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AN ADAPTIVE COMPUTER SYSTEM FOR LINGUISTIC CATEGORIZATION OF "SOFT" OBSERVATIONS IN EXPERT SYSTEMS AND IN THE SOCIAL SCIENCES

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ABSTRACT

This paper describes a human-guided feature classification system. A person teaches the denotation of subjective linguistic feature descriptors to the computer system by reference to examples. The resulting knowledge base of the system is used in the classification phase for interpretation of descriptions made by the teacher. Interpersonal descriptions are communicated via semantic translations of subjective descriptions. The advantage of a subjective linguistic description scheme over more traditional objective arithmomorphic schemes is their high descriptor - feature consistency. This is due to the relative simplicity of the underlying cognitive process. The result is a high feature resolution for the overall cognitive perception and description process. At present, the system is being used for categorization of "soft" observations in psychological research, but applications in any person - machine system are conceivable.

INTRODUCTION

In pure artificial intelligence systems, a knowledge base can be designed according to specific system requirements. The representation of knowledge in person - machine systems, particularly in expert systems, is constrained by properties of the human knowledge base. This paper is concerned with constraints resulting from the cognitive process which leads from feature perception to feature description. We investigate properties of a human feature extraction system in order to design an appropriate pattern classification system for the perceived information. The result is an expert system for pattern description which combines expertise of a human observer with memory, combinatoric ability, and speed of a computer.

This paper will first report on results of an experiment in cognition in which human feature extractors describe their observations by different methods. The results are analyzed to determine the knowledge that is captured by the representations of the observations. A representation scheme is proposed to fully preserve this knowledge. Advantages of representing cognition processes by subjective rather than objective descriptors are discussed. Finally, a learning procedure for meaning acquisition of subjective descriptors is presented.

COGNITIVE FEATURE DESCRIPTION

At the MPI-P we performed an experiment to determine accuracy and consistency of human feature descriptions. As a simple feature dimension we chose "height" of persons, since this is an unambiguous feature which can be measured and has been used in related studies. In the experiment, we compared three methods for describing height as perceived by the observers, two arithmomorphic and one linguistic method [FREKSA, 1981, 1982]. The objects of observation (23 medical students) were asked in non-systematic order to present themselves in front of the observers (the remaining 22 students). The observers noted their judgment of the height of the "objects" on a prepared sheet containing the names of the "objects".

METHOD 1: The observers were asked to estimate the height of the objects in centimeters.

METHOD 2: The observers were asked to indicate four values (in centimeters) to express their judgment:

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1. a lowest height value which they considered possible at all as an estimate of the actual value;

2. a pair of two height values to specify a range in which they believed the actual height value to be;

3. a greatest height value which they considered possible at all as an estimate of the actual value.

METHOD 3: The observers were asked to select from an ordered vocabulary of seven terms (very small, small, rather small, medium, rather tall, tall, very tall), all those terms which appeared appropriate to designate the actual height of the persons. In case they selected several terms they could indicate preferences of some terms over others.

After completion of these judgments, the height of the objects was measured (in centimeters) by a conventional method.

RESULTS

With method 1, the maximum mis-judgments of the observers ranged between 8 and 13 centimeters. The mis-judgments were non-systematic, i.e., all observers sometimes overestimated and sometimes underestimated the actual height in a given vicinity of height values.

Method 2 did not yield better results. Most observers apparently did not have a good feeling for the accuracy and precision of their own centimeter judgments. Frequently, the observers overestimated their ability by indicating too narrow possibility ranges for the height value. In many instances, the measured height value fell into the ranges which were considered entirely impossible by the observers.

Method 3 avoids the problem of erroneous label assignment by letting the labels denote just what the observer used it for. But surprisingly, the ranges of referenced height values rarely become larger than for the centimeter labels and frequently the specificity is even higher. In addition, by multiple assignment of labels with overlapping reference ranges the specificity of a description can be further increased.

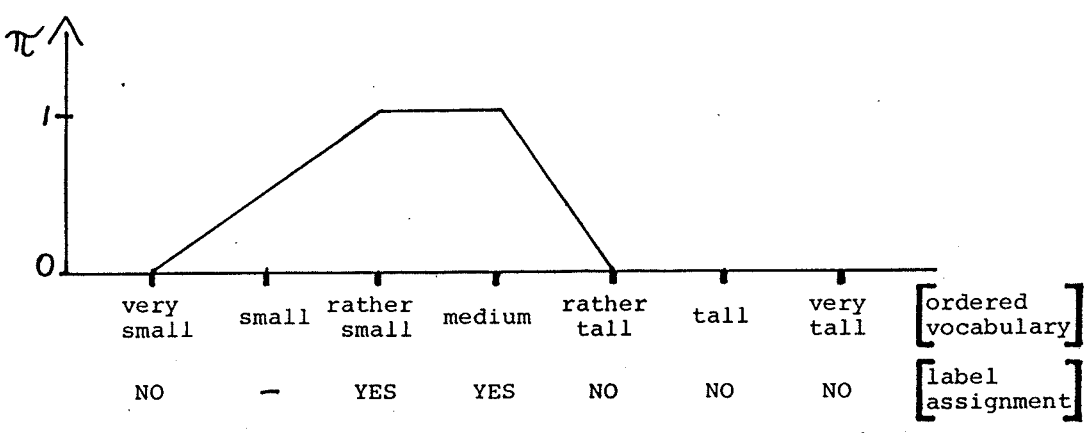
INTERPRETATION OF RESULTS

The foregoing experiment shows that the human judgment ability may be better than it appears if we analyze numerical estimates. If we allow observations to be expressed in a more appropriate language, higher precision may be obtained. At first glance, this may appear contradictory, since a centimeter scale suggests higher resolution than a set of seven linguistic labels for a range of about 40 centimeters. However, by permitting simultaneous assignment of several labels we increase rather than decrease the potential of resolution. In addition, if these labels are applied in a more consistent manner than the centimeter values, they may resolve specific height values particularly well.

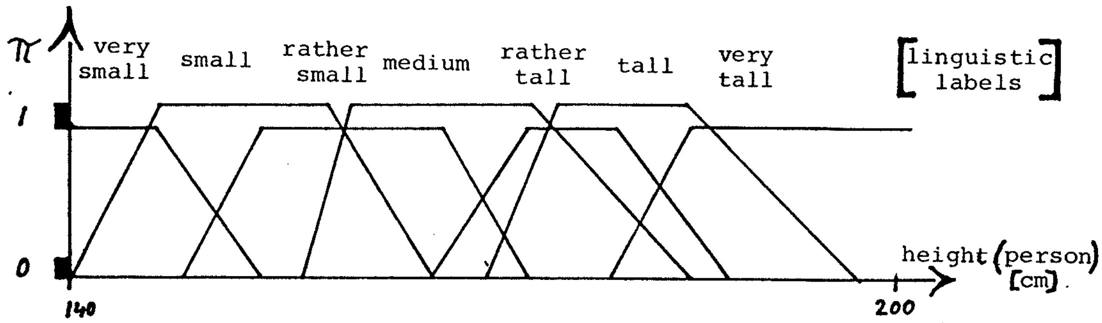
The experiment shows that not only the resolution of the perception process but also the description process limit precision and reliability of the resulting knowledge. Thus, if we use a description scheme which only minimally distorts the perception information we should retain maximum knowledge [FREKSA, 1980]. Subjective verbal descriptions can be constructed rather spontaneously by many observers while arithmomorphic descriptions appear to require additional transformations on the perceived information which may introduce additional distortion into the data.

REPRESENTATION OF LINGUISTIC DESCRIPTORS

We represent the spectrum of applicable linguistic descriptors for a given observation by a simplified possibility distribution [ZADEH, 1978] over the range of applicable linguistic terms. Clearly applicable terms are assigned a possibility value of 1, clearly non-applicable terms are assigned a possibility value of 0. In between there are penumbra regions representing the terms which are neither fully included in nor fully excluded from the set of applicable terms. An example for such a distribution for a given observation is shown in the following figure:



From a set of these distributions we construct a semantic representation of the linguistic terms by arranging the example features in the order of their feature intensity and assign a possibility value of 1 to the contiguous range of features in which a given term was consistently applied. Accordingly, we assign a possibility value of 0 to the regions to which this term was consistently not applied by the particular observer. Again, we obtain a penumbra region for which the term neither is fully accepted nor clearly rejected. The following figure shows a semantic representation of linguistic terms from the previous example:



SUBJECTIVE VS. OBJECTIVE DESCRIPTIONS

Usually, in scientific research, we aim for objective rather than subjective descriptions for our observations. If we measure features, an objective representation is clearly superior over a subjective representation since objective representations can be compared more easily with one another. However, if we observe features, subjective representations may be more reliable since the perception and description process is inherently subjective. An objectivization of an observation by the observer himself may only pretend an objective result which is not really objective. To overcome this problem, we should stick with a subjective description of the observer which is made objective by external criteria. External criteria can be measurements of the observed features, an agreement between several observers to which the subjtive observation can be related, an expert opinion, etc. In the experiment described in the beginning of the paper, the measurement of the height of the observed persons served to give a semantic interpretation to the linguistic height descriptions of the observers.

LEARNING PROCEDURE FOR MEANING ACQUISITION

We have been developing learning procedures for establishing fuzzy reference ranges for linguistic labels from the observer's vocabulary [WINSTON, 1975; LOPEZ DE MANTARAS, 1980; LOPEZ DE MANTARAS et al., 1981; AGUILAR-MARTIN et al., 1982]. The output of these procedures is a data base associating linguistic labels with reference ranges in the feature dimension that is characterized by the label set. This data base is used during the classification phase for associating sets of reference objects with target object descriptions made by the observer. In this way, users of the system always can communicate on the level of relevant objects and natural descriptions rather than on an abstract level using an artificial language. We consider three approaches to setting up the reference ranges for the linguistic labels:

1. non-specific, highly sensitive initial state
2. highly specific, non-sensitive initial state
3. non-specific, non-sensitive initial state

The first approach assumes that -- unless we are told otherwise -- a linguistic label may denote any feature value from the domain. By learning about counter-examples, the reference range is restricted and the specificity increases.

The second approach assumes that -- unless we are specifically informed about a valid reference range -- a linguistic label has no denotation. By learning about new instances of valid references, the specificity of the label may decrease.

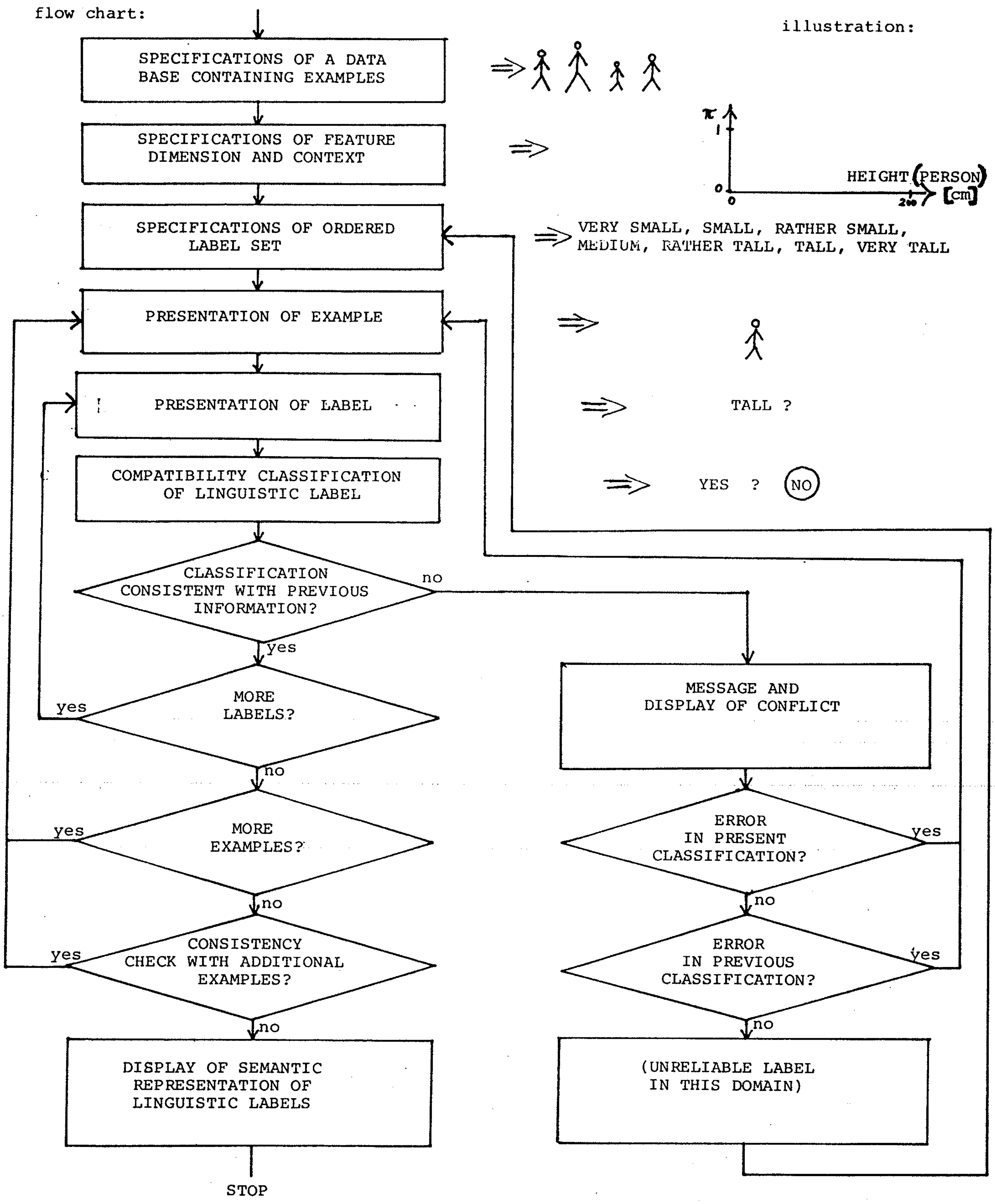
The third approach is a combination of the former two. Initially, a label is uncommitted with respect to denotation or non-denotation of values. Valid instances increase the sensitivity and counter-instances restrict the possible expansion of the sensitivity of a label.

All three approaches share the assumption that the labels of the vocabulary refer to an ordered dimension of features and that a partial ordering of the labels by the same ordering criterion is known. Furthermore, we admit only linguistic labels with unimodal possibility distribution over the reference range on this ordering. This permits interpolation of possibility values which have been assigned to certain reference values according to the following rules:

1. two points with equal possibility value can be connected by a line of the same possibility value (unimodality condition)
2. two points with different possibility values can be connected by some monotonous function, i.e., a feature which is close to some high-possibility feature obtains at least the same possibility value as a feature with greater distance along the feature dimension.

STRUCTURE OF LEARNING PROCEDURES

The sequence of operations for the learning procedures is illustrated in the following diagram for approach 3:



The label classifications "yes" and "?" as well as the classifications "?" and "no" are considered compatible. If for the same feature value a label is classified one time by "yes" and one time by "no", an inconsistency is detected and the classifier must decide whether one of the assignments was an error that can be corrected or whether the label may not have a consistent denotation in the given context and therefore should be eliminated from the vocabulary.

CONCLUDING REMARKS

The presented approach is based upon the contention that incomplete information may lead to an imprecise and fuzzy image which may be a coarse -- but nevertheless correct -- representation of a given situation. This is in contrast to the view that incomplete information must lead to holes or errors in the representation. Furthermore we assume that human observations usually lead to imprecise and fuzzy rather than to incomplete and erroneous representations of the observed phenomena.

This view leads us to construct a representation system which can represent features with variable precision and which can use new information to refine an existing feature representation. Since human observations are subjective by nature, we construct subjective representations for each observer at first. If we have some reference criteria for the observations of different observers, we may be able to objectivize the subjective representations by translation into the reference domain. The advantage of using an intermediate subjective representation level is an increased consistency of the descriptions chosen by the observer since he does not have to transform his personal description into a -- possibly for him unnatural -- representation and in the process distort the available information by introducing errors.

Our approach is primarily intended for domains in which expertise has not yet been formalized or in which the formalizations have not become as familiar to the users as their own language.

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