ultimate moment); and productivity $I_p = (I_{mat} + I_{man} + I_t)/I_{man}$. Practically, for the fuzzification process (I_{mat}, I_{man}, I_t, and I_d are interpreted as fuzzy goals and I_{si} and I_p as fuzzy constraints), an exponential membership function $I_k = e^{-k|x|}$ (where k is the importance coefficient) is proposed. Thus by this procedure, the optimal investment is alternative a_3, and the hierarchization of the alternatives is a_3, a_4, a_2, a_1. A computer program was written to process the data and produce the results.

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Set-Valued Temporal Knowledge Representation for Fuzzy Temporal Retrieval in ICAI

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The Student Record (SR) is an essential part of any Intelligent Tutoring System (ITS), since it represents the key to individualized instruction. The SR's task is to capture the system's knowledge about each student including his or her development over time during the whole sequence of sessions. This paper proposes a relational representation as an underlying model for a Student Record and then extends this by allowing a set-valued extension of the representation and finally by adding temporal aspects to this relational representation. The impact of these two enhancements of the relational data model on the representation and on the manipulation is analyzed; then the relational algebra, a query language for the relational data model, is extended to cope with these aspects. The result is a fuzzy temporal relational algebra (FTRA). An essential feature of this approach is its completeness—the operations of this query language default to their crisp nontemporal counterparts if no fuzzy or temporal extensions are specified in them. Altogether, a set-valued temporal relational representation schema with fuzzy temporal retrieval capabilities is presented, which is claimed to be of use as a knowledge representation schema for other artificial intelligence applications.

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Decision Making and Fuzzy Windows

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Physical classification consists of performing tests and comparing results to the ranges in value of alternative classes. Matching test results to the acceptable range (i.e., "standard") for a parameter within a class is like forcing the former through a filter or a

"window": The similarity between input and output is a measure of the compatibility between test results and standard. A window is a subset of a segment and represents the range of values that are of particular interest. In most cases the boundaries of the windows cannot be defined with certainty.

Most decision processes involve many alternatives that may depend on several dimensions. For each alternative, a "stack of windows" is defined by specifying a window for each dimension. Then decision making is equivalent to filtering the characteristics of a given situation through the stacks. The acceptability of each alternative is determined by an evaluation function that assesses the extent of individual matches.

Available knowledge-acquisition techniques support this form of knowledge representation. Fuzzy windows facilitate the establishment of consensus among experts and the analysis of composite solutions. Classification systems built with this approach allow the use of different evaluation functions and support the development of a database that can be searched. Knowledge representation by fuzzy windows is substantiated by findings in decision making and creative thinking.

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Backward Chaining with Fuzzy Goals and Rules

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This paper describes a knowledge engine that employs a backward-chaining control structure that is generalized to fuzzy variables and rules. The engine extends earlier fuzzy linguistic variable processing systems developed by the authors that employ fuzzy linguistic variables and fuzzy logic in their data and rules. The backward control mechanism permits more sophisticated, efficient use of diagnostic knowledge-centered decision support systems. Design criteria, implementation notes, and possible extensions are discussed. This is a publicly owned, research-oriented system; the procedures, dubbed BACHFUGUE (written in the APL programming language), are available from the authors.

Related systems exist or are under development. BACHFUGUE is being interfaced with a synthetic grammar system that manages the linguistic terms in SAPIR. Although originally written in LISP, SAPIR has been translated into APL for compatibility with BACHFUGUE.

Relations, as well as if-then rules, are powerful expressive mechanisms in symbolic knowledge systems. Fuzzy relations in the present system must be decomposed (edited) into if-then rules. A more automatic means of dealing with such relations is being explored.

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A New Concept of Fuzzy Rule-Based Expert Systems

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