Role of Case-Based Reasoning in Neurology Decision Support

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ABSTRACT: Case-based Reasoning (CBR) has become a successful technique for knowledge-based systems in different domains including medicine. Medicine is a suitable domain for application of CBR because the knowledge of experts consists of mixture of textbook knowledge and experience, which consists of cases. The possibilities of employing CBR in neurology are analyzed in the paper. A suitable architecture for CBR decision support system in neurology is proposed. System is going to be used in Institute of Neurology Novi Sad.

1. INTRODUCTION

Case-Based Reasoning (CBR) has become successful technique for knowledge-based systems in different domains. This promising technique is based on use of previous experience in form of cases to better understand and solve new problems in particular domain. The main idea is an assumption that, for many particular domains, similar problems usually have similar solutions.

Generally speaking, the CBR systems have not only to provide solutions to problems but also to take care of other tasks occurring when it is used in practice. However, CBR can mean different things depending on the intended use of reasoning:

- Explain current situation according to previously experienced similar situation,
- Critique current situation based on old cases,
- Reason from precedents to understand a current situation,
- Combine old solutions in order to solve a current problem,
- Obtain concensued solution based on previous cases.

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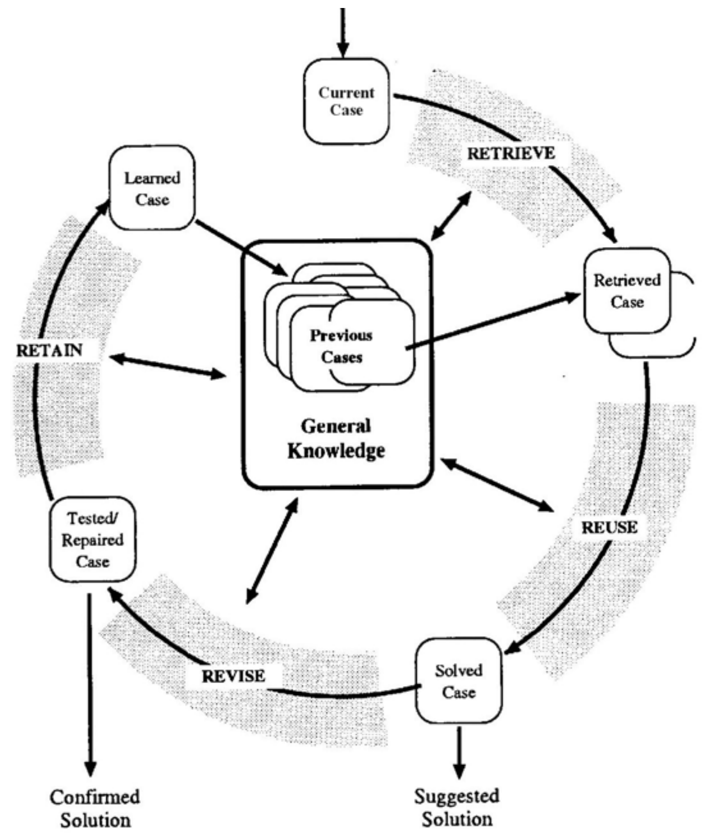

Fig 1. *CBR-cycle* of Aamodt and Plaza (1994)

To summarize, mentioned aspects could be divided into two types: interpretative and problem solving CBR [6]. In interpretative CBR systems the essence is to achieve whether or not a current situation should be treated like previous ones based on similarities or differences among them. In problem solving CBR systems the main task is to propose a solution to a current situation based on the adaptation of solutions to past cases. However in practice, many problems have components of both types of CBR and certainly combination of both methods is employed.

The main phases of case-based reasoning activities are described in the CBR-cycle [1,2] in fig. 1.

In the retrieve phase, the most similar cases to the problem case (current one) are retrieved. In reuse phase some modifications to the retrieved case is done in order to provide better solution to the problem (phase of case adaptation). As the CBR only suggests solutions, there may be a need for a correctness proof or an external validation of expert in particular domain. That is the task of revise phase. In the retain phase the knowledge learned from current case is integrated in the system by modifying some knowledge containers.

Medicine is rather suitable domain for application of CBR because the knowledge of experts consists of mixture of textbook (objective) knowledge and experience (subjective) knowledge, which consists of cases. The problem of updating the changeable subjective knowledge can partly be solved by incrementally incorporating new up-to-date cases [3]. Usually two sorts of knowledge can be clearly separated, and represented in an appropriate manner. Objective knowledge can be represented in forms of rules or functions, while subjective knowledge is contained in cases. So, there are several obvious facts for usage of case-oriented methods in medicine [13]:

1) Reasoning with cases corresponds to the decision making process of physicians.

2) Incorporating current cases obtains automatically updated parts of the knowledge.
3) Two distinguished types of knowledge can be clearly separated.
4) Integration into clinic communication system is easy (cases are routinely stored).

CBR has been mainly applied in medicine for diagnostic and partly for therapeutic tasks. It is often necessary, in diagnosis, to adapt an old case to fit a current problem.

In this paper architecture for CBR decision support system is suggested and its application in neurology domain is analyzed. The rest of the paper is organized as follows. In section 2 some open problems of CBR systems, are outlined. Section 3 is devoted to specification of a particular CBR prototype in neurology. Section 4 concludes the paper.

2. OPEN PROBLEMS OF CBR SYSTEMS

CBR is interesting Artificial Intelligence (AI) technique for application in different domains, but also a learning paradigm which has several advantages [10]:

1) Based on cases stored in memory, instead of deriving new solution from scratch, a CBR system remembers and adapts old ones.

2) CBR reasoner becomes more competent over time, can avoid previous mistakes, and can focus on the most important parts of a problem.

3) CBR approach to learning is most similar to human learning. People take into account and use past experiences to take future decisions.

Apart from these positive aspects, there are still a lot of open problems in building commercial tools. Current commercial tools are mostly oriented towards acquisition and retrieval of cases and its simple adaptation and evaluation. The well-known open problems appearing in CBR systems are mentioned below.

1) Retrieval/selection – the most basic problems are retrieval and selection of cases, since the remaining operations (adaptation and evaluation) will succeed only if the past cases are the relevant ones.

2) Memory organization – good memory organization is extremely important because when the case memory is large retrieval can be very inefficient.

3) Matching – to select the best case it is necessary to be able to match cases. Usually the match cannot be perfect because: - the values of the comparable features are not exactly the same, - there are missing values for some or even many of features.

4) Adaptation/evaluation – a good adaptation of old cases to fit the current case is really important possibility of CBR system. It can reduce significantly the amount of work needed to solve the problem. Evaluation gives to the case-based reasoner feedback about whether or not the current case was solved adequately.

5) Forgetting – another important problem is how to control growth of the case memory. So, it is important to obtain technique for storing and deleting cases.

6) Integration with other techniques – application of CBR in different domains usually requires combination of CBR with other reasoning techniques [12].

2.1. Problems of CBR in medical applications

Some authors [13] think that the main problem of CBR is the adaptation task. It still depends on domain and application characteristics. In medicine, adaptation can be a serious problem, because cases often consist of an extremely large number of features. So some adaptation solutions, typically for medical domains, have been developed:

1) Focusing on retrieval – An idea to avoid adaptation problem is to build retrieval-only systems. Retrieval is used only to find similar cases and present them to the user. Some systems have possibility to point out important differences between current and previous cases. The justification for giving up the adaptation task is that physicians are interested to get information about former similar cases, but wish to reason and bring diagnosis for current patient themselves [11]. A similar approach is to combine CBR with rule-based methods. In some concrete systems if no similar case can be found or if not all adaptation problems can be solved, a separate rule-based component of the system is applied.

2) Generalized cases – in this solution, the main idea is to form abstracted prototypes by generalization from single cases. Though, generalization obtains to structure the case base, to decrease the storage amount by erasing redundant and highly similar cases, additionally it can at least partly help to solve the adaptation problem.

3. A PROPOSITION OF CBR SYSTEM IN NEUROLOGY

Last year a small team at Institute of Mathematics and Informatics, started investigation in the field of CBR methodology. The main proposed task was implementation of CBR system based on [7]. Recently, at Institute of Neurology, appears need to systematize and automatise records of patients has been collecting for ten years. Their basic idea was to store all necessary features for determination of multiple sclerosis disease, and to use previous experiences in diagnosis of current cases.

As it is well known medical diagnosis from surface etiology is difficult since there involves lots of complications. A physician has to carefully investigate a patient's symptoms and testing results, major complaints and pathology examination in order to make a differential diagnosis. It is rather difficult process and it takes years of training and practice for a physician to make correct decisions.

Also it is not easy task to update the medical knowledge incrementally in a traditional medical diagnosis system. Mentioned difficulties can be made easier and more reliable if supplied with a system that contains and provides recommendations from the past diagnosis cases of different morbidity. Since the physician can benefit a lot from prior experiences and cases the CBR approach is rather appropriate for medical domains. So, it seems that unification of these two research directions could be mutually useful.

Multiple sclerosis (MS) is a chronic disease of unknown cause that affects the nervous system (brain, spinal cord and peripheral nerves) in form of multifocal lesions of myelin nerve sheet. It causes damage of vision, muscle strength, sensation, coordination, speech, and bladder control and may affect cognitive functions. MS usually appears in young adulthood (more in females) and Vojvodina is region with high incidence of disease.

Clearly, investigation in this field, which will bring better and more reliable results in diagnosis and maybe some exceptional conclusions of reasons of disease appearence, is extremely important. Based on some mutual requirements and analysis of different medical CBR systems [3, 4, 11, 12, 13] as well, in fig. 2, architecture of CBR system for diagnosis of MS disease is proposed. Proposed architecture has the following main characteristics:

1) Employs CBR technique for retrieval of similar cases with key notifications and evidences between the current and similar cases.
2) Suggests possible diagnosis and gives appropriate explanations of solutions.

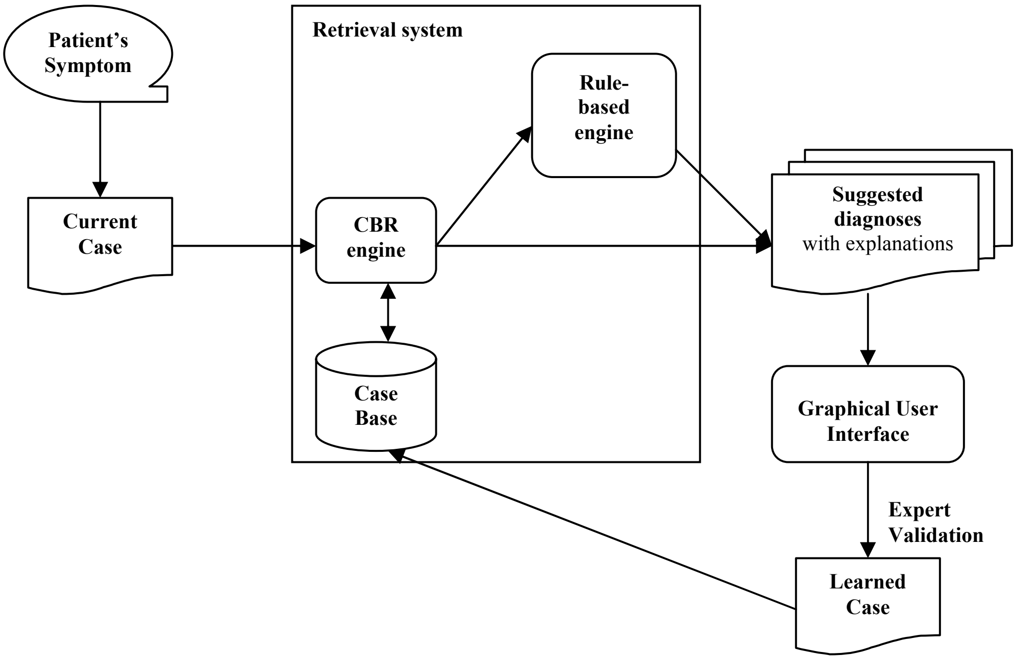

Fig. 2. Proposed architecture of a CBR decision support system in neurology.

To build proposed architecture, a lot of necessary activities have to be analyzed and taken into account:

1) Determination of representation forms for cases and extracting important features.
2) Avoidance of an infinite growth of the case base by clustering cases in prototypes and removing redundant cases.
3) Selection of appropriate retrieval algorithm.
4) System suggests possible diagnoses. But, expert must analyze current patient data and similar prototypes enriched by explanations, in order to achieve final diagnosis.
5) As already mentioned, the main problem of CBR systems in medicine is adaptation task. In the first phase of realization of proposed architecture, expert will be supposed to decide whether current case is different enough to be added in the case base as the new case or even as a new prototype. In future, plans are to automatise as much as possible this process of adaptation and decision. For that, we considered combining CBR with rule-based methods that is rather fruitful mixture in such kind of systems.

By analysing the diagnoses problem of MS disease the appropriate case structure with characteristic features is given in the Table 1. The case has 16 different features representing the most important observations in the diagnoses process of MS disease. List of the features can be extended with some additional ones (it will be done in future versions), if these features are significant for the diagnoses process. The last row in the table represents the correct diagnosis for the corresponding cases.

The cases are stored in the special memory structure - Case Retrieval Net (CRN) [7, 8]. Case Retrieval Nets are memory model that has been developed for efficient retrieval in large case bases. For the efficiency improvement, the cases are grouped into prototypes. All cases of the same prototype are cases with the same diagnoses, so the memorizing of the diagnoses feature of the case is needless because the diagnosis of the case is determined by its prototype.

Table 1. Some MS cases

	Case #1	Case #2	Case #3	Case #4	Case #5
I Natural History and neurological findings					
Course of disease	Relapsing /remitting	Secondary-progressive	Primary-progressive	Relapsing /remitting	Transient retrobulbar neuritis
Duration of the disease (years)	10	15	10	20	3
Motor symptoms	Mild hemiparesis	Paraparesis	Quadriparesis	Mild hemiparesis	-
Spastically	+	+	+	-	-
Cerebella symptoms	Increasing intention tremor	Ataxia	Ataxia of lower limbs, dysmetria, dysarthria	-	-
Sensory symptoms	Paresthesiae dysaesthesiae	Paresthesiae, Trigeminal neuralgia	Paresthesiae	Paresthesiae dysaesthesiae	-
Gait abnormalities	+	+	+	+	-
Bladder dysfunction	Micturition urgency	Retention	Incontinence	Micturition urgency	-
Bowel dysfunction	-	-	+ (mild)	-	-
Visual symptoms	Transient optic neuritis	Diplopia	Permanent loss of visual acuity	-	Isolated retrobulbar neuritis
Cognitive dysfunction	Memory disturbance difficulty in sustaining attention	Memory disturbance	Dementia	Memory disturbance,	-
Psychiatric symptoms	Depression, Drug induced psychosis	Euphoria Pathological laughing and crying	-	Euphoria	-
II Laboratory tests in diagnosis CSF (Cerebrospinal fluid) Oligoclonal IgG bands	+	+	+	-	-
III Visual evoked potentials P100	130/121	171/176	170/165	125/121	137/130
IV Magnetic resonance imaging (TVLL total vol. lesion load) mm^3	170	920	1600	250	0 (optic nerve demil.)
Diagnosis	Definite multiple sclerosis	Definite multiple sclerosis	Definite multiple sclerosis	Probable multiple sclerosis	Possible multiple sclerosis

Table 1 displays results of 16 different features for 5 cases. Fist 3 cases are with the same diagnostics (definite multiple sclerosis) and are to be grouped in the same prototype. Cases 4 and 5 are characteristic for other two possible diagnoses (probable and possible multiple sclerosis). Sign + in appropriate cells designates presence of specified feature, while sign – designates the absence of the feature.

The next problem in medical case-based reasoning systems is avoidance of infinitive growth of case base. Although every case in the diagnoses process is important, it might be redundant for the system, because maybe the system already has the knowledge to propose that diagnoses, or maybe some similar or more general cases already exists in the system. Maintenance of the system will be implemented using *case properties* [5]. For each additional case, system evaluates *correctness, consistency, uniqueness, minimality* and *incoherence,* and makes decision if the case is needed for the system or not. Of course, the neurology expert must firstly decide if the diagnosis is correct. The evaluation of the case properties is the just additional filter, which improves accuracy of the system and reduces the case base growth without losing of correctness.

In this phase of realisation, the problem of forgetting is not realised. We will observe the growth of case base and if the growth will turn to be significant we will develop some forgetting algorithms based on deleting not recently used or least used cases.

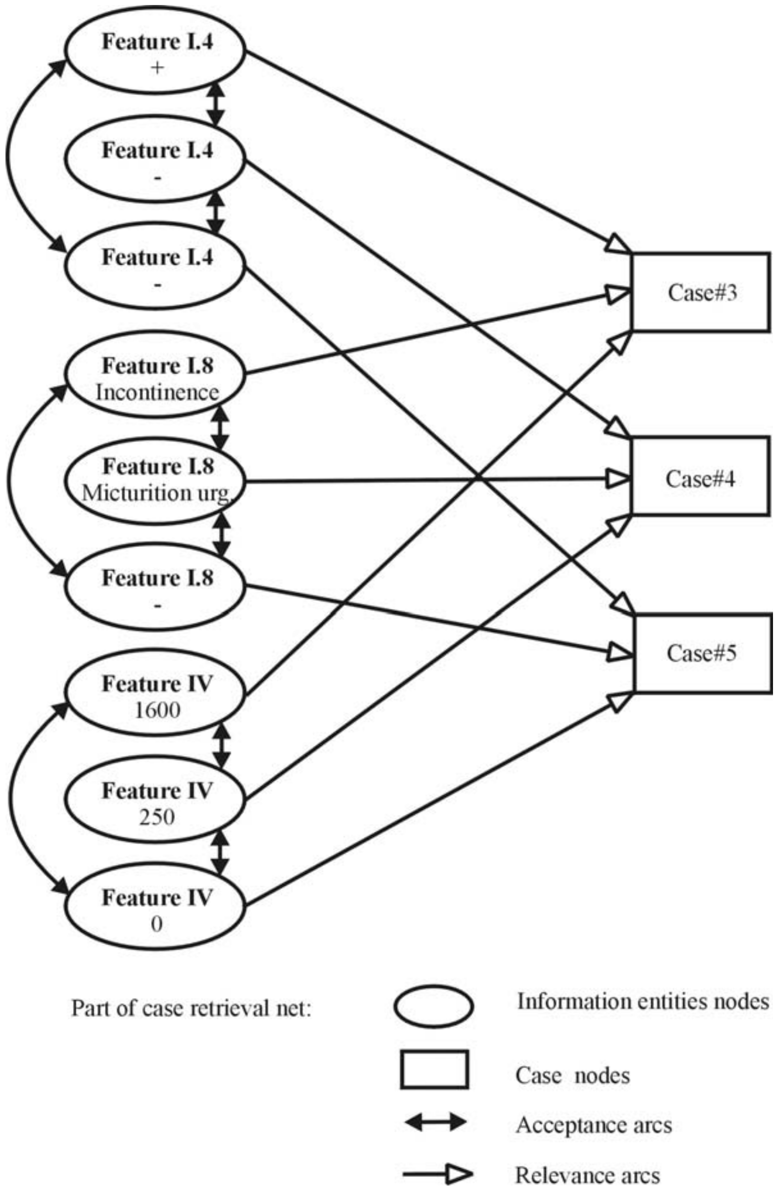

Fig. 3. Example of CRN in the neurology domain.

As mentioned before, cases are organized in the Case Retrieval Net. This net has nodes for each case and nodes for each value of every feature - these values are called *information entities*. There exists an acceptance arc between every two corresponding information entities - information entities of the same feature. Also there exists a relevance arc from information entity to the case, if that information entity is relevant for that case. All the values in the net are weighted with appropriate values.

In Fig. 3 a part of case retrieval net, from this domain, is given. In this figure only 3 features (Spastically - I.4, Bladder dysfunction – I.8, Magnetic resonance imaging – IV) with 3 values for each attribute and for different cases, which makes 9 information entities, are presented. Acceptance arcs are connecting only information entities nodes of the same feature, which means that local acceptance function is defined only between information entities of the same feature. Furthermore, only 3 cases (Case#3, Case#4, Case#5) from this domain are presented in the figure. Relevance arcs represent the influence of information entities on cases. All arcs in the net are weighted by corresponding functions.

At the beginning of the retrieval process, physician has to enter his observations in form of the query, which consists of the values of existing features. For every feature *i* the special numeric value α_i called *importance* is defined. This value contains the information how much is the corresponding feature important for the diagnosis. High values indicate high importance, while lower values indicate lower importance. At the beginning, all importance values have the same default values. Of course, the physician can increase value α_i if he believes that feature *i* has higher importance then some of the others. The physician will decrease the default value of α_i if he considers that the value of the feature *i* is not precise or that this feature is not just so important.

Retrieval process consists of evaluating *acceptance* values for each prototype. Acceptance values are computed by spreading activation process in the net as follows: Information entity nodes are initially activated by α_i. The computation is performed by propagating along the acceptance arcs to further information entity nodes and from all activated information entity nodes over relevance arcs to case nodes. The acceptance value for every prototype is obtained by summing the activations of all cases from that prototype.

If the acceptance values of several prototypes is relatively high then diagnoses of these prototypes is suggested to the physician. However, if acceptance values of all prototypes are below some determined threshold, that means that diagnoses system "never saw something like that before", and that CBR-system cannot suggest the correct diagnoses. In that case physician's query is passed to the rule-based reasoning system, which attempts to solve the problem using some rules from the textbook knowledge. The combination of CBR with rule-based technique is very useful.

System always offers several possible diagnoses. However, the physician must decide which diagnosis is correct. Proposed system just helping him in decision making process. When the physician sets the correct diagnosis, that diagnoses together with the query is passed to the CBR engine in order to learn the new experience. If this case has not any contradictions in relation to all case properties mentioned before the case is included in the case base as the new knowledge. But if just one contradiction has occurred this means that this case is redundant for the system and the case is neglected.

4. CONCLUSIONS AND RELATED WORK

Case-based reasoning technique seems to be suitable for medical knowledge-based systems [1, 7, 10]. Main intention of proposed architecture of CBR system with decision-support elements, was to apply it in a specific medical domain. As Vojvodina is region with high incidence of multi sclerosis disease, research in this field employing promising AI technique, is rather important. Especially, possibility to discover reasons for disease appearance could be significant achievement.

Mutual research is good starting point for employing two emerging fields in achieving useful tool. It could support process of decision making and could help human expert to choose the final diagnosis. Analysis of different CBR medical systems [3, 4, 11, 12, 13] obtains insight in necessary and useful representation techniques, rules, functions and algorithms. Assimilation and application of some well known developed mechanisms like CRN, prototypes, forgetting algorithms, case properties etc. in unique architecture make our approach interesting for realization in neurology domain in Vojvodina.

CRN proved to be a suitable memory organization for decision support applications in medicine domain, because subjective knowledge of medical experts consists of large number of successfully solved problems – cases, and CRN is able to handle case-base of huge size. Prototypes are used for the efficiency improval, and case properties are included for reducing the case base growth.

Now, we are in the beginning phase of implementation of the proposed system. We expect that gathering experience of concrete realization will help us to improve characteristics of the system in future.

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