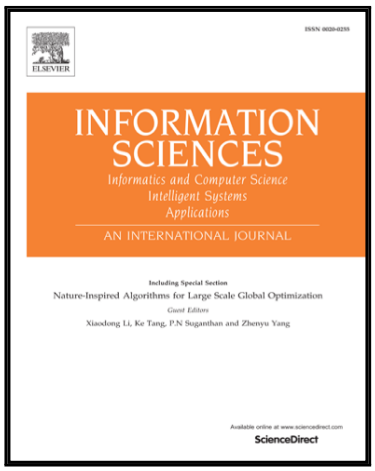


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# Linguistic terms with weakened hedges: A model for qualitative decision making under uncertainty

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**Abstract**

When expressing the experts' opinions in qualitative decision making (QDM), linguistic hedges can be considered to modify the force expressed by a predefined linguistic term. If an expert is not sure to select one term, weakened hedges would be a natural way to express the uncertainty. This is usually implemented by using a hedge to modify the most possible term, like the expression "more or less good". To model the uncertainty implied by hedges in QDM, this paper presents a novel linguistic representational and computational model in which the linguistic expressions take the form of a weakened hedge and a linguistic term, which is named as linguistic term with weakened hedge (LTWH). The syntax of LTWHs is defined by a set of hedges and a set of linguistic terms. The semantics of a LTWH is determined, objectively, based on the semantics of the term and a similarity measure of the reference domain. Accordingly, the negation, order relations and some basic operations of LTWHs are defined. To illustrate the effectiveness of LTWHs in granular computing, the connection to some multi-granularity linguistic models is exploited and a process for unifying multi-granularity linguistic information is developed. The major contritions of this paper are: (1) The proposed model enables a new manner to express and operate uncertain linguistic information in QDM; (2) it possesses clear syntax and semantics and the computational results are very interpretable; and (3) the proposed solution of multi-granularity linguistic unification maintains the semantics of the original linguistic information.

*Keywords:* Decision making, linguistic hedges, linguistic term sets, multi-granularity linguistic decision making, semantics

## 1. Introduction

Computing with words (CWW) is very useful and effective for qualitative decision making (QDM) problems, especially if the decision information is not quantifiable due to its nature or too expensive to obtain precise quantitative information [28, 17]. Different from the common sense of soft computing, such as the techniques proposed in Refs. [1, 3, 32, 43], CWW focuses on processing words and expressions constructed by a natural or artificial language rather than precise numbers. Since was introduced by Zadeh [62, 63, 64], CWW has become more and more popular for representing and computing linguistic information during the recent decades. Two main concepts of CWW are linguistic variables and granules. Roughly, a linguistic variable is "variable whose values are not numbers but words or sentences in a natural or artificial language" and thus is less specific than numerical ones but closer to the human thinking and knowledge [62]. A granule is usually treated as a fuzzy set of points drawn together by similarity or resemblance [16, 65]. In this paper, we will propose and develop a new CWW model for QDM under uncertainty.

Frequently, all the possible values of a linguistic variable are a finite set of linguistic terms defined by linguistic descriptors and semantics. This set is referred as a linguistic term set (LTS) denoted by $S = \{\alpha | \alpha = 0, 1, \ldots, \tau\}$. Given a non-empty domain $U$, the semantics of each $s_\alpha \in S$ is defined by a fuzzy membership function, such as linear trapezoidal membership function (or triangular membership function) [12], taking the form of fuzzy numbers defined in $U$. The terms serve as a fuzzy partition of $U$ and the parameter $\tau + 1$ indicates the granularity of knowledge. Usually, three aspects should be defined to form the basis of a computational model, which are the order of terms, the negation operator and some basic operations. For example, a LTS with 7 linguistic terms defined in the interval $[0, 1]$ could be (as shown in Fig. 1): $S = \{s_0 = nothing, s_1 = very\ low, s_2 = low, s_3 = medium, s_4 = high, s_5 =$