A formal framework for inter-agent dialogues

Peter McBurney and Simon Parsons
Department of Computer Science
University of Liverpool
Liverpool L69 7ZF, United Kingdom
{p.j.mcburney,s.d.parsons}@csc.liv.ac.uk

ABSTRACT

We present a logic-based formalism for modeling of dialogues between intelligent and autonomous software agents, building on a theory of abstract dialogue games which we present. The formalism enables representation of complex dialogues as sequences of moves in a combination of dialogue games, and allows dialogues to be embedded inside one another. The formalism can be readily operationalized and its modular nature enables different types of dialogues to be represented.

Keywords

Computational Dialectics, Conversational Agents, Dialogue Games, Multi-agent Communication/Collaboration

1. INTRODUCTION

Recent work in the design of systems of autonomous software agents has utilized argumentation theory, the formal study of argument and dialogue, for modeling agent interactions, e.g. [5, 6]. Influential in this work has been the typology of human dialogues of [7], which identified six primary types of dialogue. These were: *Information-seeking dialogues*, in which participant seeks the answer to some question from another participant; *Inquiries*, in which all participants collaborate to answer some question to which none has the answer; *Persuasion dialogues*, in which one participant seeks to convince others of the truth of some proposition; *Negotiations*, in which participants attempt to divide up a scarce resource; *Deliberations*, in which participants collaborate to decide what actions to take in some situation; and *Eristic* (strife-ridden) dialogues, in which participants quarrel verbally as a substitute to physical fighting. The aim of our work is to provide a formal and generative framework for representing the five non-Eristic kinds of dialogue, as well as dialogues *about* dialogues. A more detailed account of our work is presented in [3].

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2. DIALOGUE GAMES

Formal dialogue games were first proposed in philosophy [2] and have recently been adopted by designers of multi-agent systems [1]. They define a game between two or more players, whose moves in the game are locutions. The game rules typically define what locutions are permitted under what circumstances, and what responses are possible or required. Abstracting from the rules for any one game, we can identify several types of dialogue game rules, as follows. We assume that the issues of discussion between the agents can be represented in some logical language, whose well-formed formulae are denoted by the lower-case Roman letters, p, etc.

Commencement Rules: Rules which define the circumstances under which the dialogue commences.

Locutions: Rules which indicate what utterances are permitted. Typically, legal locutions permit participants to assert propositions, permit others to question or contest prior assertions, and permit those asserting propositions which are subsequently questioned or contested to justify their assertions. Justifications may involve the presentation of a proof of the proposition or an argument for it, and such presentations may also be legal utterances.

Combination Rules: Rules which define the dialogical contexts under which particular locutions are permitted or not, or obligatory or not. For instance, it may not be permitted for a participant to assert a proposition p and subsequently the proposition $\neg p$ in the same dialogue, without in the interim having retracted the former assertion. Similarly, assertion of a proposition by a participant may oblige that participant to defend it in defined ways following contestation by other participants.

Commitments: Rules which define the circumstances under which participants express commitment to a proposition. Typically, assertion of a claim p in the debate is defined as indicating to the other participants some level of commitment to, or support for, the claim. In a negotiation dialogue, for example, assertion of an offer may express a willingness to undertake a transaction on the terms contained in the offer. However, depending on the rules of the game, commitment may express merely that the speaker has an argument for p, and this is not necessarily the same as belief in p, nor does it necessarily imply any intention to act. We track commitments in publicly-accessible stores called Commitment Stores.

Termination Rules: Rules which define the circumstances under which the dialogue ends. These rules may be expressible in terms of the contents of the Commitment Stores of one or more participants.

Instantiating these rules for different types of dialogue has been a recent research focus: e.g. [7] models persuasion dialogues. Given such formal models of each dialogue type, how do we then represent conversations which consist of multiple types? The only previous proposal are the Dialogue Frames of Reed [6]. These enable multiple types of dialogue to be represented, but do not specify the form of the dialogue utterances, nor the rules which govern their formation and issuance. Consequently, Dialogue Frames are analogous to tape-recordings of human conversations, rather than to the rules of syntax and dialogue used by the speakers in the conversations recorded. Consequently, they can not be used to generate automated agent dialogues, which our proposal remedies.

3. AGENT DIALOGUE FRAMEWORKS

In [3], we present a hierarchical formalism for agent dialogues which has three levels: At the lowest level are the topics which are the subjects of dialogues. At the next level are the dialogues — information-seeking, inquiry, etc — each of which we represent by means of a dialogue game formulation. At the highest level are control dialogues, where agents decide which types of dialogues over which topics to enter, if any. Our motivation for this structure is the Game Logic of Rohit Parikh [4], a form of dynamic modal logic developed for representing games in multi-game contexts.

We define an Agent Dialogue Framework (ADF) as a 5-tuple $(\mathcal{A}, \mathcal{L}, \Pi_0, \Pi_{CON}, \Pi)$, where $\mathcal{A}$ is a set of agents, $\mathcal{L}$ is a logical language for representation of discussion topics, Π_0 is a set of atomic dialogue-types, Π_{CON} a set of Control dialogues and Π the closure of $\Pi_0 \cup \Pi_{CON}$ under a defined set of dialogue-combination rules. These rules permit the following operations on dialogues: repeated iteration of dialogue; undertaking two or more dialogues in sequence; undertaking two or more dialogues in parallel; the embedding of one dialogue in another; and the testing the truth of a formula. Each formal dialogue in $\Pi_0 \cup \Pi_{CON}$ is represented in dialogue game form as a 4-tuple, $G = (\Theta^G, \mathcal{R}^G, \mathcal{T}^G, \mathcal{CF}^G)$, where: Θ^G is the set of legal locutions, $\mathcal{R}^G$ the set of combination relations, $\mathcal{T}^G$ the set of termination relations, and $\mathcal{CF}^G$ the set of commitment functions of the dialogue type G.

In [3], we explore the formal properties of dialogues represented in this framework. In particular, we show that the framework enables the automatic generation of each of the five, non-Eristic dialogue types we listed above. We also consider the question of the circumstances under which a dialogue will terminate, an issue of on-going interest.

4. DISCUSSION

The major contribution of this work has been to develop a formal and potentially-generative language for dialogues between autonomous agents which admits different types of dialogues. Abstracting from recent work in philosophy and artificial intelligence developing formal dialogue games, we have proposed a meta-theory of such dialogue games, and used this as the basis of our Agent Dialogue Framework. A second contribution has been to provide a simple game-theoretic semantics for each of these dialogue types.

We see a number of advantages of our approach. Firstly, the formalism provides a single, unifying framework for representing disparate types of dialogue. Although most work to date in agent interactions has involved some form of negotiation, other types of dialogue are arguably as important to the development of full agent societies. Indeed, negotiations may have other types of dialogues embedded within them. Secondly, the use of an explicit representation for the dialogue-type means that the nature of the current dialogue being undertaken is always known to the participants. Thirdly, our formalism is modular, so that other dialogue types may be inserted readily into the framework. Similarly, our formalism permits incorporation of specialized sub-types of dialogues, for instance, public policy debates over environmental risk assessment; these comprise a complex combination of aspects of inquiry, persuasion, deliberation and negotiation dialogues in a specialized domain.

These three advantages are also features of Reed's Dialogue Frames [6]. However, a fourth advantage, not shared by Dialogue Frames, is that the ADF can be used to generate automatic dialogues. Also, because it is based on a meta-theory of dialogue-games, the ADF enables us to use the recent work in computational dialectics in designing such games. A final advantage arises from the use of a logical formalism, which permits us to study the formal properties of these systems, for example, their termination properties. The issue of participant strategies in dialogue games is another area potentially amenable to formal analysis.[1]

5. REFERENCES

[1] L. Amgoud, N. Maudet and S. Parsons. Modelling dialogues using argumentation. In E. Durfee, editor, *Proc. Fourth Intern. Conf. on Multi-Agent Systems (ICMAS-2000)*, pages 31–38. Boston, MA, USA, 2000. IEEE.

[2] C. L. Hamblin. *Fallacies.* Methuen and Co, London, UK, 1970.

[3] P. McBurney and S. Parsons. Agent Ludens: games for agent dialogues. In P. Gmytrasiewicz and S. Parsons, editors, *Proc. Stanford Spring Symp. on Game-Theoretic and Decision-Theoretic Agents*, Menlo Park, CA, USA, 2001. AAAI.

[4] R. Parikh. The logic of games and its applications. *Annals of Discrete Mathematics*, 24:111–140, 1985.

[5] S. Parsons and N. R. Jennings. Negotiation through argumentation — a preliminary report. In *Proc. Second Intern. Conf. on Multi-Agent Systems (ICMAS96)*, pages 267–274. 1996.

[6] C. Reed. Dialogue frames in agent communications. In Y. Demazeau, editor, *Proc. Third Intern. Conf. on Multi-Agent Systems (ICMAS-98)*, pages 246–253. IEEE, USA, 1998.

[7] D. N. Walton and E. C. W. Krabbe. *Commitment in Dialogue: Basic Concepts of Interpersonal Reasoning.* SUNY, Albany, NY, USA, 1995.

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