that is currently relevant, they will decide to act. They evaluate the relevance of the goal depending on whether they are in the same location as the player and whether their knowledge base has the required knowledge. We use Example ??-Example 4.5.2 to demonstrate how to select actions.

#### Example 4.5.2 (Vertices 4 and 5)

*In act one in the Afghan Poppy drama, the OC  $a_1c_1$  is giving gives the officer  $a_2c_2$  information about a Poppy farmer, see Section ?? see Section 4.2, which includes all the information*

that the OC has in the FOREIGN\_FORCE\_0 submodel, ~~see Figure 4.4.2. We use~~ see Figure 4.4.2. ~~In this example, we use we use~~ vertices 4 and 5 ~~in this example, to~~ see their initial state ~~in Figure 4.5.3~~ in Figure 4.5.3, and conditional probability ~~in Definition 4.5.6~~ in Table 4.5.6. The vertices represent the following knowledge:

1.  $4_0$ , the UK has destroyed a Poppy crop for this farmer.
2.  $4_1$ , the UK has not destroyed the crop.
3.  $5_0$ , the UK knows that the farmer is growing poppies.
4.  $5_1$ , the UK does not know if the farmer is growing poppies.

**Table 4.5.6** The conditional probability distribution for both 4 and 5 is identical

parent	$s_0$	$s_1$
$s_0$	0.7	0
$s_1$	0.3	1

The actor  $a_1$  filters out unviable actions that have a lower utility than the initial state, and, therefore, would not improve  $c_1$ 's situation, as follows:

1.  $a_1$  creates an action for all the states in vertices 4 and 5~~they are~~:  $[4_0, 4_1, 5_0, 5_1]$ .
2.  $a_1$  assigns a utility of 100 to all of the information goals, ~~for~~ for vertices 4 and 5~~they are~~:  $[4_1, 5_0]$ .
3.  $a_1$  assigns a utility of 1 to all the instantiated states as a reward for truthfulness, ~~for~~ for vertices 4 and 5~~they are~~:  $[4_1, 5_0]$ .
4.  $a_1$  evaluates the EU(no action) of the neutral state, the uninstantiated state, and assigns that as the minimum required value.

$a_1$  finds the initial max by calculating the EU as previously introduced, ~~see Definition ??~~ see Definition ??, and recapped here for this simple case, ~~see Definition ??~~ see Definition ???. Where for the current state  $s_i$ ; where N is the number of utilities, V is the number of chance vertices, and e is evidence.

**Definition 4.5.1 (The EU function adapted to one chance vertex per utility)**

*equation:expectedUtilityVanilla*

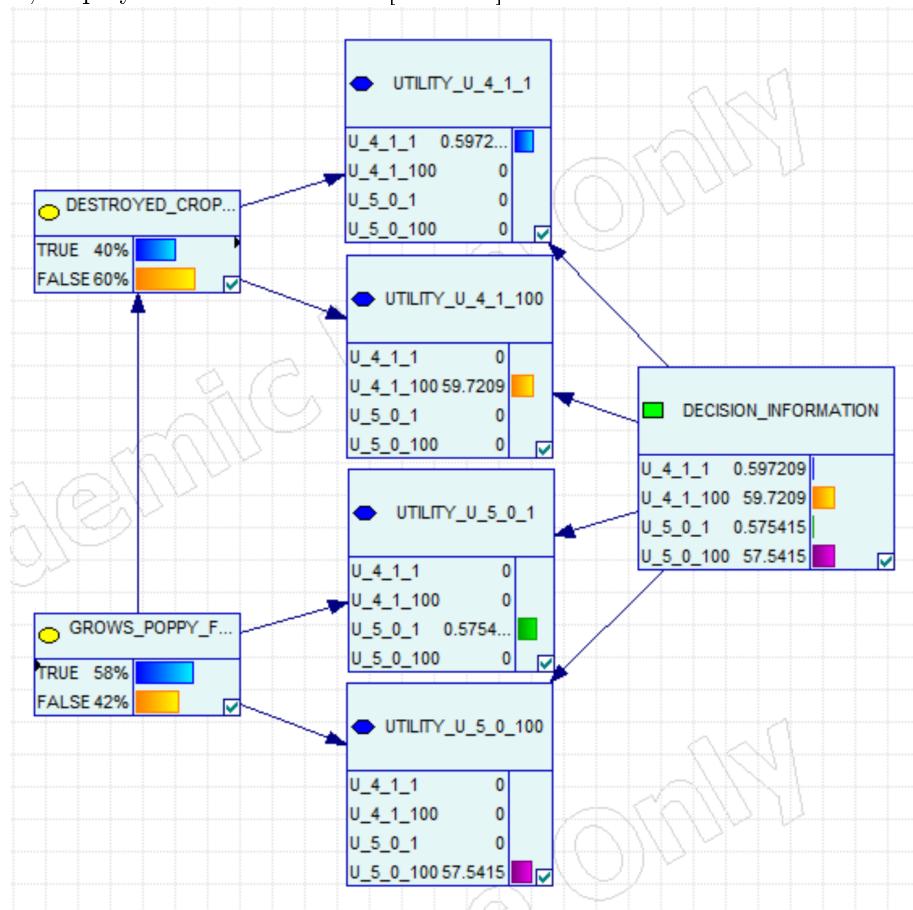
$$EU(s_i) = \sum_{n=1}^N u(V)P(V|s_i, e)$$

See Example ?? See Example 4.5.3 on how to calculate EU for the initial state

**Example 4.5.3 (Calculating EU(no action) with no state instantiated. )**

$EU(\text{no action})$	=	<del>0.597209</del> <u>0.60</u>	*	1
	+	<del>0.597209</del> <u>0.60</u>	*	100
	+	<del>0.575415</del> <u>0.58</u>	*	1
	+	<del>0.575415</del> <u>0.58</u>	*	100
$EU(\text{no action})$	=	<del>0.597209</del> <u>0.60</u>		
	+	<del>59.7209</del> <u>59.72</u>		
	+	<del>0.575415</del> <u>0.58</u>		
	+	<del>57.5415</del> <u>57.54</u>		
$EU(\text{no action})$	=	<del>118.435024</del> <u>118.44</u>		

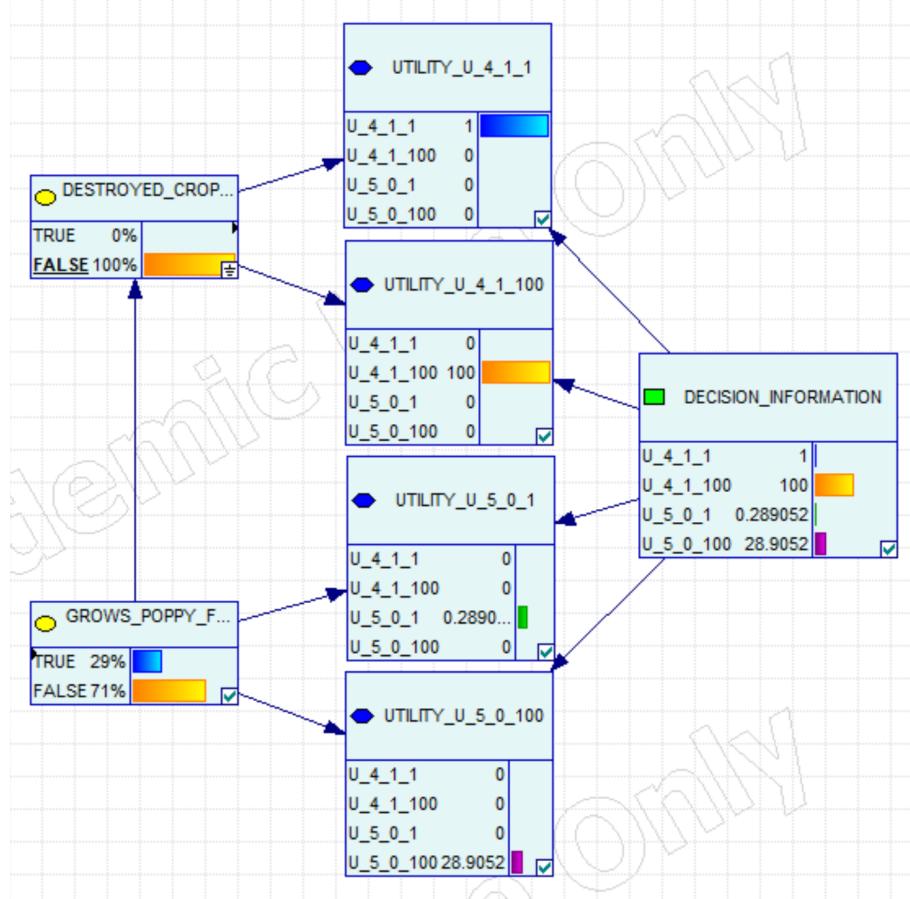
**Figure 4.5.3** Utility vertex for evaluating an action in an uninstantiated BN, displayed in the GeNIe UI [DSL07a].



The initial EU(no action) calculated in Example ?? in Example 4.5.3 is 118.44, which  $a_1$  sets as the minimum value to filter out all sentences that are unviable because they have an EU that is less than doing nothing at all. An example of an instantiated state and its utility values is in Figure 4.5.4 in Figure 4.5.4.  $a_1$  now uses the EU(no action) to eliminate unviable actions:

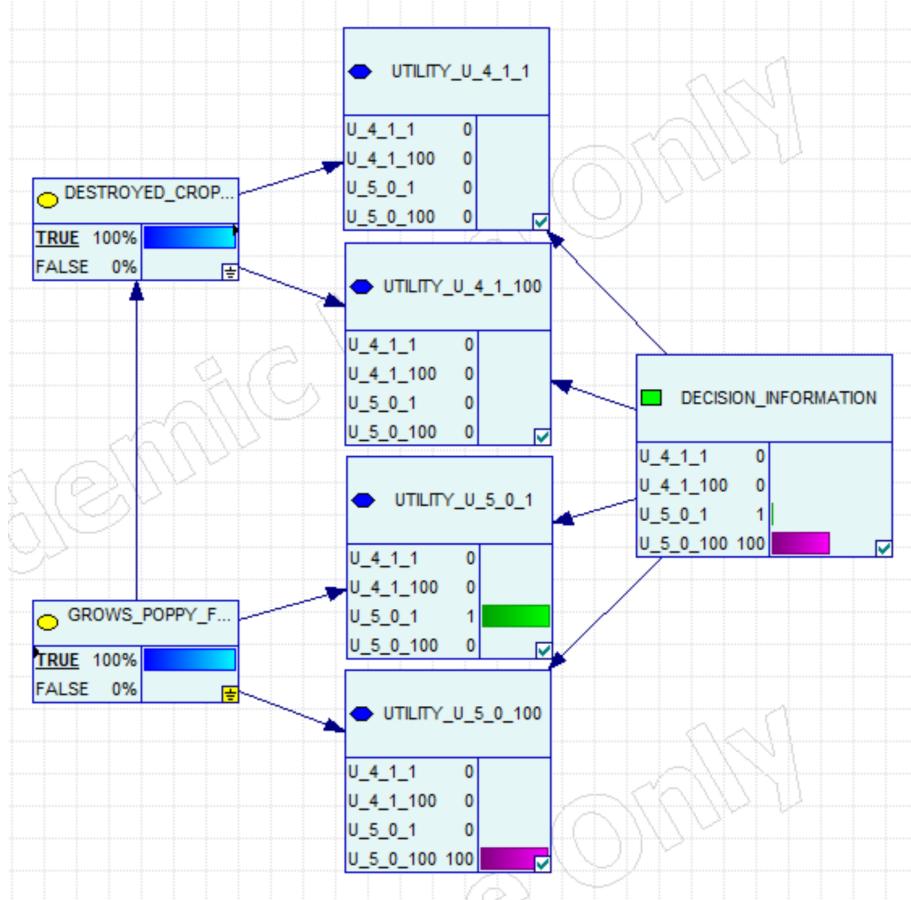
1.  $a_1$  instantiates a state,  $s_i, e$ .
2.  $a_1$  calculates the EU of this state,  $EU(s_i|s_i, e)$ .
3.  $a_1$  eliminates the state if the  $EU(s_i|s_i, e)$  is less than EU(no action).
4.  $a_1$  clears the evidence of  $s_i$ .
5.  $a_1$  repeats from step #1 for all the actions that were generated.

**Figure 4.5.4** Vertex 4 instantiated to  $4_1$  which is its goal condition, displayed in the GeNIE UI [DSL07a].



~~In Figure 4.5.5 the~~ In Figure 4.5.5 we remove  $\text{EU}((4_0)) = 101.00$ .  $4_0$  is, therefore, eliminated because it has an that since it is lower than the initial max of 118.44.  $4_0$  is neither a goal nor supporting a goal; it is, therefore, not yielding any increase in EU.

**Figure 4.5.5** The  $\text{EU}((4_0))$  is less than  $\text{EU}(\text{no action})$ , displayed in the GeNIE UI [DSL07a].



We show the EU for all for states in Example ?? in Example 4.5.4.

**Example 4.5.4 (States with EU less than  $\text{EU}(\text{no action})$  are eliminated.)**

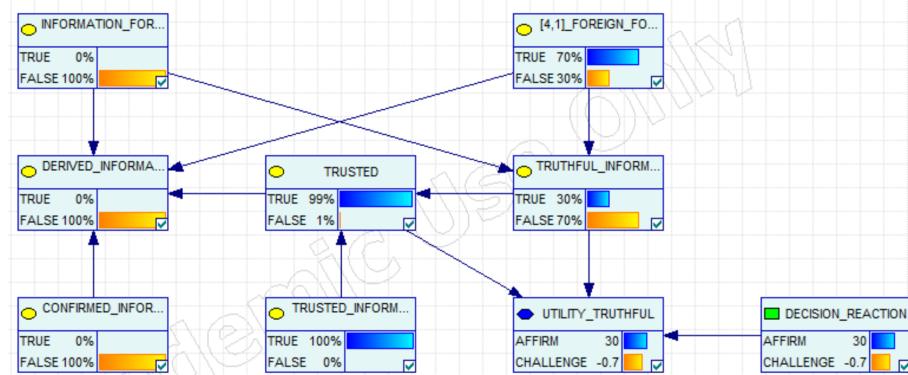
<i>DESTROYED_CROP</i>	$\text{EU}(4_0)$	101.00	$< 118.44$	
<i>DESTROYED_CROP</i>	$\text{EU}(4_1)$	130.19	$> 118.44$	<i>Included</i>
<i>GROWS_POPPY</i>	$\text{EU}(5_0)$	131.30	$> 118.44$	<i>Included</i>
<i>GROWS_POPPY</i>	$\text{EU}(5_1)$	101.00	$< 118.44$	

#### 4.5.4 Finding an optimal action

The Actor  $a_1$  has found a set of viable possible actions in the selection process in Section ?? in Section 4.5.3, and needs to evaluate how the opponent will respond. We continue with Example ?? Example 4.5.2. Now  $a_1$  evaluates each action for the opponents reaction, whether  $c_2$  will believe  $c_1$ . In Section ?? In Section 4.5.2.4, we explained how information is evaluated before being entered into a characters knowledge base. We now show how  $a_1$  uses this evaluation to evaluate how  $c_2$  will react to  $4_1$ , see Figure 4.5.6 see Figure 4.5.6.

and needs to evaluate how the opponent will respond. We continue with Example 4.5.2. Now,  $a_1$  considers each action for the opponent's reaction, whether  $c_2$  will believe  $c_1$ . In Section 4.5.2.4, we explained how to evaluate information before storing it in the characters knowledge base. We now show how  $a_1$  uses this evaluation to determine how  $c_2$  will react to  $4_1$ ; see Figure 4.5.6.

**Figure 4.5.6**  $a_1$  evaluating how  $c_1$  expects that  $c_2$  will react to  $4_1$ , given that  $c_2$  first received  $5_0$ , displayed in the GeNIe UI [DSL07a].



1.  $a_1$  takes the EU( $4_1$ ) values for the opponents opponent's response.
2.  $a_1$  adds them to the current EU, which is 130.19, see Example ??; see Example 4.5.5
3.  $a_1$  repeats this for  $5_0$ .
4.  $a_1$  collects the set of sentences with the maximum total EU as a list of vertex and state, in this case: [50]

**Example 4.5.5 (Stage two, EU is calculated for each state and states with reduced EU are eliminated.)**

$EU(4_1)$	=	130.19
	+	30
	+	-0.7
$EU(4_1)$	=	159.49

The actor  $a_1$  now updates  $c_1$ 's knowledge base as follows.

1.  $a_1$  adds  $[5_0]$  to  $c_1c_2$ 's knowledge base to reflect what  $c_1$  believes that  $c_2$  knows.
2.  $a_1$  adds  $[5_0]$  to  $c_1c_2c_1$ 's knowledge base to reflect what  $c_1$  believes that  $c_2$  believes that  $c_1$  knows.
3.  $a_1$  instantiates the BN with the evidence that was added to  $c_1c_2$ 's knowledge base, updates the BN and gathers any propagated evidence to  $c_1c_2$ 's knowledge base.
4.  $a_1$  instantiates the BN with the evidence that was added to  $c_1c_2c_1$ 's knowledge base, updates the BN and gathers any propagated evidence to  $c_1c_2c_1$ 's knowledge base.
5.  $a_1$  sends  $[5_0]$  to  $c_2$ .

Step 3 and 4 are ~~important~~ essential for subsequent reasoning. In some cases, new evidence will cause related vertices to become instantiated. For Example  $4_0$  will cause  $[5_0]$ ,  $[4_0]$  will cause  $[5_0]$  to be instantiated because the UK cannot destroy the Poppy crop if they ~~have no knowledge of~~ do not know it. For the actor to evaluate if there are relevant goals, the actor needs an updated knowledge base. For Example, when the officer has all the information required, the officer can report back to the OC. The actor knows this by comparing its goals checking to the knowledge base.

The officer,  $c_2$ , receives  $[5_0]$ . ~~The, and the~~ actor,  $a_2$ , starts by evaluating

$\vdots$

1. ~~Evaluates~~ whether  $c_2$  should trust and believe the information.  ~~$a_2$  applies the following steps consecutively for each item received.  $a_2$  gets the same result as  $a_1$  because  $a_1$  assumption that  $c_2$  has no prior knowledge is accurate.  $a_2$  trusts the and considers the information to be a confirmed information, therefore, adds the information to~~
2. ~~Receives identical result as  $a_1$  since they have identical assumptions.~~
3. ~~Trusts the OC and confirms the information~~
4. ~~Adds it to~~ all three views of the knowledge base ~~as described in Section ??~~

After  $c_2$  processes  $5_0$ , as described above, the knowledge base is updated and as a result the  $P(4_1)$  is reduced because now it is in fact the  $P(4_1|5_0)$ . As seen in Figure 4.5.6 in Figure 4.5.6, the  $P(4_1)$  has fallen from 60%, shown in Figure 4.5.3 in Figure 4.5.3 to 30%, making it less believable.

#### 4.5.4.1 Asking a question

We will use [Example ??](#) Example 4.5.6, to explain how to ask a question.

##### Example 4.5.6 (Giving aid to the farmer)

*In act II, the officer starts to carry out ~~the orders received in his~~ ~~orders from~~ act I. ~~The orders are~~; to visit a nearby farmer and determine whether the farmer is growing poppies. The army is trying to reduce Opium farming and offers aid to those who are not growing poppies or are willing to stop. The farmer has an incentive to lie about his Opium farming ~~in order to gain aid to gain support~~.*

Actor  $a_2$ 's goal is to determine whether the farmer  $c_3$  is growing poppies. From this goal the  $a_2$  can generate relevant questions by finding the parents and grand parents of the aid vertex. Based on the aid vertex ancestors,  $a_2$  has three things to ask about; is  $c_3$  growing poppies, what is he growing on his farm and will he grow Poppy in the future. The officer asks about the Poppy, whether he is growing poppies and what he is growing on each farm.

Actor  $a_2$ 's goal is to determine whether the farmer  $c_3$  is growing poppies. From this goal, the  $a_2$  can generate relevant questions by finding the aid vertex's parents and grandparents, which yields three questions for  $c_3$ , the farmer:

1. Is the farmer growing poppies?
2. What is the farmer growing on each of his farms?
3. Will the farmer grow Poppy in the future?

Extraversion affects how many of the available options the character uses. In our example, the officer has high extraversion and chooses all three questions.

#### 4.5.4.2 Replying to a question

An essential part of drama is conflict and deception; everything is not as it first appears. It is also an essential part of games, to have the player work at solving a problem or a mystery. Therefore, characters do not always tell the truth<sup>3</sup>.

Continuing with [Example ??](#) Example 4.5.6, we explain how  $c_3$  can respond given its knowledge base and that  $c_3$  is growing poppies, see [Example ??](#) see Example 4.5.7 for  $c_3$ 's crop per farm.

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<sup>3</sup> See Appendix ?? for the C++ code

**Example 4.5.7 ( $c_3$ 's crop on each farm, where  $v_0 = \text{Poppy}$  and  $v_1$  is Grain.)**

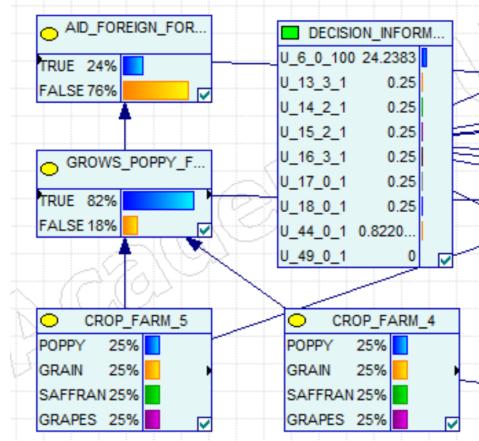
13 <sub>1</sub>	GRAIN
14 <sub>1</sub>	GRAIN
15 <sub>0</sub>	POPPY
16 <sub>0</sub>	POPPY
17 <sub>0</sub>	POPPY
18 <sub>1</sub>	GRAIN

The  $a_3$  starts by selecting viable actions, as described in Section 4.5.3.  $a_3$  has the goal of getting aid  $v_s = 6_0$  with a value of 100. vertex 44 is whether he is growing poppies and vertex 49 is whether he intends to grow Poppy in the future.

There are 3 actions that have a max, [13<sub>1</sub>, 14<sub>1</sub>, 18<sub>1</sub>], seen Example 7 see Example 4.5.8, These are the three farms where  $c_3$  is growing grain and not Poppy. He could now send all of these, but he does not have a high extrovert trait and so he picks one of these and sends it.

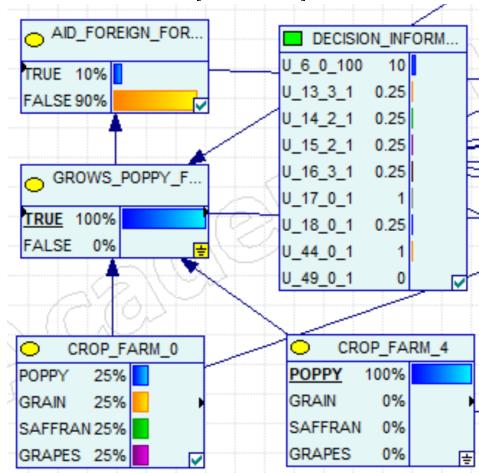
Initially  $c_3$  loses EU by saying that he is growing poppies, see 4.5.8 see Figure 4.5.8, compared with unset state in 4.5.7 in Figure 4.5.7, and, therefore, does not select it as a viable action initially. He gains far more from revealing other farms where he grows something else than Poppy, for example Grapes as seen in Figure 4.5.9 in Figure 4.5.9

**Figure 4.5.7** The EU(no action) for  $c_3$  is circa 25, displayed in the GeNIE UI [DSL07a].

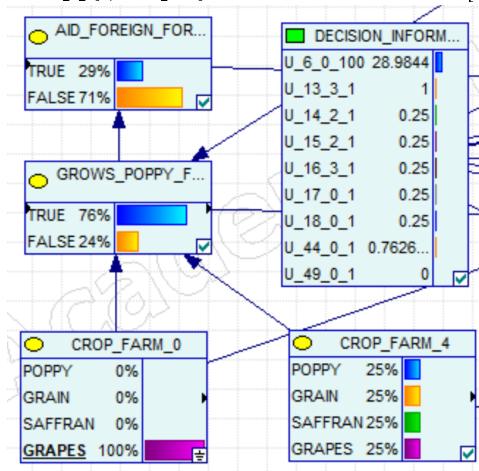


**Example 4.5.8 ( $a_3$  eliminates any reply that is less than the EU(no action) = 45.315820,  $a_3$  considers how  $c_2$  will respond and adds it to the EU.)**

**Figure 4.5.8** Initially  $c_3$  loses from saying he is growing poppies, EU = 13.25, displayed in the GeNIe UI [DSL07a].



**Figure 4.5.9** He gains far more from revealing other farms where he grows something else than Poppy, displayed in the GeNIe UI [DSL07a].



$v$	$s$	$Goal$	$Value$	$Included$	$Opponent$	$EU$
13	0	0	<del>36.950000</del> <u>36.95</u>			
13	1	1	<del>48.771094</del> <u>48.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>35.896094</del> <u>35.9</u>
13	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
13	3	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
14	0	0	<del>36.950000</del> <u>36.95</u>			
14	1	1	<del>48.771094</del> <u>48.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>35.896094</del> <u>35.9</u>
14	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
14	3	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
15	0	1	<del>37.950000</del> <u>37.95</u>			
15	1	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
15	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
15	3	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
16	0	1	<del>37.950000</del> <u>37.95</u>			
16	1	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
16	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
16	3	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
17	0	1	<del>37.950000</del> <u>37.95</u>			
17	1	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
17	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
17	3	0	<del>36.950000</del> <u>36.95</u>			
18	0	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
18	1	1	<del>48.771094</del> <u>48.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>35.896094</del> <u>35.9</u>
18	2	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
18	3	0	<del>47.771094</del> <u>47.77</u>	$> 45.315820 \geq 45.32$	<del>-12.875000</del> <u>-12.88</u>	<del>34.896094</del> <u>34.9</u>
44	0	1	<del>37.308257</del> <u>37.31</u>			
44	1	0	<del>82.300000</del> <u>82.30</u>	$> 45.315820 \geq 45.32$	<del>-50.500000</del> <u>-50.50</u>	<del>31.800000</del> <u>31.8</u>
49	0	1	<del>31.443625</del> <u>31.44</u>			
49	1	0	<del>68.815706</del> <u>68.82</u>	$> 45.315820 \geq 45.32$	<del>-50.500000</del> <u>-50.50</u>	<del>18.315706</del> <u>18.3</u>

$a_3$  sends  $14_1$  to the  $a_2$ , and then adds this answer to  $c_3$ 's knowledge base as described in Section ?? in Section 4.5.2. When  $a_2$  receives the response and evaluates it, then  $a_2$  gets a negative evaluation which means that  $c_2$  wants to challenge the reply.

To challenge information received  $a_2$  needs to find some argument to challenge it with. To do this  $a_2$  looks at all parent vertices for any evidence and gathers all vertices that have evidence. The traits, Openness and conscientiousness affect this reasoning, the higher a character is in either trait the larger part of the BN it can search.  $a_2$  finds one vertex with evidence,  $c_2$  knows that  $c_3$  is growing poppies because  $c_1$  informed  $c_2$  of this in act one. Next  $a_2$  starts to go through the same steps as before and calculates the EU(no action), which is 75.000000. Then  $a_2$  calculates EU for  $44_0$ . the goals

are the other crop types, [see example ??](#) see Example 4.5.9. The  $\text{EU}(44_0|44_0)$  is 150.018510 which is greater than 76.804277. So  $c_2$  will gain by revealing it to the  $c_3$ . Then  $a_2$  evaluates the  $c_3$  response which is 73.214233. The final evaluation is, therefore 150.018510.

**Example 4.5.9 ( $a_2$ 's goals when challenging  $c_3$ )**

$v$	$s$	$Goals$
14 <sub>0</sub>	100	
14 <sub>2</sub>	100	
14 <sub>3</sub>	100	

$a_2$  has now determined that there is a gain by saying that  $c_3$  grows Poppy, so  $a_2$  marks the sentence, 14<sub>0</sub>, from  $c_3$  with challenge tag and the 44<sub>0</sub> with an AFFIRM tag.

When  $c_3$  receives these,  $a_3$  removes the challenged item from the databases.  $a_3$  evaluates the 44<sub>0</sub> and finds it believable.  $a_2$  adds it to  $c_2$ 's knowledge base.

$a_2$  marks this as resolves and sends the director an update, but  $a_2$  still has questions regarding what  $c_3$  is growing on his farms and whether  $c_3$  will continue to grow Poppy. So  $a_2$  follows up with questions about what  $c_3$  is growing on the farms.

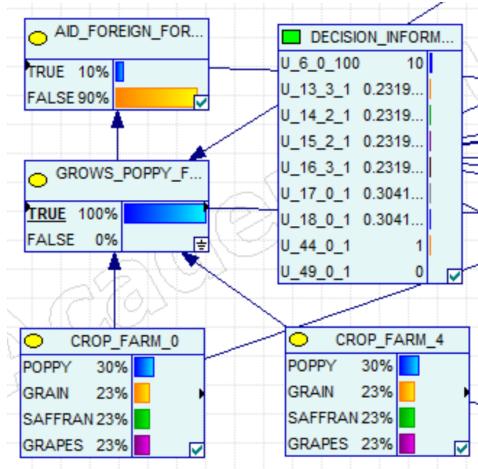
**Example 4.5.10 (Stage two and three after  $c_2$  has told him he knows of his Poppy farming, the  $\text{EU}(\text{no action})$  is 35.61)**

$v$	$s$	$Goal$	$Value$	$Included$	$Opponent$	$EU$
13	0	0	<del>35.250000</del> <u>35.25</u>			
13	1	1	<del>36.431498</del> <u>36.43</u>	$> 35.608257 \geq 35.61$	<del>-15.590437</del> <u>-15.59</u>	<del>20.841061</del> <u>20.8</u>
13	2	0	<del>35.431498</del> <u>35.43</u>			
13	3	0	<del>35.431498</del> <u>35.43</u>			
14	0	0	<del>35.250000</del> <u>35.25</u>			
14	1	1	<del>36.431498</del> <u>36.43</u>	$> 35.608257 \geq 35.61$	<del>-15.590437</del> <u>-15.59</u>	<del>20.841061</del> <u>20.8</u>
14	2	0	<del>35.431498</del> <u>35.43</u>			
14	3	0	<del>35.431498</del> <u>35.43</u>			
15	0	1	<del>36.250000</del> <u>36.25</u>	$> 35.608257 \geq 35.61$	<del>-4.728690</del> <u>-4.73</u>	<del>31.521310</del> <u>31.5</u>
15	1	0	<del>35.327785</del> <u>35.33</u>			
15	2	0	<del>35.327785</del> <u>35.33</u>			
15	3	0	<del>35.327785</del> <u>35.33</u>			
16	0	1	<del>36.250000</del> <u>36.25</u>	$> 35.608257 \geq 35.61$	<del>-4.728690</del> <u>-4.73</u>	<del>31.521310</del> <u>31.5</u>
16	1	0	<del>35.327785</del> <u>35.33</u>			
16	2	0	<del>35.327785</del> <u>35.33</u>			
16	3	0	<del>35.327785</del> <u>35.33</u>			
17	0	1	<del>36.250000</del> <u>36.25</u>	$> 35.608257 \geq 35.61$	<del>-4.728690</del> <u>-4.73</u>	<del>31.521310</del> <u>31.5</u>
17	1	0	<del>35.327785</del> <u>35.33</u>			
17	2	0	<del>35.327785</del> <u>35.33</u>			
17	3	0	<del>35.327785</del> <u>35.33</u>			
18	0	0	<del>35.250000</del> <u>35.25</u>			
18	1	1	<del>36.431498</del> <u>36.43</u>	$> 35.608257 \geq 35.61$	<del>-15.590437</del> <u>-15.59</u>	<del>20.841061</del> <u>20.8</u>
18	2	0	<del>35.431498</del> <u>35.43</u>			
18	3	0	<del>35.431498</del> <u>35.43</u>			

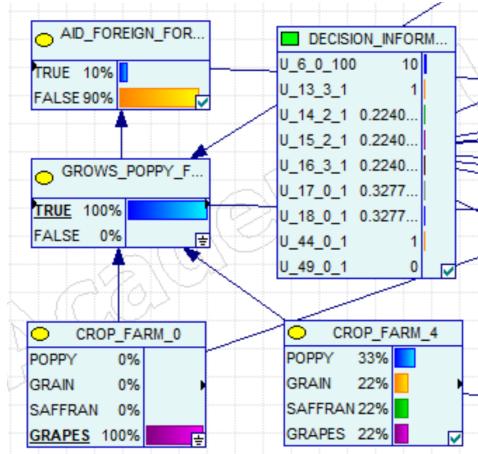
The second time that  $c_2$  asks what crop  $c_3$  is growing,  $c_3$  has  $44_0$  (Growing Poppy True) instantiated in all three knowledge models;  $c_3$ ,  $c_3c_2$ , and  $c_3c_2c_3$ . When  $a_3$  starts the reasoning the numbers are different from before, see Example ??see Example 4.5.10. Now it has become advantageous to admit that he is growing poppies to be truthful. The connection between the crops and the AID vertices is a serial connection and, therefore, evidence on the grows Poppy vertex, see 4.5.10see Figure 4.5.10, results in a between the crop vertices and the AID. Evidence give to the crop vertices are therefore no longer affecting the AID utility. In fact, now there is a somewhat higher EU for admitting to a Poppy farm because of the truthful goal. Furthermore, there is a convergent connection between the crops. Before any evidence on grows Poppy true, then evidence to one crop did not affect the other crops, but after the evidence is entered then evidence to on ecrop can affect the others. For example, evidence to Saffran wil increase the probability off Poppy in other vertices since it must be true that one of the crops is Poppy, see 4.5.11see Figure 4.5.11. Conversely if the grows Poppy vertex is

instantiated to false then there is no longer any reward for saying Poppy, since it cannot be true that any of the crops is Poppy. In fact it is not possible to instantiate it, see 4.5.12 see Figure 4.5.12.

**Figure 4.5.10** Instantiating a state on vertex 44 will cause a , displayed in the GeNIe UI [DSL07a].



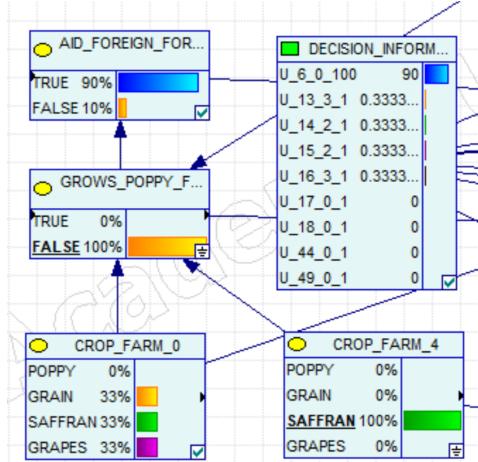
**Figure 4.5.11** Setting crop as Saffran will affect the belief of what is growing in other farms, displayed in the GeNIe UI [DSL07a].



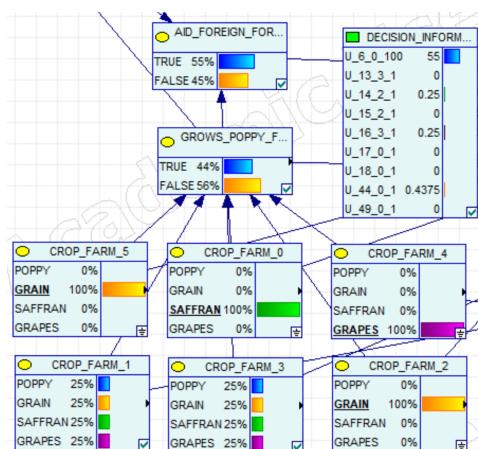
#### 4.5.4.3 Deception

Another scenario could evolve if  $c_2$  does not know any information to use to challenge  $c_3$  with.  $c_2$  will then affirm the knowledge to  $c_3$ , and add it to the  $c_2c_3$ , and  $c_2c_3c_2$  knowledge bases since he has no reason not too. The actor will not add it to the confirmed knowledge,  $c_2$ .  $c_2$  will start to believe  $c_3$  more and more as the knowledge base is increasingly populated with

**Figure 4.5.12** Saying that the crop is Poppy is no longer possible because  $c_{41}$  is instantiated, displayed in the GeNIE UI [DSL07a].



**Figure 4.5.13** By choosing to talk about only non Poppy crops,  $c_3$  can make it seem unlikely that he is growing poppies, displayed in the GeNIE UI [DSL07a].



evidence from  $c_3$ .  $c_3$  doesn't even need to lie, if he chooses to only discuss the non Poppy crops then the probability of growing poppies vertex changes from probably true to probably false, [see 4.5.13](#) see Figure 4.5.13. This continues until saying "I'm not growing poppies" becomes the optimal sentence and  $c_2$  has no reason to challenge it. For example, in Figure 4.5.14 is a screenshot of a test run where  $a_3$  decides to deceive  $c_2$ . In this particular run  $c_3$  has the crops [in Example ??](#) in Example 4.5.11.

**Example 4.5.11 ( $c_3$ 's crop on each farm when deceiving  $c_2$ .)**

13 <sub>1</sub>	GRAIN
14 <sub>3</sub>	GRAPES
15 <sub>0</sub>	POPPY
16 <sub>0</sub>	POPPY
17 <sub>1</sub>	GRAIN
18 <sub>3</sub>	GRAPES

**Figure 4.5.14** A screenshot of the console showing the farmer informing of the non poppy farms.

```
[improbable.bridge.v3.async.workerlogging.WorkerLogMessageHandler] [NPCWorker0:] [10][FARMER][Send Update Knowledge]
[improbable.bridge.v3.async.workerlogging.WorkerLogMessageHandler] [NPCWorker0:] [10][FARMER][
#####
[Send information] [1] speechType [INFORM] aimType [INFORM]
[0], [FARM], [CROP], [GRAIN], [INFORM]
[1], [FARM], [CROP], [GRAPES], [INFORM]
[4], [FARM], [CROP], [GRAIN], [INFORM]
[5], [FARM], [CROP], [GRAPES], [INFORM]
#####
1
```

$a_2$  accepts those statements by affirming them and adds them to [in Figure 4.5.15](#) in Figure 4.5.15

**Figure 4.5.15** A screenshot of the console showing the officer affirming the non poppy farms.

```
[improbable.bridge.v3.async.workerlogging.WorkerLogMessageHandler] [PlayerWorker0:] [1][OFFICER][Send Update Knowledge]
[improbable.bridge.v3.async.workerlogging.WorkerLogMessageHandler] [PlayerWorker0:] [1][OFFICER][
#####
[Respond To Information] [10] speechType [AFFIRM] aimType [INFORM]
[0], [FARM], [CROP], [GRAIN], [AFFIRM]
[1], [FARM], [CROP], [GRAPES], [AFFIRM]
[4], [FARM], [CROP], [GRAIN], [AFFIRM]
[5], [FARM], [CROP], [GRAPES], [AFFIRM]
#####
1
```

[In Figures 4.5.14, 4.5.15](#) In Figure 4.5.14 [see Figure 4.5.15](#) the numbers to the far left (0, 1, 4, 5) refer to the number of the *FARM* subnet while the vertex identifier [in Example ??](#) in Example 4.5.11 refers to the identity of the vertex within the BN<sup>3</sup>.

<sup>3</sup> [An XML of the knowledge base for all three is in Appendix ??](#)

#### 4.5.4.4 Giving goals to other actors

When the OC  $a_1$  in act I gives the officer  $c_2$  orders then  $a_2$  receives goals that are assigned to  $c_2$  and aimed at the farmer  $c_3$ .  $a_2$  first needs to translate these into goals for  $c_2$ . The goal from  $a_1 =$  is sent to the actor as other messages, it has the type *ORDER* and applies to *FARMER* and type *GAIN\_INFORMATION* the sentence part is (subnet number, subnet, vertex, state) = (0, *REASONING*, *AID*, *UNKNOWN*). From this information the  $a_2$  understands that it needs to ask  $c_3$  questions that will determine the state of the *AID* vertex. To asks questions  $a_2$  generates questions as described previously [in Section ??](#) in Section 4.5.3.  $a_2$  then proceeds to ask them as described [in Section ??](#) in Section 4.5.4.1.

This process of creating goals for themselves and ask other actors to create goals is used by the actors whenever they need to know what to do to satisfy a goal.

When  $a_2$  creates these goals, it marks the goals with action *ORDER* and role *OFFICER\_COMMANDING* to be able to create the goal of informing the officer when the order has been carried out.

#### 4.5.4.5 Response to a Request

[In Section ??](#) In Section 4.5.4.3,  $c_2$  can be deceived by  $c_3$  and may end by walking away believing that  $c_3$  is not growing poppies. If it is a drama goal for  $c_2$  to learn that  $c_3$  is growing poppies then it could be an issue that  $c_2$  is unsuccessful in extracting the information.

We resolve this problem by having the actors reaching out to each other for aid, and we call this the duality of drama and character goals. The actors will always prioritise character goals and stay in character. When they realise that they are acting contrary to a drama goal, then they will ask another actor to carry out the drama goal.

In our example above  $a_3$  realises that  $c_3$  is contradicting a drama goal when  $c_2$  affirms that  $c_3$  is not growing poppies, given that the drama goal is for  $c_2$  to learn that  $c_3$  is growing poppies.  $a_3$  then asks another actor to assist. To do this the  $a_3$  will send a request similar to the order [in Section ??](#) in Section 4.5.4.4 except that it is marked as *ASSIST* rather than *ORDER*. The receiving actor then knows to create goals from this message.

$a_3$  will try to pick an actor that would be better able to assist, in our example, someone that already knows of the poppies. For example, a journalist that was asking questions or a merchant that travels the country to sell their merchandise.  $a_3$  knows this by looking at their knowledge base look for all the actors they have in their knowledge base whether they believe that they know vertex (growing poppy = true). If they do not find anyone that they believe has this information, then they pick one actor at random. They exclude themselves and their current opponent from the set of possible

actors to assist.

## 4.6 Players

In the DED the player is handled as any other actor, as the actors. The director passes schemas with goals to the player as well as the other actors and to the players as if they were an actor; it is not aware of any difference when selecting schemas or when assigning initial knowledge base. The director does know that the player has a specific role according to an initial configuration and it will assign that role to the player as part of assigning roles to the actors. After the initial role assignment, the director has the player in its list of actors and has no further exception in handling this "actor", i.e. the player handles the player the same as the actors.

Similarly, for the actors, when they are interacting with other actors, they use a map of identifiers and roles,  $(map < id, role >)$ , where both they and the player is listed along with other actors. They have information off who the player is, i.e. the player identifier but it is not used in their reasoning in that map in the same way as the actors are. For example, in Figure 4.6.1 where in Figure 4.6.1, which shows the world view of the farmer NPC<sub>10</sub>, the player is listed with, the player's listing is identical to other NPCs. At this stage in this particular drama, the farmer only knows of the officer and the OC.

The player receives goals as the other actors, both character and drama goals, and the player also has the same blueprint of the world knowledge that the other actors have. Additionally, like the other actors, the player receives the initial knowledge pertaining to the player's role similar to the other actors base from the director. The main difference between player and NPCs is that the player makes players make decisions for their role rather than character instead of the reasoning algorithm that the NPCs actors use.

An interface for the player has not been built for our SpatialOS implementation, but it has been implemented for other applications that we have tested. We discuss these in Chapter 5.

SELECTED ENTITIES: 11

- ▶ NPC for director 6 3 [ ] delete
- 18 [ ] delete
- 9 [ ] delete
- 11 [ ] delete
- ▶ Director for player 1 1 [ ] delete
- ▶ PlotWorker-worker 1 [ ] delete
- ▶ PlayerWorker-worker 1 [ ] delete
- ▶ Drama for director 6 1 [ ] delete
- ▶ Plot for director 6 1 [ ] delete
- ▶ DirectorWorker-worker 1 [ ] delete
- ▶ NPCWorker-worker 1 [ ] delete
- ▶ player 1 [ ] delete

DETAILS: 10 (NPC FOR DIRECTOR 6)

- ▶ npc\_ids Array(3)
  - ▼ [0]
    - key 1
    - value 1 (Value1OFFICER)
  - ▼ [1]
    - key 9
    - value 3 (Value3OFFICER\_COMMANDING)
  - ▼ [2]
    - key 10
    - value 1 (Value1FARMER)
- player\_id 1
- plot\_id 7
- role 1 (Value1FARMER)
- ▶ submodel\_group\_map Array(1)
- ▶ improbable
- ▶ EntityAcl
- ▶ Metadata

Figure 4.6.1 The player is listed with the NPCs in the farmer's world view.

The screenshot shows a game development interface with two main sections: 'SELECTED ENTITIES: 11' and 'DETAILS: 10 (NPC FOR DIRECTOR 6)'.

**SELECTED ENTITIES: 11**

- NPC for director 6
  - 10
  - 9
  - 11
- Director for player 1
- PlotWorker-worker
- PlayerWorker-worker
- Drama for director 6
- Plot for director 6
- DirectorWorker-worker
- NPCWorker-worker
- player
  - 1

**DETAILS: 10 (NPC FOR DIRECTOR 6)**

- npc\_ids Array(3)
  - [0]
    - key 1
    - value 2 (Value2OFFICER)
  - [1]
    - key 9
    - value 3 (Value3OFFICERCOMMANDING)
  - [2]
    - key 10
    - value 1 (Value1FARMER)
- player\_id 1
- plot\_id 7
- role 1 (Value1FARMER)
- submodel\_group\_map Array(1)
- improbable
- EntityAcl
- Metadata

## 4.7 Directed emergence

We extend improv techniques by having the agents (*DED actors*) assist each other within each scene so that they are free to play out their roles and fulfil their character goals. Because agents can pass messages between themselves (where *human* actors cannot), the agents can contradict each other without this being a blocking action and can pass drama goals between themselves as required. While the uses , the actors are still Coherent in that they only choose causally related actions and that help them in carrying out their character goals. They only choose rational actions, i.e. the optimal action.

Since , and the , is for the games, it is imperative to offer the player the highest level of interaction. The player should be the protagonist and sit in the pilot seat. We facilitate a high level of interactivity and free play in the ; by having the player solely interact with the scene and the actors rather than the director. The director is ignorant of the player in everything except which goals it assigns them. The director assigns roles to the players equal to any other actor. The player receives goals like the actors and their , and they generate similar to the actors. The only difference is that the player can choose which action to take. The director never overrules the actors, and there is no intervention to block the player. The facilitates a very high level of interaction between the actors and player. This enables a continuous emergent logical dialogue that is unparalleled in other systems in the field, which is essential because it facilitates a truly emergent , i.e. a that emerges from player and actors interactions rather than following a pre-scribed or generated path.

## 4.8 Creating a new drama

The DED's novel approach calls for an alternative means of creating a new drama scenario than that of authoring storylines, branching stories of episodes. Instead the main task is to structure the BN, pace the drama, design characters, and to design a user interface.

### 4.8.1 Bayesian Network

As introduced in [Section 2.3.1.6](#), [2.4.2 sections ??, ??](#), and 4.5, the BN must be causally structured. It does not call for strict causality, but rather that the direction is from perceived cause to perceived effect. The algorithms rely on this structure for the actors reasoning to produce what can be perceived as coherent. For [Example, in Section ?? example](#), in Section 4.5.4.2 where the officers uses prior knowledge to challenge what the farmer just said. The officer does this by searching related vertices for evidence that will help in proving that the farmer is not telling the truth. He was able to verify that the evidence could help him by evaluating the expected utility. If the BN is

not causally constructed but is connected by correlation ~~then~~, this reasoning could go badly. The officer might, for example, say that there is a drought, so he is probably growing poppies. That does not appear coherent to us, we find it to be improbable that poppies ~~grows~~ grow well in a drought, but in Afghanistan there is a high rate of both drought and poppies growing and there is, therefore, a likely correlation. We realise that they are hardly ~~occurring simultaneously~~co-occurring.

Similarly ~~in Section ??,~~ in Section 4.5.4.3, where the farmer manages to deceive the officer by first talking about the farms where he is growing something else than poppies. ~~Gradually the~~ The probability that the farmer is growing poppies is gradually reduced in the officers reasoning, with each information that the officer accepts. We rely on the causal structure and the manner in which works to accomplish this, ~~see Section 2.3.1.10 see Section ??~~ for introduction to .

In this thesis, all the BN's are manually structured as a proof of concept. Manual construction is not sustainable and cannot meet the needs of high-end simulations and games. Instead, we are directing our future research efforts to create automated procedures that create the networks from ~~real world data to use in real-world data to~~ modelling training simulations. There is good quality research work to build on, the networks used for medical diagnostic tools are also causally structured, for example, in the words of B. Liew & Co:

*The present study is the first to apply BN modelling to understand the causal mechanisms of recovery in whiplash associative disorders. In doing so, it is anticipated that such analytical methods could increase the precision of treatment in individuals with chronic whiplash associative disorders.*

– (FA: we added emphasis for clarity) [LSP<sup>+</sup>19, p. 1]

#### 4.8.2 Pacing the drama

~~The~~ As explained in Section 4.3.1, the drama is divided into acts and to move between acts all goals for the act need to be fulfilled. The author can use this to guide the drama to emerge along the dramatic arc. There can be as many acts as the author needs. The author defines each drama goal and for which act and schemas it belongs. This is the authors way of guiding the emergence of the drama and can increase the complexity gradually by increasing the number or difficulty of drama goals and character goals. A schema can only trigger in its designated act. Therefore the author designates schemas to the acts that they should trigger in. In a 5 act drama then introductory schemas are designated for act 1 and 2. Schemas that build tension are designated to act 3 and 4, and Schemas for the climax, i.e to reveal a murderer to act 4 and the resolution schemas to act 5.

**Roles** Each actor has at least one role that ~~is assigned by the director the~~ ~~director assigns~~ at the start, and this role decides what initial knowledge the actor receives. In our Afghan poppy scenario, the main roles are officer, OC and farmer. There are also side-roles: merchant, journalist, smuggler, and terrorist. Each of these roles will need some accompanying characteristics or traits to identify them; for example, the journalist is ~~an~~ extrovert and high in openness. There can also be lesser roles ~~that can be~~ assigned on the fly as needed by the director, for example, a brother or a husband in family affairs. Also ~~in crimes~~, there can be ~~a victim and a culprit~~ roles. The merchant could for example, also be a victim of a theft.

**Goals** schemas contain all drama and character goals that the actors and player use. ~~The~~ ~~the~~ goals map to specific vertex and state in the BN. ~~Unorder to To~~ To create more exciting drama, it is good to have together drama goals and character goals that conflict and cause the characters to attempt deception and ~~to~~ pass their drama goals to other actors. This is what causes ~~greater more significant~~ conflict and suspense and increases the interestingness [SER16] of the drama.

#### 4.8.3 Author speech

similar to constructing the BNs we have manually authored sentences to match the states in the BN, ~~but this should be done from natural text via natural language processing~~.

### 4.9 Comparison to related and former work

~~In this section we compare the to related work, we start by discussing how it compares with narrative, see Section ??, and drama, see Section ??, followed by how compatible it is with games in Section ??.~~ We compare the to former work, in Section ??, noting the similarities and listing what the delivering that was not part of former work and how it extends existing technology with more advanced algorithms. Finally we compare the to related work in Section ??.

#### 4.9.1 ~~Narrative~~

~~As we discussed in Section 2.2.1, a narrative is to recount events and is essentially not interactive. A narrative has spectators that are not able to affect it. In some versions, the spectators can choose a path of several predefined paths which can be very entertaining and exciting, but it is not truly interactive as play is interactive. Everything is still a recount of pre-authored events. Which is very unlike the where there is no pre-authored~~

storyline or episodes; instead, it emerges from the interactions of goal-driven actors.

#### 4.9.1 Drama

We discussed the drama concept in Section 2.2.2, and emphasised its element of action and play, and how we use play as part of our everyday life, education and entertainment from early childhood. This action-based nature of drama and its natural participatory form is why we call our engine . Because its emphasis is on emergent drama, a play between actors, some of the actors are players and some are and the drama emerges from their actions and choices. We use the causally structured and to mimic real life and how we would expect characters to react.

We use lessons from k. Johnston on improvisation that we introduced in Section ??, and abandon rigid structures and micromanagement of the actors. Instead, we embrace free action for the actors, empowering them with rational decision algorithms. We are aware that this means that the drama will not always emerge as expected, and it may sometimes not be perfect. We can say the same about the written text; not all novels are good; most are never published. Only a few authored stories reach the market of millions. Becoming an author is no easy task and most who try, fail. Only the most exceptional authors manage to make a living of it, while others less successful find themselves other work for their penmanship, such as translating or writing for magazines or newspapers.

Additionally, we use the improv idea of accepting offers as a way for the actors to stay even when it does not serve the needs of the drama progression and instead request aid from other actors. Our actors make an offer to other actors to accept the drama goal that they were not able to fulfil. For example, when the farmer is not able to fulfil the goal of letting the officer know that he is farming poppies. The farmer will send a request to another actor and offer the goal to them. They will then accept it and work it into their goals if they can. The player cannot see this interaction, and it can, therefore, appear to the player that the actors are not cooperating.

#### 4.9.1 Games

There is a possibility a high probability, that the player will ignore their current goals in favour of the character goals, which is common in popular and is not harmful behaviour. Players judge the quality of games like Skyrim [LLC17], and similar massive open-world in terms of the extent to which the games support this. In the words of S. Andrews, a professional games reviewer:

Skyrim is also a world that encourages exploration. The game has a central plot and it's a good one but Skyrim is a game where side quests

never feel like side quests, just another facet of your mission to be the best hero (or anti-hero) you can be. You can't turn a corner of a mountain path without spotting a ruin that demands investigation or a bandit camp that could be cleared out, and each settlement has at least one decent subplot, whether it's a serial killer on the loose or a mysterious fire that might just be linked in to something darker.

And it's a world upon which you're free to stamp your own identity. Whose side will you take in political struggles and racial conflicts? Do you want to be a gruff warrior who lets a gleaming war-axe do the talking, or a silver-tongued charmer with a bag of illusions and tricks? Will you join the Companions or hook up with the Thieves Guild? It's up to you, and you really don't have to make up your mind at once. One of the beauties of *Skyrim* is that your character can emerge and evolve over time.

The popularity of titles like *Skyrim*, *Heavy Rain* and *Assassin's Creed* demonstrate that there is a market for games that provide more vibrant story worlds and character development calling for even greater emphasis on character development and emergent drama. A merge between drama and game-play, influenced by player actions that provide a structured experience.

The autonomous rational actor agents engage proactively with the player without restricting or blocking and remain realistic while simultaneously progressing the drama. They use advanced reasoning with a dynamic knowledge base modelled in causally structured s, which enables them to interact with players at a far higher level of artificial intelligence than previous agents. The actors' primary aim is to stay in character, to remain believable and plausible and suspend disbelief.

The director is shallow, looking at the drama progression at an abstract level to resolve the problem of micromanaging actors, which is intractable in modern, fast-paced computer games.

The duality of drama and character goals, where drama goals progress the central plot and character goals introduce conflicts and suspense is specifically designed to meet the requirement for engaging drama situations in .

#### 4.9.1 Former work

#### 4.9.1 Related work

As we discussed in Chapter 3, the field is divided into and . We will start by comparing the to and then compare it to .

The systems have a pre-authored story, either they pick an existing novel or have someone author a story specifically. They install many functions that enforce that the pre-authored story is carried out, and interrupt the player if necessary. There is no similar pre-authoring for the ; there are only goals defined in schemas that guide the actors and players. For example, in , the

~~officer has the goal of gaining information from the farmer about whether the farmer is growing poppies. Since the dialogue is free, it depends on the character of the farmer how they respond; a devious farmer will be able to deceive the player.~~

~~Additionally, in modern with vast game worlds and multiple quests, the player will often not go immediately and ask the farmer. Instead, the player will wander off somewhere else, perhaps to explore or to solve another quest or to sell things they found. The player is very likely to come across the merchant when selling their stuff. They could also run into the journalist; when stopping by the coffee shop to see if there are any quests. Either one could tell them about the poppies. It is also likely that the player may explore around the farm first and find the poppies. All of this is normal player behaviour that we need and want to accommodate. We consider it to be the players game that we are adding more excellent entertainment too with the.~~

~~For example, in IN-TALE[RS06a, RS06b, RS06c], if a bomb must go off for the training scenario to commence. They decide a specific culprit in advance and author a storyline that sees him set off the bomb, and even if the player spoils it, they will have the culprit still somehow set the bomb off. Which effectively means that the scenario is not replayable because the player will know what is about to happen. In the the culprit can offer the goal of setting a bomb to another actor instead, or the can be used to create an additional plot twist for this the same as it does for murder mysteries. In both versions, the setting of the bomb is coherent and believable because the culprit will have reasons for doing it that are caused by their causally structured. Which gives the player a realistic experience, and removes the need for all the planning and intervention actions to fix the story. It allows the player to thwart the bomb before the explosion, which is an added training opportunity.~~

~~The uses schemas that may seem similar to episodes and similar structures used by systems, but the schemas do not have scripted actions and sentences. They are, therefore, unlike the beats in Façade [Mat02, MS05a] which are carefully scripted sequences of sentences and actions for each character or FearNot!'s episodes[VSPA07], IDA's plot points[Mag06] or Mimesis story mediations[YR03, RSY03, YRB<sup>+</sup>04]. The schema goals are also unlike the goals in IDA[Mag06], which are only active when the director is not micromanaging the actors. Instead, the schema goals are the exact opposite the director never micromanages, and the actors prioritise their character goals over the drama. Furthermore the introduces the concept of duality, i.e. that actors have two types of goals, character goals and drama goals that the actors choose between themselves using dee AI and are aware of playing in a drama. We make the actors resolve conflicts between drama goals and character goals with improv inspired actions of offering their drama goals to other actors, which no other system does. Rather than it being the director agent that~~

~~orders them as in In-Tale or overtakes them as in FearNot!.~~

~~We use roles for the actors to play; unlike roles in many other systems these roles do not have pre-authored routines or behaviour, instead, they are there for the director to assign goals to and for the other actors to know whom to address their actions to when carrying out their own goals. They are also not explicitly based on Propp's roles[Pro68] like in TEATRIX[MPP00]. A schema role is not pre-scripted because it is "a part played in a motif or a situation". Rather than "a part played in a scene or episode".~~

~~Another significant difference between existing systems is the use of goals is the use of causally structured to reason about how to fulfil a goal rather than plan paths towards them as in for example ID-Tension[Szi08] or HDA[Mag06]. Additionally, there is no right or wrong path for the player to take, unlike Thespian[SMP10, SM10]. They are also unlike the (OPIATE) goals [FC03, FC04, Fai04] which are in the form of specific behaviour or objects.~~

~~Our use of is also unlike other systems that have used them, like NOLIST, who use the to navigate the storyline. They use the probability to decide on how to the story will go. The does similar but for the past rather than along with the player playing the game. In the however the are used for the actor's knowledge base and to create coherent reasoning, which has not been done by other systems.~~

~~The rationality of the actors is also unlike that of the rationality in Schank's scripts[SLB80] or Tale-Spin[Mee81]; both are using first-order logic as their concept of 'rational' and natural language processing to read in scripts to use. The rationality in is from . defines rationality in terms of a player always choosing the optimal action based on a calculated .~~

#### 4.10 Summary

The DED architecture is decentralised drama management; comprised of a director agent that guides rather than directs the drama through the deployment of relevant schemas.

In DED the director gives the actors drama goals which inform the actors on how to progress the drama, and character goals for their character play. The director does not know what the actors or players do.

The actors are aware that they are actors playing characters in a drama and are the prima motor of the drama. They are responsible for progressing the plot, engaging the player and responding timely, coherently and IC to the players actions.

This is unlike any other system that has a director type agent.

We are using improv which is applicable for cooperative games because it assumes that the actors are cooperative and aid each other. Improv is not really applicable for non-cooperative games. Using improv the actors take responsibility for the drama and are the prima-motor of the drama management. The actors communicate between them selves to further the drama goals. The actors are aware of the drama and their responsibility to manage the drama. The actors use character and drama goals to understand whether they are furthering the requirements of the drama or just chasing **selfish** **selfish** goals. This is coined as the single biggest problem of interactive drama in the overview of the “UK network RIDERS Research in Interactive Drama Environments, Role-Play and Story-telling, running for 36 months from September 2011” [ALW11, p. 1].

The DED has implemented, tested and published in [AK08, AK09b, AK09a, AK10, AK12]

# 5

## Evaluation & Conclusion

We start this Chapter by introducing applications. In this chapter we first introduce each application that we have implemented to test the DED, see Section ??, in addition to the Afghan poppy scenario we discussed in Chapter 4. The applications are listed below in the temporal order of their implementation:

1. Section 5.1: Murder mystery in Second Life.
2. Section 5.2: Web-based murder mystery.
3. Section 5.3: Mistlethorpe: a web-based murder mystery.
4. Section 5.4: Merchants of Jorvik: a web-based dramatisation of life in York during the Icelandic Sagas.
5. Section ??: Poppy farming scenario, introduced in Section see Section 4.2 and used as a running scenario throughout Chapter 4

For each of the above applications we describe and discuss the following elements:

1. Development, design and authoring.
  2. Emergent drama. Followed by a brief discussion on evaluating the drama with computational models rather than user evaluation, see Section 5.3.
  3. Evaluation.
- 
1. Section 3.2 After introducing the systems and our evaluation of each system we compare our drama metrics' scores against the drama metrics

that we established in Section 3.2 and compare our results with related systems' scores.

2. Section ??

## 5.1 Applications of DED Murder mystery in Second Life

~~There have been five applications of the ; We describe these systems below and their functionality and evaluate their performance.~~

### 5.1.1-

~~SL is a VR where users can create their own avatar and engage in several activities, including:~~

- ~~Personalise their 3D avatars.~~

~~SL is a complex commercial VR that offers an enormous amount of content and freedom of interaction.~~

### 5.1.1 ~~Second Life~~ Development, design and authoring

We used an open source library, called LibOpenMetaverse [HRK<sup>+</sup>08], to developed a scenario in SL using the LibOpenMetaverse library [Met09] to connect with the Second Life servers. & social experiences to share or sell in a global marketplace. The platform we use for tests is the Second Life (SL) [Lab03]; a virtual reality, with over 16 million users. Library called LibOpenMetaverse [HRK<sup>+</sup>08]. The university of York (UofY) paid for an island in SL that we and other within the UofY could use.

Using the LibOpenMetaverse library [HRK<sup>+</sup>08] we programmed actors that logged in to SL as if human users controlled them. The SL VR supplies a lot of content that is free of use by the community and we mainly used props from them including most of the gestures that we used. However, we needed to create an animation of the victim dying and a few of the simple gestures like waving hello and adjusting an animation for shooting from a pistol to that of drinking from a glass. We used a number of gestures to indicate emotions, such as anger, happiness, grief and shock. We uploaded all the animations to the repository along with threeee videoclips of the actors being interrogated.<sup>1</sup>

1. All the code base is available at our Department's Github account.<sup>2</sup>
2. Additionally, we provide logs of our work from 2008 to 2011 in that repository.<sup>3</sup>

---

<sup>1</sup><https://github.com/uoy-research/DED/tree/main/SecondLife/SL%20Animation>

<sup>2</sup><https://github.com/uoy-research/DED/tree/main/SecondLife>

<sup>3</sup><https://github.com/uoy-research/DED/tree/main/SecondLife/logs>

### 5.1.2 Mistlethorp Gameplay

In the implementation, five logged in and started playing characters in a murder mystery. First, they greeted the , offered the a drink or a seat. Talked about why they were all gathered together. Each actor had a of introducing themselves to the player. They would wait for an opportunity to approach the player and introduce themselves, they would also try small talk, for example: "Do you enjoy the party?!"

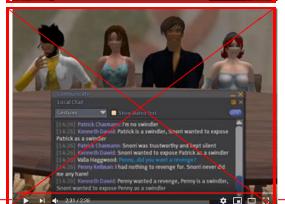
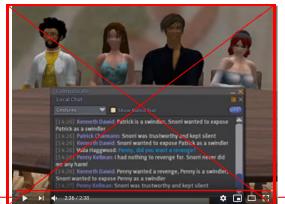
- i. Valla: Penny, was Snorri blackmailing you ?
- ii. Penny: Snorri was blackmailing me. Snorri knew a lot, I have secrets... they are deeply personal...

At some point during the introductions, one of the characters dropped dead from poisoning, with a graphic death scene. The still-living actors showed their reactions to the murder, and then the user could interrogate the suspects.

The suspects would find an empty seat, and the player could walk up to them and ask them questions. For example, where Snorri is the name of the victim, "Kenneth, did you have a reason to kill Snorri?", see Figure ???. Kenneth would deny and send a request for help to one of the other actors which would expose his motive.



In another scene the player asks: "Penny, were you swindling Snorri?", see Figure ???. Penny denies and sends a request for aid to Kenneth-



**Figure 5.1.1** Kenneth exposes penny as a swindler, screenshot from Second Life [Lab03].



### 5.1.3 Merchants of Jorvik Evaluation

As a case study and proof of concept, we implemented an example of an interrogation scene in which the user can interrogate a crime suspect. The platform we use for tests is the Second Life (SL) [Lab03] virtual world, with over 16 million users. With a library called LibOpenMetaverse [Met09], we programmed actors that logged in to Second Life virtual reality as if humans controlled them. Additionally, duality is part of the web game in Section ??.

In the following scene, the other actors aid the interrogated actor in revealing a motive. An example conversation, in which the user (called "Valla") asks the character, Lydia, whether the murder victim Snorri was blackmailing her. Snorri was blackmailing Lydia, and she has a low integrity value (20%):

**Valla:** Lydia, was Snorri blackmailing you? **Lydia:** Snorri was not blackmailing me **Penny:** Snorri was blackmailing Lydia, Snorri knew all about Lydia's secrets, Lydia has deep dark secrets

In the next scene Penny was blackmailed by the murder victim Snorri and she has a high integrity value (80%), see Figure 5.1.1 and below. She both admits her motif and also shows a downcast gesture:

**Valla:** Penny, was Snorri blackmailing you? **Penny:** Snorri was blackmailing me, Snorri knew a lot, I have secrets... they are deeply personal...



We ran a number of tests of this type to test the duality and the effect of various personality traits on their honesty. We found that it was straightforward to configure their level of traits to have expected effects on their

## 5.2 User evaluation Web-based murder mystery

### 5.2.1 Development, design and authoring

The web-based murder mystery used the same C# DED as SL; we only changed the interface to a web environment for our user study. We found that running a user study in SL was infeasible due to the difficulties in sourcing and setting up a test environment for remote participants; we wanted a diverse pool of participants for a broad and realistic user evaluation.

Another significant cause was that UofY was cancelling their SL island. We were the island's primary users over approximately two years, and we rarely saw our colleagues there.

Therefore, we developed a simple web interface and deployed our study to the UofY web-servers.

The game had a few modes for different type of activities:

- i. **Cause of death:** The player determines cause of death.
- ii. **Motive:** The player determines the motive, if any, of each character.
- iii. **Examination:** The player investigates the murder scene; see Figure 5.2.1.
- iv. **Speech:** The player can talk to the characters in the story; see Figure 5.2.2.

### 5.2.2 User interaction

We created a web based mystery game for user evaluation. As the game starts, the player finds a body and can examine the body and determine the cause of death. Each initiated game has a randomly generated cause of death, and the BN is used to generate clues on the body to be found by the user that are logically consistent with the cause of death. For example, a

**Figure 5.2.1** The player examined the body in the web game, an image used is painted over for copyright reasons.



**Figure 5.2.2** A screen shot of a dialogue with suspects in the web game, images used are painted over for copyright reasons.



**Table 5.2.1** The 7 Cattell's traits used for the characters

<u>Low range</u>	<u>High range</u>
reserved	warm
reactive	emotionally stable
deferential	dominant
serious	lively
expedient	rule-conscious
utilitarian	sensitive
relaxed	tense

**Figure 5.2.3** A screen shot of the sentence authoring tool.

The figure shows a user interface for creating sentences. On the left, there are input fields for Variable, State, Target, Title, and Sentence, along with an 'Add' button. On the right, a panel displays seven personality traits with two radio button options each:

- Warmth:** Warm () or Impersonal ()
- Emotional Stability:** Emotionally stable () or Reactive emotionally ()
- Dominance:** Dominant () or Deferential ()
- Liveliness:** Lively () or Serious ()
- Rule-Consciousness:** Rule-conscious () or Expedient ()
- Sensitivity:** Sensitive () or Utilitarian ()
- Tension:** Tense () or Relaxed ()

Below these traits is a preview window titled 'S\_blackmailer' containing a numbered list of generated sentences:

- 1
 

**OTHER**

of course {1} was not blackmailing (victim), ... just not the type...

Tense  
Sensitive  
Deferential

Of course {1} was not blackmailing (victim), it is illegal

Oh surely not! You don't think {1} was blackmailing (victim)...it can't be!

{1} was not blackmailing (victim)

{1} would never blackmail anyone, what a silly idea!

strangled victim has marks around the neck, and there may be a strange odour from a poisoning, see Figure ??.

The player can then explore other rooms and interrogate suspects on their possible motives and attempt to determine which motive, if any, each suspect has. An example dialogue with two suspects shows how they are significantly different personalities, see excerpt below and in Figure ??

Dialogue (Miss Jane Marple and Mr Bryan Eastley):

- i. *Miss Jane Marple* - Did you lose a fortune?
- ii. *Mr Bryan Eastley* - what. Why? I have all my money
- iii. *Miss Jane Marple* - Did you have a reason to kill Harold?
- iv. *Mr Bryan Eastley* - Me? no..no reason!

Dialogue (Miss Jane Marple and Mr Cedric Crackenthorpe):

- i. *Miss Jane Marple* - Did you lose a fortune?
- ii. *Mr Cedric Crackenthorpe* - No, I have all my money
- iii. *Miss Jane Marple* - Did you have a reason to kill Harold?
- iv. *Mr Cedric Crackenthorpe* - I assure you, I'm no murderer!

### 5.3 Computational drama evaluation Mistlethorpe

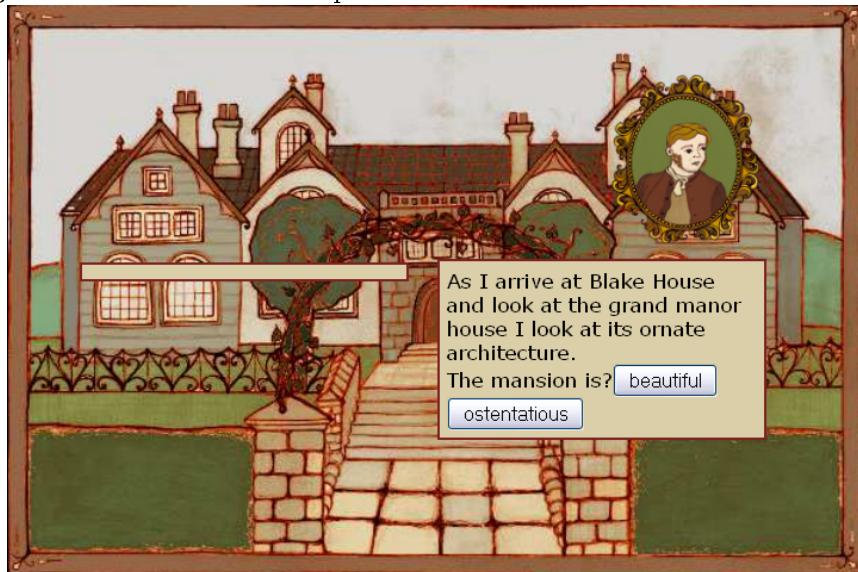
Mistlethorpe is a web-based game that we presented at Venturfest Venturefest in York, England. It is a web-based game with the first full mystery implemented. The player enters an English village called Mistlethorp Mistlethorpe and receives an invitation to the village mansion where all is not as tranquil as it first appears. The player gets access to the whole mansion and can go between rooms and interrogate the suspect.

Soon after entering the mansion and starting to talk to the player enters the mansion and talks to the hosts, someone finds the cook murdered on the kitchen floor. The player can now investigate the murder scene and travel around the mansion. In this game, the actors are far more pro-active than before. They initiate a conversation with the player. They also update their knowledge base, and future conversations reflect their updated knowledge.

We also-added narrative messages, for example, when the player approaches the mansion he is offered to have an opinion as to whether the mansion is beautiful or ostentatious, see Figure 5.3.1. the engine offers the player two options, see Figure 5.3.1: Whether the mansion is:

- i. mansion is beautiful or
- ii. ostentatious?

Figure 5.3.1 The Mistlethorpe mansion



Several events take place to increase the suspense and finally, over supper, the detective discovers the murderer. This game is

aaccessible from [weenrich.com](http://weenrich.com).

## 5.4 MERCHANTS OF JORVIK

~~Was created specifically~~ Merchants of Jorvik is a game we created for the Jorvik Viking Museum. ~~A web based~~ It is a web-based game optimised for mobile devices. Specifically iPhones. devices—specifically iPhones. According to Egils saga, Skallagrímssonar, then Arinbjörn was a lord in York during the Viking era. The game starts in the house of Lord Arinbjörn which was a real character that lived in York in Viking time, see Figure 5.6.1 Lord Arinbjörn's house, see Figure 5.6.1

~~In this game, we developed new roles, actions and events.~~ The game offers two quests, ~~the former is a~~:

- i. ~~A~~ haggling quest; the player is given a set of objects to buy and must haggle down the prices. For this, the player must travel around Jorvik, ~~see Figure 5.4.2~~ see Figure 5.4.2 and haggle with merchants on their stalls, see Figure 5.4.3 ~~If the player is successful in solving the haggling quest she is given the task to find~~ see Figure 5.4.3.
- ii. ~~Find~~ a thief that stole a valuable brooch. ~~In this game we see new types of roles and, actions and events. This game is accessible from [weenrich.com](http://weenrich.com).~~

The interaction between player and actor agents is in dialogue and physical actions:

- The player is presented with a dynamic list of multiple choices of relevant sentences to choose from.
- The player can pick up and examine any object made available in the scene.
- The player can travel between scenes.
- The player can initiate conversation verbally.
- The player can initiate conversation via physical actions such as examining an object.
- The actors can initiate conversation with the player.

In Mistelthorp, ~~see Section 5.1.2~~ see Section 5.3, and Merchants of Jorvik, ~~see Section 5.1.3~~ see Section 5.4, web games we offer key words rather than sentences to the user which reduces the feeling of clutter, see example from the Merchants of Jorvik, ~~see Figure 5.4.4~~ see Figure 5.4.4

We show the results in Figure 5.4.5 in Figure 5.4.5, the player is in the study and is interrogating Cedric. Bryan and Elspeth are also present, but neither Alfred nor Emma is present. The player can also talk about Emma and Alfred with the actors that are in the room. Selecting the option 'Talk about' will offer similar sentences, but instead of asking about Cedric, it asks Cedric about

Figure 5.4.1 Lord Arinbjorn

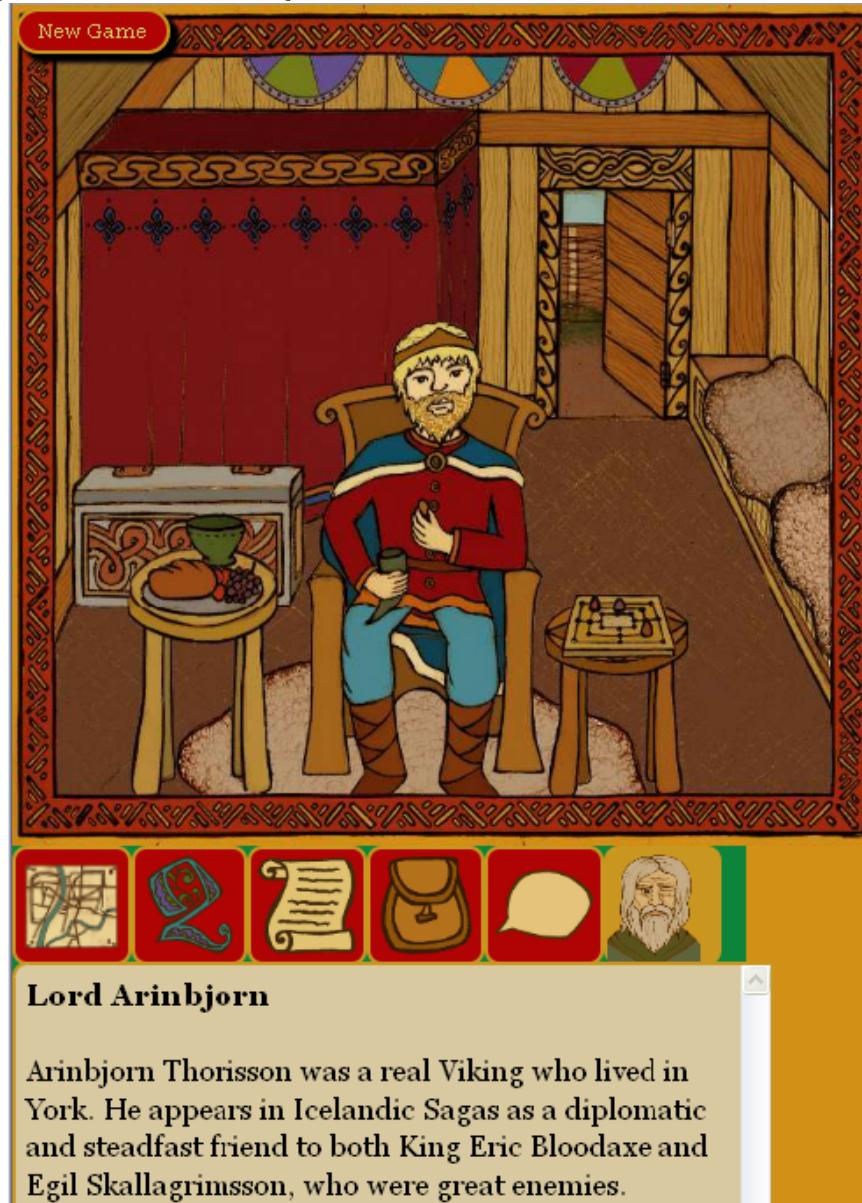


Figure 5.4.2 Map of Jorvik

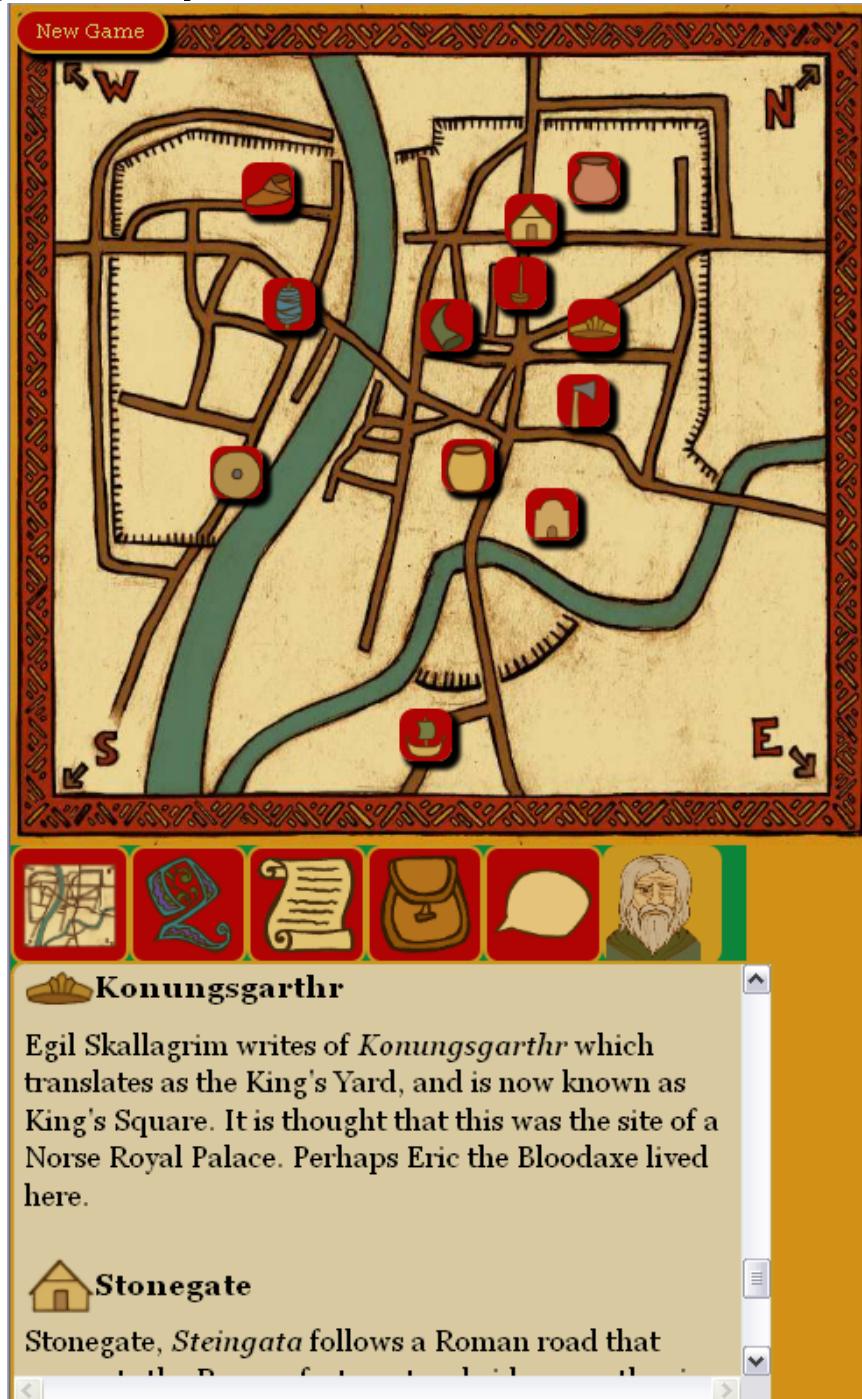


Figure 5.4.3 The weaver's stall

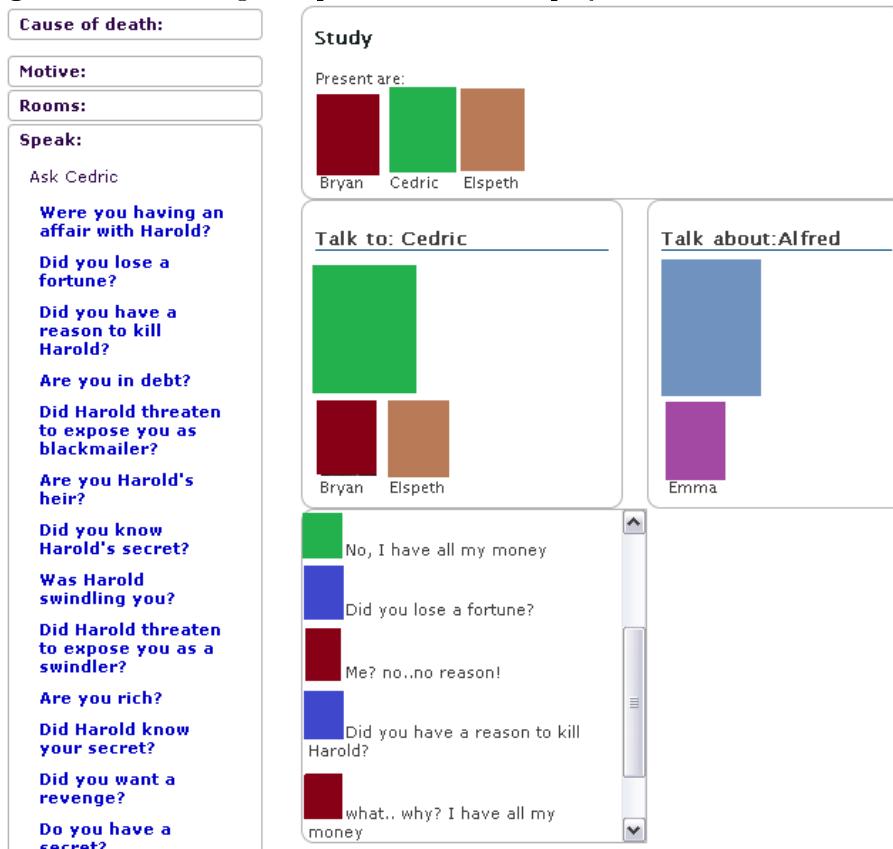


Figure 5.4.4 Key words as options rather than whole sentences



Alfred in this case. For example “Are you rich?” becomes “Is Alfred rich?”.

**Figure 5.4.5** A range of speech acts for the player



All the sentences are generated based on the BN, by looking at parent and children vertices and leaving the decision of what to say to the player.

## 5.5 Poppie scenario

- 5.5.1 Development, design and authoring
- 5.5.2 Emergent drama
- 5.5.3 Evaluation

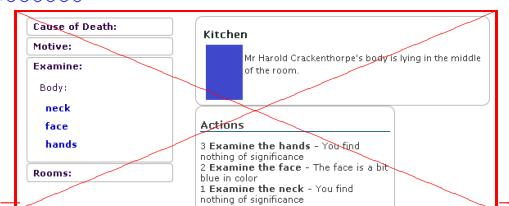
## 5.6 User evaluation

We created a web-based mystery game for user evaluation. As the game starts, the player finds a body and can examine the body and determine the cause of death. Each initiated game has a randomly generated cause of death, and this is used to generate clues on the body to be found by the user that are logically consistent with the cause of death. For example, a strangled victim has marks around the neck, and there may be a strange odour from a poisoning, see Figure ??.

### 5.6.0.1 Computational evaluation

#### 5.6.1 Setup

Playtime. A total of 34 participants answered the questionnaire, from the logs we can gain some information in addition to what they answer. We can filter the logs for those that played for more than half an hour and for more than an hour. Some play for a while and then stopped for an hour and came back, and it is difficult to say how long those played in total. So as not to inflate the c-values we filtered out anyone who had spent more than 2 hours as those are mostly people that didn't play for that entire time.



The player can then explore other rooms and interrogate suspects on their possible motives and attempt to determine which motive, if any, each suspect has. An example dialogue with two suspects shows how they are significantly different personalities, see excerpt below and in picture ??

Dialogue (Miss Jane Marple and Mr Bryan Eastley): *Miss Jane Marple* Therefore we filtered out those that had played between 30 minutes - Did you lose a fortune? *Mr Bryan Eastley* - what. Why? I have all my money *Miss Jane Marple* - Did you have a reason to kill Harold? *Mr Bryan Eastley* - Me? no. no reason!

Dialogue (Miss Jane Marple and Mr Cedric Crackenthorpe): 2 hours.

- i. *Miss Jane Marple* - Did you lose a fortune? > 30 minute: 28  
of 34

- ii. *Mr Cedric Crackenthorpe* - No, I have all my money  $\geq 1$  hour: 9 of 34
- iii. *Miss Jane Marple* - Did you have a reason to kill Harold? *Mr Cedric Crackenthorpe* - I assure you, I'm no murderer!  $\geq 1$  hour and 30 minutes: 7 of 34

### 5.6.1 Participants selection

We sourced participants through social media, primarily Facebook. Over 500 invitations to play the game were sent out to individuals by the researcher and friends of the researcher. We used this method so that we would get more genuine responses, i.e. invitations were sent to a large number of individuals entirely unknown to us. Rather than count on fellow students, family and friends. In total, 70 registered and started playing the game. In order to be able to answer the survey, the players needed to play through the game until they had interrogated each character and asked each character at least five specific things. Thirty-four participants answered the questionnaire, and twenty-nine distinct players answered the questionnaire, which means that five players played through the game twice and answered the questionnaire again. Which was encouraged because replayability is one of the issues we are interested in measuring. Participants could skip as many questions as they liked. Further more the 4 years of logs that we have accumulated and give access to in the code repository demonstrate that the characters answer within a second.

#### 5.6.0.1 User evaluation

##### Questionnaire page 1

Gender: In total, 32 individuals gave their gender: women (17), men (15). There was a good distribution of age. Most were

Age: Participants age ranged from 20 to 60 years old, although more than half where between 30-40 years old, but at least a quarter (26.46%) of the More than a quarter of participants was over 40 years old, see Table ??.: see Table 5.6.2, and see Figure 5.6.2.

### 5.6.1 Results

We base the results of the web-based game on the questionnaire and the log files generated by the engine. We look at players

**Table 5.6.1** Participants that played the game between half an hour to two hours



Playtime	Start time	end ti
0:49:45.203000	2010-10-18 13:22:20	2010-10-18 14:1
0:31:25.672000	2010-10-18 22:52:44.921000	2010-10-18 23:2
0:32:14.484000	2010-10-19 22:25:36.687000	2010-10-19 22:5
0:32:58.110000	2010-10-20 12:34:06.921000	2010-10-20 13:0
0:34:17.515000	2010-11-03 12:34:51.750000	2010-11-03 13:0
1:16:50.594000	2010-11-03 23:38:54.359000	2010-11-04 00:5
0:30:39.359000	2010-11-05 01:40:24.578000	2010-11-05 02:1
1:44:54.485000	2010-11-05 11:36:57.593000	2010-11-05 13:2
1:14:07.625000	2010-12-14 13:33:33.093000	2010-12-14 14:4
0:51:21.047000	2010-12-16 11:38:57.843000	2010-12-16 12:3
0:36:53.907000	2011-01-24 13:38:05.921000	2011-01-24 14:1
0:41:44.672000	2011-02-02 23:23:18.164000	2011-02-03 00:0
1:52:41.313000	2011-02-08 10:55:39.515000	2011-02-08 12:4
0:34:37.468000	2011-03-08 11:46:55.875000	2011-03-08 12:2
0:43:47.261000	2011-03-11 01:34:04.423000	2011-03-11 02:1
1:58:49.531000	2011-03-21 22:29:59.812000	2011-03-22 00:2
0:32:58.172000	2011-05-22 14:47:49.265000	2011-05-22 15:2
1:24:56.094000	2011-05-22 15:22:00.593000	2011-05-22 16:4
0:35:08.703000	2011-05-23 01:41:37.265000	2011-05-23 02:1
1:33:51	2011-05-26 15:10:59.171000	2011-05-26 16:4
0:35:32.250000	2011-05-27 11:12:09.718000	2011-05-27 11:4
1:59:32.969000	2011-05-27 14:32:58.031000	2011-05-27
0:37:09.484000	2011-05-28 13:36:25.609000	2011-05-28 14:1
0:32:27.953000	2011-05-28 20:38:54.312000	2011-05-28 21:1
0:35:36.719000	2011-05-30 12:44:12.140000	2011-05-30 13:1
0:47:30	2011-05-30 13:28:20.609000	2011-05-30 14:1
1:46:18.140000	2011-05-31 12:21:49.953000	2011-05-31 14:0
0:45:14.281000	2011-05-31 14:23:42.609000	2011-05-31 15:0

**Figure 5.6.1** Screenshot of page 1 of the questionnaire

**Page 1 of 3**

---

Gender?       Female       Male

What is your age range?

How many Role-Playing Games have you played?

How many First Person Shooters have you played?

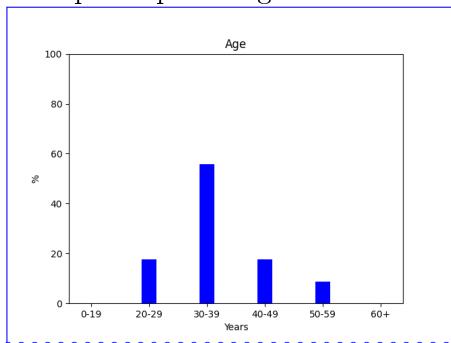
demographics, actor response time, the period of play, and how coherent the actors were.

**Table 5.6.2** A table of participants' ages

Age	responses	%
0-12	0	0
0-19		
12-19	6	17.64
0-0 20-29		
30-39	19	55.88
40-49	6	17.64
50-59	3	8.82
60-69	0	0
0 07060+		
Total	34	100

What is your age range?

**Figure 5.6.2** Barplot of participants' ages



Only 41.18% had played more than three before, or slightly less than half of the respondents. Nearly 29.41% had never played a before while 29.4% had played more than

Games played: Around three fifth of respondents had played none or few RPG or FPS games before; see Table 5.6.3 and see Figure 5.6.3. Only around one fifth had played 10 , see Table ?? . Which helps to show that there was a good range of participants or more RPG or FPS games before.

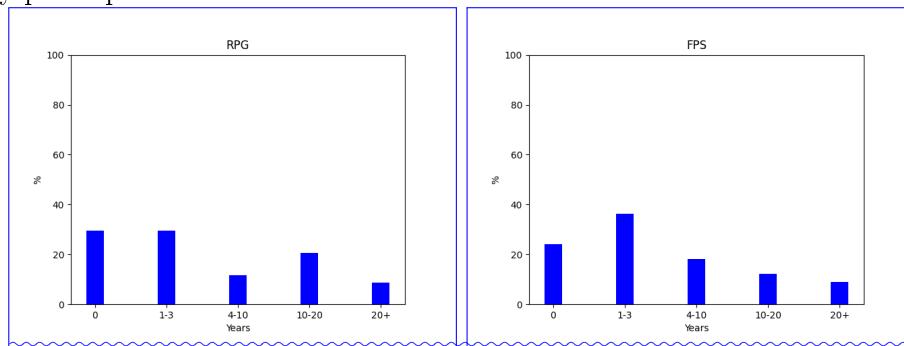
Slightly less had played more than 3 FPSs before, or 39.39. Nearly 24.24% had never played an FPS before while 21.21% had played

**Table 5.6.3** A table showing the number and percentage of RPGs and FPSs that participants had played.

Option	responses RPG	%	FPS	%
0	10	29.41	8	24.24
1-3	10	29.41	12	36.36
4-10	4	11.76	6	18.18
10-20	7	20.58	4	12.12
20+	3	8.82	3	9.09
Total	34	100	33	100

Games have you played?

**Figure 5.6.3** Barplots of the number of RPGs (left) and FPS (right) played by participants



more than 10 FPSs, see Table ??). Again this helps to show that there was a good range of participants

**Figure 5.6.4** Screenshot of page 2 of the questionnaire

Page 2 of 3

	1 Not at all	2 very little	3 somewhat	4 mostly	5 Very
<b>Where the actors responsive?</b> Did they respond to your questions or comments within an acceptable time limit?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Where the actors coherent?</b> Did they respond in context to what you said to them?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>In your opinion did you find the characters to be believable rather than purely robotic?</b>	1 robotic	2 mostly robotic	3 inbetween	4 mostly believable	5 Believable
Mr Alfred Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mr Bryan Eastley	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mr Cedric Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mrs Elspeth McGuillicuddy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mr Harold Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[Page 1](#) [Page 3](#)

Questionnaire page 2

Question: “Where the actors responsive?” *Did they respond to your questions or comments within an acceptable time limit?*

Most respondents, 73.52% found the actors to be mostly or very responsive, see Table 5.6.4, and see Figure 5.6.5.

Question: “Where the actors coherent?” *Did they respond in context to what you said to them?*

Most respondents, 85.29%, considered the actors to be mostly or very coherent, see Table 5.6.4, and see Figure 5.6.5.

Question: “Where the actors responsive?” *Did they respond to your questions or comments within an acceptable time limit?* In our definition of emergent drama we say that a believable character is both timely and coherent. Additionally in our hypothesis we say that for realtime applicable systems the actors need to be sufficiently responsive to players’ actions with a response that is in context to the players’ actions according to players’ evaluation.

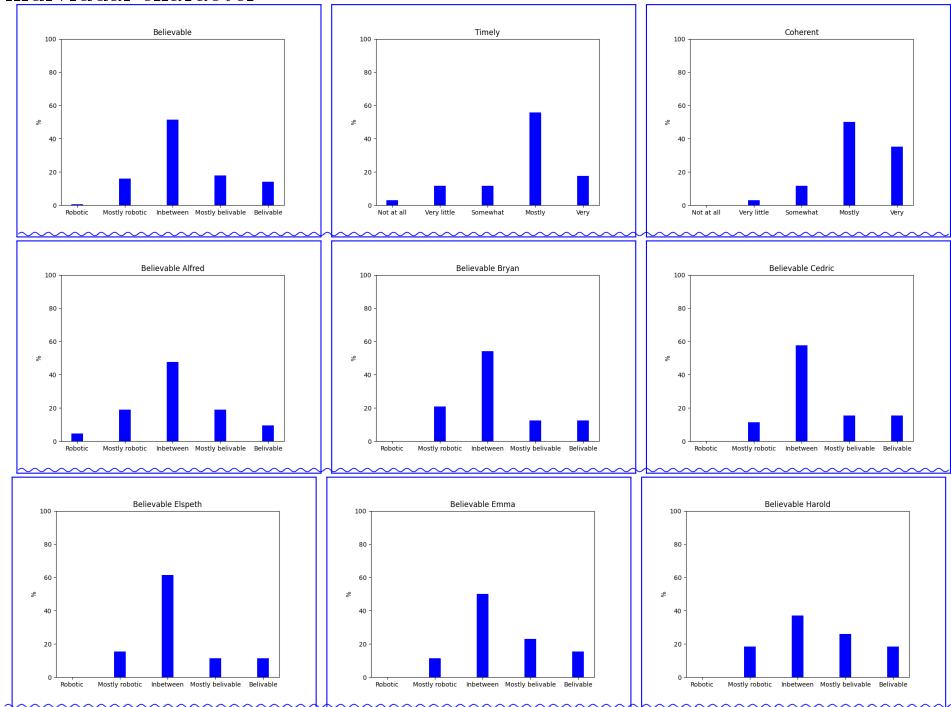
73.52% found the actors to be mostly or very responsive, see Table ???. The log of each decision shows that most, 95.72%, were

**Table 5.6.4** A table showing the number and percentage of replies to the actors' timeliness and coherent responses.

Option Timely	%	Coherent	%
1em1.7cm0 Not at all	24.24 2.9	0	0
1em1.7cm1-3 Very little	36.36 11.76	1	2.9
1em1.7cm4-10 Somewhat	18.18 11.76	4	11.76
1em1.7cm10-20 Mostly	22.12 55.88	17	50
1em1.7cm20+ Very	9.09 17.64	12	35.29
1em1.7cmTotal	100	34	100
1em1.7cm			

Shooters (FPS) have you played?

**Figure 5.6.5** Barplots that show how believable, timely and coherent the players found the characters overall. Also how believable they found each individual character



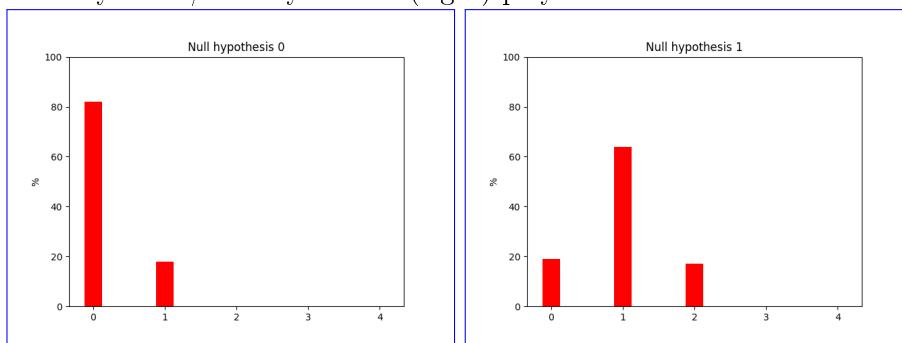
made in less than 100 milliseconds, see graph ??.. Another 61.80% in less than a millisecond, the average time is 20.87 milliseconds and the maximum time is 996 milliseconds. Added to the actual actor response time is the time it takes for Our null-hypothesis is that players would have found the actors to be not timely or coherent and primarily responded with either “Not at all” or “Very little”. Similarly they would have found them to be “robotic” or “mostly robotic” to reflect those responses we generated a Gaussian normal distribution with 0.5 standard deviation for both of these responses; see Figure 5.6.6.

We compared these null-hypothesis against the responses from the players with  $p < 0.05$  as significant difference, see Table 5.6.5.

There is a significant difference between the null-hypothesis and the web program to send the sentence to the engine and then to read and display the time. Sometimes this process fails and results in dissatisfied players , which is why some players players responses.

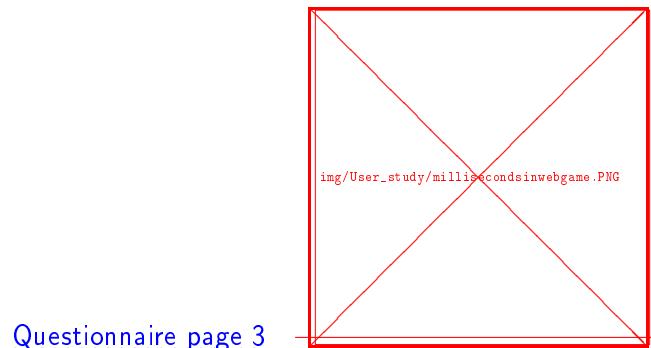
Therefore we reject the null-hypothesis and say that the players found the actors not to be responding in a timely fashion to be both timely and coherent.

**Figure 5.6.6** Barplots that show null hypothesis “Not at all”/“Robotic”(left) and “Very little”/“Mostly robotic”(right) players found the actors



**Table 5.6.5** A table showing a significant difference between the null hypothesis and the players responses.

	%	t	p	Significant	
1.71.53 cm responses On Null	1.71.53 cm	-21.48464	2.90.00000	True	
Tinately all	1.71.53 cm	-4.12.26684	11.760.00000	True	
Tinately tle	1.71.53 cm	-29.87181	0.00000	True	
Cohotent at all	1.71.53 cm	-55.88	17.15571	0.00000	True
Coherent little	1.71.53 cm	-17.64	18.13663	0.00000	True
Befolvabile	1.71.53 cm	-100	9.53956	0.00000	True
Befimostyle robotic	1.71.53 cm	-14.80357	0.00000	True	
Alfred	1.71.53 cm	-6.78671	0.00000	True	
Alfiobotic	1.71.53 cm	-16.53351	0.00000	True	
Bryan	1.71.53 cm	-7.75474	0.00000	True	
Bryahotic	1.71.53 cm	-18.61588	0.00000	True	
Cedric	1.71.53 cm	-9.24743	0.00000	True	
Gerbhotic	1.71.53 cm	-17.55252	0.00000	True	



**Figure 5.6.7** Screenshot of page 3 of the questionnaire

Page 3 of 3						
			<b>Warmth</b>			
			High	4	3	Low
			Mr Alfred Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
			Mr Bryan Eastley	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
			Mr Cedric Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
			Mrs Elspeth McGuilliguddy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
			Mr Harold Crackenthorpe	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
				2	Can't say	

Playtime: It took the players on average 42 minutes to complete all goals after which they were redirected to the questionnaire, see Figure ???. On page 3 we asked about the 7 Cattell's traits that we had used. The screenshot in Figure 5.6.7 shows how we asked about the trait; naming both the low and high end of the trait with a brief description and the player was asked to indicate for each character.

Question: "Where the actors coherent?" Did they respond in context to what you said to them?

Most respondents, 85.29%, considered the actors to be mostly or very coherent, see Table ??.

**Table 5.6.6** A table showing convergence towards character traits.

$\frac{\%}{1.715\text{cm}} \text{Options}$	$\frac{\%}{1.715\text{cm}} \text{Not}$	$P$
<u>Character</u>		
0 - 2.51738	0.01312	
1.715cm Not at Reserved all Alfred		
2.9 - 1.95845	0.05246	
1.715cm Very little Serious Alfred		
11.76 - 2.58678	0.01092	
1.715cm Somewhat Alfred-e-conscious		
50 - 1.01679	0.31120	
1.715cm Mostly Br Dominant		
35.29 - 3.15795	0.00197	Where the actors coherent?
1.715cm Very Celicely		
100 - 1.96462	0.05170	
1.715cm Total Emotionally Sensitive		
3.17356	0.00191	
1.715cm Emotionally Hostile		
2.06205	0.04126	
1.715cm Dominant		
-3.07975	0.00254	
1.715cm Fearful		
2.87256	0.00482	
1.715cm Intellect conscious		
1.7cm 2cm		

## 5.7 Computational drama evaluation

### 5.7.1 Drama interestingness

N. Szilas & Co proposes a computational model to measure interestingness in drama [SER16], which is very promising and useful work since it is challenging to measure complex algorithms with user evaluation accurately ~~and~~; there is minimal availability of comparison results. Scientists are not necessarily, even rarely, also game developers or proficient artists. It is, therefore, very constructive to develop computational models to measure our systems.

We looked at the Afghan poppy scenario with the modelling suggested by N. Szilas & Co. and stepped through a scenario as follows:

- i. We say that a positive conflict, +1, is generated when an actor prioritises a character goal over a drama goal. ~~Which means that a game designer should be able to use that to measure the rise of the dramatic arc.~~
- ii. ~~However we~~ We also say that ~~when an actor uses deception because of their character goals, deceiving character~~, for example, the farmer deceiving the officer ~~in Section ?? is also~~ in Section 4.5.4.2 is also a positive increase, +1.
- iii. Furthermore, when the actor offers another actor the drama goal, and the other actor accepts, it is also positive, +1.
- iv. A new character has entered the scene, which is also a +1 in interestingness.
- v. Furthermore, the new character is likely related to the farmer, another +1 in interestingness.
- vi. The new character also has their own character goals, which add still another +1.

At this point, we have already 6 points as a result of one character deception, and we can go on like this, which has caused us some pause.

~~It can be that when we start testing When we start to run the DED on more extensive auto-sourced datasets, as we intend, we could have the drama become too complicated against large data sources, the drama could become to complex for the player to take it all in. Which may be a limitation that further work may need to take into consideration effectively grasp.~~

## 5.8 Summary

# 6

## Conclusion

Decentralised drama management and actors drama awareness The is a system that gives the actors free choice in running the drama and managing the designed conflict between drama and character goals. The player participates in the drama as if they were another actor. The only difference is that the player makes the decisions rather than the Game-Theoretic algorithm that the actors use. s We have fully decentralised the drama management by having the actors decide which goal to prioritise and to give them methods to resolve conflicts between their character goals and drama goals. We use lessons from improvisation to have the actors offer their unresolvable drama goals to other actors that can resolve them. Which means that the actors can remain while simultaneously work towards resolving the conflict. Additionally, this method increases the interestingness of the drama. For example, when the farmer in the Afghan poppy scenario deceives the officer, it increases the conflict and tension. The resolution to involve another actor to resolve the drama goal of revealing the poppy farming also increases the interestingness because now there is a new character in the drama involved in the plot. The helping actor has character goals of their own, which they will start trying to satisfy, which further increases the interestingness. In this manner, we argue that the emergence caused by decentralised drama management and the actors' drama awareness results in a very powerful emergence, which continues to increase the interestingness significantly as a side effect from one minor action.

**Real-time applicable** For all the applications, response time was well within a second. In the user evaluated, in Section 5.2; the actors decided on an action in less than 100 milliseconds 95.72% of the time. Additionally, they decided 61.80% in less than a millisecond, the average time is 20.87 milliseconds, and the maximum time is 996 milliseconds. Additionally, most users, 73.52%, found the actors to be mostly or very responsive. as discussed in the evaluation we have 4 years of logs that demonstrate this. We were also able to have the actors respond within a second in the Second Life despite considerable overhead caused by other resources required to run the actors in the Second Life virtual world. In the latest experiment, we ran it using the SpatialOS technology stack, and all actor decisions take less than a second.

We intend to test the performance further using much larger BNs than we have up to now. The current plan is to use automated processes to create BN from real-world data to use in synthetic training.

that include several characters, behaviours and scenes and run for extended periods we have implemented five distinctly different scenarios all with different characters and scenes without any significant overhead. Characters are defined abstractly as roles that have certain base traits; for example, an officer is likely conscientious. The characters do not need to have specific instructions or scripts to interact with each other, the goals are not specific to characters, instead, they are specific to roles, and we can, therefore, try a similar scenario with multiple different characters in the designated roles to create varied interactions and conflicts between different personality types.

It took the players circa 42 minutes to complete the drama which exceeds our 30-minute goal. Future work is to test this further with more massive worlds and a greater range of roles and characters.

**Minimise authoring** We aim to significantly reduce or eliminate the authoring bottleneck that significantly restricts the development of interactive drama with branching storylines. Since the has no pre-authoring, it skips that complexity. The main challenge is to write the sentences that the characters can say. There needs to be a sentence for each state in the that the characters will use for speech actions. Which can certainly be tedious to do, and it is preferable to have several sentences per state to get a variation in character speech. We have authored sentences for

four applications, Second Life, Murder mystery web game for user testing, in Section 5.2, Merchants of Jorvik, see Section 5.1.3, and Mistelthorp, see Section 5.1.2; it only took a few days each time.

These were not large applications, and we aim to develop much more extensive applications in the future where this manual entry would become unfeasible. It is, therefore, future work to alleviate this part of the authoring with natural language processing, as well as to provide gestures via similar automation.

If we take the extreme measure from “Façade required 3 person years of just authoring ... only 27 beats were created in the end” [MS05a, p. 6] and 30-minute gameplay. Compare it against the murder mystery that we used for our user evaluation, in Section 5.2, and apply our evaluation from Section 1.4. The murder mystery took one week to author and users played it for around 42 minutes:

$$\text{Authoring Index} = \frac{\text{Authoring time}_{\text{months}}}{\text{Playing time}_{\text{minutes}}}$$

$$\text{Facade} = \frac{36}{30} = 1.2$$

$$\text{DEDMurderMystery} = \frac{0.1}{42} = 0.0024$$

We can see that the authoring index is significantly reduced from 1.2 to 0.0024. We gave evidence in the evaluation that the drama plays for an extended period of time, some playing for over an hour.

## 5.1 Limitations

We are aware that our tests are on small manually configure data sets and that when we start to test the system on more extensive data sets, primarily auto-sourced sets. We may encounter unexpected side effects of decentralised drama management. When looking at the system with computational modelling in Section [refsee:evaluation:computational](#) in Section ??, we saw an advanced warning of this possibility, which is something we will be looking at further.

We also know that the system is not suitable for scenarios where a specific storyline is required since there is minimal top-down au-

thor control. We are not aiming for applications that require pre-authored stories. We aim to test the DED further in a synthetic training environment where it is more important that the system behaves realistically and imitates opponents behaviour based on real-world data.

### 5.1 Future work

We find our tests to date very promising and are looking to try more advanced ~~tests examinations~~ on a more extensive database with real-world data and natural language processing. We will also look at computational modelling based on N. Szilas & Co to evaluate interestingness ~~as well as and~~ other factors. For example, to understand the situations formed during training scenarios and when designing new ~~scenarios scenes~~. To see if we can use such modelling to evaluate the ~~training value of the scenario scenario's training value~~ to name a few possible avenues for future testing of the DED. We are currently working with Improbable 's Enterprise Defence department on future emphasis.

# Glossary

## Symbols

**radio drama** Is a purely acoustic dramatisation. 19

**virtual reality** According to Wikipedia: “A virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world.” [citevr-wiki](#) plural. 1, 189, 191

## A

**actor** Autonomous agents with deep AI that play characters in emergent drama. 133–135, 139, 141, 142, 144, 145, 150–152, 158, 161, 174

**autonomous agent** Computer based autonomous agents. 4

## B

**Bayesian Network** Belief Networks structured as a directed acyclic graph (DAG) that use [Baye's Bayes](#) rule to evaluate its probabilities. 5, 12, 30, 60, 187, 190

**Belief Network** Probabilistic graphs comprised of vertices and directed arcs that indicate conditional dependency. 30

## C

**character** character. 133, 135–141, 144, 152, 155

**character goal** Goals for characters in emergent drama that are specific for the character role and to stay in-character. 79, 133, 134, 137, 161

**Computer-Based Role-Playing Games** An RPG as a computer game. 25, 190

## D

**directed acyclic graph** A graph that has directed arcs and no cycles. 30, 187, 190

**Directed Emergent Drama** Directed Emergent Drama. 6, 116, 169, 190

**director** Autonomous agent, a drama manager that guides emergent drama with schemas. 141

**drama** A play for theatre, radio, television, and computer games that has a set of characters, and a plot. 1, 7–9, 17–21, 23, 24, 27, 28, 30, 62, 133, 137, 144, 152, 161, 171

**drama goal** Goals that structure emergent drama and guide the actors in developing the plot. 79, 119, 133, 134, 174

**drama proper** A play for theatre that includes; a stage, set of actors that play characters, a plot, props, a director, and an audience. 18–20

**Dynamic Plot Generating Engine** An engine that creates new plots dynamically. 12, 61, 190

## E

**emergent drama** Drama for computer games, virtual realities and training software, that emerges from the interaction between characters played by NPCs and players. 3–9, 28, 29, 83, 133

**expected utility** Expected utility is the calculated value of an action or state given observed evidence. 6, 47

## G

**Game Theory** Game Theory. 12, 30, 60, 190

**GeNIE** A user interface to design and display Bayesian Networks (BNs), [DSL07a]. 5, 190

## I

**in character** An actor or player that is playing a character in a play or a game and act as that character. 22, 190

**interactive drama** Drama for computer games, virtual realities and training software, where the player is one of the actors and takes on a role in the drama. 1, 3, 4, 7, 23, 24, 83, 84, 93, 94, 97, 100, 101, 103, 116, 122, 170, 171, 174

## M

**Massively Multiplayer Online Game** Massively Multiplayer Online Game. 6, 189, 190

**Multi-Agent Influence Diagram** Multi-Agent Influence Diagram. 30, 190

## N

**narrative** A recount of a sequence of real or unreal events. 11

**Nash Equilibrium** A method of calculating an optimal strategy that has an expected utility (EU) that is equal or higher to any other EU in the game. 4, 133

**Non-Player Character** Characters in computer games that are played by the computer. 1, 191

## O

**Object-Oriented Bayesian Networks** A method of dividing the network up into manageable pieces in order to construct a much larger network through the reuse of the individual objects. 6, 118, 191

**officer** A military personnel with command over other personnel, in the context of the Afghan poppy scenario, an officer is second in command to the OC. 161

**Officer Commanding** An officer in command of a minor unit in the British Army. 119, 191

**out of character** An actor or player that is playing a character in a play and starts to behave in a manner that is uncharacteristic for the character they are playing. 133

## P

**Pen & Paper Role-Playing Game** An RPG played in a group with pen & paper and dice to decide game events. 25, 191

**player** A person playing a game. 1–4, 62, 85, 133, 137, 141, 144, 152, 174

## R

**Rational Dialogue Engine** An engine that creates dialogues based on rational non-cooperative play. 8, 12, 191

## S

**Second Life [Lab03]** A virtual reality-environment-virtual reality (VR) that allows developers to program agents that can joint the world and interact with the game world as the players plural. 1, 191

**SpatialOS** A cloud service tool that manages the complexity and scaling difficulties of distributing Massively Multiplayer Online Game (MMOG) over multiple servers and maintaining a single vast game world. 10, 163, 185

**strong autonomy** “The characters maintain strong autonomy (call this the strong autonomy position), with only occasional guidance from the drama manager”[Mat02, p.41]. 184

## V

**vertex** Vertex in a graph. 4–8, 30–39, 43–50, 63, 67–70, 73–75, 79, 126, 139, 141–145, 147, 148, 150–153, 155, 157, 158, 160, 166, 187

# Acronyms

## B

**BN** Bayesian Network. 5, 6, 8, 12, 30, 32, 33, 35–39, 43, 45–48, 60–65, 67, 68, 78, 79, 95, 100, 116, 117, 126, 131–133, 135, 141, 142, 147, 151, 155, 160, 166–172, 185, 187, 188

**BSc** Bachelor of Science. 12

## C

**CB-RPG** Computer-Based Role-Playing Games. 25, 26, 78

## D

**DAG** directed acyclic graph. 30, 88, 187

**DED** Directed Emergent Drama. 6, 7, 10–12, 30, 60, 61, 79, 116, 117, 122, 125, 131, 133, 163, 168–174, 184, 186

**DPGE** Dynamic Plot Generating Engine. 12, 61–63, 65–69, 78, 118, 124, 131, 141, 171, 172

## E

**EU** expected utility. 6–8, 47, 48, 51, 52, 145, 146, 148–150, 153–157, 173

## G

**GeNIE** GeNIE. 5–7, 32, 33, 36, 38–42, 46, 48–50, 64, 69, 74, 75, 117, 131, 132, 142, 147–150, 153, 154, 158, 159

**GT** Game Theory. 12, 30, 50–52, 54, 57, 60, 77, 78, 86, 117, 129, 133, 139, 170, 173

## I

**IC** in character. 22, 119, 133, 169, 174, 184

## M

**MAID** Multi-Agent Influence Diagram. 30, 60, 61, 78, 117, 119, 133, 134, 141, 169

**MMOG** Massively Multiplayer Online Game. 1, 6, 10, 128, 129, 133, 141, 189

**MSc** Master of Science. 12

**N**

**NPC** Non-Player Character. 1, 3, 4, 7, 24–28, 66, 79, 83–85, 90, 117, 141, 163, 165, 169, 184

**O**

**OC** Officer Commanding. 119, 121, 123–125, 131, 135, 140, 142, 144, 151, 161, 163, 167

**OOBN** Object-Oriented Bayesian Networks. 6, 45, 60, 79, 118, 119, 131, 132

**OOC** out of character. 133

**P**

**PP-RPG** Pen & Paper Role-Playing Game. 25, 26, 78

**R**

**RDE** Rational Dialogue Engine. 8, 12, 61, 67, 70, 78, 139

**RPG** A game where the players take on a role in a fantasy adventure. 25–27, 93, 169–171

**S**

**SL** Second Life [\[Lab03\]](#). 1

**V**

**VR** [virtual reality](#). 1–3, 14, 84, 189

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