Proceedings of

Symposia on Mathematical Techniques Applied to Data Analysis and Processing (SMATAD)

May 18th-21th 2017
Fuengirola, Málaga (Spain)
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Some observations on paraconsistent degree-preserving fuzzy logics

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In the recent past, formal systems of fuzzy logic, under the umbrella of mathematical fuzzy logic (MFL) [2], have been proposed and studied as suitable tools for reasoning with propositions containing vague predicates. One of their main features is that they allow to interpret formulas in linearly ordered scales of truth values, which makes them specially suited for representing the gradual aspects of vagueness. Particular deductive systems in MFL have been usually studied under the paradigm of (full) truth-preservation which, generalizing the classical notion of consequence, postulates that a formula follows from a set of premises if every algebraic evaluation that interprets the premises as true also interprets the conclusion as true. An alternative approach that has recently received some attention is based on the degree-preservation paradigm [1, 6], in which a conclusion follows from a set of premises if, for all evaluations, the truth degree of the conclusion is not lower than that of the premises. It has been argued that this approach is more coherent with the commitment of many-valued logics to truth-degree semantics because all values play an equally important rôle in the corresponding notion of consequence [5].

Moreover, while the truth-preserving fuzzy logics are explosive, i.e. from any theory containing a formula \( \varphi \) and its negation \( \neg \varphi \) everything follows, in two recent papers [3, 4] some (extensions of) degree-preserving fuzzy logics have been shown to exhibit some well behaved paraconsistency properties. In particular, this is the case of the well-known Lukasiewicz logic \( \mathbb{L} \), whose degree preserving companion \( \mathbb{L}^\leq \) is not explosive, i.e. it is paraconsistent. Actually, the degree-preserving companions of finitely-valued Lukasiewicz logics \( \mathbb{L}_n \) belong to the family of the so-called logics of formal inconsistency (LFI).

In this paper we introduce \( \text{RPL}^\leq \), the degree-preserving companion of well-known Rational Pavelka logic \( \text{RPL} \) (the expansion of Lukasiewicz logic with rational truth-constants as defined by Hájek in [7]) and study some of its properties. The use of truth-constants allows us to explicitly show what is the inferential loss in some reasoning patterns when moving from \( \text{RPL} \) to its weaker, paraconsistent companion \( \text{RPL}^\leq \).

Recall that the logical consequence relation for \( \mathbb{L}^\leq \) is defined as follows [6]: for every set of formulas \( \Gamma \cup \{ \varphi \} \), \( \Gamma \models_{\mathbb{L}^\leq} \varphi \) iff for every evaluation \( e \) over the standard MV-algebra \( [0,1]_{\text{MV}} \) and every \( a \in [0,1] \), if \( a \leq \nu(\gamma) \) for every \( \gamma \in \Gamma \), then \( a \leq \nu(\varphi) \). For this reason \( \mathbb{L}^\leq \) is known as the Lukasiewicz logic preserving degrees of truth, or the degree-preserving companion of \( \mathbb{L} \). In fact, \( \mathbb{L} \) and \( \mathbb{L}^\leq \) have the same tautologies, and for every finite set of formulas \( \Gamma \cup \{ \varphi \} \) we have:

\[
\Gamma \models_{\mathbb{L}^\leq} \varphi \text{ iff } \models_{\mathbb{L}^\leq} \varphi^\uparrow \Rightarrow \varphi,
\]

where \( \Gamma^\uparrow \) means \( \gamma_1 \land \ldots \land \gamma_k \) for \( \Gamma = \{ \gamma_1, \ldots, \gamma_k \} \) (when \( \Gamma \) is empty then \( \Gamma^\uparrow \) is \( \top \)). It is worth noticing that the usual rule of modus ponens is not sound for \( \mathbb{L}^\leq \). However, the logic \( \mathbb{L}^\leq \)

Acknowledgement The support of the Spanish MINECO project RASO (TIN2015-71799-C2-1-P) is kindly acknowledged.
admits a Hilbert-style axiomatisation with a weaker form of modus ponens. Indeed, by letting the axioms of $L^\leq$ be the same axioms as $L$ having the following deduction rules:

\[
\begin{align*}
\text{(Adj-\land)} & \quad \varphi \land \psi \\
\text{(MP-r)} & \quad \frac{\varphi \land \psi}{\psi} \\
\end{align*}
\]

one gets a sound and complete axiomatisation of $|=_{L^\leq}$ for deductions from a finite set of formulas [1].

Now we can introduce the logic $RPL^\leq$. First we extend the language of $L^\leq$ by introducing a rational truth-constant $r$ for every rational $r \in [0,1]$. The notion of logical consequence, $|=_{RPL^\leq}$, is defined as $|=_{L^\leq}$ with the proviso that every evaluation $e$ over the standard MV-algebra $[0,1]_{MV}$ additionally satisfies $e(r) = r$ for every rational $r \in [0,1]$. On the other hand, one gets a sound and finite strong complete axiomatisation for $|=_{RPL}$ just adding to the axiomatic system for $L^\leq$ the usual booking axioms for truth-constants. Moreover, an analogous Pavelka-style completeness result for $RPL^\leq$ can also be obtained: for any set of $RPL$ formulas $T \cup \{\varphi\}$, define:

- truth degree of $\varphi$ in $T$: $\|\varphi\|_T^\leq = \inf\{e(T) \rightarrow e(\varphi) : e \text{ RPL-evaluation}\}$,
- provability degree of $\varphi$ from $T$: $|\varphi|_T^\leq = \sup\{r | T \vdash_{RPL}^\leq r \rightarrow \varphi\}$,

where $e(T) = \inf\{e(\psi) : \psi \in T\}$.

**Theorem 5.** For any set of $RPL$ formulas $T \cup \{\varphi\}$, we have:

$|\varphi|_T^\leq = \|\varphi\|_T^\leq$.

This shows that $RPL^\leq$ is well-behaved in a sense. However, we have mentioned above that the usual rule of modus ponens is not sound in $L^\leq$, and hence neither in $RPL^\leq$. Actually, in $RPL^\leq$, one can show that the following deduction holds: $\{\varphi, \varphi \rightarrow \psi\} \vdash_{RPL}^\leq 0.5 \rightarrow \psi$. That is, in $RPL^\leq$ we are forced to lower the truth-degree of the conclusion in order to have a sound but weaker modus ponens rule. We will discuss this and other facts about $RPL^\leq$ that may be seen as a somewhat questionable price to pay for enjoying a paraconsistent behaviour.

**References**


