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The Beauty of Vagueness

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The words "vagueness" and "vague" are often used to describe a quality, a thought, or a statement which is "incomplete" or "lacking precision." The Oxford English Dictionary defines vagueness (the quality or condition of being vague) as "a lack of distinctness or preciseness; indefiniteness." Similarly, the word "vague," is defined as "not definitely or precisely expressed; deficient in details or particulars." Often in the scientific context, the expressions "lacking precision" and "deficient in details" bring negative connotations. We live in the era, in which scientific perspective and the utmost precision of digital computers are highly regarded. Thus, in a way, the "vagueness" of our thoughts, "fuzziness" of our linguistic expressions, "indefinability" of our feelings, and "intangibility" of our perceptions of the external world are undervalued. The transcendental aspects of our human existence are reduced by "precise" description and "quantitative" analytical methods. In the age of fast, exact, digital computers, precision is deemed a virtue. We strive to be precise; we attempt to create absolute statements about the perceived reality, and we try to explain with an utmost accuracy the surrounding world and our place in the universe. Nothing is inherently wrong with precision or definiteness; yet the world and our place in it, are, in many ways, vague and indefinite. We cannot unequivocally quantify our feelings, perceptions, and interpretations of stimuli because vagueness is inherently present in our language, and fuzziness is a part of our perception. Our interpretation of the world is context-dependent, time-dependent, and, often, contradictory. Moreover, the world itself is constantly changing, we as human beings are constantly changing, and the perceptions of us and the external world, too, are constantly changing.

To address the obvious impossibility of precise expression, we split our perception of the world: we insist on precision in science, and we delegate vagueness to arts, humanities, and social studies. However, precision is a matter of a degree and, in fact, every scientific measurement or statement displays certain level of imprecision. Thus, in fact, precision does not exist or, at least, cannot be achieved given our finite limitations. On the other hand, imprecision and vagueness are in the center of artistic expressions and allow us to experience what in Kant's tradition would be called the "transcendent." Poetry uses ambiguous, interpretable, vague language to describe, express, and evoke the undefined, imprecise, yet beautiful feelings and emotions. Paintings are created with blurred shapes, soft edges, and flickering light. Their visual and symbolic ambiguity allows us to create our own fuzzy or crisp perceptions and to freely interpret or not interpret them at the same time. *There is vagueness in beauty, and there is beauty in vagueness.*

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We exist in a beautifully imprecise reality, and we should integrate the precise quantitative approach with the fuzzy, yet mystical, qualitative approach. We constantly should connect and re-connect our detailed, precise, logical left-brain with the holistic intuitive, fuzzy right-brain. We need to address and continue to re-address the dichotomy between arts and science. We need to capture the beauty of vagueness and the vagueness of beauty.

My personal answer to this quest is the use of fuzzy logic for the modeling of vagueness in medical applications, particularly, applications in sleep medicine and psychiatry. Medicine is both an art and a science; therefore, it is based on scientific facts and, at the same time, it applies the scientifically-based reasoning in a humanistic way. The notion of imprecision (vagueness), missing or partial information, and degrees of uncertainty are specific to all medical data. Moreover, vagueness is intrinsic to many medical concepts. Concepts such as "quality of life," "mental health," "sleepiness," "sadness," and "depression" are difficult to define, measure, and quantify. Furthermore, many medical decisions must be made based on subjective, uncertain, and imprecise information. In particular, the diagnostic process in sleep medicine and psychiatry is based not only on objective data, but relies, in a large proportion, on subjective data. The subjective data are obtained from clinical interviews with patients and self-reporting instruments, such as questionnaires, standardized scales, patient's logs, and family reports. The objective data involve medical examinations, clinical tests (e.g., Electroencephalography, EEG, the recording of the electrical activity of the brain; EEG is used, for example, in the diagnosis of sleep disorders), lab results, and medical images (e.g., functional magnetic resonance imaging, fMRI, the images representing the brain activity associated with the changes in blood flow; fMRI is used in the diagnosis of neurological disorders). Thus, the computerized models in order to represent medical data and human decisions used in diagnosis, prognosis, and treatment, must explicitly represent vagueness and must provide reasoning methods which tolerate vagueness.

Therefore, the traditional approaches of hard computing operating on precise numbers and using categorical approaches of true and false values must be replaced by computational models and reasoning techniques allowing for degrees of imprecision, uncertainty and non-monotonic reasoning. In 1965, Lotfi Zadeh published his paper "Fuzzy sets," in which he introduced the term "fuzzy set", extended the fuzzy set theory, and created fuzzy logic as a new field of study. Lotfi Zadeh introduced the quantitatively-expressed measurement of vagueness, which allows representation of "fuzzy" concepts. As stated by Lotfi Zadeh "most of the concepts encountered in various domains of human knowledge are, in reality, much too complex to admit of simple or precise definition." The many clinically important, yet, imprecise, concepts such as "sleepiness," "high blood pressure" "feelings of depression," "level of physical activity," "obesity" can be defined using linguistic variables, fuzzy membership functions, and fuzzy inference systems. This fuzzy-logic based representation allows for the creation of computer-based systems to support diagnosis and treatment of disorders such as, for example, obstructive sleep apnea and clinical depression.

As it was emphasized by Zadeh, imperfections must be studied and accounted for in the models of reality. With the availability of large clinical data sets and electronic

patient records, mismatched levels of precision (imprecision) have been recognized as a crucial issue in database systems, decision-support systems, data mining, machine learning, and information retrieval on the Web. In my research, I concentrate on imprecision, its definition, classification, and interpretation in context of medical data and medical decision making. Furthermore, I work on modeling and creation of clinical decision rules and clinical decision support systems (CDSS). These systems should model and manage all aspects of imprecision in data, information, and knowledge. Three questions are particularly important in the context of the research on imprecision: (1) how to model different types and levels of imprecision in data, information, and knowledge, (2) how to integrate data, information, and knowledge characterized by various levels of imprecision, and (3) how to model and manage the notion of acceptable and unacceptable imprecision in the context of decision-making process.

The motivation for my research in vagueness comes from medical and computational domains. From the medical perspective, there is a need to support the creation of diagnostic rules that could be applied in specialized clinics and primary care, as well as in medical research and education. Furthermore, with the increasing availability of patients' electronic records and electronically stored research data, there is a need for a conceptual framework capable of representing the complexity, varied granularity, heterogeneity, imprecision, and incompleteness of medical data. From a computational perspective, traditional computational models were designed for mechanical systems. Clinical systems are inherently qualitative, context-dependent, incomplete, and imprecise. Moreover, the clinicians expect the CDSS to be transparent, i.e. human-readable and updatable. Therefore, there is a need to create computational models that are appropriate for modeling of biomedical systems and sufficiently formalized for automation, yet comprehensible and interpretable by humans. In my research, I have applied a fuzzy-logic framework to practical medical problems. In collaboration with clinicians, Dr. Najib Ayas, Dr. Frank Ryan, Les Matthews, and Dr. Krzysztof Kielan, I have represented a number of medical concepts and diagnostic rules by the sets of fuzzy rules. These representations have been used by a fuzzy inference mechanism to evaluate the data and support the diagnostic process.

I am deeply indebted to the founder of fuzzy logic, Lotfi Zadeh, and the numerous fuzzy logic researchers involved in creating the link between what is precise and quantitative and what is imprecise and qualitative. I wish to thank all of them for the many opportunities for learning how to integrate our perception of reality and connect the world of science to the world of arts. Moreover, I would like to thank the many organizers of NAFIPS annual conferences, during which I have had the opportunity to present and discuss some of my and my students' findings. As a special memento, I cherish the picture below from NAFIPS 2008, where my student, Michelle Broadway, and I had an opportunity to present fuzzy systems for the evaluation of physical activity and for the evaluation of treatment methods for obstructive sleep apnea (a common and serious respiratory disorder caused by the repetitive collapse of the soft tissues in the throat as the result of the natural relaxation of muscles during sleep).

Fig. 50.1. NAFIPS 2008, New York. Dr. Lotfi Zadeh with the author of the paper (left) and TRU student, Michelle Broadway (right).