Journal of Applied Logic 13 (2015) 458–479

Contents lists available at ScienceDirect

Journal of Applied Logic

www.elsevier.com/locate/jal

A Dempster–Shafer model of imprecise assertion strategies

Henrietta Eyre [a,*], Jonathan Lawry [b,*]

[a] Black Swan Data, 11 York Road, Tower Building, London SE1 7NX, UK
[b] Department of Engineering Mathematics, University of Bristol, Bristol BS8 1UB, UK

ARTICLE INFO

Article history:
Received 31 January 2014
Available online 24 December 2014

Keywords:
Multi-agent communication
Assertion strategies
Uncertainty
Vagueness

ABSTRACT

A Dempster–Shafer theory based model of assertion is proposed for multi-agent communications so as to capture both epistemic and strategic uncertainty. Treating assertion as a choice problem, we argue that for complex multi-agent communication systems, individual agents will only tend to have sufficient information to allow them to formulate imprecise strategies for choosing between different possible true assertions. In a propositional logic setting, an imprecise assertion strategy is defined as a functional mapping between a valuation and a set of true sentences, where the latter is assumed to contain the optimal assertion given that particular state of the world. Uncertainty is then quantified in terms of probability distributions defined on the joint space of valuations and strategies, naturally leading to Dempster–Shafer belief and plausibility measures on sets of possible assertions. This model is extended so as to include imprecise valuations and to provide a meta-level treatment of weak and strong assertions. As a case study, we consider the application of our proposed assertion models to the problem of choosing between a number of different vague descriptions, in the context of both epistemic and supervaluationist approaches to vagueness.

1. Introduction

Any satisfactory theory of natural language communication must give an account of assertion. That is, how and why do we choose the particular assertions which we make in a given context? Certainly, veracity cannot be the only factor since, for a particular state of the world, there are usually a huge, perhaps infinite, number of grammatically correct true sentences available as possible candidates. But what are the additional factors at play and how can they best be modelled? Dating back to Lewis' work on *coordination games* [18], game theory provides one established approach to the assertion problem. More recent contributions in this area include communication games proposed by Parikh [20] which are based on Grice's maximums of cooperation in language [11]. Typically, communication games involve two players, a speaker and a listener,

* Corresponding authors.
E-mail addresses: henrietta.eyre@blackswan.com (H. Eyre), j.lawry@bris.ac.uk (J. Lawry).

http://dx.doi.org/10.1016/j.jal.2014.12.003
1570-8683/

each with a payoff function depending on the decisions and actions taken as a result of interactions between agents.[1] In many cases there are optimal strategies for playing the games, taking the form of Nash equilibria. However, communication games which attempt to model the rich and varied multi-agent interactions which make up natural language communications in general, are likely to be highly complex. Individual agents involved in the game will tend to have only imprecise and uncertain knowledge both of the state of the world and also of the exact nature of the game itself. This will then make the identification of optimal strategies, if they exist, difficult or even impossible. Furthermore, given the dynamic nature of language there is an inherent problem with identifying a fixed optimal strategy. Although a communication strategy may be optimal for a fixed point in time we would need a more general strategy to be constantly adapting in order for it to remain optimal within a dynamical system. Instead, we suggest that in such situations agents will consider applying robust imprecisely defined strategies which take account of the best available evidence, but which are then unlikely to identify single optimal assertions. In this paper we propose a Dempster–Shafer theory approach to modelling imprecise assertion strategies in the presence of uncertainty both about the state of the world and about the exact nature of the communication game being played. It is important to note the distinction between these uncertainties. Indeed, Parikh [21] argues that the assertability of an expression must depend on both an agent's belief in the truth of a sentence as well as factors external to that belief. Factors such as how a sentence is likely to be interpreted, recognition of differences in beliefs and motivations across a population and the consequences of any misinterpretations, may all contribute to uncertainty about the nature of a communication game. Here we consider only a very simple type of communication game in which the speaker identifies a single, one-off assertion to make to the listener. For instance, we do not attempt to model an interactive dialogue between the speaker and, potentially multiple, listeners, in which the speaker's choice of her next assertion would need to take into account both her previous assertions and any responses made to them by the listeners. However, while the proposed model is preliminary and developed only for propositional logic, it does provide some initial insight into how imprecise probabilities, such as Dempster–Shafer belief and plausibility, could be applied to the assertion problem. Furthermore, we believe that this elementary model could be subsequently developed so to take account of a more interactive dialogue game, although such an extension lies beyond the scope of this current paper.

The assertion problem is becoming of increasing practical importance in areas of artificial intelligence including natural language generation systems [24], and language evolution in robotics. Natural language generation systems are software tools which receive a representation of the state of the world as input, usually in terms of certain key attributes, and then output natural language text in the form of a description, summary, diagnosis or forecast. Existing systems include those developed for automatic weather forecasting [10] and as medical diagnosis tools [23]. The assertion problem is also of great importance in language games. This is a paradigm introduced by Steels [27] in order to study the evolution of communication protocols between agents in a simulated or real environment. As with communication games, language games are played between two agents. One agent, acting as a speaker, will formulate a linguistic utterance to be asserted to the interacting agent (the listener) given the agent's conceptual model, a goal and the constraints placed upon this goal (for example by the environment). The listener must then recognise the assertion given to her, interpret its meaning in relation to her conceptual model and update this model so as to satisfy any constraints implied by the assertion.

In both the types of AI system described above, the assertion problem tends to be formulated as a kind of decision problem. For instance, in natural language generation systems, rather than viewing the problem as one of translation from some formal representation of the state description into natural language text, it is instead thought of as a problem of choosing between a number of alternative viable texts [28]. Similarly, robotic agents playing a form of Steels' language game must choose between different available descriptions of the objects they encounter. Here we adopt essentially the same approach, in which agents attempt to

[1] See Allot [2] for a nice overview of game theoretic models of communication.