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Case-based Reasoning for Medical Knowledge-based Systems

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Abstract

In many domains Case-based Reasoning (CBR) has become a successful technique for knowledge-based systems. In medical domains, attempts to apply the complete CBR cycle are rather exceptional. Some systems have recently been developed, which on the one hand use only parts of the CBR method, mainly the retrieval, and on the other hand enrich the method by a generalisation step to fill the knowledge gap between the specificity of single cases and general rules. So, in this paper we discuss the appropriateness of CBR for medical knowledge-based systems, point out problems, limitations and possibilities how they can partly be overcome.

1. Introduction

Case-based Reasoning (CBR) has become a successful technique for knowledge-based systems in many domains, while in medical domains some more problems arise to use this method. We are going to discuss the appropriateness of CBR for medical knowledge-based systems, point out problems, limitations and possibilities how they can partly be overcome.

Case-based Reasoning means to use previous experience in form of cases to understand and solve new problems. A case-based reasoner remembers former cases similar to the current problem and attempts to modify their solutions to fit for the current case (Fig.1. shows the Case-based Reasoning cycle developed by Aamodt [1]). The underlying idea is the assumption that similar problems have similar solutions. Though this assumption is not always true, it holds for many practical domains.

CBR consists of two main tasks [1, 2]: The first is the retrieval, which is the search for or the calculation of most similar cases. If the case base is rather small, a sequential calculation is possible, otherwise faster non-sequential indexing [2, 3] or classification algorithms (e.g. ID3 [4] or Nearest Neighbor match [5]) should be applied. For this task much research has been undertaken in the recent years and actually it has become correspondingly easy to find sophisticated CBR retrieval algorithms adequate for nearly every sort of application problem.

The second task, the adaptation (reuse and revision) means a modification of solutions of former similar cases to fit for a current one. If there are no important differences between a current and a similar case, a simple solution transfer is sufficient. Sometimes only few substitutions are required, but sometimes the adaptation is a very complicated process. So far, no general adaptation methods or algorithms have been developed; the adaptation is still absolutely domain dependent.

Why Case-based Reasoning for medical decision making ?

Especially in medicine, the knowledge of experts does not only consist of rules, but of a mixture of textbook knowledge and experience. The latter consists of cases, typical and exceptional ones, and the reasoning of physicians takes them into account [6]. In medical knowledge based systems there are two sorts of knowledge, objective knowledge, which can be found in textbooks, and subjective knowledge, which is limited in space and time and changes frequently.

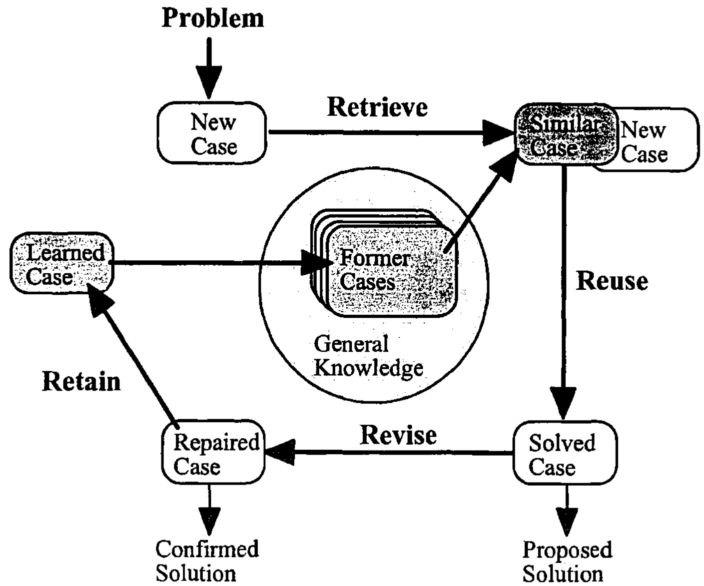

Figure 1. The Case-based Reasoning cycle developed by Aamodt

The problem of updating the changeable subjective knowledge can partly be solved by incrementally incorporating new up-to-date cases [6]. Both sorts of knowledge can clearly separated: Objective textbook knowledge can be represented in forms of rules or functions, while subjective knowledge is contained in cases.

So, the arguments for case-oriented methods are as follows:

1. Reasoning with cases corresponds with the decision making process of physicians.
2. Incorporating new cases means automatically updating parts of the changeable knowledge.
3. Objective and subjective knowledge can be clearly separated.
4. As cases are routinely stored, integration into clinic communication systems is easy.

2. Medical Case-based Reasoning systems

In medicine, CBR has mainly been applied for diagnostic and partly for therapeutic tasks. Related methods have been used in further fields, case-oriented methods for tutoring (e.g. D3 [7]) and retrieval methods to search for similar images (e.g. MACRAD [8]). So, here we first present four diagnostic and systems. Additionally, we present the therapeutic system ICONS; further systems are mentioned in [9].

One of the earliest medical expert systems that uses CBR techniques is CASEY [10]. It deals with heart failure diagnosis. The system uses three steps: A search for similar cases, a determination process concerning differences and their evidences between a current and a similar case, and a transfer of the diagnosis of the similar to the current case or - if the differences between both cases are too important - an attempt to explain and modify the diagnosis. If no similar case can be found or if all modification attempts fail, CASEY uses a rule-based domain theory. The most interesting aspect of CASEY is the ambitious attempt to solve the adaptation task by general adaptation operators. However, as many features have to be considered in the heart failure domain and as consequently many differences between cases can occur, not all differences between former similar and current cases can be handled by the developed general adaptation operators.

The FLORENCE system [11] deals with health care planing in a broader sense, for nursing, which is a less specialised field. It fulfils all three basic planing tasks: diagnosis, prognosis, prescription. Diagnosis is not used in the common medical sense as the identification of a disease, but it seeks to answer the question: „What is the current health status of this patient?“ Rules concerning weighted health indicators are applied. The health status is determined as the score of the indicator weights. Prognosis seeks to answer the question: „How may the health status of this patient change in the future?“ Here a Case-based approach is used. The current patient is compared to a similar previous patient for whom the progression of the health status is known. Similar patients are searched for first concerning the overall status and subsequently concerning the individual health indicators. As the further development of a patient not only depends on his situation (current health status, basic and present diseases), but additionally on further treatments, several individual projections for different treatments are generated. Prescription seeks to answer the question „ How may the health status of this patient be improved?“ The answer is given by utilising general knowledge about likely effects of treatments and also by considering the outcome of using particular treatments in similar patients. That means it is a combination of a rule-based and a case-based approach.

The most interesting aspect of MEDIC [12] is its memory organisation. MEDIC is a schema-based diagnostic reasoner on the domain of pulmonology. Schemata represent the problem solvers knowledge. These are packets of procedural knowledge about how to achieve a goal or a set of goals. The memory does not only consist of schemata, but additionally of diagnostic memory organisation packets of individual cases of diagnosis and of scenes. A scene represents an instantiation of a schema in a particular case. This memory organisation and retrieval allows a reasoner to find the most specific problem-solving procedures available.

GS.52 [13] is a case-based expert system that has been routinely used in the children‘s hospital of the University of Munich for many years. It is a diagnostic support system for dysmorphic syndromes. Such a syndrome involves a non-random combination of different disorders. The major problems are the high variability of the syndromes (hundreds), the high number of case features (between 40 and 130) and the continuous modifications of the knowledge about dysmorphic syndromes. Each syndrome is represented by a prototype that contains its typical features. The prototypes are acquired during an expert consultation session. A physician selects a new or an existing syndrome and typical cases for this syndrome. Subsequently, GS.52 determines the relevant features and their relative frequencies. The diagnostic support occurs by searching for the most adequate prototypes for a current case. A similarity value between each prototype and the current case is calculated and the prototypes are ranked according to these values. GS.52 differs from typical CBR systems, because cases are clustered into prototypes which represent diagnoses and the retrieval searches among these prototypes and not among cases. The adaptation consists of two examinations of the probable prototypes: A plausibility check with general rules (constraints) and a check of evidences for specific syndromes (some syndromes are nearly a proof for or against some diagnoses).

ICONS [14] is an antibiotics therapy adviser for intensive care patients who catch an infection as additional complication. As intensive care patients need an immediate introduc-tion of an appropriate antibiotics therapy, before the pathogen has been identified in the laboratory, a spectrum of probable pathogens has to be calculated. Besides this expected spectrum, which has to be covered by the antibiotics, the current resistance situation, contraindications of the patient and the sphere of activity of antibiotics have to be considered. CBR techniques are used to speed up the process of finding suitable antibiotics therapies and to update those parts of the knowledge base that are modified frequently. The principal argument for CBR, that it is often faster to solve a new problem by modifying the solution of a similar case than to start from scratch [2], also applies to the process of finding adequate therapies. Considering the close relation concerning the group of patients and the affected organ, a similar case is retrieved from a hierarchical and generalising storage structure containing prototypes as well as cases. As features the contraindications and as method a Tree-Hash-Retrieval algorithm [3] are applied. Furthermore, a criterion for adaptability is used during the retrieval, because similar cases with additional contraindications in comparison to the current patient are not adaptable. Consequently, the adaptation is rather simple. It is performed by a solution transfer of the advisable therapies of a similar case and subsequently by a reduction concerning additional contraindications of the current patient.

3. Problems of Case-based Reasoning for medical applications

To use Case-based Reasoning a few problems have to be solved: A representation form for cases has to be determined, an appropriate retrieval algorithm has to be selected and an infinite growth of the case base has to be avoided e.g. by clustering cases into prototypes and removing redundant cases or by restricting the case base to a fixed number of cases and updating the case base during an expert consultation session [8], but the main problem of Case-based Reasoning is the adaptation task. Little research has been undertaken on this topic and only formal adaptation models [15], but no general methods have been developed so far. The adaptation still depends on domain and application characteristics. Sometimes no adaptation is necessary, because e.g. the field and the cases are as unspecialised as in FLORENCE, sometimes the adaptation is a simple solution transfer or only a little bit more (e.g. ICONS), sometimes just a few constraints have to be checked (e.g. GS.52), but sometimes many differences between current and former similar cases have to be considered (e.g. CASEY). The latter situation is not only a problem for medical applications. However, in medicine it increases, because cases often consist of an extremely large number of features. In non-medical CBR applications, the adaptation is usually solved by a set of specific adaptation rules, which usually have to be acquired during expert consultation sessions. As these rule sets have to consider all possible important differences between current and former similar cases, for medical applications it is mostly impossible to generate such sets. So, some adaptation solutions have been developed that are not limited to, but are rather typical for medical domains.

Focusing on retrieval. An idea to avoid the adaptation problem is to build retrieval-only systems. These are programs that only retrieve similar cases and present them as information to the user. Some of them additionally point out important differences between current and similar cases. The justification for giving up the adaptation task is that in some application domains it is much too complicated or even impossible to acquire adaptation knowledge [16] and that physicians are interested to get information about former similar cases, but wish to reason for current patient themselves [8]. Examples of succesful retrieval-only systems are mainly in the fields of images [8] and of organ function courses [17].

A similar idea is to combine CBR with rule-based methods. In CASEY [10] and in ICONS [14] this combination is extremely lose: If no similar case can be found or if not all adaptation problems can be solved, a separate rule-based program is applied. However, in some systems there are much closer relations between a CBR component and other components. In CARE-PARTNER [18] CBR retrieval is used to search for similar cases to support evidences for a rule-based program. In a program for decision making for insulin dependent diabetic mellitus patients [19] a CBR part and a rule-base are applied in parallel, the results and the co-ordination of further steps is handled by meta-rules. However, these systems do not perform the complete CBR cycle, but only incorporate CBR retrieval.

Generalised cases. As one reason for the adaptation problem is the extreme specificity of single cases, a different idea is to generalise from single cases into abstracted prototypes [20] or classes [21]. Though the main ideas for this generalisation are to structure the case base, to decrease the storage amount by erasing redundant cases, to speed-up the retrieval and sometimes to learn more general knowledge, additionally it can at least partly help to solve the adaptation problem. An example is the diagnostic system for dysmorphic syndromes (GS.52), where each case is characterised by a list of features, which usually contains between 40 and 130 symptomes and syndromes. This means, there are so many differences between a current and a similar case that an adaptation that takes all of them into account is impossible. So, for all cases with the same dysmorphic syndrome a prototype is created, which contains the most frequent observed features of these cases. Such an abstracted prototypical case represents a dysmorphic syndrome and usually contains only up to 20 features. For a current case the most similar prototypes are calculated. Subsequently, for the adaptation only few constraints have to be checked.

The idea to partly solve the adaptation task by generalising can only work for diagnostic tasks where abstracted typical cases represent diagnoses and additional specific features of former single cases can be neglected. Abstracted cases fill the gap between general rules and specific cases. If a hierarchy of abstracted cases exists (as in MEDIC), adaptation can be seen as a top down search to find the most specific case that fits the current problem [15].

4. Conclusion

Case-based Reasoning seems to be a suitable technique for medical knowledge based systems. However, the adaptation task is the bottleneck that has to be solved. Though adaptation is sometimes a rather easy task (as in ICONS and FLORENCE), in medical application it may become an insurmountable difficulty. In this paper we have presented three possible solutions, all of them are justified for specific applications and none of them is an ultimate solution. Retrieval-only systems are especially useful for visualisation tasks, e.g. of images or organ function courses, because the users wish to see and interpret all specific details themselves [8]. Solving the adaptation by generalising is restricted to diagnostic problems where the condition holds that: The more abstracted a case the more typical are its features. This means to adapt by searching top down in a hierarchy of abstracted cases, the further down the cases are placed in the hierarchy, the more specific and less typical are their additional features [15]. Combining CBR with rule-based components should not really be seen as a solution for the adaptation problem, but as an opportunity to incorporate CBR subtasks (mainly the retrieval) into rule-based programs instead of applying the complete CBR cycle.

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