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Introducing validity in fuzzy probability for judicial decision-making

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ABSTRACT

Since the Age of Enlightenment, most philosophers have associated reasoning with the rules of probability and logic. This association has been enhanced over the years and now incorporates the theory of fuzzy logic as a complement to the probability theory, leading to the concept of fuzzy probability. Our insight, here, is integrating the concept of *validity* into the notion of fuzzy probability within an extended fuzzy logic (FLe) framework keeping with the notion of collective intelligence. In this regard, we propose a novel framework of possibility–probability–validity distribution (PPVD). The proposed distribution is applied to a real world setting of actual judicial cases to examine the role of validity measures in automated judicial decision-making within a fuzzy probabilistic framework. We compute valid fuzzy probability of conviction and acquittal based on different factors. This determines a possible overall hypothesis for the decision of a case, which is valid *only to a degree*. Validity is computed by aggregating validities of all the involved factors that are obtained from a factor vocabulary based on the empirical data. We then map the combined validity based on the Jaccard similarity measure into linguistic forms, so that a human can understand the results. Then PPVDs that are obtained based on the relevant factors in the given case yield the final valid fuzzy probabilities for conviction and acquittal. Finally, the judge has to make a decision; we therefore provide a numerical measure. Our approach supports the proposed hypothesis within the three-dimensional contexts of probability, possibility, and validity to improve the ability to solve problems with incomplete, unreliable, or ambiguous information to deliver a more reliable decision.

1. Introduction

We live in a world of radically growing availability of information as well as growing uncertainty, and judicial cases are no exception. Generally, judicial discretion is a process that can involve a series of steps, including initial investigation, the use of information generally given in natural language, and discretion concerning defendants. Strongly related to the judicial process is the decision-making issue, which involves more than learning rules and applying them to specific cases. Rather, judicial decision-making is an area of daunting complexity that is affected by many factors such as the format and size of courts (single judge or panels), court composition, procedural rules, factual circumstances of cases, content of relevant rules, existing evidence, and the standards used to decide based on facts [35]. Judicial decision-making is a constellation of analysis of law, past cases, experimental methods, matters of fact, and common sense as well as judges' personality, values, background, and legal education. Judges' decisions must have several characteristics [6]: they must "uphold rights,

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create predictability and certainty, and support the workings of successful social and economic systems." Note that these attributes must be satisfied in an uncertain environment [13]. Judges must make decisions by hearing possibly *unreliable* statements, assessing possibly *doubtful* evidence, analyzing possibly *unclear* rules, and identifying possibly *hidden* facts, all while enduring possible attempts to *divert* their attention from the truth and possible attempts to *manipulate* their feelings.

The literature about how judges make decisions can be divided into two main fields: rational choice theory [10] and theories that posit simple decision rules and intuition [9]. Theories of judicial decision-making that are grounded in rational choice theory are based on models of the process; hence, there is a mismatch between theory and practice. In contrast, several approaches have considered simple, logical rules for judicial decision-making, as the rule-based systems have knowledge-based rules that have been elicited from human experts. This is the basis for the case-based reasoning that is a primary focus of Artificial Intelligence in law [3]. In [1], the authors proposed case-based legal reasoning using background knowledge to organize multi-case arguments, consider differences between cases, and assess past cases. The concept of ontology is also used in legal reasoning [40]. To reconstruct text features for web crime mining, event ontology as a prior knowledge is proposed in [19]. Furthermore, several researches are conducted on crime analysis using data mining techniques [12]. Inducing a Bayesian belief network from crime data is addressed in [29] where the authors use machine learning techniques in order to facilitate automated analysis. Keppens [17] introduced an approach that uses argument diagrams based on Bayesian networks for legal evidential reasoning. The authors in [36] used neural network by learning from past court decisions for judgment in murder cases. An experimental investigation using a multi-layer support-vector-machine model is offered in [8] for recognizing the emotion behind the courtroom statements in order to help judges make rational decisions. An agent-based approach based on an analytic hierarchy of conditions such as personage specification is proposed in [24]. In [13], the authors explored subjective logic in legal reasoning for dealing with the weighing of evidence and quantification of proof; they also considered the Dempster–Shafer evidence theory. Moreover, Halliwell developed a linguistic probability theory to evaluate the strength of evidence in a judicial criminal case [11].

Considering judicial procedures, one may conclude that the above approaches while may achieve reasonable results, cover only a narrow range of relevant uncertainties. Despite the many reported advantages of fuzzy logic to deal with uncertainty in general, and while fuzzy logic and judicial decision-making have each been studied extensively, it is surprising that the literature on judicial decision-making based on fuzzy logic is relatively few [18].

In the analysis of judicial cases, there are two types of data. First involves background (judicial expert) knowledge and soft data that carries uncertainty in the form of linguistic imprecision and ignorance while the second is statistical data, which may be hampered by scarcity and insufficiency. In practice, information regarding the latter is best conveyed using probability distributions while fuzzy logic theory is a leading theory for dealing with the former, that is, the problem of imprecision and approximations in human language. However, being provably valid is a necessary condition for the results when applying fuzzy logic. Most problems including judicial decision-making do not meet this criterion due to the involved unprecisiated imperfect information. Zadeh has recently introduced an extension of fuzzy logic that can deal with this kind of information. This extension is based on adding unprecisiated fuzzy logic that yields to extended fuzzy logic (FLe) [48]. FLe is derived from fuzzy logic when the validity of results is also taken into account. In fact, the concept of fuzzy validity can help transition from fuzzy logic to extended fuzzy logic and completes our understanding by modeling unprecisiated issues.

In this paper, we present a theoretical foundation for judicial decision-making, particularly under highly uncertain conditions, where neither the available statistical data nor the available background knowledge are sufficient while the necessary condition of provable validity of results is also contradicted. In the proposed approach, we identify and consider most effective factors in judicial decision-making. More specifically, this paper posits FLe to capture the notion of unprecisiated information in the judicial decision-making process as well as to exploit the collaboration between possibility, probability, and validity by investigating validations of individual solutions and taking advantage of both background and statistical data. We introduce a novel approach to compute the validity of fuzzy probabilities, which is particularly helpful to obtain the validity of imprecise probabilities derived from background knowledge. In the proposed approach, we integrate validity into the well-developed possibility–probability distribution [16] based on FLe thinking and introduce possibility–probability–validity distribution (PPVD). Hence, we should select a probability distribution p consistent with possibility π and validity v.

We herein claim that this collaboration can overcome many restrictions in unprecisiated problems including judicial decision-making. To examine this claim, we apply the proposed approach to an actual complex judicial case and compare the result with the decisions of human judges. The chosen case is particularly complex since it was reversed in the appeals court. We also compare our results on 15 different cases with those of fuzzy, neural, and FLe systems, as well as those obtained using the fuzzy probability approach. These approaches have been applied to the same database under the same conditions.

The paper proceeds as follows. Section 2 presents an overview of FLe. It briefly reviews the concepts of f-transformation, the cointensive assumption, the P/I principle, S-answers, f-rules, and f-constraints. Section 3 studies the issue of uncertainty modeling in FLe. Section 4 considers the proposed probabilistic possibilistic validity distribution (PPVD) and its structure as well as proposes an approach for determining validity. Section 5 describes the selected judicial decision-making case study and examines the proposed approach through an actual example. It also provides the results of alternative approaches for comparison. Finally, Section 6 draws conclusions.