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The Judge's apprentice

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Case-Based Reasoning (CBR) means solving problems by utilizing the experience gathered in precedent cases. The legal domain is an ideal domain for CBR since it relies on extensive utilization of precedents. The research presented in this paper deals with constructing the prototype of a computerized working system called The Judge's Apprentice. This system is designed for practical use in Israeli criminal cases to aid sentencing in two categories of crimes. The proposed system is intended to reinforce the principle of uniformity in sentencing i.e. passing similar sentences for similar offenses. Senior legal experts have welcomed the system. Most of them were of the opinion that the system could definitely be of advantageous use to judges and that the idea of using CBR for sentencing is relevant and should be applied. The system has been tested on 54 non-representative cases. A rather high success rate has been achieved in cases for which a precedent with high similarity has been retrieved. Future directions for research are: elaboration of the model for the handling of other types of offenses; elaboration of the model to other domains requiring case-based evaluation.

1. Introduction

Case-based reasoning (CBR) has been one of the promising new and widely developing domains in Artificial Intelligence research during about the last twenty years. CBR refers to solving new problems by utilizing the experience gathered in precedent cases. CBR in computers has been successfully employed in a variety of domains such as: law[1], mediation[2], medicine[3], cooking[4], and chess[5]. A full and deep review of CBR is available in Kolodner's book[6].

In CBR, the assumption is that the world is consistent. Although this assumption is not always true, in many domains it is dominant and practical. The legal domain in general and the Anglo-American legal system valid in Israel in particular, is an ideal domain for CBR since it relies on extensive utilization of previous precedents.

The research presented in this paper deals with constructing the prototype of a computerized working system called The Judge's

Apprentice. The full research is described in detail in Hacohen-Kerner's dissertation[7]. This system is based on a case-based model and designed for practical use in Israeli criminal law to aid sentencing in cases of either robbery or rape.

The proposed system is intended to reinforce the principle of uniformity in sentencing i.e. passing similar sentences for similar offenses. This principle is essential in the legal domain and is widely agreed upon by relevant experts on the subject. This overall agreement is due to the fact that uniform sentencing is a valuable tool for achieving equality before the Law by which justice is perceivable and not merely carried out. In addition, uniform sentencing improves the courts' credibility in the public eye and reduces arbitrariness, so that when judges are called to decide on a case, the sentences they pass are less likely to deviate from the norm.

This paper is organized as follows. Section 2 gives background concerning the relevant case-based systems. Section 3 introduces the selection of indexes and the sentencing tree. Section 4 describes the case-based model. Section 5 details an illustrative example. Section 6 presents the results of the experiment and analyzes them. Finally, Section 7 summarizes the research and proposes future directions.

2. Relevant Case-based Systems

MEDIATOR[2,8] is one of the oldest CBR systems. The system accepts an argument between two sides and attempts to suggest a compromise between them on the basis of detailed precedents and a rich common-sense knowledge base.

SWALE[9] is a case-based system that explains unusual death stories using creative explanations. The explanations are created through an adaptation process carried out by existing explanation patterns whilst relying on an elaborate common-sense knowledge.

JUDGE[10,11] is a CBR model for sentencing. Bain constructed a CBR model that attempts to characterize how a judge decides on the sentence; he had no intention of creating a sentencing model using CBR. JUDGE uses limited knowledge of a very specific type of crime and is not intended for practical use. JUDGE decides on the sentence with the aid of a formula without presenting explanatory details.

HYPO[1] and GREBE[12] are two other CBR systems in the legal field. HYPO is a legal planning and analyzing system in the domain of transmitting professional secrets. GREBE is a legal analyzing system in the domain of compensation for workers' injuries. Neither of them deals with passing sentences for the case at hand.

There are a few legal systems in the world that assist in actual sentencing. These systems deal, each in its own way, with the problem of

a lack of uniformity in sentencing. None of these systems are relevant to our research because they are not case-based.

Neither are most of the case-based systems reviewed in this research really relevant here, since they require the essential use of common-sense knowledge. In our opinion, these systems can only be the prototype for a model whose practical application in industry is either highly improbable or impossible.

3. Selection of Indexes and the Sentencing Tree

3.1. Selection of Indexes

Indexes (access-keys) are the collection of the details that enable presentation of any case in the model for retrieval and reasoning. Therefore, correct choice of indexes is critical for a case-based model.

The indexes the judges use for retrieval and sentencing were found in the two main methods of formulating and collecting indexes presented by Kolodner[6] :

- The functional approach: In this approach, indexes and data are gathered by examination of the cases at hand and the tasks needed to be carried out on them.
- The reminding approach: indexes and data are gathered in this approach by analyzing and characterizing the various remarks of four experienced judges.

The tendency of the judges to classify these indexes and the similarity between various either concepts or groups of concepts guide us to construct an hierarchical tree that contains legal concepts relevant to sentencing. The indexes input for any case, become the indexes stored in the tree's leaves.

3.2. Sentencing Tree

The sentencing tree is an hierarchical classification of 371 legal concepts relevant to criminal sentencing at different levels of abstraction. At the root of the tree, we have the concept of "criminal sentencing". Each leaf (a node at the last level) in this tree represents an index (e.g., "victim is elderly" and "use of force"). This tree is used primarily for determining index similarity in the retrieval process in our model.

The tree has been constructed by a research team with the help of a senior judge. Firstly, it has been constructed in the functional approach and presented in its first version by Ehrlich[13]. The tree has been improved and enlarged over a few years of this research. Indexes have been formulated and collected by the functional and the reminding approaches.

The structure of our tree is similar in some ways to the E-MOP, the memory structure introduced by Kolodner[14]. Our legal concepts resemble Kolodner's generalized information items and our indexes can be viewed as her "events."

4. The Model

The model has been applied to a system intended for use in real life. Therefore, the system deals with a limited domain (criminal sentencing) and the necessary information is well defined and bounded. This information includes: a data base of about fifty precedent cases and appeals for twelve of them; the legal knowledge relevant to sentencing; and an hierarchical tree that contains concepts relevant to sentencing.

The aim to which we aspire is constructing a prototype of the model that will develop into a useful system that will serve judges in the sentencing process. The main aim of this system would be to contribute to uniform sentencing and guard it. We therefore base ourselves on the supposition that domain knowledge, including the database of precedents, will be set by an accepted legal body. Therefore, there will be no foreseeable contradictions between similar precedents from the point of view of sentencing. This database will include selected representative precedents that encompass the types of crimes under discussion. A general description of the case-based algorithm applied in The Judge's Apprentice is given below.

4.1. Case-based Algorithm

This description does not include all the sub-stages of the algorithm, rather, it describes the principal ones in general.

1. Inputting a New Case (NC) and its processing.
2. Initial retrieval of relevant precedents.
3. Retrieval of the most relevant precedents by a similarity measure.
4. If a failure occurred during retrieval, that is, no precedent passed the similarity measure necessary, then the system announces that there is no relevant precedent and does not allow a solution to be constructed.
5. If the retrieval was successful, the closest, most similar precedent is set as the Old Case (OC).
6. Constructing a solution for the NC by using the OC:
   - 6.1. Construction of an MXP that analyzes and explains the NC.
   - 6.2. Computation of sentence for the NC.
   - 6.3. The proposed sentence for the NC is expressed qualitatively by a description of the difference between the sentences for the NC and the OC.
   - 6.4. The qualitative proposal for the sentence is then explained according to the similarities and differences between the NC and the OC (taking into account the relative priority of their identical points).
   - 6.5. A reliability measure of the retrieval and the proposal is presented. This measure is based on the similarity measure that was used at stage 3.
7. Examination of the solution by the system is not relevant due to the limitations of carrying out simulation. Such an examination will be possible at the next stage described there.
8. If a sentence for the new case has been input together with the NC, the model then enables automatic evaluation of the computed sentence. This evaluation is expressed by an acceptance/rejection measure that is computed by evaluating the difference between the computed sentence and the sentence input into the system.
9. In a case where the computed sentence failed according to the measure mentioned in the previous stage, an opportunity to recover is offered. The user can move on to a new inference for the NC, not according to the retrieved precedent, but by appeal against the retrieved precedent if it exists, or according to another precedent amongst those that were retrieved as relevant for the NC if it exists.
10. If the appeal or another precedent is chosen, then this case is defined as the OC and the system returns to stage 6.
11. Learning, as in acquiring cases and deleting cases, is not enabled, in order that the desired goal of uniform sentencing not be defeated.
12. Limited learning has been enabled, however, by the option of building a personal version of the case-base for a specific judge by acquiring the NC as a precedent at the judge's initiative.

In the following subsections of this Section we shall give a detailed description of the most important CBR stages of the algorithm.

4.2. Retrieval of suitable cases and selection of the best case

Given a NC, we retrieve all cases that include at least one index found in the NC. Then, for these retrieved cases (OCs) we compute a similarity value between the NC to each OC. Cases are retrieved only if their similarity value is at least equal to the bottom limit of the similarity value that is considered medium (0.4 in our application). The case with the highest similarity value to the NC is chosen for the next stage of the algorithm.

Our similarity measure is similar to contrast measure introduced by Tversky[15]. Tversky's similarity measure has the following general definition:

$$\mathrm{sim}(NC, OC) = \alpha * f(NC \cap OC) - \beta * f(NC - OC) - \gamma * f(OC - NC)$$

FORMULA 1: *Tversky's contrast measure*

where, α, β and γ are specific constants, f (NC $\cap$ OC) represents the weight of the identical features found in both cases, f (NC - OC) represents the weight of the features found in the NC but not in the OC, and f (OC - NC) represents the weight of he features found in the OC but not in the NC.

The specialty of this formula is that it does not only take the positive contribution of the identical characteristics into account, it even considers the negative contribution of the foreign characteristics in each of the two groups.

Our similarity measure has a more complicated general definition, as follows:

$$\text{sim}(NC, OC) = \alpha * f(NC \cap OC) + \beta * f(NC \sim OC) - \gamma * f(NC - OC) - \delta * f(OC - NC)$$

FORMULA 2: *Our similarity function*

where, α , β, γ and δ are specific constants, and f (NC $\cap$OC) represents the weight of the identical features found in both cases, f (NC ~ OC) represents the weight of the features found in one of the cases with a similar feature found in the other cae, f (NC ~ OC) represents the weight of the features found in the NC but are neither in the OC nor have similar features in the OC, and f (OC - NC) represents the weight of the features found in the OC but are neither in the NC nor have similar features in the NC.

In addition to the structure introduced in Tversky's contrast measure, our similarity measure includes a component of the similarity between similar indexes from a conceptual point of view. This refers to considering non-identical concepts that are similar enough according to the tree of hierarchical concepts.

4.3. Construction of the Solution for the NC

The solution for the NC contains two main components: A Multiple eXplanation Pattern (MXP) and a proposed sentence.

Construction of the Solution for the NC is based on the most n important indexes found in the NC. The value of n has been set at 7. Any number smaller than 7 would be too weak for comparison between the NC and the retrieved OC. Furthermore, the number 7 is accepted as the number of items that the average person is able to remember without apparent effort, according to the cognitive rule called "7±2". This means that the average person is capable of remembering approximately 7 information items (between 5 and 9) over a relatively short term.[16]

The MXP for the NC is proposed after combining all explanation patterns (XPs) for the most n important indexes found in the NC. The XP structure has been firstly introduced by Schank[17]. Schild and Kerner[18] have defined the XP structure for criminal sentencing. The MXP is an analysis that contains evaluative comments for the most significant indexes found in the case. The analysis of the case is presented by an appropriate MXP, while the analysis of each index is presented by a suitable XP. The construction is carried out automatically with the aid of the knowledge tree by creating XPs, one for each of the n indexes under discussion.

Computing the sentence for any case is based on an evaluation of the measure of difference, either more severe or more lenient, from the base-sentence. The base-sentence is the sentence that would have been passed on the case without indexes towards severity or leniency. The base-sentence is presented by a positive whole number that describes the number of months of active imprisonment that would have been passed on such a case.

In accordance with the above definition, for each type of criminal offense (robbery, rape) a separate base-sentence is defined. The values of the base-sentence (in months of active imprisonment) for each of the offenses that we deal are 36 months for robbery and 48 months for rape offenses.

Computation of the sentence for the NC with the aid of the OC is based not only on the base-sentence but also on the weight of the n most important indexes of comparison between the NC and the OC. The weights of these n indexes are computed with the aid of a process that matches the weights of the n most important indexes of the OC. The formula we use for computing sentences is described in detail in Hacohen-Kerner's dissertation[7].

5. An illustrative example

In this section, we illustrate the use of The Judge's Apprentice. The chosen NC is a robbery case (file-number: 2/98) whose abstract is as follows:

A youth helped an elderly lady to her home. There, he beat her head and body with harsh blows using a chair. The elderly lady suffered from physical injury (a broken arm and wounds) and psychological injury. The youth stole 350 New Israeli Shekels (NIS) from her purse and fled. The accused had an expansive history in the same field.

The summary of the OC (file number: 919/80) retrieved for the NC is as follows: A thief was found guilty of group robbery of an old woman of about 80 in her home. The robbers, carrying a knife, with nylon socks over their heads, broke into the house, beat the old woman and stole the sum of 13,000 LI (i.e., Israeli liras, an old currency). The old woman was seriously injured both physically and psychologically. The accused had a history of major offences. Two suspended sentences of an inclusive period of 22 months were enacted against him. The judges decided that the crime was repulsive and that it was a national blow that could be copied by others. The accused was sentenced to 84 months of active imprisonment + the 22 months of suspended sentence that ware enacted, a total of 106 months of active imprisonment.

Presented below are the 7 most important points of comparison between the NC and the OC, and the system's proposition for the sentence:

Main Identical details
Detail
1. Repulsive act
2. Victim is elderly
3. Psychological injury

Main Similar Details			
NC Detail	**OC Detail**	**Source of Detail**	**Comparison**
Expansive history in same field	History of major offences	Heavy criminal history	More Lenient
Use of cold weapon	Carrying a knife	Weapon	More Serious
Use of excessive force	Use of force	Use of force	More Serious

Main details in OC but not in NC	
Comparison	**OC Detail**

Main Details in NC but not in OC	
Comparison	**NC Detail**
More Serious	1. Dangerous injury

TABLE 1 : *Comparison of Details between the NC (2/98) and the OC (919/80)*

The proposed sentence for the NC is very slightly more lenient in comparison to the sentence for the OC. This is because the computed sentence for the NC by the system is 103 months of active imprisonment, while the sentence that was passed for the OC was 106 months. That is, the percentage of relative change is only -3%.

6. Research Results

A sample run of the system was demonstrated before four senior legal experts. To their opinion the system is intelligent and interesting. Three of them were of the opinion that the system could definitely be of advantageous use to judges and that the idea of using CBR for sentencing is very relevant and should be applied.

The results of the model's application will be able to undergo authentic examination and evaluation only when the knowledge-base is constructed by an accepted legal body. Since this knowledge is not yet available, the system was tested on a non-typical database comprising fifty-four authentic precedents. A test was carried out for each precedent comparing the sentence computed by the system and the sentence that was actually passed. The test was carried out according to the "Leave One Out" method, in which each of the cases was tested as if it was a new case with each of the other cases as precedents for it.

A sentence for the NC (constructed by the system in accordance

with the retrieved precedent) is compared to the sentence that was actually passed for the NC (since this is an authentic case). Success is considered when the difference between the percentage of the sentence for the NC, which was proposed by the system, from the actual sentence passed, is relatively small. In the current version, the difference is defined by the interval (-0.33, 0.33). Failure is defined by when the difference is greater in either direction. In a case of a failure, an opportunity to recover is offered. The user can move on to a new inference for the NC by appeal against the OC if it exists, or according to another precedent amongst those that were retrieved as relevant for the NC if it exists. The results of our test are shown in Table 2.

No precedent retrieved	First precedent retrieved of medium similarity			First precedent retrieved of high similarity (At least)			Type of retrieval
Failure	Failure after recovery	Success after recovery	Success with first precedent	Failure after recovery	Success after recovery	Success with first precedent	Success/ Failure
14	10	3	6	5	4	12	No. of cases
14	21			19			Total
100%	53%	16%	31%	24%	19%	57%	Percentage

TABLE 2: *Results of similarity measure between the sentences according to the similarity measure in the retrieval*

A number of conclusions were gleaned from these results:

1. The database of precedents available does not cover the domain of cases that it is supposed to encompass. For 14 cases (over one quarter of the cases) no relevant precedent was retrieved. Moreover, for 15 other cases no relevant case was retrieved in practice. The reason for this is that the precedents were judged by a relatively large number of judges, in various law-courts, over a period of more than twenty years.
2. Attempts at recovering did improve the results (3 + 4 = 7 cases). However, this is an improvement of only 13%. It must be noted, however, not all of the possibilities at recovering were attempted, that is we did not try to develop a solution by relying on the third retrieved precedent onwards nor on appeals of the second precedent onwards.
3. As a result of the limited attempts at recovering that were carried out, it became clear that for almost one half of the cases (25 out of 54, a little over 46%), solutions were constructed that were considered successful. This is a reasonable result considering running a prototype based on a non-representative database of precedents.
4. The system reveals far better results for cases for which a first precedent of a relatively high similarity is retrieved. This means that a case can be solved with greater success if the precedents retrieved for it are of a relatively high similarity. The results were as follows: The

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An intelligent assistant for design and material engineers in the submarine cable industry

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This paper describes an industrial application of case-based reasoning in engineering. The application involves an integration of case-based reasoning (CBR) retrieval techniques with a relational database. The database is specially designed as a repository of experiential knowledge and with the CBR application in mind such as to include qualitative search indices.

The application is for an intelligent assistant for design and material engineers in the submarine cable industry. The system consists of three components; a material classifier and a database of experiential knowledge and a CBR system is used to retrieve similar past cases based on component descriptions. Work has shown that an uncommon retrieval technique, hierarchical searching, well represents several search indices and that this techniques aids the implementation of advanced techniques such as context sensitive weights.

The system is currently undergoing user testing at the Alcatel Submarine Cables site in Greenwich. Plans are for wider testing and deployment over several sites internationally.

1. Introduction

In the submarine cable industry, as in all industries, a major requirement is to reduce costs throughout the design, qualification and manufacturing process without compromising quality. Material selection is an important but neglected part of this process. Improper choice of materials can, at its worst, lead to premature and even catastrophic failures. Less severely and more commonly it can lead to greatly increased costs. Materials databases can serve a useful function in the materials selection process, giving up to date information on the physical properties and costs of candidate materials for a task. However, experiential knowledge of the use of materials in a particular application domain is not commonly available from such databases.

Application knowledge extends the context of material selection into component manufacture. For example, an inexpensive material