

# Extending Believable Agent Frameworks with Predicate Logic Dialogue Generation

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## Abstract

Despite advances in graphics, physics, and AI, modern video games are still lacking in believable social simulation. Story, dialogue, and character behaviour are more often scripted than allowed to emerge dynamically. The more complex and interactive stories in modern games may allow the player to experience different paths in dialogue trees, but such trees are still required to be manually created by authors. Recently, there has been research on methods of creating emergent believable behaviour [CITE facade, fatima, acton, etc.], but these are lacking true dialogue construction. Because the mapping of natural language sentences to meaningful computational representations (logical forms) is still an unsolved problem [CITE Zettlemoyer], it may be best to represent inter-character dialogue as logical forms. The proposed thesis will extend an existing believable agent framework with a predicate logic-based dialogue module that will allow for true construction and interpretation of dialogue by non-player characters.

## 1 Introduction

Throughout the history of video gaming, the majority of efforts to increase believability have focused on advancement in graphics and physics, powered largely by advances in computer hardware. Modern games often have near-photorealistic graphics and highly believable physical simulation. However, advances in AI, although present, have not added much to believability. Rather, developments in game AI are focused on providing challenging and interesting gameplay by creating agents that can either cooperate or compete with the player. Such agents, although effective in creating entertaining gameplay, fail to create believable characters, specifically with regards to social behaviour.

In addition to social behaviour, the ability to generate dialogue dynamically is also lacking. Modern games which are praised for their complex dialogue systems, such as the Mass Effect series [CITE Mass Effect] do not in fact have their characters generate dialogue, but rather select from pre-written (and voiced) dialogue based on certain conditions. Even experiments in interactive drama such

as Facade [CITE facade] rely on complex ways of selecting from a set of existing dialogue acts. Faade is a highly variable game experience taking only about 20 minutes to play through and consisting of a very limited environment (a single room with one player character and two NPC's), and yet several hundred thousand lines of code were written of handle all possible dialogue acts [?]. Clearly, such an approach is not scalable to open world, multi-agent environments.

Believable agent frameworks are already in place which simulate emotional and social interactions. These systems allow for autonomous agents to form goals based on their current emotional state and social relations, and perform actions to satisfy those goals.

The proposed thesis will involve the implementation of an extension to FAtiMA [?], an existing believable agent framework. Currently, the agents in FAtiMA are limited to selecting from an existing finite set of actions to perform based on their goals and current state. Using the same goals and current state, the dialogue module would allow agents to perform not only action selection, but action construction, creating arbitrarily logical expressions to communicate to other agents. Additionally, the module will allow for the interpretation of such logical expressions to affect the current state of an agent.

## 2 Background and Previous Work

This thesis will involve the synthesis of both Believable Agent Frameworks (abbreviated here as BAF) and Natural Language Processing (NLP). This section will provide background and previous research from each of these areas.

### 2.1 Believable Agent Frameworks

A BAF is any framework that simulates the social and emotional behaviours of humans in a believable way. The term “Believable” is difficult to define because it is subjective by nature. However, it is often suggested that believability is not truly an attempt to fool the user into actually believing what is presented. It is rather an attempt to allow the user to willingly suspend disbelief. [?]

A well-known attempt to create more believable narrative and gameplay is the Facade project [?]. Facade is a one-act interactive drama with a natural written language interface. The player takes on the role of a character visiting a married couple, and is able to converse in real-time with the other two characters by typing natural language utterances.

Although Facade was created to select appropriate responses to many situations, each of these responses was hand-authored. Additionally, natural language input from the user was not interpreted to its fullest possible extent by the program. Rather, surface text processing was used which searched user input for a number of key words and phrases and mapped it to one of a finite, pre-defined set of discourse acts. [?] In some ways, Facade can be considered similar to dialogue trees in games such as Mass Effect, but with an interface that gives the illusion of natural language interaction.

Some of the same people who created *Facade* were also involved in the creation of the “Comme il Faut” (CiF) [?], a social AI system. The intention of CiF was to provide a “system for authoring playable social models” [?]. Rather than authoring dialogue trees, which the authors called “burdensome” and “highly constrained”, the Social AI System would allow the authoring of a “space of possible stories”. Through the definition of social and cultural rules that can be applied to a given social state, believable social behaviour is allowed to emerge.

CiF was used to implement the game *Prom Week* [TODO: Cite the game itself?]. *Prom week* pioneered what the creators termed “Social Physics” [?] – intuitive rules of social interaction that could guide the user’s gameplay toward accomplishing the game’s goals, similar to how physics are used in many puzzle games. However, like *Facade*, and despite its advanced modelling of social and emotional phenomena, the dialogue is still composed of a finite number of templates that are selected in the appropriate situations.

A more easily accessible (in terms of source code) and more modular BAF is the FearNot Affective Mind Architecture (FAtiMA) [?]. FAtiMA was developed initially as an engine for *FearNot!* [TODO: Cite fearnot game?], a serious game aimed at teaching school children between ages 8 and 12 how to deal with being bullied.

FAtiMA has a number of modules, each based around modelling aspects of believable agents. These include modules for modelling Theory of Mind [?], memory, emotional intelligence, dialogue, and others. It also has the ability to be easily extended by adding new modules. This feature allows different models of the same phenomena to be implemented and tested for validity within the same framework (e.g. evaluating different theories of emotion appraisal for their believability).

In terms of dialogue, FAtiMA currently has a module that maps Theory of Mind - related goals to pre-defined discourse actions. Theory of Mind goals differ from other goals in that they seek to affect the state of another agent’s beliefs rather than the state of the world itself. These dialogue acts, however, are not created dynamically and must be manually authored and explicitly mapped to corresponding agent goals.

## 2.2 Natural Language Processing

Natural language processing is still an ongoing area of research. Recent developments have lead to more advanced search engines and data mining techniques, as well as computer-aided natural language translation. However, the problem of mapping natural language sentences to meaningful forms that can be effectively interpreted by a computer is still a very open problem.

Zettlemoyer [?] has conducted some interesting research on the topic of mapping natural language sentences to lambda calculus expressions, which can be easily represented as sentences in first-order logic. His research makes use of combinatory categorical grammars (CCG) [?] generated by advanced machine learning techniques in order to parse sentences of various natural language.

An example of a mapping of natural language to lambda calculus is demonstrated below. Here, the sentence “What states border Texas?” is mapped to an equivalent lambda expression. The expression takes as a parameter a single unbound variable  $x$ , which must satisfy the condition of being a state and bordering Texas. When the expression is used as a query to a knowledge base,  $x$  unifies with all values that satisfy both conditions.

“What states border Texas?”

$$\lambda(x).(state(x) \wedge border(x, Texas))$$

$$x = \{NewMexico, Oklahoma, Arkansas, Louisiana\}$$

Although the specifics of the theory and implementation are beyond the scope of – and likely of little relevance to – this proposal, the important realization is that natural language sentences could be transformed into these forms, as well as the fact that software exists that can accomplish this transformation [TODO: Reference Openccg?]. Using software to translate logical expressions into natural language could allow the creation of language-independent dynamic dialogue systems that can be easily localized into different languages.

### 3 Problem Description and Proposed Solution

Although many of the Believable Agent Frameworks researched so far have had extensive flexibility in the use of authored dialogue, the fact still remains that the dialogue must be authored. For each dialogue act, its representation (i.e. words used in the dialogue) as well as each of its effects on the world or other agents must be explicitly defined. Additionally, explicit mappings between agents’ states or goals to dialogue actions must be provided (e.g. the goal to make another character laugh must explicitly relate to the “tell joke” action).

The proposed solution is to create a system that alleviates the need to explicitly author dialogue acts. Rather than providing a set of mappings between domain-specific dialogue acts and goals, a domain-independent module will be created that constructs dialogue acts to match goals. The system will be implemented as an extension to FATiMA’s existing dialogue system.

FATiMA uses knowledge bases to represent both the state of the world and the beliefs of individual agents. These knowledge bases have capabilities similar to first-order logic systems. Rather than generating natural language dialogue, first-order logic expressions will be created to accomplish the goals that have been specified by the agents.

If possible, the solution may also include natural language “rendering” and “de-rendering” modules. These would allow logical expressions to be converted to and from natural language sentences. This is not necessary in the implementation, but may be included if time allows in order to demonstrate how natural language could further improve believability.

## 4 Design

### 4.1 Overview of FAtiMA

Figure 1 shows the high-level architecture of FAtiMA. Agents exist in the world and are able to perceive their environments with Sensors and change their environments with Effectors. When an event is perceived, it is emotionally appraised. This appraisal tells the agent how the event should be interpreted and how it should affect its memory, emotions, intentions, and plans. After appraisal, the agent begins its coping process. Coping determines how the agent should act given the state of its emotion and memories.

Both appraisal and coping act on two different levels – reactive and deliberative. The reactive level deals with instantaneous, reflexive actions. These typically equate to actions that result from instinct, such as yelling when hurt. The Deliberative level deals with long-term actions which require more deliberated planning. The deliberative layers make use of continuous planners with partial-order plans in order to achieve goals. [?, ?]

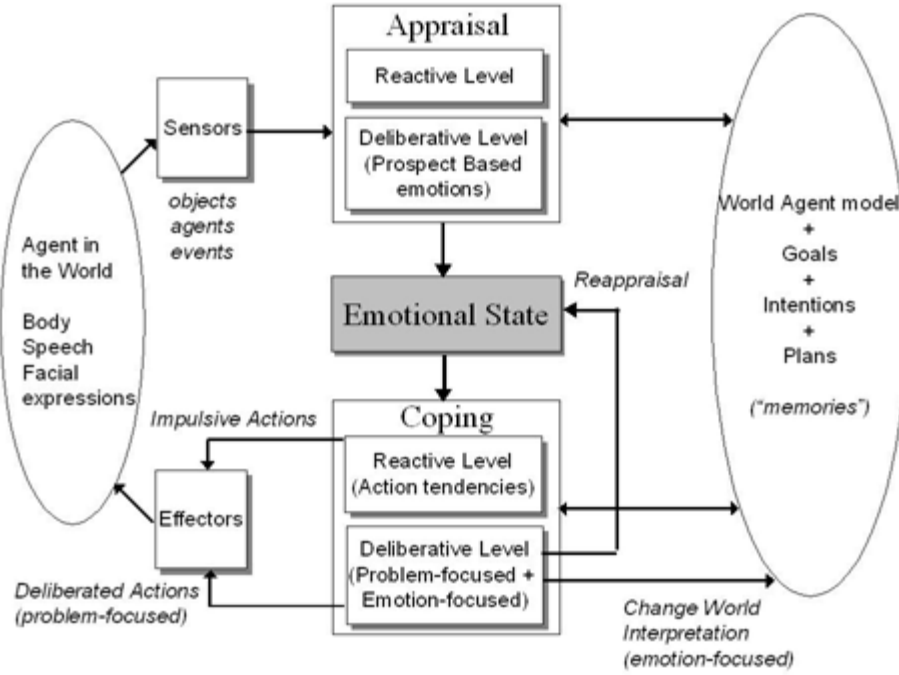


Figure 1: FAtiMA's architecture [?].

## 4.2 FAtiMA World and Knowledge Representation

FAtiMA’s planning modules construct plans that affect the world state and agents’ knowledge states. In fact, the world state in FAtiMA is a special case of agents’ knowledge states. The world state consists of all knowledge that is consistent across all agents in the world. That is, if all agents believe the same fact, it is true (the potential philosophical implications of this view are profound, but I won’t get into that).

Figure 2 shows an example of how actions may be defined for agents in FAtiMA. This particular action is part of a simple scenario in which the user guesses which box a coin is hidden in. The Open action is described here. Its preconditions state that the target (a box) must be on the table, another agent ([AGENT]) must be present, and be a person, and not equal the original agent (SELF).

The next two predicates specify further preconditions relating to individual agents. In general, predicates specify only a name attribute, which allows description of general facts about the world. For instance, [target](OnTable) specifies that the target is on the table. However, a ToM (Theory of Mind) attribute may be specified, which restricts the predicate to describe only the knowledge of the selected agent. The fifth precondition specifies ToM to be SELF. Therefore, while ![target](Contains, coin) would usually mean “the target does not contains the coin”, the ToM attribute restricts it to mean “I think do not think that the target contains the coin”. Therefore, the last two preconditions (which determine the outcome of the game) state that the original agent must not think that the box contains the coin, and that the other agent must think that it does. The final result of taking this action is that the original agent has the coin.

Figure 3 shows a specification of a goal in the same XML format. Like the action, the goal specifies a set of preconditions. However, rather than specifying effects directly, it specifies success conditions. These success conditions allow the planner to select actions that can accomplish the goal. For instance, the success condition here is SELF(has,coin). Since this matches the effect of the action in figure 2, the planner will select that action to accomplish this goal (as long as the preconditions match).

## 4.3 Action Construction vs. Action Selection

This thesis aims to enable action construction in this system. In those cases where goals are defined with success conditions that have ToM attributes specified (i.e. when they attempt to make another agent believe something rather than affecting the world), the planner should not have to select from a set of pre-written actions. Instead, actions will be constructed as first-order logic expressions that affect the knowledge base.

These expressions will be produced by a sender agent and received by another receiver agent. The receiver will interpret the expression and affect its own knowledge base accordingly.

The specific format used for communication of first-order logic expressions, as well as the algorithms used for action construction, have yet to be determined.

## **5 Timeline**

TODO: I'll discuss this with you.

```

<Action name="Open([target])" probability="0.8">
  <PreConditions>
    <Predicate name="[target] (OnTable)" />
    <Predicate name="[AGENT] (isPerson)" />
    <Property name="[AGENT]" operator="!=" value="SELF" />
    <Predicate ToM="SELF" name="! [target] (Contains,coin)" />
    <Predicate ToM="[AGENT]:SELF" name="[target] (Contains,coin)" />
  </PreConditions>
  <Effects>
    <Effect probability="1.0">
      <Predicate name="SELF(has,coin)" />
    </Effect>
  </Effects>
  <EffectsOnDrives>
  </EffectsOnDrives>
</Action>

```

Figure 2: Example of an action defined in FAtiMA's XML format.

```

<ActivePursuitGoal name="Test([target])">
  <PreConditions>
    <Property name="[target] (isPerson)" operator="=" value="True" />
    <Property name="[target]" operator="!=" value="SELF" />
    <RecentEvent ToM="[target]" occurred="True"
      subject="[target]"
      action="SpeechAct"
      target="SELF"
      parameters="starttest" />
    <Property name="[box] (type)" operator="=" value="Box" />
    <Predicate ToM="[target]:SELF" name="! [box] (Contains,coin)" />
  </PreConditions>
  <SuccessConditions>
    <Predicate name="SELF(has,coin)" />
  </SuccessConditions>
  <FailureConditions>
  </FailureConditions>
  <ExpectedEffects>
    <OnSelect drive="Affiliation" target="SELF" value="+2" />
  </ExpectedEffects>
</ActivePursuitGoal>

```

Figure 3: Example of a goal defined in FAtiMA's XML format.