Computing With Words and Perceptions—A Paradigm Shift

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There are many misconceptions about what Computing with Words (CW) is and what it has to offer. A common misconception is that CW is closely related to natural language processing. In reality, this is not the case. More importantly, at this juncture what is widely unrecognized is that moving from computation with numbers to computation with words has the potential for evolving into a basic paradigm shift—a paradigm shift which would open the door to a wide-ranging enlargement of the role of natural languages in scientific theories.

In essence, CW is a system of computation which adds to traditional systems of computation two important capabilities: (a) the capability to precisiate the meaning of words and propositions drawn from natural language; and (b) the capability to reason and compute with precisiated words and propositions.

As a system of computation, a CW-based model, or simply CW-model, has three principal components. (a) A question, Q, of the form: What is the value of a variable, Y? (b) An information set, $I=(p_1, ..., p_n)$, where the p_i, $i=(1, ..., n)$, are propositions which individually or collectively are carriers of information about the value of Y, that is, are question-relevant. One or more of the p_i may be drawn from world knowledge. A proposition, p_i, plays the role of an assignment statement which assigns a value, v_i, to a variable, X_i, in p_i. Equivalently, p_i may be viewed as an answer to the question: What is the value of X_i? X_i and v_i, may be explicit or implicit. A proposition, p_i, may be unconditional or conditional, expressed as an if-then rule. Basically, an assignment statement constrains the values which X_i is allowed to take. To place this in evidence, X_i and v_i are referred to as the constrained variable and the constraining relation, respectively. More concretely, what this implies is that the meaning of a proposition, p, may be represented as a generalized constraint, X isr R, in which X is the constrained variable, R is the constraining relation and r defines the modality of the constraint, that is, the way in which R constrains X. When v_i is a word or a combination of words, X_i is referred to as a linguistic variable, with v_i being its linguistic value. When it is helpful to stress that p_i assigns a value to a variable, p_i is referred to as a valuation. Correspondently, the information set, I, is referred to as a valuation system, V.

The third component is an aggregation function, f, which relates Y to the X_i.

$$Y=f(X_1, ..., X_n)$$

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The principal difference between CW and conventional systems of computation is that CW allows inclusion in the information set, I, of propositions expressed in a natural language, that is, linguistic valuations. Legalization of linguistic valuations has important implications. First, it greatly enhances the capability of computational methodologies to deal with imperfect information, that is, information which in one or more respects is imprecise, uncertain, incomplete, unreliable, vague or partially true. In realistic settings, such information is the norm rather than exception. Second, in cases in which there is a tolerance for imprecision, linguistic valuations serve to exploit the tolerance for imprecision through the use of words in place of numbers. And third, linguistic valuations are close to human reasoning and thus facilitate the design of systems which have a high level of machine intelligence, that is, high level of MIQ (machine IQ).

What does Computing with Words have to offer? The answer rests on two important tools which are provided by the machinery of fuzzy logic. The first tool is a formalism for mm-precisiation of propositions expressed in a natural language through representation of the meaning of a proposition as a generalized constraint of the form X isr R, where as noted earlier X is the constrained variable, R is the constraining relation and r is the modality of the constraint (Zadeh 1986).

The second tool is a formalism for computing with mm-precisiated propositions through propagation and counterpropagation of generalized constraints. The principal rule governing constraint propagation is the Extension Principle (Zadeh 1965, 1975). In combination, these two tools provide an effective formalism for computation with information described in a natural language. And it is these tools that serve as a basis for legalization of linguistic valuations.

What is important to note is that the machinery of fuzzy if-then rules—a machinery which is employed in almost all applications of fuzzy logic—is a part of the conceptual structure of CW.