

# Narrative Structures for Multi-Agent Interaction

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## Abstract

*Multi-agent interaction involves extended exchanges of asynchronous messages among the conversing agents and requires supporting technology in order to manage and keep track of the progress of the conversations. In this paper we outline our current work that extends our previous efforts in the area of improved agent interaction protocols by incorporating techniques inspired by narrativity analysis. We introduce in this context the notion of Narrative nets, a representation based on coloured Petri nets that models progress in the current narratively-based concerns of the communicating agent. The basic ideas behind Narrative nets are presented and an example system modelled after commodities trading is discussed.*

## 1. Introduction

There are several motivating factors behind the current interest in intelligent agents and multi-agent system technology:

1. Based on experiences in human society, particularly in connection with organisations involved in the production of goods and services, it is observed that complex problems can be solved by a collection of cooperating specialists (experts in some narrow subdomain of the problem), none of whom can solve the problem by themselves.
2. Similarly, sophisticated distributed tasks can often be performed more effectively by a collection of specialized agents with local domain knowledge than by a centralized facility.
3. In a dynamic, changing environment, a system of cooperating agents is likely to be able to incorporate new behaviors that can respond to unpredictable events

more effectively than other types of system architectures. If the multi-agent system is open, new agents can appear, and their new capabilities may enhance the overall system performance.

4. Advances in telecommunications have increased the opportunities for inter-organizational communication, creating an electronic environment that appears to be conducive to multi-agent system technology.

In connection with each of these notions, there is the idea that individual agents with some specific, local domain knowledge must cooperate and exchange information so that some overall system goals may be attained. Thus inter-agent communication is crucial, and this paper is concerned with improved methods for agent interactions.

A major research thrust in the area of agent interaction has been concerned with the development of standards for agent communication [1] based on general, commonly-understood speech acts [2], such as *inform*, *query*, and *request*, that incorporate more specific message information that is encoded in some declarative format. In order for the specific message information to be understood by the recipient under these conditions, the sender and receiver must share an understanding of what the terms of the message mean, the formal characterization of which may be encoded in an ontology [3].

The multi-agent system paradigm assumes that agent communication is asynchronous and that message delivery is not guaranteed. Agent communication thus takes place over a period of time, comprising the exchange of several messages that are sent with respect to their situated context in the ongoing “conversation”. In an effort to provide standard mechanisms for these extended agent message exchanges, research has been directed towards the specification of “conversation policies” or “interaction protocols” [4]. Although some research has been directed

towards connecting the agent message with the presumed internal belief states of the sender and recipients [5], other researchers [6] have emphasized that in order to sustain the presumed strengths of the agent paradigm, it is important to maintain communication standards that are understood purely in terms of their public statements and are independent of (not inherently connected to) any internal states of the communicating agents. In this regard the Foundation for Intelligent Physical Agents (FIPA) [1] has sought to establish some standard interaction protocols (IPs) that can be used in connection with the FIPA Agent Communication Language (ACL) standard. Like networking protocols, these interaction protocols specify the agent messages that are allowed in response to other agent messages in the course of a named specific type of agent interaction.

Although the existing work on agent interaction protocols is very important for establishing standards for agent communication, this paper argues that it can be useful to consider agent interaction in terms of other, higher-level structures that are inspired by narrative studies [7]. We characterize these structures in terms of narrative nets, which are described in this paper. Some examples of narrative nets are given and their association with interaction protocols is discussed in the context of agent communication as specified by FIPA. We also discuss some issues concerning how new narratives may be constructed by agents in the course of their experiences.

## 2. Narrative

Narrative studies in the humanities and social sciences have been concerned with the ways in which human beings understand and structure their experiences in terms of stories [7]. For example, it seems that even though our dreams may often seem like a collections of loosely-connected successions of images, we often relate them to others in terms of more coherent story structures. From these studies, it is argued that when we relate our experiences to others, we present them in terms of narrative structures. Moreover, it is also suggested that we “relate” these stories to ourselves, too, and store them in our memories in terms of stories: the original experiential details are lost and only the stored stories are retained. Schank [8] has argued that all of our understanding is structured in terms of stories. This is in sharp contrast to earlier prevailing linguistic theories [9] that have assumed we maintain our memories in terms of linguistic, logical structures. Certainly Schank’s earlier categorical claims that story structuring is the sole organizing principle of human memory have been disputed [10], but many researchers in the social sciences have at least conceded the

point that narrative structuring is a major aspect of human comprehension and hence communication.

For example anthropological studies of preliterate societies suggest that much of the culture has been understood in terms of stories and myths [11,12]. These stories provide a situated context in which to understand significant values and activities associated with the culture. Australian aborigines have been able to navigate through vast tracks of seemingly featureless outback terrain by remembering learned stories associated with their culture [11].

From our perspective, narratives or stories represent one kind of diachronic model that we maintain about the world. We have other models about the world, too – for example logical, structural, and geometric models. But all of these models are built up in our minds (and stored for later recall) as a result of our experiences in connection with interacting with people and things in the world. When new sequences of events are experienced, we are prone to select one of these stored models from our memories that match the events of current concern. When we are dealing with diachronic sequences, we match *narrative* structures. Thus narratives represent a very important type of (but by no means the only) mental model.

Another thread of research that relates to the study of narrative is the linguistic study of metaphor [13]. Here the work has focused on speech and text and so ‘metaphor’ has been the dominant term, but in fact this research overlaps closely with that of narrative. Many of the primary metaphors that have been identified by Lakoff and Johnson [14] are essentially primitive narrative structures. For example the JOURNEY metaphor and the OBJECT EVENT-STRUCTURE metaphor discussed by Lakoff and Johnson are really elemental elementary narrative prototypes.

The use of narrative understanding to aide computer understanding has been pursued by several researchers. Schank was interested in story structures for human memory organisation. Wilensky has been concerned with story understanding. Others [15] have been interested in identifying narrative structures for the support of embodied human interface agents. Our interests here are to investigate the extent to which we can employ narrative structures to assist and coordinate the agent interaction over extended periods of time.

## 3. Narrative and Interaction Protocols

So the question then presents itself: how do narrative structures, if they are to be employed, relate to agent

interaction protocols? Here it is necessary to recall the specific purposes for which interaction protocols have been designed. Agent interaction protocols, are usually specified nowadays as statements external to the internal state of the sending agent. Figure 1 shows a UML sequence diagram of one of the elementary FIPA interaction protocols, the Query Interaction Protocol Specification [1].

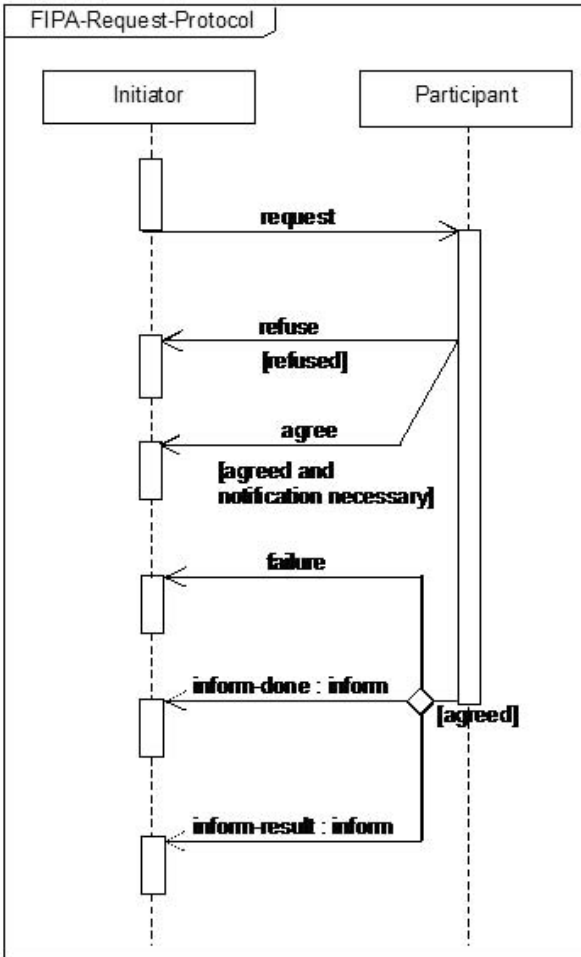


Figure 1. FIPA Request interaction protocol.

We have argued previously [16] that even with the specification and implementation of interaction protocols, it is useful to include some aspects of the local agents' state. For this reason we have used coloured Petri nets [17] to characterize (and ultimately implement) agent interaction protocols. Figures 2 and 3 show our depiction of the request interaction protocol, where places are represented by circles and transitions are represented by rectangles, but with net incriptions (arc inscriptions, place colour

notations, markings, and guards) omitted for simplicity of presentation.

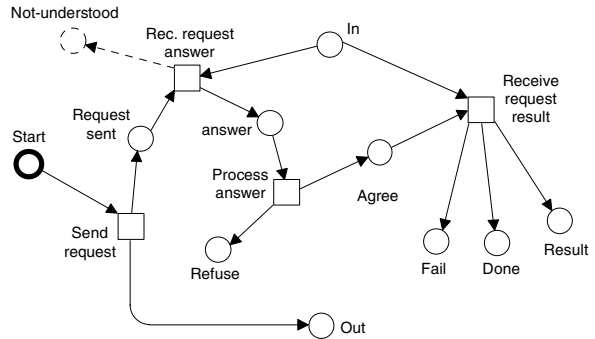


Figure 2. Request IP for the Initiator role.

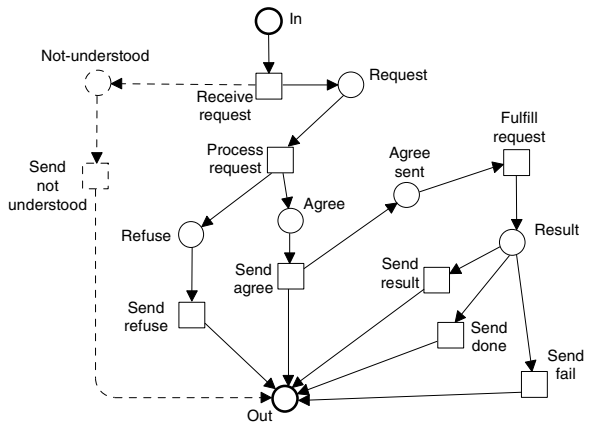


Figure 3. Request IP for the Participant role.

As can be seen from these figures, some inclusion of local agent state is useful in order to keep track of where the participating agent is the interaction, which can facilitate the support of multiple concurrent interactions of the same type of IP. However the narrative context includes more aspects of the participating agents' local state: the goals and intentions of the principal participating agents, which means that internal agent states are necessarily involved. In addition, a narrative may encompass several interactions with different participants during the course of the events covered by the narrative. So we can think of the interaction protocol as the specific rules of engagement and interaction concerning how the participating agents interact. The narrative, of which specific agent interactions may be a part, has the shape and structure of a story with an overall outcome.

## 4. Narrative Nets

In order to characterize narrative structures, we employ what we call “narrative nets” (N-nets), which are also based on colored Petri nets. Narrative nets include the usual formally specified graphical elements of colored Petri nets, but with extensions for capacities and inhibitor arcs [18] and with associated ‘page’ data structures connected with the overall narrative and with the structures of the token colors. A ‘page’ is a non-hierarchical net and includes the specification of the data structures used in the tokens in that page. Objects defined for a page have variable scope restricted to the given page. N-nets can also be refined hierarchically by means the substitution transitions, which relate the given transition and its surrounding arcs to more detailed net structures that represent a refinement of the given transition [17].

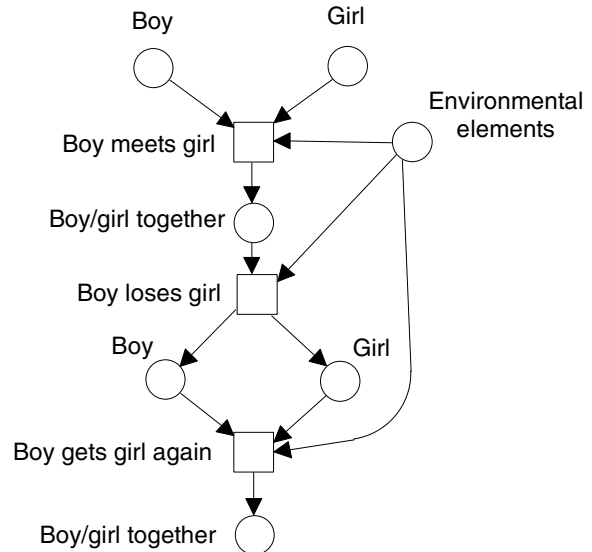
There are two types of narrative structures that are commonly discussed in the narrative studies literature, and they are designated by their original technical terms, *syuzhet* and *fabula* [7,19]. The *syuzhet* represents the sequence of events that is presented to a customary audience (or is experienced by the agent). This is sometimes thought of as the “plot” of the story. The *fabula* is the causal model that is constructed by the audience concerning what actually happened. Narrative nets are intended to be able to represent both *syuzhet* and *fabula* structures. In literature, drama, and film, there can be a complex interplay between *syuzhet* and *fabula*, and many authors construct complicated plots in order to entertain their public audience. For example Bordwell [19] identifies the following sequence of events that appears in genre detective narrative *syuzhets*:

- a. Crime:
  1. Cause of crime
  2. Commission of crime
  3. Concealment of crime
  4. Discovery of crime
- b. Investigation:
  1. Beginning of criminal investigation
  2. Phases of investigation
  3. Elucidation of crime
  4. Identification of criminal
  5. Consequences of identification

The viewer or reader may be given only parts of this sequence with the expectation that he or she will be able to construct a coherent *fabula* by the end of the story. For our purposes, we will not be concerned with complicated *fabula* constructions, but we will discuss this activity at the end of

the paper. So in the following we will assume that the N-nets represent *fabulas* that have been encoded in a straightforward fashion.

Consider, for example, a simple structure for a love story represented by a N-net.



**Figure 4.** N-net of simple relationship story.

In a typical N-net, there is usually a single ‘protagonist’; here it happens to be the boy. There can also be other key agents, including one or more antagonists. If two agents are involved in this story, each may have its own N-net representation, with differing ‘protagonists’ depending on the roles played by the agents. When the individual agents are engaged in specific interactions, then the transitions shown in the N-net, such as “Boy meets girl”, actually represent abstractions of more detailed interactions that may be specified by interaction protocols.

Although the simple boy/girl story in Figure 4 only has a single token for each agent (because there is only a single plot line), stories in general can involve multiple, concurrent plot lines. So just as in a film, where there can often a primary dramatic or adventure plot and a parallel “relationship” plot involving the main characters, there can also be concurrent plot structures represented by N-nets. Thus there may be several tokens in the N-net that characterize specific aspects of the agent, especially when there are concurrent story lines. The overall state of an agent at any moment is represented by the states of all that agent’s tokens in the N-net.

N-nets are initially provided as generic narrative templates which are then filled in with more detail for specific situations. The number of N-net templates can vary, depending on the level of detail they carry. Bordwell [19] indicated that there was common agreement among story comprehension researchers on the following common template structure:

- [1] introduction of setting and characters
- [2] complicating action
- [3] ensuing events
- [4] outcome
- [5] ending

However one wonders if this scheme is too general to be of much use. Vladimir Propp [20] tried to be more specific, but still attempted to characterise the deep structure of all stories and myths and came up with 31 basic plot elements based on the notion of a heroic quest or journey. Example plot elements included such items as “villain attempts to deceive hero with trickery” and “hero acquires special agent/object which will assist in the quest”. Although Propp’s work has been influential, subsequent work has suggested that it is too specific to be of general use. So our most suitable narrative templates probably lie somewhere in between the characterizations of Bordwell and Propp.

In addition to basic plot elements, Schank [8] and Branigan [21] have identified additional narrative structural components. Drawing from their work, we use the following structural features (“page” data structures) to complete the N-net structure:

- roles
- goals (of protagonist)
- initiating event
- initial intentions or tactics
- relevant present (or past) state of affairs and key constraints
- resolution, exposition
- summary observation or lesson

When an N-net is used, these features can be modified or adjusted for specific circumstances. They are to be used by the agent to guide it through the narrative. The final two items can be referenced by the agent in connection with past experiences of the same narrative type.

## 5. An Example Multi-agent Interaction

In this section we discuss a multi-agent example based on the *Pit* card game [22], which is modeled after commodity business trading. In this game, players trade cards whose ‘suits’ represent commodities, such as *wheat*,

*barley*, etc. When play begins, the players independently and asynchronously exchange cards with each other, attempting to “corner” the market by getting all the cards of any one commodity. On any single exchange, all the cards traded must belong to a single commodity type. Trading is carried out by a player (the “bidder”) announcing that he has some cards to trade. If another player (a “trader”) wishes to trade the same number of cards, the two players may make an exchange. Whenever a player manages to get a ‘corner’, he announces that fact and the given “hand” is finished (the interaction protocol shown here is for a single hand). Players who get a corner in ‘wheat’ (by getting all nine ‘wheat’ cards) get 100 points, a corner in ‘corn’ gets 75 points, in ‘oats’ gets 60 points, etc. The winner of the game is the first player to collect 500 points.

In our version of the *Pit* game, players participate as part of teams. So it is in the interest of a player to help his or her teammates. For example, if a player guesses that one of his teammates is close to getting a corner on ‘wheat’, it will trade any cards of that commodity to its teammate. On the other hand, defensive tactics can be employed, too. If an opposing player is only offering to trade a single card, it may be interpreted that the opposing player is on the verge of getting a ‘corner’. It may then be tactically advantageous to attempt to trade to that player a “contaminating” card that is known to be unsuitable for the opposing player’s potential ‘corner’.

We have implemented this system using the Opal agent platform [23] and incorporating the JXTA protocols [24], so that the game can be played by any number of agent players and without the necessity of having a ‘dealer’ [25]. In addition, new players may appear at any time and enter into play. When new agents appear and are to be incorporated into the network of available agents, they are sent a FIPA *Propose* message by one of the current players with a message content containing an action proposal to interact according to an enclosed protocol specified by an XML serialization of a Petri net. The interaction protocol comprises a coloured Petri net and the associated ontology, represented in UML, for the terms used in the interaction protocol. Both the Petri net and the UML-encoded ontology information are encoded in XML and sent to the newcomer agent when it joins a group.

The interaction protocol for a participant (whether ‘bidder’ or ‘trader’) is shown in Figure 5. Here, again, colored Petri nets are used for the interaction protocol so that the manner in which an agent player keeps track of existing bids and trades can be depicted.

In the course of play, a player always checks to see if he



implementations of these systems are based on the Opal agent platform [23], which employs FIPA ACL communication and on the JFern coloured Petri net engine and simulator [26]. Our approach can accommodate situations in which interaction protocols or narrative strategies may change dynamically. In such a situation, new XML-encoded protocols or N-nets may be sent to the participating agents so that they may interact according to the new schemes.

Narayanan's work [27] in connection with the analysis of linguistic metaphor has some similarities to our approach, but his concerns have so far been restricted to the analysis of the linguistic aspect of individual phrases and has not been used in connection with multi-agent systems. Nevertheless there are potentially fruitful connections between the modeling concerns of narrative studies and metaphoric discourse analysis.

A future area of interest concerns the use of narrative techniques to construct new narrative structures in the course of agent interaction with the environment. The works of Schank, Bordwell, and Branigan in connection with narrative templates are suggestive but will require more specific experimentation in order to investigate the potential of these approaches.

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