Working with Uncertainties in Knowledge Assessment

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Abstract: Boolean logic appears to be unable to draw conclusions in the presence of inconsistent and/or incomplete information. Fortunately, what seems to be impossible to solve applying binary logic can be achieved using non-binary logic. In this work we use the theory of many-value logic to facilitate the deductive process of knowledge assessment.

Key–Words: Web-based assessment, learning, intelligent tutoring systems

1 Introduction

Nearly all intelligent tutoring systems are asking students to point the correct answer (in case of exactly one correct answer), to recognize all correct answers (in case several correct answers are suggested), or to provide a solution (if the system suggests open ended questions). Such systems do not provide customized guidance if f. ex. a question receives an incorrect answer or is not answered at all.

In this paper we discuss automated assessment of students' understanding of new components. Application of a many-valued logic allows the system to handle situations with inconsistent and/or incomplete input. Many-valued logic is a generalization of Boolean logic and as such offers solutions to many Boolean problems.

The rest of the paper is organized as follows. Related work and statements from many-valued logic is presented in Section 2. System responses are placed in Section 3. The system architecture is described in Section 4. The paper ends with a conclusion in Section 5.

2 Background

Let P be a non-empty ordered set. If $sup\{x, y\}$ and $inf\{x, y\}$ exist for all $x, y \in P$, then P is called a *lattice* [1]. In a lattice illustrating partial ordering of knowledge values, the logical conjunction is identified with the meet operation and the logical disjunction with the join operation.

A three-valued logic, known as Kleene's logic is developed in [8] and has three truth values, truth, unknown and false, where unknown indicates a state of partial vagueness (Fig. 1). These truth values represent the states of a world that does not change. Two natural orderings concerning 'amount of knowledge' and 'degree of truth' are suggested [2]. Thus applaying 'knowledge' ordering we place the value unknown below both truth and false, while applaying 'degree of truth' ordering results in unknown better than false, and truth better than unknown, i.e. false, unknown, truth.

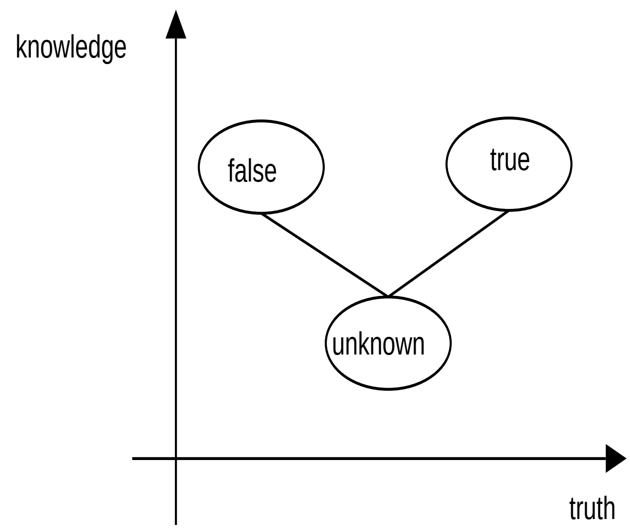

Figure 1: Kleene's strong 3-valued logic

A brief overview of a six-valued logic, which is a generalized Kleene's logic, has been first presented in [10]. The six-valued logic was described in more detail in [6]. In [2] this logic is further developed by assigning probability estimates to formulas instead of non-classical truth values.

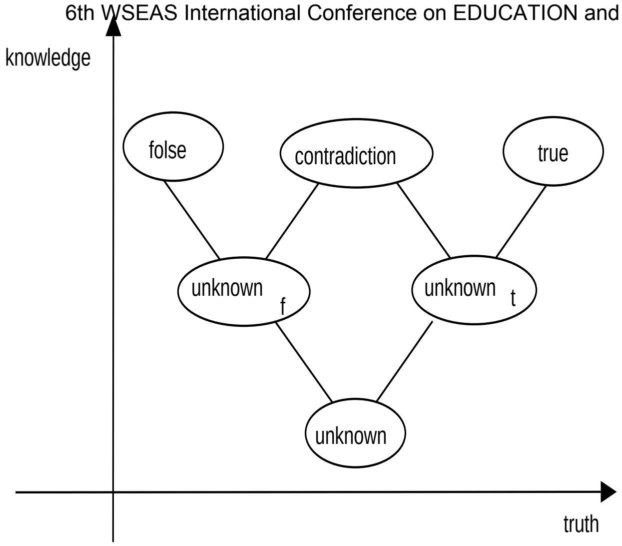

Figure 2: Knowledge lattice

The six-valued logic distinguishes two types of unknown knowledge values - permanently or eternally unknown value and a value representing current lack of knowledge about a state [5].

A lattice showing a partial ordering of the truth values *false*, $unknown_f$, *unknown*, $unknown_t$, *contradiction*, *true* by degree of knowledge is presented in Fig. 2. The knowledge lattice illustrates how the truth value of a formula that has a temporary truth value can be changed as more knowledge becomes available. Suppose a sentence has a truth value $unknown_f$ at one point of time and *false* at another. Its truth value is then determined as *false*, i.e. the system allows belief revision as long as the revision takes place in an incremental knowledge fashion.

3 System Response

Each test is composed of two questions, where understanding of a component is achieved if a student gives a correct answer to each of the two questions about that component.

Applying on the theory of many-valued logic in [3], and [4] we propose the following:

- 2 *ca* → understanding.
  System response - terminate questioning.

- 1 *ca*, 1 *na* → some doubt.
  System response - hints and one new question from the database.

- 1 *ca*, 1 *ia* → doubt.
  System response - hints and two questions where one is new and the other is the one that has received an incorrect answer.

- 2 *na* → uncertainty.
  System response - hints and two new questions from the database.

- 1 *na*, 1 *ia* → doubt.
  System response - hints and the same questions.

- 2 *ia* → lack of understanding.
  System response - hints and the same questions plus one new question from the database.

Notations

- *ca* - correct answer,
- *na* - no answer is provided, and
- *ia* - incorrect answer.

4 System Architecture

The system can be implemented using a LAMP Web server infrastructure and a deployment paradigm. It is a combination of free software tools of an Apache Web server, a database server and a scripting programming platform on a Linux operating environment.

Communication framework based on XML-RPC is used to connect the Web application middle-ware and the intelligent assessment/diagnostic system together.

A dynamic page publisher compiles a page to be presented to the user from a template file in relation to the user response, current state variables and activities history.

An intelligent assessment agent provides an early diagnostic about absorption of knowledge.

5 Conclusion

This paper presents an intelligent sub-system assessing students initial understanding of new terms. The decision making process is based on many-valued logic. Our motivation for employing such logic is that a system based on it will be of better assistance to both students and course builders.

References:

[1] B.A. Davey and H.A. Priestley, Introduction to lattices and order, *Cambridge University Press*, Cambridge 2005

[2] M. Fitting, Kleene's Logic, Generalized. Journal of Logic and Computation, 1(6) (1991) 797–810

[3] Fitting, M.: Kleene's three-valued logics and their children. Fundamenta Informaticae, **20** (1994) 113–131

[4] Fitting, M.: Tableaus for many-valued modal logic. Studia Logica, **55** (1995) 63–87

[5] O. N. Garcia and M. Moussavi, A Six-Valued Logic for Representing Incomplete Knowledge. Proceedings of ISMVL, IEEE Computer Society Press, Charlotte, NC, USA, May(1990) 110–114

[6] J. Garca-Duque, M. Lpez-Nores, J. Pazos-Arias, A. Fernndez-Vilas, R. Daz-Redondo, A. Gil-Solla, Y. Blanco-Fernndez and M. Ramos-Cabrer, A Six-valued Logic to Reason about Uncertainty and Inconsistency in Requirements Specifications. Journal of Logic and Computation, 16(2) (2006) 227–255

[7] Kacprzyk, J. and Roubens, M.: Non Conventional Preference Relations in Decision Making. Springer Verlag, LNMES **301**, Berlin, (1988)

[8] S. Kleene, Introduction to Metamathematics. D. Van Nostrand Co., Inc., New York, N. Y., (1952)

[9] J. Lukasiewicz, On Three-Valued Logic. Ruch Filozoficzny, 5, pp.170-1. (1920), English translation in Borkowski, L. (ed.) 1970. Jan Lukasiewicz: Selected Works. Amsterdam: North Holland. (1920)

[10] M. Moussavi and O. N. Garcia, A Six-Valued Logic and its application to artificial intelligence. Proceedings of the Fift Southeastern Logic Symposium (1989)

[11] G. Priest, An Introduction to Non-Classical Logic, Cambridge (2001)

[12] A.N. Prior, A Statement of Temporal Realism. In Copeland, B.J. (ed.) Logic and Reality: Essays on the Legacy of Arthur Prior. Oxford: Clarendon Press (1996)