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ABDUCTIVE LOGIC PROGRAMMING IN ALLERGY DIAGNOSIS

WNIOSKOWANIE ABDUKCYJNE W DIAGNOZIE ALERGII

PIOTR WALECKI[*], WOJCIECH LASOŃ[*], GRZEGORZ PORĘBSKI[**], KRYSTYNA OBTUŁOWICZ [**]

[*]*Zakład Bioinformatyki i Telemedycyny, Collegium Medicum Uniwersytetu Jagiellońskiego, 31-501 Kraków, ul. Kopernika 7e*
[**]*Katedra Toksykologii Klinicznej i Środowiskowej, Zakład Alergologii Klinicznej i Środowiskowej, Collegium Medicum Uniwersytetu Jagiellońskiego, 31-531 Kraków, ul. Śniadeckich 10*

Abstract. This paper presents an abductive model of diagnosis, which was designed for medical care (diagnosis and treatment) of certain types of allergy.
The reasoning is defined to have three forms: deduction, induction and abduction.
The American philosopher Charles S. Peirce was the first to notice abduction. It was characterized as the probative adoption of a hypothesis that explains observed facts (results) in accordance with known laws.
Abduction, as cognitive operation, creates the framework, which makes it possible to attribute a singular symptom to a disease. The interpretation of symptoms is always abductive. H.R. Fisher said that every medical diagnostic statement functions as an abductive inference.
The abductive schema will become a (nomologically-deductive) principle, if the first premise (the result) contains an unexplained surprising fact (perception, observation) – a symptom in medical diagnosis, which is then explained casually as the effect of a cause.
The abductive mode of interference involves two steps. In the first step a fact (a "result" in Peirce's terminology) to be explained or understood is presented, as the derived conclusion in classical schema. The second step introduces an available or newly constructed hypothesis (rule/law) by means of which the case is abducted. Knowledge becomes intelligible by way of its abductive incorporation into a coding system (i.e. medical classification) the logic, which the frame forms by means of new facts.

Key words: inference, abduction, medical diagnosis

Streszcznie: W pracy zaprezentowano model diagnozy lekarskiej bazujący na wnioskowaniu abdukcyjnym. Model ten został zaprojektowany w celu wspomagania diagnozy i terapii w pewnych przypadkach alergii.
Rozumowanie jest definiowane przez trzy podstawowe typy wnioskowania: dedukcję, indukcje i abdukcję.
Pierwszym, który wyróżnił i opisał wnioskowanie abdukcyjne był amerykański filozof Charles S. Peirce. Scharakteryzował je jako metodę dochodzenia do hipotezy, która najlepiej wyjaśnia obserwowane fakty w zgodzie ze znanymi prawami.
Abdukcja, jako wnioskowanie logiczne tworzy ramy odniesienia dzięki którym możliwe staje się przypisanie pojedynczego objawu do konkretnej jednostki chorobowej. H.R. Fisher stwierdził, że każda opinia diagnostyczna w medycynie bazuje na wnioskowaniu abdukcyjnym.
Jeśli początkowa przesłanka zawiera niewyjaśniony zaskakujący fakt – objaw w medycznej diagnozie, który spontanicznie tłumaczy się jako efekt określonej przyczyny, to wtedy wykorzystujemy schemat wnioskowania abdukcyjnego.
Abdukcyjny sposób wnioskowania składa się z dwóch etapów. W pierwszym etapie fakt („result" w terminologii Pierce'a), aby został wytłumaczony czy zrozumiany, zostaje potraktowany, jako konkluzja w klasycznym schemacie inferencji. Drugim etapem jest wprowadzenie dostępnych lub na nowo skonstruowanych hipotez (zasad/praw), za pomocą których dany przypadek jest abdukowany. Objawy wyjaśniane są poprzez ich abdukcyjne włączenie w kodujący system (np. klasyfikacja medyczna) logiki, której postać formuje się dzięki nowym faktom.

Słowa kluczowe: wnioskowanie, abdukcja, diagnoza medyczna

1. Introduction

Allergy is the most important health problem nowadays and unfortunately it continues to escalate. In the next few years almost fifty percent of population will be suffering from that disease. Many people are already sensitised for various reasons. To obtain a diagnosis, they should consult with their physician or an allergist/immunologist, a physician specially trained in this area. Numerous cases must be permanently monitored. This has to require huge expenditures, therefore there have been working out computer systems, which would aid diagnostic and therapeutic process.

Aspirin (acetylsalicylic acid) is one of the most broadly used drugs in the world. It is applied as analgesic, antipyretic, and as a coronary disease prevention. In patients, the aspirin causes hypersensitivity symptoms – asthmatic or angioedema and urticaria symptoms. In the face of wide-spreading of this drug it seems adequate to create freely available telemedical

system. To provide every interested party with information on the subject of hypersensitivity symptoms about aspirin and to perform self prediagnosis – is the aim of such system. The information about dermatological lesion hypersensitivity was colleted by conducting: 1) a search out in Medline and EMBASE medical database for key words “aspirin”, “urticaria” and “angioedema”; 2) information analysis current publications; 3) a consultation with specialist clinical centers [1].

A pilot telemedical system for information and diagnosis of skin hypersensitivity to aspirin was created, which on the day of insertion into the system allows (in autodiagnostic mode) differentiation of causes of the oedema, and later allows obtaining information about next management (low-salicylic diet, cross-reaction with nonsteroidal anti-inflammatory drugs, treatment of exacerbation, medical centers specialized in management of aspirin idiosyncrasy). The widespread using of the acetylsalicylic acid and the frequent angioedema episode in general population gives reasons creation common-accessible information sources for health professionals [2].

We projected low-cost Internet-based diagnosis support system for certain types of allergy. The telemedical system for information and diagnosis may be seen as a very sophisticated portal that allows access to data, and to allow its meaningful input into expert decisions. The proposed method was evaluated on a medical database, the experimental results of which show that abducted (Abductive Logic Programming) rules correctly represent experts’ decision processes. According to the rules acquired from medical experts, medical differential diagnosis is a focusing mechanism: first, medical experts focus on some general category of diseases, such as asthma or angioedema. After excluding the possibility of other categories, medical experts proceed into the further differential diagnosis between diseases within a general category. The above experiments show that rule abduction with this grouping generates rules, which are similar to medical experts’ rules and they suggest that our proposed method should capture medical experts’ reasoning. In order to determine a probability of successful diagnosis as a function of clinical data and experience in which a diagnosis is refined and updated based upon subsequent medical data obtained for a particular patient or subsequent additions and updates to the collection of clinical medical data, Abductive Logic Programming (ALP) based methods are utilized.

2. Abductive Logic Programming (ALP)

H. R. Fisher said: “Every diagnostic statement by a medical functions as an abductive inference” [3]. The American philosopher Charles S. Peirce was the first to notice abduction. It was characterized as the probative adoption of a hypothesis that explains observed facts (results) in accordance with known laws.

Peirce introduced the new kind of inference as reasoning *a posteriori*, thus setting it apart from deduction *a priori*. Abduction is “the process of forming hypothesis. It is only logical operation, which introduces any new idea; for induction does nothing but determine a value, and deduction merely evolves the necessary consequences of a pure hypothesis. Deduction proves that something must be; induction shows that something actually is operative; abduction merely suggests that something may be” [4]. The reasoning is defined to have three forms among which locate abduction. General rules applied to particular cases with the inference of a result feed analytic process of reasoning known as deduction. A form of synthetic process distinguished as induction infers the rule from the case and the result, and abduction – another form of synthetic inference, but of the case from a rule and a result [5].

- Deduction is an analytic process based on the application of general rules to particular cases, with the inference as a result.
- Abduction is synthetic reasoning which infers a case (or a fact) from the rules and the result.
- Induction is synthetic reasoning which infers a rule from the case and the result.

The Peirce’s conception of inference is presented in Fig. 1. First column contain a schema of the classic syllogism, and in round brackets are Peirce’s terms. The categorical syllogism relates three concepts, S (subject), P (predicate), and M (middle), in three statements (major premise, minor premise, conclusion) in order to examine their validity. Next column contain a schema of three distinguished kinds of inference. Boxes with continuous lines contain premises/hypothesis that are presupposed as given/true. Boxes with dotted lines contain hypotheses that are inferred. Numbers in round brackets are sequence of inferring. Deduction is analytically true (redundant) and was considered to be merely an “explanatory statement”. Deductive conclusion completely contained in the premises, therefore it is not synthetic (content-increasing), does not lead to new knowledge. In the case of induction the premises are observational statements, and an inferred conclusion is considered to be content-increasing but not truth-conserving, because it is only a hypothesis that cannot be proved with ultimate certainty [6]. In Peirce’s description: induction – the discovery of laws, abduction (hypothetic inference) – the discovery of causes, deduction – the prediction of effects.

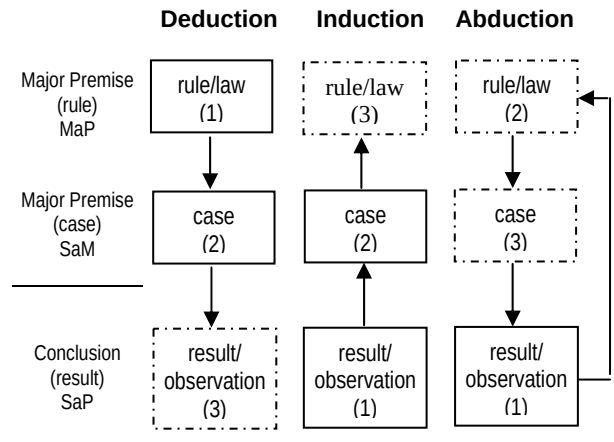

Fig. 1. Forms of inference [6].

The abductive schema will become a (nomologically-deductive) principle, if the first premise (the result) contains an unexplained surprising fact (perception, observation) – a symptom in medical diagnosis, which is then explained casually as the effect of a cause. The abductive mode of interference involves two steps. In the first step a fact (a

"result" in Peirce's terminology) to be explained or understood is presented, as the derived conclusion in classical schema. The second step introduces an available or newly constructed hypothesis (rule/law) by means of which the case is abducted. Knowledge becomes intelligible by way of its abductive incorporation into a coding system (i.e. medical classification) the logic, which the frame forms by means of new facts. Knowledge becomes intelligible by way of its abductive incorporation into a coding system (i.e. medical classification) the logic of with form the frame within witch the facts (phenomena) acquire meaning by virtue of having become signs [6].

Abductive inference in medical diagnosis is shown in Fig. 2. Abduction, as cognitive operation, creates the framework, which makes it possible to attribute singular symptom to disease. The interpretation of symptoms is always abductive. Eco wrote: "Abduction, therefore, is the experimental and risk-laden searching-out of a system of rules of signification which make it possible for a sign to gain its meaning(s)" [7].

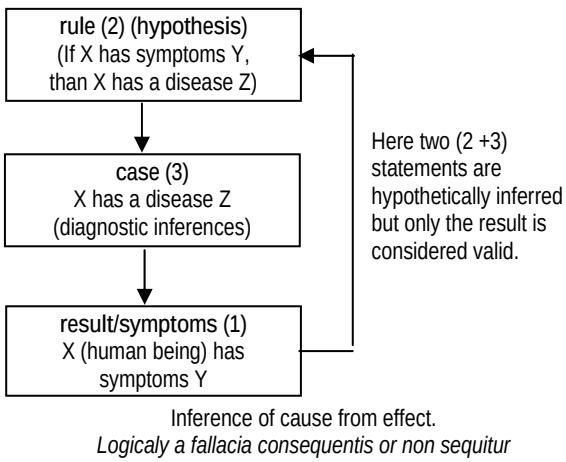

Fig. 2. Abductive inferences in diagnosis – an example of a medical diagnosis [6].

The abduction in its most general form sounds like this: is given a background theory T and an observation q to explain, to find an explanation theory Π such that $\Pi \cup T \models q$. Some additional conditions want normally to be put on Π, that it is consistent with T and that contains only those proportions called abducibles. For instance in prepositional logic, given a background theory T, a set A of assumptions or abducibles, and a proposition q, an explanation S of q is commonly defined to be a minimal set of literals over A such that $\Pi \cup T \models q$ and $\Pi \cup T$ is consistent [8].

A hypothesis concerning the presence or absence of disorders as a faults or abnormal processes solve a diagnostic problem in medicine. The research on formal aspects of diagnosis, casual knowledge represented by means of a binary casual relation, which is employed for computing diagnoses, have been undertaken with the help of logic as primary tool. In the logical theory of abductive diagnosis, identification of disease is formalized as reasoning from effects to causes, with casual knowledge implicated in the form: *causes* → *effects*, where causes are usually abnormalities or faults, or they may also include normal situations. This abductive type of reasoning is contrasted with deduction, which for implications of the form above and under certain conditions, like that given causes and effects are conjunctions of positive literals, would amount to reasoning from *causes* to *effects* [11]. The logical theory of abductive diagnosis links to set-covering theory, because casual relations are also use to find causes for certain observed findings, however at the same time, by possible explicit representation of various types of interaction, is more expressive [12].

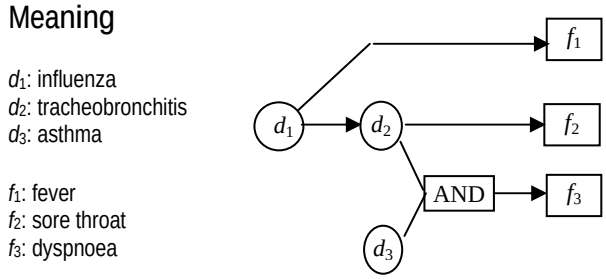

Fig. 3. Causal net [16].

Consider the following piece of medical knowledge: "influenza causes fever and infection of the trachea and bronchial tree (tracheobronchitis), which causes a sore throat; if the patient suffers from asthma, shortness of breath (dyspnoea) will occur as well". In Fig. 3, the directed-graph representation of the causal knowledge embodied in this medical description is depicted, where an arc denotes a cause-effect relationship. The medical meaning ascribed to the elements in the causal graph is indicated in Fig. 3. Using logic as our representation language, the figure may be assumed to correspond to a *causal specification* $C = (\Delta, \Phi, R)$, were $\Delta = \{d_1, d_2, d_3\}$ denotes to set of disorders, $\Phi = \{ f_1, f_2, f_3\}$ denotes a set of observable findings, and R is a collection of rules in prepositional logic: $d_1 \rightarrow d_2$, $d_1 \rightarrow f_1$, $d_2 \rightarrow f_2$, $d_1 \wedge d_3 \rightarrow f_3$. Such a causal specification is typically used in medical diagnosis based on the ALP [15]. Note that the disorders d_1 and d_2 are causally related to each other; causal interaction is expressed by logical implication. A causal specification can be used for predicting observable findings. Assuming the presence of certain disorders, e.g., influenza (d_1), $R \cup \{d_1\} \models \{f_1, f_2\}$ expresses that a patient with influenza will have symptoms and signs of fever (f_1) and sore throat (f_2) via a causal mechanism, where $\models$ denotes standard logical entailment. Here, the interaction between disorders, and between disorders and observable findings, is monotonic, due to the monotonic nature of ordinary logical entailment: by assuming more disorders, more observable findings will be predicted. Knowledge of normal and abnormal functional behaviour can be effective for diagnosing device problems, where the behaviour of the device is described in terms of relationships between input and output signals. These relationships are obtained from knowledge of the behaviour of the device's components and of the way in which these components are interconnected, i.e., the structure of the device [16].

3. Conclusions

The telemedical diagnosis support is a knowledge-based system, developed by the Department of Bioinformatics and Telemedicine and Department of Allergy and Immunology at the Medical College Jagellonian University, which advises on the treatment of certain types of allergy [21-25]. An application of abduction in inference systems brings a new scope to the structure of our knowledge. This was first noticed by C. S. Peirce, but the importance of this conception for mental word-making rediscovered H. R. Fisher. He wrote: 'the (potential) confirmation of such hypotheses (logical inferences or theories) says nothing about reality (ontology) in the sense of a representation or mapping but only that the hypotheses are functioning. Therefore, the structures of our logic(s) or our theories do not mirror the structures of things nor are they derived (deduced) from them. With the primary act of the formulation of such a hypothesis a paradigm, a rule, a method of measurement is provisionally laid down by means of which we then *measure* or *compare* what we conceive of as *nature*. Only in a second act arise the notions of correct/incorrect, fitting/non-fitting, rule-conforming/rule-breaking etc. The actual constructive act consist in the a priori specification of a *measuring method* by the cognizing subject (the scientific community) because the world cannot determine for us directly what kind of measuring method or paradigm we must use. And just as the measuring method must be specified before measuring can take place, so induction must be directed/governed/controlled by hypothesis that has been constructed abductiviely beforehand' [18].

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