MONOLOGICAL REASON-BASED LOGIC

A Low Level Integration Of Rule-based Reasoning And Case-based Reasoning

Jaap Hage

University of Limburg

Department of Metajuridica

P.O. Box 616

6200 MD Maastricht

Netherlands

tel. +31 43 883053 / 883020

email: jaap.hage@metajur.rulimburg.nl

ABSTRACT

This paper contains an informal introduction to a theory about legal reasoning (reason-based logic) that takes the notion of a reason to be central. Arguing for a conclusion comes down to first collecting the reasons that plead for and against the conclusion, and second weighing them. The paper describes how we can establish the presence of a reason and how we can argue whether the reasons for or the reasons against the conclusion prevail. It also addresses the topic of meta-level reasoning about the use of rules in concrete cases. It is shown how both rule-based reasoning and case-based reasoning are naturally incorporated in the theory of reason-based logic.

1. REASON-BASED LOGIC IN COMPARISON TO OTHER TECHNIQUES OF LEGAL REASONING

Both in the Common and in the Civil Law tradition, legal reasoning presently contains a mixture of case-based reasoning (CBR) and rule-based reasoning (RBR). An important difference between the traditions hinges on the role of stare decisis, the doctrine that previous decisions are, in certain instances, binding on courts that deal with similar cases [Lloyd 1976, p. 273]. The acceptance of this doctrine has made case law a much more important source of law in Common Law countries than it is in Civil Law countries.

Case law can be used in two fashions, that are not mutually exclusive. The decisions in particular cases can be used collectively as materials to induce rules from [Farrar and Dugdale 1990, p. 88; Dworkin 1978, p. 110 f.], or they can be used individually to argue new cases by analogy or distinction. The latter use of cases is what I will refer to as case-based reasoning (CBR).

In the Civil Law tradition statutes take a more prominent place. In statutes, the law is given in abstract. The lawyer's task is to translate the abstract law into solutions for particular cases. The focus is on interpretation instead of abstraction [MacCormick and Summers 1991]. The paradigm of legal reasoning is rule-based reasoning (RBR).

RBR and CBR are often used together, where the use of rules is supplemented with the use of cases that determine the scope of the rules [MacCormick 1987; Gardner 1987; Skalak and Rissland 1992; Walker et al. 1991]. But this combination of RBR and CBR does not exhaust the gamut of instruments available to lawyers. Another technique is to reason on the basis of legal *principles* [Dworkin 1978; Alexy 1979; Eckhoff 1992]. Moreover, there are several ways of reasoning on the basis of goal-like entities, such as *values* (justice) [Larenz 1983, p. 133 f.; MacCormick 1978, p. 129 f], rule *purposes* [Twining and Miers 1976, p. 113 f.; Hage 1992a], or *policies* [Bell 1983; Farrar and Dugdale 1990, p. 265 f.].

Lawyers do not use these techniques separately, but intertwined. The different reasoning techniques are not watertight compartments, but form different aspects of a general framework for legal reasoning. This framework is, in my opinion, based on reasons that support or undercut theses. Reasoning consists of adducing arguments that state these reasons, and determining which conclusions

can, and which cannot be upheld on the basis of the adduced reasons. The different techniques of legal reasoning such as RBR and CBR represent different ways of establishing reasons and of 'weighing' them.

The theory of reason-based logic (RBL) describes this underlying framework for reasoning with reasons. Moreover, it provides criteria to evaluate chains of arguments. Evaluation can take two forms. In monological RBL (MRBL), evaluation answers the question whether some thesis 'follows' from the argument's starting points (premises). In dialogical RBL (DRBL), that analyzes adversarial reasoning, the outcome indicates which party in the debate, if any, has won. This paper especially describes MRBL. DRBL is elaborated in [Hage et al 1992; Hage and Leenes, submitted]. The description of MRBL in this paper is informal and necessarily open-ended; it focuses on the aspects of legal reasoning that can be modeled in MRBL.

The appendix contains a prolog-implementation of a theorem-prover that works according to the rules of MRBL. The classical example of Tweety, the non-flying penguin, illustrates its operation.

2. AN EXAMPLE OF WEIGHING REASONS[1]

The Dutch Unemployment Insurance Act contains a provision to the effect that if an unemployed person refuses to accept suitable employment, this person is liable to sanctions. Let us call this provision **rule 1**.

This provision has given rise to much case law about the question what counts as suitable employment. An analysis of this case law might give rise to the following (fictional) rules concerning suitable employment:

rule 2: Employment that is similar to the former employment, and that earns at least the same money, is suitable.
rule 3: Employment that is identical to the former employment is suitable, if the unemployment has a duration of more than a year.
rule 4: Employment that is more than thirty kilometers from the employee's home is unsuitable, if no convenient means of public transport are available.

It will be clear that none of the rules 2-4 gives hard exceptionless criteria for the suitability of employment. Each of them only provides us with prima facie indications of the circumstances under which employment counts as suitable. These rules tell us what factors count as reasons for the (un)suitability of employment.

If, for instance, the rules 3 and 4 both apply, there are both a reason for and a reason against the suitability of the employment. Although in the end the employment is either suitable or not, it is not the case that only one of the applicable rules should be applied. Both rules should be applied, and both give rise to a reason for respectively against the suitability of the employment. The conflict is resolved by 'weighing' these reasons, and not by leaving one of the rules unapplied. This insight is the basis for reason-based logic.

3. ELEMENTS OF REASON-BASED LOGIC

3.1. Two iterating phases

According to RBL, an argument consists of two phases. In the first phase, the reasons that plead for and against a thesis are collected. In the second phase it is determined whether the thesis follows as a conclusion on the basis of this collection. This is done by 'weighing' the reasons. 'Weighing' is between scare-quotes, because no actual weighing takes place; instead a kind of meta-level reasoning is involved.

Establishing a reason and weighing reasons are arguments in themselves, and RBL can be applied to these arguments too. As a consequence the evaluation of an argument is an iterative procedure. In this respect RBL differs from logics that approach an argument as one chain of statements that together constitute a proof [Mendelson 1987, p. 28]. The advantage of having an iterative procedure is shown by Prakken [1991 and 1993, p. 129 f.], in the discussion of multiple conflicts.

3.2. What is a reason?

A reason is a set of one or more facts that are in some sense relevant for something else. An important category of reasons pleads for behaviour; they are reasons why one *should or ought to do something.*

There are also *reasons why something belongs to a particular category.* For instance, the fact that someone has taken some else's property on purpose is a reason why he is a thief. Or the fact that the bailee never left the depository unguarded makes that she applied due care.

Some facts are *reasons why other facts are necessary, possible, or impossible.* For instance, the fact that two bodies have gravitational mass makes it necessary that they attract each other. The fact that a person is a minor makes it impossible that he validly engages into a contract. (He lacks the *power.*)

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[1] The example in this section is inspired by the research of the LEIDRAAD-project, described in De Wildt and Quast 1989 and in Quast and De Wildt 1990.

Often one fact is a reason to *believe* some other fact. For instance, the fact that a masked man with a gun ran out of the bank just after the robbery is a reason to believe that he committed the robbery. Or the fact that the contract was undersigned by Jane is a reason to believe that she agreed to its contents.

3.3. Rules

3.3.1. Universalizability

If some set of facts is a reason for something else, similar sets of facts are reasons too. For instance, if the fact that John is a thief is a reason for punishing him, the fact that Alice is a thief is a reasoning for punishing her too. This phenomenon has, in ethical theory, been called universalizability [Hare 1961].

Note that we are only speaking of reasons. It may be the case that there are also reasons not to punish Alice, which lack in the case of John, so that the overall conclusion is that John ought to be punished, while Alice ought not.The latter possibility does, however, *not* withhold the fact that Alice is a thief from being a reason to punish her.

3.3.2. The notion of a rule

Reasons and rules are tightly connected. Most facts that are reasons have an underlying rule that makes them into reasons. I take the notion of a rule in a very broad sense, that includes amongst others rules and principles of law, criteria for the use of words, and rules of evidence. Rules in this sense connect facts of one type to facts of another type. The former are the reasons, the latter what they are reasons for.

Examples of rules are:

a) A fruit that tastes sour-sweet, is approximately round and has a thin yellow-red peel, is an apple (rule of classification).
b) Thieves ought to be punished (deontic rule).
c) Somebody who comes running out of a bank under suspicious circumstances may be taken to have robbed the bank (rule of inference).
d) Minors are not capable to engage in valid contracts (alethically modal rule).

Rules can be divided into a condition-part and a conclusion-part. The condition-part indicates which facts count as a reason; the conclusion-part tells what they are reasons for. Application of the rule 'If B and (C or F) then Z' to the case {A, B, D, F}, for instance, would make the facts {B, F} into a reason for Z.

The mechanism through which rules make sets of facts into reasons is identical to the way in which rules are applied to facts in RBR. The important difference, however, is that the application of the rule does not directly lead to the conclusion, but 'only' to making the facts corresponding to the rule-condition into a reason for the conclusion. If this reason remains the only one, 'weighing' reasons leads to exactly the same conclusion as would have obtained if RBR had been applied, instead of RBL.

3.3.3. Legal rules and exclusionary reasons

In the context of law it appears strange that the application of a rule only leads to a reason for the rule's conclusion. This appearance is correct because of peculiarity of legal rules. If one rule is applied to a case, other rules with conflicting conclusions normally cannot be applied [Hage 1991]. The potential conflict between legal rules is ideally solved by meta-rules indicating which of the conflicting rules can be applied [Kelsen 1960, p. 209 f.]. As a consequence there should be no reasons for and against a conclusion based on conflicting rules of law. That is why Raz calls mandatory rules *exclusionary reasons*, that is reasons excluding other reasons [Raz 1975, p. 73 f].

Since the impossibility of rule-conflict only applies to rules of law, and not to legal principles, these last may not only conflict mutually, but also with legal rules. Such a conflict is illustrated by the famous case Riggs vs. Palmer [Dworkin 1978, 1986]. Notice, by the way, that in the broad sense in which I use the notion of a rule, legal principles are also a kind of rules, although not rules of law.

4. REASONING

4.1. Collecting reasons

The process of reasoning that leads to a conclusion consists of two phases: collecting the reasons that plead for or against the conclusion, and weighing them. In AI-terminology, the collection-phase can be described as a backward-chaining search. The search itself consists of two steps. The first step is to establish the truth of the facts that are potential reasons; the second step is to establish their relevance.

4.1.1. Establishing truth

Strictly it is incorrect to write about the truth of facts. It is sentences describing facts that are true, and not the facts themselves [Strawson 1971, p. 196]. For shorthand, I will nevertheless continue to write about the truth of facts.

The truth of a fact can be established in two ways. First it may be given; the fact is a premise. Second it may be argued for; the fact then becomes the conclusion of a sub-argument. This sub-argument is conducted along the same

lines as the main argument, which means that the reasoning-procedure iterates.

It is beyond the scope of this paper to discuss the situation where a fact is given as a premise while its negation can be argued for (a kind of inconsistency). The situation in which both a fact and its negation can be argued for cannot occur, since in both reasonings the same reasons are involved and the weighing of reasons leads to one outcome.

4.1.2. Relevance

To establish the relevancy of a set of facts as a reason for some other fact on the basis of a rule, two steps must be taken. First it must be shown that the rule is valid or acceptable, and second it must be established that the rule should be applied in this specific case.

The validity of a rule may be given as a premise, as will be the case with many rules in legal knowledge systems; otherwise it must be argued for. The types of reasons that are relevant for the validity or acceptability of a rule differ from domain to domain. In law, on the one hand, validity can be established by showing that a rule is given by a lawgiver, or is based upon authoritative judiciary decisions [cf. Raz 1979]. The acceptance of rules of evidence, on the other hand, should usually be argued for by means of shown correlations between types of events [Williams 1979a and 1979b; but cf. also Cohen 1980].

4.1.3. Application of a rule

Even if a set of facts satisfies the conditions of a rule, it is not certain that these facts constitute a reason on the basis of this rule. Moreover, even if a set of facts does not satisfy the conditions of a rule, it may still be possible that these facts constitute a reason on the basis of this rule.

This is possible because of the distinction between what I will call the *applicability* and the *application* of a rule. Application means that the facts that satisfy the rule conditions are actually made into a reason for the rule conclusion.

A rule is said to be *applicable* to a case if the facts of the case satisfy the conditions of the rule. If a rule is applicable, this is a reason to apply the rule. If a rule is not applicable, this reason lacks and usually the rule will not be applied.

In exceptional cases, a rule can be applied *analogously*. In that case exists a reason to apply the rule, that is based on the similarity of the present case to the type of case identified in the rule conditions.

Next to reasons why a rule should be applied, there can be reasons to not-apply a rule. An important reason in this connection is that application would be against the rule's *purpose*.

There may, however, also be different reasons why a rule should not be applied in a particular case. In the law an important reason against application of an applicable rule is that application would lead to a conflict with another applicable rule. In the case of conflict between applicable rules, there will be *meta-rules* such as Lex Specialis, Lex Superior or Lex Posterior that usually determine which rule should be applied.

Moreover, rules (of law) often have a *scope* outside which they should not be applied although they are applicable [Toulmin 1953, p. 112/3; 1958, p. 101 f.]. The rules of Dutch Criminal law, for instance, are only applicable within the Netherlands. The fact that a case is outside a rule's scope is a reason not to apply the rule.

4.1.4. Exclusionary reasons against application

If a rule is applicable, this is a reason why it should be applied. If application would be against the rule's purpose, this is a reason not to apply the rule. What should we do if application of an applicable rule would be against the rule's purpose? Should we follow the rule's conditions, or should we follow the rule's purpose? There is no general answer to this question; all reasons for and against the rule's application should be 'weighed' and the outcome determines whether the rule should be applied.

This is different if there are reasons against the application of a rule on the basis of meta-rules, or on the basis of the rule's scope. These reasons are exclusionary, which means that they exclude the applicability of the rule as a reason for the rule's application. This exclusion means that there is no need to weigh the reason against application against the reason for application based on the rule's applicability [Raz 1975, p. 35 f.]. Normally only a reason against application remains, and the rule should not be applied.

4.1.5. The difference between non-application and non-validity

Both non-application and non-validity of a rule have as a consequence that the rule cannot underlie reasons. The difference between the two is that non-validity means that the rule can never underlie reasons, since, in a sense, it does not even exist.

Non-application, on the other hand, is strictly confined to particular cases. That a rule is not applied in a particular case, has no implications whatsoever for other cases. The rule remains just as valid or acceptable as it was, and a next time that it is applicable, there is a reason to apply the rule.

4.1.6. A short comparison with default logic

There are several approaches in nonmonotonic logic that can be used to deal with the situation where the conclusion from an argument is not the conclusion of a rule the conditions of which are satisfied. From these approaches such as circumscription [McCarthy 1980], autoepistemic logic [Moore 1985], Poole's framework for default reasoning [Poole 1988], and default logic [Reiter 1980], I will take default logic as the object for a short comparison with MRBL[2].

If a rule is not applied, the facts corresponding to its conditions do not become reasons for the rule's conclusion. Let us say in this situation where a rule is not applied that the rule is *defeated*. Defeat should be distinguished from the situation in which a rule is applied and a reason is constituted, but this reason is *outweighed* by other reasons. It is not possible to infer that the rule was defeated from the fact that the conclusion of an argument conflicts with the conclusion of a rule. Neither can it be inferred that the rule was not applicable because of some implied exception [Susskind 1987, p. 93f].

The distinction between defeat and outweighing does not occur in default logic (nor in any other of the approaches mentioned above). A default is a rule of inference the conditions of which are divided into two parts, the *prerequisite* and the *justification*. The *consequent* can be derived from the prerequisite if the justification is consistent with everything that is believed, including the consequent.

Defaults can easily be used to model defeat that rests on an *exclusionary reason*. For that purpose it is only necessary to provide each default with an identifier[3] and to state in the justification that there is no reason that excludes the application of the default.

It is not so easy, however, to model the situation where reasons have to be weighed. Weighing reasons can occur to determine whether a rule should be applied, for instance if the purpose of the rule conflicts with the literal conditions of the rule. It also occurs to establish which conclusion to draw from conflicting reasons if more than one rule has been applied.

The following seems to be the most promising approach to model the weighing of reasons by means of default logic:

1. make the facts constituting a reason for the consequent into the prerequisite, and
2. state in the justification that this reason for the consequent is not outweighed by other reasons against the consequent.

In this manner there could be a default for each reason that pleads for the consequent.

The problem with this approach is, however, that it loops. To find out whether the justification of a default is fulfilled, it is necessary to test all other defaults that have the same conclusion. But these test in turn involve the tests of all other defaults that have the same conclusion.

The only way to solve this problem is to gather all defaults with the same consequent, weigh them, and decide on the basis of the outcome which justifications are met. But this is exactly the procedure of MRBL and if one chooses for this approach one implicitly adopts the latter logic instead of default logic.

From this, admittedly very short and superficial, comparison between MRBL and default logic I provisionally conclude that default logic can only cope with weighing reasons in a manner that is so much like MRBL that one should prefer the latter because it provides better insight in what really happens. Where defeat on the basis of exclusionary reasons is concerned, there is hardly any difference between MRBL and default logic.

4.2. Weighing reasons

4.2.1. The problems

The suggestion originating from the expression 'weighing reasons' is only partly correct. It is correct in the sense that reasons have a dimension that might be called 'weight' and that this dimension plays a role in determining which of the conflicting reasons determines the outcome of an argument. It is incorrect in the sense that it is not possible to assign each reason a number representing its weight and simply to add these weights to determine which group of reasons weighs most [Ashley and Rissland 1988].

But how, then, is it possible to 'weigh' conflicting reasons? Part of the answer is that we should distinguish between the causal and the rational level. Most probably the awareness of reasons for and against a conclusion exercises a causal influence in forming our opinion about a thesis. These causal influences interact in a hitherto unknown manner to determine our final opinion. This interaction is one denotation of weighing reasons and we can be rather sure that this type of 'weighing' happens, although we do not know how.

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2 Default logic seems to be the most attractive alternative to RBL, because defaults are a kind of inference rules, instead of propositions. Representing legal rules as propositions leads to a number of difficulties that are described in Prakken 1992, p. 114.

3 Cf. Poole's naming convention, in Poole 1988.

But what about the rational level? Is it possible to argue reasonably about which group of reasons should in the end determine our beliefs?

4.2.2. Case-based reasoning

It is, amongst others, possible to argue reasonably about which group of reasons should in the end determine our beliefs on the basis of authoritative cases. A mechanism to this purpose has been described by Ashley [1988, 1991]. In my opinion CBR is about weighing reasons. A case consists of a collection of reasons pleading for and against a particular solution together with the outcome of weighing these reasons. Such cases may derive from judicial decisions, from examples given by the legislator expressing a statute's purpose, or they may just be hypothetical.

4.2.3. How cases are handled in MRBL

All reasoning in MRBL is based on reasons. Cases are relevant in MRBL because they give rise to reasons. How cases contribute to reasons for conclusions depends on the rules one accepts. For instance, one may adopt the rule that the fact that the most on point case [Ashley 1988. 1991] had a particular conclusion, is a reason to draw the same conclusion in the current case. That a case is most on point should also be established on the basis of reasons with underlying rules that define what counts as most on point.

Dependent on the rules one chooses, the reasoning facilities of, for instance, HYPO can fully be modeled in MRBL. This does of course not mean that MRBL provides the mechanisms to index cases, etc. MRBL is not a tool for CBR. It only means that the HYPO techniques to reason with cases can be described in MRBL-rules.

Moreover, MRBL makes it easy to group the aspects of a case into reasons that plead for and against the conclusion of the case[4]. The function of the aspects can be determined on the basis of the underlying rules that make them into reasons pleading for or against the conclusion.

Let, for instance, the rules 2-4 of our example in section 2 be formalized as:

rule 1 IF (A AND B) THEN C.
rule 2 IF (P AND Q) THEN A ,
rule 3 IF (T AND U) THEN A.
rule 4 IF (R AND S) THEN NOT-A,

A = the employment is suitable
B = the employment was rejected
C = there is a liability for sanctions
P = the employment is similar to the former employment
Q = the employment earns at least the same money as the former employment
R = the employment is identical to the former employment
S = the unemployment has a duration of more than a year
T = the employment is more than thirty kilometers from the employee's home
U = no convenient means of public transport are available

A case-database contains the following cases:

1. {P, Q, R, S, T, U, B} with the conclusion C (and subconclusion A).
2. {P, Q, R, S, U, B} with the conclusion non-C (and subconclusion non-A).
3. {P, R, S, T, U, B} with the conclusion non-C (and subconclusion non-A).
4. {P, Q, T, U} with the conclusion non-C.

The rules allow us to combine the aspects into the groups {A and B}, {P and Q}, {T and U}, and {R and S}. Aspects that are present but that are not accompanied by their group member have no force. For instance, the aspect U in the second case is forceless.

The same even counts for the combination of P and Q in the fourth case, because they lead to the conclusion A. Since A's 'partner' B is lacking, A has no meaning and so have not P and Q. The same counts for T and U.

From the first case we can conclude that the reasons {P and Q} and {T and U} together outweigh the reason {R and S}.

From case 2 we conclude that {P and Q} by itself is outweighed by {R and S}.

From case 3 we conclude that also {T and U} by itself is outweighed by {R and S}.

From case 4 we can conclude that the factor B is essential in deriving C from A.

This knowledge taken together makes it possible to forecast the outcome of the case

{Q, R, S, T, U, B}.

Q on its own is irrelevant. {T and U} by itself is outweighed by {R and S}. Therefore we must first conclude that *non-A*. As a consequence, the legal rule IF A AND B THEN C is not applicable. Since reasons to apply that rule by analogy are lacking, the conclusion C cannot be drawn. Neither can non-C be derived, since we do not have a rule or a case in which the combination of non-A and B lead to the conclusion non-C.

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[4] The relationship between aspects of a case and reasons is comparable to that between prerequisites and dimensions in the HYPO-system.

This example also shows that in MRBL it is possible to employ (portions of) cases to find reasons that plead for or against subconclusions [cf. Branting 1989, 1991a and 1991b]. Although it is not shown in the example, it is also possible to distinguish within the facts of a case reasons that plead for a change in the weight of other reasons. In general, MRBL makes it possible to distinguish underlying structures in CBR. These structures can be employed to use more powerful techniques of CBR.

4.2.4. No answer

Weighing reasons does not always lead to a conclusion. If there are both reasons for and against a thesis and there are no reasons to decide which group of reasons should prevail, the result is rationally indeterminate. The same counts if there are reasons for weighing the reasons, but these weighing-reasons are in an unresolvable conflict themselves. Finally it is possible that neither reasons for nor reasons against the thesis can be found. In these cases, neither the thesis nor its negation can be derived. These situations are the equivalents in MRBL of hard cases in the law [Hage and Leenes, submitted].

5. CONCLUSIONS

MRBL offers a framework by means of which legal reasoning, both rule-based and case-based, can be described and evaluated. Since the conclusions for or against which reasons plead can be of a very diverging nature, the theory of MRBL has a wide scope of application.

MRBL has handles to cope with peculiarities of legal reasoning such as weighing reasons, the use of exclusionary reasons, arguments about analogous applications of rules, about non-application of rules, etc. Moreover, it enables us to discover structure in CBR that can be used to use CBR for more powerful inferences.

As a technique for nonmonotonic reasoning, MRBL allows us to distinguish between different causes of nonmonotonicity, especially between defeat and outweighing, and it offers a way to deal with outweighing that is not found in important other theories about nonmonotonic reasoning.

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APPENDIX

The following contains a commented Prolog-implementation of the classical example of Tweety the penguin that cannot fly although it is a bird. The implementation consists of a query and a knowledge base on the one hand, and an inference mechanism that works as a theorem-prover on the other hand. It is not possible to explain all the details of the implementation, so the following must suffice:

The knowledge base

There are four rules: Birds can fly, Penguins cannot fly, Penguins are birds, and More specific rules prevail over less specific ones. Moreover, there are the facts that Tweety is a penguin, and that rule 2 is more specific than rule 1.

Why Tweety is a bird; weighing reasons

On the basis of rule 3 and the fact that Tweety is a penguin, it can be derived that there is a reason why Tweety is a bird. There is no ground for reasons why Tweety is not a bird, so weighing reasons leads to the conclusion that Tweety is a bird.

Twere are two situations in which weighing reasons leads to an outcome, namely if either the set of reasons for the conclusion, or the set of reasons against the conclusion is empty, and the other set is not. In the former case, the conclusion is drawn, in the latter case not. If weighing reasons does not lead to an outcome (neither set of reasons is empty) the conclusion is not drawn.

Notice that the numeral weights are not used and that only qualitative weighing is used.

An exlusionary reason

Because it can be derived that Tweety is a bird, rule 1, saying that birds can fly, is applicable. Rule 2 (penguins cannot fly) is also applicable and has a contrary conclusion. Moreover, rule 2 prevails over rule 1 because it is more specific. (The latter fact is given in the database.) Therefore the applicability of rule 1 must be weighed against the applicability of the more specific rule 2. Since nothing is given to resolve the conflict between these reasons, the conflict ends undecided, and it cannot be concluded that rule 1 should be applied. So, although it is appicable, rule 1 does not give a reason for the thesis that Tweety can fly. The applicability of rule 2 turns out to be an exclusionary reason against the application of rule 1.

A reason against the conclusion

Rule 2 is applicable. Although rule 1 with a contrary conclusion is also applicable, the latter is less specific than rule 2 and does not prevail over it. So there are no reasons against the application of rule 2. This rule can be applied,

and as a consequence the fact that Tweety is a penguin is a reason against the thesis that Tweety can fly.

The final decision

There are no more reasons for or against the thesis that Tweety can fly. Weighing this negative reason against the empty set of reasons for the thesis results in a negative conclusion: it is not derivable that Tweety can fly.

An alternative conclusion

Notice on the basis the present reasoning the thesis that Tweety cannot fly is derivable. Were MRBL considered as an inference engine, it would draw this conclusion. Considered as a logic, we can only conclude that the thesis that Tweety cannot fly is derivable, while its positive version is not derivable.

If rule 1 prevails

It should finally be observed that if rule 1 had prevailed over rule 2, rule 1 should be applied and rule 2 should not be applied. In that case, the fact that Tweety is a bird would be a reason why Tweety can fly, while that fact that it is a penguin would not be a reason. Weighing reasons would then have led to the conclusion that Tweety can fly.

If no rule prevails

If neither rule 1 nor rule 2 would have prevailed over the other one, there would both have been a reason for and against the thesis that Tweety can fly. Without further information about which of the resons would outweigh the other, no conclusion could be drawn. Neither the thesis that Tweety can fly, nor its denial could be derived.

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/* test query */

fact(can_fly([], [tweety]), case).

/* test database */

rule 1: Birds can fly, weight 5. It is also stated that this
rule is a valid one.
valid([], [rule(can_fly([], [Animal]),
     [is_bird([], [Animal])], 1, 5)]).

/* rule 2: Penguins cannot fly, weight 5. The negative
weight -5 indicates that the reason pleads against the
conclusion. */
valid([], [rule(can_fly([], [Animal]),
 [is_penguin([], [Animal])], 2, -5)]).

/* rule 3: Penguins are birds. */
valid([], [rule(is_bird([], [Animal]),
 [is_penguin([], [Animal])], 3, 5)]).

/* rule 4: If  a rule prevails over another one this is a
reason why it is more specific. */
valid([], [rule(prevails_over([], [rule(Id1), rule(Id2)]),
     [more_specific([], [rule(Id1), rule(Id2)])],
    4, 5)]).

/* Rule 2 is more specific than rule 1. */
fact(more_specific([], [rule(2), rule(1)]), _).

/* In the present case, Tweety is a penguin. */
fact(is_penguin([],[tweety]), case).


/* It may be derived that a rule nr. Id applies to a case
if */
fact(apply([], [rule(Concl, Conds, Id, W), Case, Inst])):-
/* the rule is applicable, that is if its conditions are
satisfied  in this case*/
applicable([], [rule(Concl, Conds, Id, W), Case,
Instantiation]),
/* the reasons for and against application are collected
in a Reasonset */
collect_reasons(apply([], [rule(Concl, Conds, Id, W), Case,
Inst]), Reasonset), !,
split_reasons(Reasonset, Reasons_for, Reasons_against),
/* the reasons for application outweigh the reasons
against */
process_reasons(Reasons_for, Reasons_against),
Inst = Instantiation.

/* It may be derived that a state of afffairs obtains in a
case if */
fact(SA, Case):-
/* the reasons for and against the fact are collected in a
Reasonset */
collect_reasons(SA, Reasonset), !,
split_reasons(Reasonset, Reasons_for, Reasons_against),
/* and the reasons for the fact outweigh the reasons
against */
process_reasons(Reasons_for, Reasons_against), !.

/* If a rule is applicable, the facts that make it
applicable in a case, that satisfy the rule's conditions
(Inst), are together a reason to apply the rule */
reason(Inst, apply([], [rule(Concl, Conds, Id, W), Case,
Inst]), 10):-
    applicable([], [rule(Concl, Conds, Id, W), Case, Inst]).

/* If a rule with a contrary conclusion is also
applicable, and this latter rule prevails, this is a reason
not to apply a rule. */
reason(applicable([], [rule(Concl, Conds2, Id2, W2), Case,
Inst2]),
    apply([], [rule(Concl, Conds1,Id1, W1), Case, Inst1]),
-10):-
    valid([], [rule(Concl, Conds2, Id2, W2)]),
    not(Id1=Id2),
    different_sign(W1, W2),
```

```
    fact(prevails_over([], rule(Id2), rule(Id1)), Case),
    applicable([], [rule(Concl, Conds2, Id2, W2), Case,
Inst2]).

/* If a valid rule is to be applied, the fact that makes it
applicable (the instantiation Inst) is a reason for the
conclusion of the rule. */
reason(Inst, Concl, W):-
    valid([], [rule(Concl, Conds, Id, W)]),
    fact(apply([], [rule(Concl, Conds, Id, W), Case, Inst])).

/* A rule is applicable to a case if its conditions are
satisfied in that case. */
applicable([], [rule(_, Conds, _, _), Case, Inst]):-
    and_satisfied(Conds, Case, Inst), !.

/* The rest consists of implementation details. */

/* evaluating conjunctive conditions */
and_satisfied([], _, []).
and_satisfied([Altconds | Conds], Case, Satlist):-
    is_list(Altconds), !,
    or_satisfied(Altconds, Case, Returnlist1),
    and_satisfied(Conds, Case, Returnlist2),
    append(Returnlist1, Returnlist2, Satlist).
and_satisfied([H | Conds], Case, [H | Satlist]):-
    fact(H, Case),
    and_satisfied(Conds, Case, Satlist).

/* evaluating disjunctive conditions */
or_satisfied([], _, _):- fail.
or_satisfied([Cumconds | _], Case, Satlist):-
    is_list(Cumconds), !,
    and_satisfied(Cumconds, Case, Satlist).
or_satisfied([H | _], Case, [H]):-
    fact(H, Case).
or_satisfied([_ | Altlist], Case, Satlist):-
    or_satisfied(Altlist, Case, Satlist).

process_reasons(Reasons_for, Reasons_against):-
    outweigh(Reasons_for, Reasons_against), !.

outweigh(Reasons, []):- Reasons \== [].

different_sign(A, B):- A > 0, B < 0, !.
different_sign(A, B):- B > 0, A < 0, !.

collect_reasons(Concl, Reasonset):-
bagof(r(Inst, W),Concl^reason(Inst, Concl, W),
Reasonset).
collect_reasons(_, []).

split_reasons([], [], []):- !.
split_reasons([r(Inst, W) | Reasonset],
r(Inst, W) | Reasons_for],
Reasons_against):-
W >= 0,
split_reasons(Reasonset, Reasons_for, Reasons_against), !.
split_reasons([r(Inst, W) | Reasonset],
Reasons_for,
[r(Inst, W) | Reasons_against]):-
W < 0,
split_reasons(Reasonset, Reasons_for, Reasons_against), !.
```

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