Default Reasoning for Forensic Visual Surveillance Based on Subjective Logic and its Comparison with L-Fuzzy Set Based Approaches

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ABSTRACT

Default reasoning can provide a means of deriving plausible semantic conclusion under imprecise and contradictory information in forensic visual surveillance. In such reasoning under uncertainty, proper uncertainty handling formalism is required. A discrete species of Bilattice for multivalued default logic demonstrated default reasoning in visual surveillance. In this article, the authors present an approach to default reasoning using subjective logic that acts in a continuous space. As an uncertainty representation and handling formalism, subjective logic bridges Dempster Shafer belief theory and second order Bayesian, thereby making it attractive tool for artificial reasoning. For the verification of the proposed approach, the authors extend the inference scheme on the bilattice for multivalued default logic to L-fuzzy set based logics that can be modeled with continuous species of bilattice structures. The authors present some illustrative case studies in visual surveillance scenarios to contrast the proposed approach with L-fuzzy set based approaches.

Keywords: Bilattice, Default Reasoning, Forensic Visual Surveillance, Fuzzy Belnap Logic, Fuzzy Four-Valued Logic, Interval-Valued Fuzzy Logic, Intuitionistic Fuzzy Logic, L-Fuzzy Sets, Subjective Logic

INTRODUCTION

Recent advances in computer vision technology have been bestowing increased vision analytic power such as detecting specific patterns of human or object behavior on intelligent visual surveillance systems. However, due to the wide proliferation of visual surveillance systems in various domains, the demand for more flexible and powerful higher-level forensic semantic

DOI: 10.4018/jmdem.2011010103
understanding and analysis of visual surveillance scenes is also growing. One of the important types of higher-level semantic analysis is the forensic sense of semantic analysis after an incident. Such forensic semantic analysis deals with a propositional assumption to be investigated and the answer to the propositional assumption should be an epistemic reasoning result upon observed evidential and contextual cues. Considering the wide variety of semantics possibly implied in visual surveillance scenes, such forensic analysis requires appropriate reuse of observed evidential metadata generated from vision analytics, and mating it with additional high-level contextual knowledge. However, unlike domains that can solely rely on deterministic knowledge model, such contextual knowledge as well as vision analytic results suffered from uncertainties, incompleteness and inconsistencies. Therefore, forensic analysis of visual surveillance data essentially requires a flexible and powerful means of knowledge representation together with a proper uncertainty representation and handling formalism. To cope with this aspect, extensional approaches (aka. rule-based systems) are gaining gradually increasing attention. Extensional approaches treat knowledge as conditional rules that are labeled with uncertainty (Pearl, 1988) and logic programming is one that is used for modeling contextual rules. When it comes to uncertainty representation formalisms, there are number of formalisms such as Bilattice (Ginsberg, 1988), fuzzy set based fuzzy logic (Zadeh, 1965, 1973), Dempster Shafer belief theory (Shafer, 1976) and traditional probability based Bayesian approaches, etc. Therefore, for the proper choice of uncertainty formalism, it is important to know their characteristics and behind philosophy on representing and handling uncertainty. Subjective logic (Jøsang, 2001) is also one such uncertainty representation and handling formalism that can be seen as extended theory derived from both the Dempster Shafer belief theory and second order Bayesian. From Dempster Shafer belief theory, subjective logic inherits the philosophy of explicit representation of ignorance about knowledge in a model called subjective opinion triangle that can be also mapped into beta distribution. The operators of subjective logic are also derived in the sense of Bayesian. Unlike traditional Dempster Shafer evidence fusion method, that is known to yield counter intuitive result when it is operated with highly contradictory evidences and also known to be inconsistent with Bayes’ rule, subjective logic comes with similar opinion fusion operators that are robust even with such highly contradictory evidences (Jøsang, 1997). Compared with bilattice that mainly consists of two lattices, one representing degree of truth and the other representing degree of information respectively, the degree of information concept is similar to degree of ignorance in subjective opinion. The main difference between bilattice and subjective logic is the operators. While bilattice comes with four operators that are compositionally defined based on two lattice operators meet and join from the perspective of set theory, subjective logic comes with 12 operators defined rather in Bayesian sense. Another formidable uncertainty handling formalism, fuzzy logic is based on fuzzy set theory that relies on degree of membership concept for a knowledge segment and again this is similar to the concept of partial ignorance in subjective logic. Interestingly, it is known that some extensions of fuzzy logics can be modeled with (bi-)lattice structures. One thing worth to note concerning fuzzy logic is that, even though there are Zadeh’s original logical operators, there are yet another ways of defining logical operators as well. However, due to this aspect, there is inconsistent between fuzzy logic operators and classical probability calculus, thereby often criticized by statisticians who prefer Bayesian (Zadeh, 2008). Thus, we advocate that above aspects make the use of subjective logic attractive as a means of representing and handling uncertainty for artificial reasoning.

In addition to uncertainty representation aspect, what is also important is the uncertainty handling in a way supporting nonmonotonic property. In reality, the truthness of a partial knowl-
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