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The mathematics of patent claim analysis

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Abstract In patent law most of the crucial legal questions such as patentability and infringement are linked to the patent claims. The European Patent Office regards patent claims as a set of independent features which are examined separately in a more or less formal way. The author has found that this approach allows for developing a simple mathematical model which treats patent claim features as logical statements and patent claims as compound statements wherein the individual statements are connected by logical connectives. The proposed mathematical model provides a uniform system for examining various legal questions that are dealt with separately under current case law, moreover, it allows for developing an expert system for resolving complex legal situations and for automating the evaluation of a large number of patent claim variants that is currently not possible.

Keywords Patent claim · Logical model · Propositional calculus · Legal evaluation

1 Introduction

Patent claims play a key role in all the national and regional patent systems as patent claims define the scope of legal protection conferred by a patent. In the patent system established by the European Patent Convention[1] (hereinafter: EPC) patent claims are assessed for establishing (1) whether the invention defined by the patent claim is novel and involves an inventive step; (2) whether an amendment of a patent claim is

[1] Convention on the Grant of European Patents (European Patent Convention) of 5 October 1973 as revised by the Act revising Article 63 EPC of 17 December 1991 and the Act revising the EPC of 29 November 2000.

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allowable during patent proceedings; and (3) whether a patent can benefit from the priority of an earlier patent application filed by the same applicant.

Currently decision making in the patent system established by the EPC (hereinafter: European patent system) relies partly on positive law (mainly the EPC) and partly on case law (mainly the decisions of the Boards of Appeal[2] and of the Enlarged Board of Appeal[3] as well as customary law laid down in the Guidelines of the European Patent Office[4]). There are currently no means for examining the logical consistency between the case law decisions relating to the above mentioned three different fields of patent claim analysis. Inconsistencies are mostly remedied on a case-by-case basis thus causing case law to remain a divergent set of rules.

In the present paper I propose a mathematical model which provides a common methodology for evaluating patent claims in situations that are presently governed by the relatively large number of relevant case law rules. The mathematical model allows for examining the logical coherence of case law as a whole by connecting the separate fields of patent claim analysis. I will demonstrate by way of a few examples how the logically inconsistent earlier case law decisions could have been predicted in advance and how the mathematical model could have pointed to the logically coherent rule that was later adopted in the form of a new decision.

In my research studies I have examined all the leading current case law decisions and found that these now form a logically consistent system which can be fitted into my mathematical model. Based on this finding the mathematical model can provide a common methodology for assisting the systematic and automated evaluation of complex legal situations.

Currently there exists no mathematical model of patent claim analysis. In absence of any methodology the authorities and patent practitioners can only rely on the relatively large number of current case law rules which are difficult to combine.

Having been a patent attorney for nearly a decade I have found in my practice that even very simple patent claims can occasion extremely complicated situations which would require the analysis of dozens or even hundreds of patent claim variants. This is currently not possible, as there are no tools for dealing with this kind of complexity. Instead, courts and patent offices make ad-hoc decisions based on only one or two patent claim variants. In Sect. 6 of the present paper I will demonstrate that my mathematical model can also address this problem.

The proposed mathematical model provides a suitable framework for developing an expert system for resolving complex legal situations and for automating the evaluation of a large number of patent claim variants that is currently not possible.

[2] Decisions of the technical Boards of Appeal are denoted by the letter T followed by the case number and the date of the appeal (e.g. T411/98).

[3] Decisions of the Enlarged Board of Appeal ensures uniform application of the law. The decisions are denoted by the letter G followed by the case number and the date of the appeal (e.g. G2/98).

[4] Guidelines for Examination in the European Patent Office, Published by the European Patent Office, Directorate Patent Law 5.2.1, D-80298 Munich (hereinafter: GL).

2 Problems of patent claim analysis

A technical invention can only be patented if it is novel (does not form part of the state of the art) and if it involves an inventive step (meaning that it is not obvious to a person skilled in the art having regard to the state of the art). The invention for which protection is sought is defined in a single complex sentence, called a patent claim. Such a patent claim sentence is treated by the European Patent Office (hereinafter: EPO) as an aggregate of the technical features of the invention.

To illustrate the denotation of patent claim features let us take a simple example: the inventor recognizes that certain materials, called ferromagnets, can be permanently magnetised by an external magnetic field and needles fabricated of such materials can be used to make a navigation tool. The inventor files a patent application with the following patent claim:

Claim 1. Navigation tool comprising a needle made of a ferromagnet

In the present example the EPO would consider the navigation tool, the needle and ferromagnet (as the material of the needle) to be features of the patent claim:

A = navigation tool
B = needle
C = ferromagnet (as the material of the needle)

When comparing the invention (Claim 1) with a prior art solution the EPO would consider whether the object of comparison is used for navigation, whether it comprises a needle, and whether this needle is made of a ferromagnet. If all three questions are answered in the affirmative then the patent claim is said to "read onto" the given prior art solution. In this case the EPO will find that the patent claim is not novel (it does not define a novel invention with respect to the given prior art solution forming part of the state of the art). If however at least one of the features is not disclosed in the prior art, then the patent claim is said to be novel. For example if a prior art medical device comprising a ferromagnet needle is held against the patent claim the EPO will find that feature A (navigation tool) does not read onto the prior art (the medical device), thus the invention defined in the patent claim satisfies the requirement of novelty. The EPO will then move onto examining whether incorporating a ferromagnet needle in a navigation tool would have been obvious to a person skilled in the art having regard to the prior art medical device. If such an application would have been non-obvious then the requirement of involving an inventive step is satisfied as well.

A prerequisite of assessing novelty and inventive step is to determine what forms the state of the art. The general rule is that everything made available to the public before the filing date of the examined patent (or patent application) constitutes a state of the art disclosure (prior art). However, a patent application may benefit from the priority of an earlier patent application filed by the same applicant in any WTO member state not later then 12 months earlier. In such cases the state of the art is determined by the filing date of the earlier patent application, called the *priority date*. Hence anything published after the priority date of the second patent

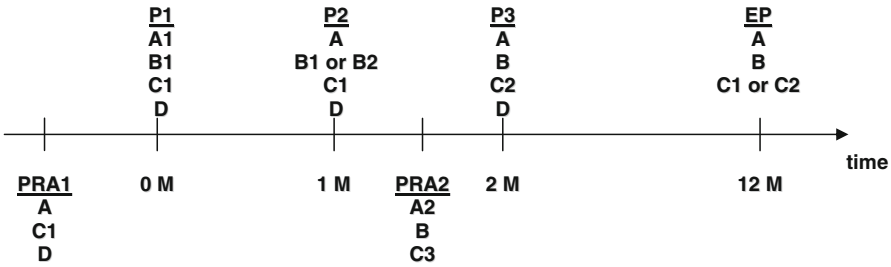

Fig. 1 EP application claiming priority if three earlier applications P1, P2, P3

application (i.e. the filing date of the earlier patent application) cannot be held against the second patent application.

A patent application may benefit from any number of priorities as long as all the earlier applications are filed within 12 months of the filing date of the patent application in question. However, only those inventions may enjoy the priority of one or more earlier patent applications which are fully disclosed in the earlier patent application.

A patent claim may cover more then one invention by using an OR-connective (e.g. "the needle is made of ferromagnet *or* ferrimagnet[5]") or by using a general term, which covers various specific embodiments (e.g. "ferromagnet" covers materials such as steel, iron, cobalt, etc.). Accordingly, a patent claim may be entitled to different priorities in respect of each invention it covers, and different prior art material may be brought up to question the novelty and inventive step of each invention. To make things more complicated the European patent law recognises prior rights, i.e. an earlier European patent application will be considered for the purpose of examining novelty even if such a prior right patent application is only published after the priority date of the examined patent application (or patent). If the examined patent claim (or any inventions covered by it) is for some reason not entitled to the priority then such a prior right patent application becomes public prior art which is also relevant in the assessment of the inventive step.

Inventors typically file their first patent application in their own country and intend to file a European patent application close to the end of the 12-month time limit for claiming priority. However, in the course of the 12 months the inventions are typically improved, often other patent applications are filed too, and at the end of the 12 months a substantially different European patent application is filed claiming priority of all the preceding patent applications. Figure 1 illustrates an exemplary situation.

In the illustrated example applicant first files patent application P1 the features of which are listed below the denotation P1. After 1 month the applicant realises that feature A1 can be generalised in the form of A and B2 can serve as an alternative for B1, so he files a second patent application P2 with a broader scope of protection. Two months later the applicant discovers that not only B1 and B2 can be used but also the more general feature B. He further substitutes C1 with C2 believing the

[5] Ferrimagnet being another type of permanent magnet.

latter to be superior (hence the patent claim features are now A, B, C2 and D). Twelve months after having filed P1 the applicant decides to file a European patent application EP claiming priority of all three earlier applications P1, P2 and P3. At this time the applicant has realised that feature D is not indispensible, he thus omits it from the patent claim in order not to restrict the scope of protection to embodiments comprising D. He also decides that although less efficient, embodiments making use of feature C2 should be claimed as well. Thus the final patent claim consists of the features A, B and C1 or C2. Subsequently, the novelty search of the EPO reveals two relevant documents; prior art PRA1 published before the filing date of the earliest application P1 and a prior right application (an even earlier European patent) published between the filing date of P2 and P3.

The present example raises many questions in connection with assessing novelty and inventive step: what inventions are covered by the examined European patent claim, which of these inventions may benefit from any of the priorities, if some of the inventions lack priority should the intermediate publication PRA2 be considered as public state of the art (in which case it may be combined with PRA1 when assessing non-obviousness), does the specific feature A2 take away the novelty of the general teaching A, etc.

Currently these questions are answered by patent practitioners by looking up various sources of law (the European Patent Convention, the Guidelines of the EPO, the case law book of the EPO). In Table 1 I have summarized the most important

Table 1 Overview of most important current case law

	Novelty	Priority	Amendments
Added feature e.g. +B (vs. PRA1)	T411/98	G3/93, G2/98	T201/83 (novelty test), T194/84 (disclosure test)
Generic feature e.g. B1 → B (vs. P1)	GL C-IV, 9.5 (specific vs. generic), T651/91, T508/91	[T828/93 (OR-claims)] → G2/98 (generic claims)	T201/83 (novelty test), T194/84 (disclosure test)
Specific feature e.g. C → C2 (vs. PRA2)	GL C-IV, 9.5 (specific vs. generic), T651/91, T508/91; selection inventions (GL C-IV, 9.8; T12/81, T198/84, T279/89, T666/89, T17/85, T12/90, T26/85, T536/95)	[G3/93] → G2/98	T201/83 (novelty test), T194/84 (disclosure test), GL C-IV, 9.5 (specific vs. generic)
Substituting feature e.g. C1–C3 (vs. PRA2)	Equivalents (GL C-IV, 9.2, T928/93)	[G3/93] → G2/98	T331/87 (test for substitution and omission)
Omitted feature e.g. − D (vs. P1, P2, P3)	Generally does not count (T411/98), disclaimers (G1/03, G2/03)	[G2/98—mathematically inconsistent finding]	[T201/83 (novelty test)] → T194/84 (disclosure test), T331/87 (test for substitution and omission), disclaimers (G1/03, G2/03)

currently applied case law for assessing novelty, right to priority and allowability of an amendment (not yet discussed). I have also indicated in rectangular brackets some of the more important earlier case law that had been over-ruled by latter decisions.

The examined patent claim of EP may exhibit four differences with respect to the object of comparison (P1, P2, P3 or PRA1, PRA2):

1. an added feature (i.e. a feature not disclosed in any form in the object of comparison);
2. a generic feature (i.e. a feature of which a specific example is disclosed in the object of comparison);
3. a specific feature (i.e. a feature, which is a specific example of a more generic teaching disclosed in the object of comparison);
4. a substituting feature (i.e. a feature replacing a feature of the object of comparison but not having a generic-specific relation thereto);
5. an omitted feature (i.e. the omission of a feature of the object of comparison).

The five possible cases are indicated in the rows of Table 1.

As can be seen the patent practitioner has to be extremely well prepared and will have to apply various case law decisions and Guidelines instructions before he can evaluate the present situation. Even then, he is unlikely to fully succeed as the exemplary situation results in 36 relevant inventions covered by the patent claim (36 patent claim variants) as will be clear in view of the proposed mathematical model. If any of the 36 inventions is not entitled to priority PRA2 may become public state of the art that can be held against such invention when assessing novelty and non-obviousness thereof. The 36 inventions should all be evaluated independently, however, in practice if the examiner of the EPO finds one claim variant that is not novel it will refuse the patent application as a whole without further examination (because a patent may not embrace any prior art solution). This way the applicant will be left in doubt as to any possibility of restricting the patent claim to one or more inventions covered that would restore novelty and non-obviousness of the patent claim. Applicants would have a better chance of considering their options if the EPO's patentability report would include the legal evaluation of each invention covered by the examined patent claim. This is obviously an unrealistic expectation without computerised assistance in such complicated situations. It should also be noted that real patent claims are far more complicated generally having ten to fifty patent claim features; thus the number of patent claim variants to be examined is commonly over a hundred.

Furthermore, considering the large amount of relevant case law and seeing that many cases have been overturned by more recent decisions one may ask whether current case law is logically consistent or whether we can expect future decisions to over write the ones applied today.

The present paper aims to introduce a simple mathematical model which on the one hand explains the current case law as being the result of mathematical logic and on the other hand provides a methodology for correctly assessing patentability in complicated legal situations whereby patent applicants could be provided with a full patentability report relating to all the relevant inventions covered by the examined patent claim.

3 Mathematical model of the patent claims

In the current section I will introduce propositional calculus (mathematical logic) for modelling patent claims and for assisting the examination of patent claims. This model allows for the separation of questions of fact and questions of law. Questions of fact relate to the evaluation of the individual patent claim features with respect to the object of examination (such as a prior art disclosure), while questions of law determine the legal findings relating to the whole of the patent claim. The mathematical model is constructed so as to reflect the decision of the competent authority (primarily the European Patent Office but national patent offices and courts as well) on questions of fact, while answering the questions of law in a logically consistent way. The proposed model thus functions as an artificial intelligence: once the basic questions of fact are answered the required complex legal finding can be automatically obtained from the model.

3.1 Defining the features of a patent claim

As explained in Sect. 2 the patent claim is a complex sentence defining the invention for which protection is sought.

Starting from the exemplary patent claim of Sect. 2, I will now introduce a different approach to modelling patent claim features.

Claim 1. Navigation tool comprising a needle made of a ferromagnet

As we have seen the EPO treats "navigation tool", "needle" and "ferromagnet" as patent claim features. Such an approach is a good starting point; however, in my model I propose to define the features of a patent claim as logical statements (for solving an exemplary case with logical statements see Kacsuk 2008). Accordingly, the patent claim in the example can be broken down into the following logical statements, which will be regarded as the features of the claim:

A = The subject is a navigation tool.
B = The navigation tool has a needle.
C = The needle is made of a ferromagnet.

Ideally, the logical statements should be atomic in the sense that they cannot be broken down into more basic statements. In reality the patent claim features as statements can never be "atomic" because the patent claims are formulated in a natural language and the words of any natural language have a *field* of meaning rather than a precise (singular) meaning. For example the meaning of the word "ferromagnet" will embrace various different materials such as steel, iron, cobalt, rare-earth magnets, etc. Even the sub-categories of ferromagnets will incorporate a range of materials, e.g. "rare-earth magnet" covers gadolinium, dysprosium, etc. Instead of the expression atomic I will refer to such statements as "basic", knowing that depending on the circumstances the basic statements may be expressed by even more basic sub-statements just like "ferromagnet" covers steel, iron, cobalt, etc.

In this approach reading a claim feature on the prior art is carried out by deciding whether the basic statement is true or false in respect of the object of comparison.

The true or false evaluation of the basic statements cannot be derived from the mathematical model; it reflects the choice of the competent authority (EPO, national patent office, national patent court, etc.) which must decide on patentability, or other patent related questions (allowability of amendments, right to priority). From the point of view of adjudication the basic statement is either true or false, there is no third possibility—the competent authority is compelled to take a binary type of decision on whether the claim defines a novel invention, whether any amendments are allowable and, whether priority can be acknowledged.

3.2 Structure of the claims

In order to decide on the nature of the mathematical connectives that should be applied between the basic statements we need to examine the legal areas where we hope to introduce the formal patent claim model. As I have stated in the introduction, patent claim analysis plays a key role in the examination of (1) patentability, in particular novelty; (2) amendments; and (3) priority. It should be noted that the present patent claim model is also applicable to examining infringement of a patent, however, this aspect of the model is not discussed in the present paper.

In each patent claim analysis category a distinction should be made between questions of law and questions of fact. *Questions of fact* are related to the truth evaluation of the basic statements expressing the claim features. The questions of fact are always assessed by the competent authority and are either answered to the affirmative (true) or to the negative (false) with respect to the object of comparison that can be a prior art solution (question of novelty), the content of the application as filed (question of amendments), or that of the priority patent application (question of priority right). On the other hand *questions of law* are a matter of positive law (principally the EPC) and case law (principally the case law of the Boards of Appeal and Enlarged Board of Appeal, see Rodes et al. 2006, as well as the customary law expressed in the Guidelines).

The EPO's patent claim feature approach implies that the basic statements expressing the claim features should be taken into account as an AND-combination (expressed by the symbol of the AND logical operator $\wedge$):

1. as regards novelty the claim determines a novel invention if no prior art exists that discloses *all* the claim features in combination ($A \wedge B \wedge C$);
2. as regards amendments, an amendment of a patent claim is allowable if the subject-matter determined by *all* the features of the amended patent claim ($A \wedge B \wedge C$) is directly derivable from the contents of the original application as filed; and
3. as regards priority, the priority claim is valid only if the invention defined by *all* the claim features ($A \wedge B \wedge C$) is directly derivable from the content of the priority application.

Hence, in the example of the navigation tool the patent claim should be expressed as follows:

$$\text{Claim 1} = (\text{the subject is a navigation tool}) \text{ AND } (\text{the navigation tool has a needle}) \text{ AND } (\text{the needle is made of a ferromagnet}) = A \wedge B \wedge C.$$

Conjunctive particles (such as "and", "furthermore", etc.) or commas of the patent claim sentence need not necessarily translate into AND-connectives in the formal mathematical model—however, positive law and case law dictates AND-connectives in the European patent system.

Determining the structure of a patent claim also requires semantic interpretation of the claim as the European patent system allows OR-claims, i.e. claims in which closely related but distinct inventions are claimed at the same time in the form of alternatives. For example:

1. Navigation tool comprising a needle made of ferromagnet *or* ferrimagnet.

In this case there are four basic statements expressing the claim features:

A = The subject is a navigation tool.
B = The navigation tool has a needle.
C = The needle is made of a ferromagnet.
D = The needle is made of a ferrimagnet.

The OR-type conjunctive particles ("or", "either", etc.) of the patent claims have been interpreted by case law[6] as indicators that the claim embraces more than one inventions the features of which are alternatives. Thus in the present case the first invention claimed is (A ∧ B ∧ C) (navigation tool comprising a ferromagnet needle), while the second invention is (A ∧ B ∧ D) (navigation tool comprising a ferrimagnet needle). The whole can be expressed as the OR-combination of the two distinct claim variants:

$$\text{Claim 1} = (A \wedge B \wedge C) \vee (A \wedge B \wedge D)$$

wherein ∨ is the mathematical symbol of the OR logical operator.

3.3 Propositional calculus as the model of patent claims

In view of the above legal and non-legal considerations and in particular the EPO's patent claim feature approach I propose to introduce a mathematical model for describing patent claims which treats patent claim features as basic statements and allows true/false interpretation of the basic statements as well as the possibility of connecting the basic statements by logical connectives.

The proposed mathematical model is based on propositional calculus (also called sentential calculus) which is a formal logical system.

[def-1] The language of propositional calculus consists of:

– atomic propositions (uppercase letters: A, B, C, etc.);

[6] See e.g. decision G2/98.

– logical operators: ¬ (not—negation); ∨ (potentially inclusive or—disjunction); as well as logical operators derived[7] from the first two: ∧ (and—conjunction); xor (exclusive disjunction).

The atomic propositions (A, B, C, etc.) will be used to model the basic statements expressing the patent claim features, while logical operators (¬, ∨, ∧, xor) are used to connect the atomic propositions the same way the AND-connectives and OR-connectives were used in the previous section to express the relationship between the claim features and thereby define the structure of the patent claim. It should be noted that the OR-connective of the patent claim language is generally an exclusive disjunction (xor), i.e. either one feature or the other, but not both. The non-exclusive (potentially inclusive) disjunction (∨) is nearly always emphasised by writing "and/or" in order to ensure a broader scope of protection.

The "meaningful" expressions of the propositional calculus are called well-formed-formulas (wffs).

[def-2] A well-formed-formula (wff) is:

– an atomic proposition, or
– if A and B are wffs, then so are ¬A; A ∧ B; A ∨ B; A xor B.

The wffs are propositions as well, but not necessarily atomic. In order to emphasize the difference with respect to atomic propositions I will be referring to propositions made up of atomic propositions and logic operators as *compound propositions*, while the term "proposition" without any adjective will be understood to mean both atomic propositions and compound propositions. Hence:

[def-3] A compound proposition is a wff that is not an atomic proposition. Compound propositions are represented by bold uppercase letters: **A**, **B**, **C**, etc.

In the proposed model the atomic propositions model declarative statements (corresponding to the patent claim features) that are either true or false. This can be modelled by introducing a truth assignment function which assigns a truth value (either the value "true" or the value "false") to each atomic proposition.

[def-4] We shall call a function b a *truth assignment function* if it assigns to each *atomic* proposition either one of the values "true" or "false". The value "true" is represented by the letter t; the value "false" is represented by the letter f.

If the competent authority finds that a patent claim feature reads onto the object of comparison (prior art, patent application as filed, priority application) we shall assign the value "true" to the atomic proposition representing the claim feature, if the competent authority makes a finding to the contrary the atomic proposition is assigned the value "false". Note that the mathematical model does not help in constructing the truth assignment function—the "true" or "false" value reflects the choice of the authority. The mathematical model serves only to derive results and conclusions in respect of the compound proposition made up of the atomic propositions and representing the patent claim as a whole.

[7] A ∧ B stands for ¬ [(¬A) ∨ (¬B)]; A xor B stands for (A ∧ ¬B) ∨ (¬A ∧ B). See Kristóf (1998).

It is also important to note that the truth assignment function is only interpreted on the *atomic* propositions. In contrast to the atomic propositions the *compound* propositions of the propositional calculus are not independent from each other—the compound propositions represent compound logic statements the truth evaluation of which should reflect the rules of logic. Accordingly, in the present model the truth evaluation of a compound proposition is not left to the competent authority, instead we shall define a truth evaluation function that assigns the value "true" or "false" to a compound proposition which takes into account the "true" or "false" value of the atomic propositions making up the compound proposition and the rules of logic:

[def-5] We shall call a function b' a *truth evaluation function* which is the extension of a truth assignment function b if:

- whenever X is an atomic proposition function b' assigns the same (true or false) value to X as the truth assignment ($b'(X) = b(X)$);
- whenever **X** is a compound proposition in the form of $\neg Y$ (not Y) the function b' assigns true (t) to **X** if the truth assignment b assigns false (f) and the other way around, i.e. $b'(\neg Y) = t$ if $b(Y) = f$ and $b'(\neg Y) = f$ if $b(Y) = t$ (informally this means that the negation of true is false, and the negation of false is true);
- whenever **X** is a compound proposition in the form of $Y \vee Z$ the function b' assigns true (t) to **X** only if the truth assignment b assigns true (t) to *at least one* of Y and Z (this being the common interpretation of potentially inclusive OR: either one or the other or both).

The evaluation function b' is none other than the logic evaluation of a compound proposition following the rules of natural (intuitive) logic.[8]

Based on the definition of the other logical operators it can be proven that the evaluation function b' further fulfils the following conditions[9]:

- If **X** is a compound proposition in the form of $Y \wedge Z$ the function b' assigns true (t) to **X** only if the truth assignment b assigns true (t) to *both* Y and Z (this being the common interpretation of AND: both the first and the second criteria must be true).
- if **X** is a compound proposition in the form of Y xor Z the function b' assigns true (t) to **X** only if the truth assignment b assigns true (t) to one and only one of Y and Z (this being the common interpretation of exclusive OR: either one or the other but not both).

In the mathematical model the truth assignment function is used to model the decision of the competent authority who examines whether a claim feature reads onto the object of examination (prior art solution, application as filed, priority application), while the extended evaluation function provides the logically correct assessment of the patent claim as a whole, i.e. whether the patent claim as a whole reads onto the object of examination.

[8] It is important to point out that the extension of the truth assignment, i.e. the evaluation function b' is well-defined, which means that that any truth assignment which assigns true or false to every possible atomic proposition has only one extension.

[9] See definition of derived logical operators, supra note 7.

When applying the mathematical model the following steps are performed.

Step 1: The claim features are expressed in terms of basic statements—i.e. statements believed to be sufficiently basic with respect to the object of comparison. For example the statement "the needle is made of ferromagnet" can be regarded as a basic statement as long as the patent claim feature is only compared with other "ferromagnet" needles, if the patent claim analysis includes reading the statement onto needles made of a specific type of ferromagnet (e.g. steel) the statement is no longer basic.

Step 2: The basic statements are modelled by atomic propositions—in practice this means assigning an atomic proposition (i.e. an upper case letter) to the basic statement.

Step 3: The logical operators reflecting the relationship between the patent claim features are established with regard to the legal frame (positive law and case law) and the semantic interpretation of any natural connective particles explicitly written in the patent claim (such as "and", "furthermore", "or", etc.).

Step 4: The patent claim is modelled by building up a compound proposition, wherein the atomic propositions are connected by the logical operators.

Step 5: The competent authority's decision is obtained as to whether the basic statement representing the claim feature reads onto the object of comparison (prior art solution, content of the application as filed, content of the priority application). In practice this may also be the decision the applicant or patentee (or the opposed party) is suggesting to the competent authority.

Step 6: The competent authority's decision is modelled by a truth assignment function whereby the atomic propositions modelling the patent claim features are assigned the values true (t) or false (f) to reflect the authority's decision concerning the given patent claim feature.

Step 7: The true or false value assigned to the compound proposition modelling the examined patent claim is obtained by applying the rules set out in **[def-5]** (i.e. the value of the truth evaluation function is determined for the examined compound proposition).

Step 8: The true or false value of the compound proposition modelling the examined patent claim is translated back to the legal language and the legal consequences are analysed. Note that the only result rendered by the model is that the evaluation of the compound proposition representing the patent claim is either true or false; it is our task to decide what legal conclusions to draw there from.

In the following sections, for the sake of simplicity, I will be less persistent in drawing a clear line between the model and the modelled object and I will often treat patent claim features (as well as the basic statements expressing such features) and the atomic propositions to be one and the same, hoping that the readers will readily distinguish the model from the actual patent claim features without the need of constant emphasis.

4 Examining novelty

An important aspect of the EPO's patent claim feature approach is the practice of performing the substantive examination in two distinct steps: (1) examination as to

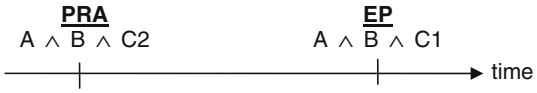

Fig. 2 Substituting patent claim feature compared to prior art solution

novelty and (2) examination as to inventive step (see Palagyi 2002; Kacsuk 2010a, b, c). In the first step the EPO assesses whether any of the patent claim features is novel with respect the examined prior art, while in the second step the examiner regards whether the distinguishing feature makes a non-obvious contribution over such prior art.[10] The present paper focuses on the examination of novelty; the various legal considerations applied in the course of examining inventive step are not discussed here although the binary-type decision making in connection with inventive step (inventive/not inventive) can be fitted into the present model.[11]

As we have seen in Sect. 1 when examining novelty, a patent claim may exhibit four differences with respect to a prior art disclosure; it may comprise (1) an added feature, (2) a generic feature (3), a specific feature (4), a substituting feature (5), or may be lacking (6) an omitted feature.

For the purpose of the following analysis we shall assume that the patent claim features are expressed by the following very simple basic statements (atomic propositions):

A = The subject is a navigation tool.
B = The navigation tool has a needle.
C = The needle is made of a ferromagnet.[12]
C1 = The needle is made of steel.
C2 = The needle is made of iron.

In the following part of Sect. 4 I will try to demonstrate the strength of the mathematical model by examining a few interesting examples from the above mentioned five possible situations (added feature; generic feature; specific feature; substituting feature; omitted feature). In my research studies I have examined all five situations and have found that the model is consistent with the current case law indicated in Table 1.

4.1 Substituting feature

As a simple example let us consider the examination of a European patent (or patent application) comprising the patent claim *"A navigation tool comprising a steel needle"*, the claim of which can be modeled by A ∧ B ∧ C1. Let PRA be prior art material disclosing a similar solution applying an iron needle, thus the object of comparison can be modeled by A ∧ B ∧ C2 (Fig. 2). Hence C1 is a substituting feature with respect to the prior art.

[10] This is called the "problem-and-solution approach". See GL C-IV, 11.7.

[11] For a decision model of inventive step see: Kacsuk (2010a).

[12] C is a basic statement as long as it is not compared to a "more" basic statement such as C1.

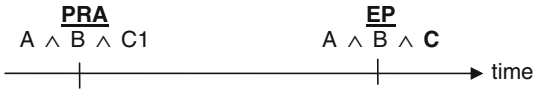

Fig. 3 Generic patent claim compared to specific prior art solution

In the present example the authority will evaluate the basic statements A and B as being true in respect of PRA, while the basic statement C1 will be found false (it is not true that the needle of PRA is made of steel). Accordingly, the truth assignment function b assigns the values true, true and false to the atomic propositions A, B, C respectively. From here on the compound proposition is evaluated automatically (without the participation of the authority). As can be derived from the definition [def-5] the truth evaluation of the compound proposition is false:

$$\begin{gathered} b(A) = t \\ b(B) = t \\ \underline{b(C1) = f} \\ b'(\mathbf{P}) = b'(A \wedge B \wedge C) = f \end{gathered}$$

When translated back to the legal language this means that because feature C1 does not read onto the examined piece of prior art therefore the patent claim as a whole does not read onto the prior art either, thus the patent claim is novel.

This finding is consistent with case law, which says that even in the case when the examined patent claim feature is the equivalent of (obvious substitution for) a prior art feature, novelty cannot be contested. Equivalents are a matter of obviousness and as such any objections can only be made in connection with the requirement of involving an inventive step (see GL. C-IV, 9.2 and T928/93).[13]

Conclusion Current patent practice of evaluating the novelty of substituting features can be fitted into the proposed mathematical model. This also indicates that in this area the applied case law has no hidden logical inconsistencies.

4.2 Generic feature

For the purpose of assessing the novelty of a patent claim comprising a generic feature let EP denote a European patent (or patent application), the claim of which can be modelled by $A \wedge B \wedge \mathbf{C}$ and let PRA be prior art material disclosing a prior solution which can be modelled by $A \wedge B \wedge C1$; **C** being a generic form of C1 (ferromagnet being generic in respect of steel) as illustrated in Fig. 3.

Thus the patent claim relates to *"a navigation tool comprising a ferromagnet needle"*, while *"navigation tool comprising a steel needle"* is known from the prior art.[14]

In the present example **C** can no longer be regarded as representing a basic statement (i.e. **C** is not an atomic proposition) since the statement **C** = "The needle

[13] Note that for any objections of non-obviousness PRA has to belong to the public state of the art as explained in Sect. 1, which may require the assessment of right to priority, if the examined European patent has an earlier priority date than the publication date of PRA.

[14] Note that the latter need not be formulated as a patent claim.

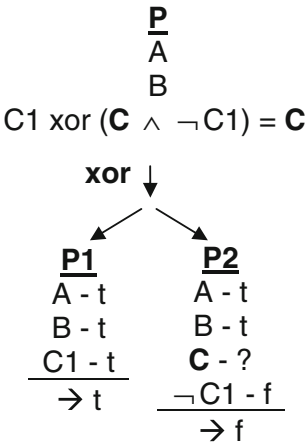

Fig. 4 Representation of generic patent claim

is made of a ferromagnet" covers a more basic statement: C1 = "The needle is of steel".

In the mathematical model **C** can be written as $\mathbf{C} = \text{C1 xor } (\mathbf{C} \wedge \neg\text{C1})$. This would translate back to English as: *"the needle is of steel" OR "the needle is of any other ferromagnet but steel"* the OR-connective being an exclusive OR.[15]

The patent claim $\mathbf{P} = \text{A} \wedge \text{B} \wedge \mathbf{C}$ can be reformulated as:

$$\mathbf{P} = \text{A} \wedge \text{B} \wedge [\text{C1 xor } (\mathbf{C} \wedge \neg\text{C1}] = (\text{A} \wedge \text{B} \wedge \text{C1}) \text{ xor } [\text{A} \wedge \text{B} \wedge (\mathbf{C} \wedge \neg\text{C1})]$$

The patent claim P is thus broken down to two mutually exclusive claim variants:

$$\mathbf{P1} = (\text{A} \wedge \text{B} \wedge \text{C1});$$
$$\text{P2} = \text{A} \wedge \text{B} \wedge (\mathbf{C} \wedge \neg\text{C1}).$$

In order to render the compound statement easier to comprehend, I will use a graphical illustration of the patent claim **P** and the claim variants **P1** and **P2** (Fig. 4).

The atomic (or compound) propositions representing the claim features are written under the letters representing the patent claim **P** and the two claim variants **P1** and **P2**. The propositions that are arranged vertically within the same column are understood to be connected by the AND-operator, while the propositions connected by any other operator are arranged horizontally and the connective operator is explicitly indicated. The truth evaluation of the atomic propositions reflecting the competent authority's choice in respect of a given feature is indicated next to the proposition.

The evaluation of the first claim variant **P1** is very simple, the authority will establish that the basic statements A, B and C1 are all true with respect to prior art PRA. As a consequence the mathematical evaluation of the first claim variant **P1** is

[15] Note that potentially inclusive OR could be used just as well since the authority will never find that a feature satisfies both conditions at the same time—exclusive OR and inclusive OR differ only if both sub-statements are true at the same time. See Tables 1 and 2.

Fig. 5 Generic patent claim compared to specific prior art solution

also true (as indicated in the bottom line of Fig. 4), meaning that the first claim variant **P1** is not novel over the prior art PRA.

In the case of **P2** the evaluation of the compound proposition **C** remains undecided since we only take into account the authority's evaluation of the basic statements. Since C1 is assigned the value true, the evaluation of the negation of C1 is by definition false: $b'(\neg C1) = f$. Due to the property of the AND-operator if one of the components is false the evaluation of the second claim variant **P2** is also false regardless of the evaluation of **C**. Hence **P2** is novel over prior art PRA.

It follows from the underlying legal considerations of the requirement of novelty[16] that if any of the patent claim variants is not novel then the whole claim should be refused for lack of novelty (unless voluntarily restricted by the applicant). Also, $b'(\mathbf{P1}) = t$ and $b'(\mathbf{P2}) = f$, which results in $b'(\mathbf{P}) = t$. When translated back to the legal language this means that the patent claim **P** reads onto the prior art PRA, thus it is not novel.

The EPO's case law applies the "specific vs. generic" rule[17] in the present situation: a specific disclosure takes away the novelty of a generic claim embracing the specific disclosure, i.e. the disclosure of steel takes away the novelty of ferromagnet as a generic concept.

Conclusion The EPO would make the same finding by applying the "specific vs. generic" rule of the Guidelines as the result yielded by the mathematical model. Consequently, the "specific vs. generic" rule is not an arbitrary interpretation adopted by the EPO but rather a logically consistent rule which can be fitted into the proposed mathematical model.

4.3 Omitted feature

Let EP be a European patent (or patent application), the claim of which can be modeled as A ∧ B and let PRA be prior art material disclosing a solution which can be modeled as A ∧ B ∧ C as illustrated in Fig. 5.

The omission of the feature C from the final European patent application EP will be treated by including a tautology in the form of the compound proposition (C xor ¬C) in the examined patent claim **P**. The truth evaluation of (C xor ¬C) is always true, regardless of the truth assignment of the atomic proposition C thus this

[16] The scope of protection must not embrace any existing solutions of the state of the art as that would be detrimental to third parties.

[17] See GL C-IV, 9.5.

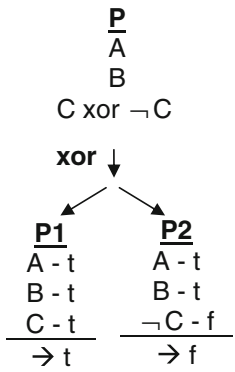

Fig. 6 Representation of patent claim lacking an omitted feature

inclusion will not effect the overall truth evaluation of the patent claim P. Accordingly, the patent claim model can be written as illustrated in Fig. 6.

The first claim variant **P1** (including feature C) reads onto the prior art PRA, while the second claim variant **P2** does not. Similarly to the situation discussed in Sect. 4.2 $b'(\mathbf{P1}) = t$ and $b'(\mathbf{P2}) = f$, resulting in $b'(\mathbf{P}) = t$. When translated back to the legal language this means that the patent claim **P** reads onto the prior art PRA, thus it is not novel.

In decision T411/98 the Board interpreted the requirement of novelty such that an invention is lacking novelty if *all* its features are known from the prior art. According to the general practice of the EPO the compared prior art may have any number of further features (which appear as omitted features when regarding the examined patent claim), such further features bare no relevance to the assessment of novelty.

Conclusion The EPO overlooks any further features disclosed in the prior art which do not appear in the examined patent claim. This practice is consistent with the mathematical model.

5 Examining amendments and priority

In the previous section I have demonstrated three types of patent claim analyses in connection with examining novelty where the current practice is consistent with my mathematical model. In the present section I will discuss the case of generalising a patent feature in order to show examples of how earlier case law has been found inadequate and how the rules of the more recent decisions resolving these situations and overturning previous case law decisions could have been predicted by using the proposed mathematical model.

I will discuss the application of the mathematical model in the field of examining amendments and right to priority in parallel as the two questions are very similar. First I will give a brief overview of the legal background in each field of application.

5.1 Legal background

5.1.1 Amendments

The European patent system is based on the first-to-file principle,[18] from which it follows, that once the patent application is filed the applicant may not improve his position by adding subject-matter that is not disclosed in the original application as filed. This is the underlying idea of Art. 123 EPC which prohibits any amendment to the patent claims that may in any way extend the subject-matter beyond the content of the application as filed. The EPC, however, does not define "subject-matter", nor is there an explanation of "extension". These terms are left to the interpretation of case law (for an overview of the criteria for an allowable amendment see Kacsuk 2010b).

5.1.2 Priority

As briefly discussed in Sect. 2, the legal institution of priority allows the applicant to file a first patent application in a first country (typical the country of residence or nationality of the applicant) and provides a certain period (12 months) within which he may decide to file further patent applications in respect of the *same invention* in other countries or regions. If the applicant claims the priority of the first application no acts accomplished within the given 12-month period will invalidate his right to the patent (acts such as the publication of the invention or the filing of a patent application by another inventor). The priority period allows the applicant to investigate market demand or negotiate with investors while safekeeping his right to obtain patent protection in other countries as well.

As regards the European patent system,[19] in the past decades the EPO has adopted the same strict patent claim feature approach for determining "same invention" according to which the patent claim features—separately as well as in combination—must find direct support in the priority application as a whole (see Svingor 2003).

5.2 Mathematical considerations

Again, five types of differences may be distinguished with respect to the original application/priority application (a new feature; a generic feature; a specific feature; a substituting feature; and an omitted feature) of which only one will be discussed here. The patent claim features are expressed by the same basic statements as in Sect. 4.

The mathematical model is applied in the same way as in the case of examining novelty. The results are recapitulated in the following tables. The same graphic

[18] According to the first-to-file principle whoever is the first to file a patent application in respect of an invention gains the right to obtain patent protection irrespective of whether anyone else has already invented the same invention (provided the earlier invention has not yet been made public).

[19] The European patent system applies two kinds of priorities: one is defined by the EPC, while the other system is regulated by the Patent Corporation Treaty (for a comparison of the two systems see Kacsuk 2010c). However, case law has established uniform interpretation for both regimes, see decision T 301/87, affirmed by decisions G3/93 and G2/98.

representation is used as in the previous section. The invention disclosed in the original/priority application is indicated by **P** irrespective of whether or not the invention appears among the claims, while the amended patent claim and the patent claim claiming priority of invention **P**, as the case may be, are indicated by **P′**.

5.3 Generic feature

In the example illustrated in Table 2 the amendment with respect to the original application/priority application is by way of generalisation. The patent claim **P′** embraces two claim variants **P1′** and **P2′** (relating to "a navigation tool comprising a needle made of steel" and "a navigation tool comprising a needle made of any other ferromagnet but steel"). As can be seen in Table 2 the first claim variant **P1′** reads onto the disclosed invention but the second claim variant **P2′** does not.

5.3.1 Amendment

The legal requirement of an allowable amendment is that it does not extend the subject-matter with respect to the original application. In the present example only the specific feature C1 is disclosed in the original patent application from the more generic feature C, hence the evaluation of patent claim variant **P2′** is false, which is interpreted in the legal language such that the subject-matter covered by claim variant **P2′** consists an unallowable extension of the original patent application.

Table 2 Comparison of examination of amendments and priority

	Amendment	**Priority**
2. Generic feature	**P'** = A ∧ B ∧ **C** compared to **P** = A ∧ B ∧ C1	
Graphical representation:	**P** A B C1	**P'** A B C1 xor (**C** ∧ ¬C1) = **C** **xor** **P1'**: A - t, B - t, C1 - t → t **P2'**: A - t, B - t, **C** - ?, ¬C1 - f → f
Evaluation:	**P1'** claim variant: b'(**P1'**) = b'(A ∧ B ∧ C1) = t **P2'** claim variant: b'(**P2'**) = b'(A ∧ B ∧ **C** ∧ ¬C1) = f	
Conclusion:	not allowable amendment	mathematical model: only the priority of **P1'** is valid case law: only the priority of **P1'** is valid
Legal background:	T194/84 (disclosure test)	G2/98

Turning to the current case law, according to decision T194/84 an amendment extends the subject-matter if as a result of the amendment the person skilled in the art is presented with new information which is not directly and unambiguously derivable from the content of the patent application as filed (so called disclosure test). In the present example the same result is reached by applying the disclosure test of decisions T194/84 as with the mathematical model: the general teaching implies additional information with respect to the specific teaching.

Former case law applied the so-called novelty test of decision T201/83 for determining the allowability of an amendment. According to the novelty test the amendment is unallowable only if the amended patent claim is novel over the original patent application. The novelty test would be unable to detect extension of the subject-matter in the present example as the generic invention is not novel over a specific disclosure as we have seen in Sect. 4.2.

Conclusion This is a clear example of how the mathematical model would have been able to predict a situation in which the former case law decision T201/83 would have proved inadequate. It can also be established that current case law decision T194/84 is consistent with the mathematical model.

5.3.2 Priority

In the case of examining priority, the first thing to be noted is that the EPC explicitly allows for claiming multiple priorities in respect of a single patent claim.[20] Accordingly, the validity of the priority claim in respect of each patent claim variant should be examined independently.

The first claim variant $\mathbf{P1}'$ corresponds to the invention **P** disclosed in the priority application, it may thus benefit from the date of priority. However, the second claim variant $\mathbf{P2}'$ does not read onto the priority application, and the priority claim is invalid in respect of $\mathbf{P2}'$. This is reflected by the evaluation of the two claim variants: $b'(\mathbf{P1}') = t$ while $b'(\mathbf{P2}') = f$.

In former case law decision T828/93 the Board of Appeal found that the possibility of claiming multiple priorities for a single patent claim is only available where the patent claim contained alternatives. Thus T828/93 is incapable of handling the present situation where the patent claim feature **C** takes the form of a generalisation with respect to the specific feature C1 disclosed in the priority application.

Decision G2/98 derived a similar answer in respect of OR-claims finding that OR-claims gave rise to multiple priorities such that each claim variant may enjoy priority of a different priority application. Expanding this thought the Board drew the conclusion that a generic term or formula encompassing specific features may also benefit from different priorities in respect of the different embodiments incorporating the specific features disclosed in the priority application.[21]

[20] Art. 88(2) EPC states: "Where appropriate multiple priorities may be claimed for any one claim."

[21] "(…) where a first priority document discloses a feature A, and a second priority document discloses a feature B for use as an alternative to feature A, then a claim directed to A or B can enjoy the first priority for part A of the claim and the second priority for part B of the claim. It is further suggested that these two priorities may also be claimed for a claim directed to C, if the feature C, either in the form of a generic

Conclusions The mathematical model makes it clear that a generic claim describes alternatives just like explicit OR-claims. The present model could have helped recognise the inadequacy of the guidelines given in T828/93 and could have pointed to the more complete rule of G2/98.

6 Treating complex legal situations

In Sects. 3 and 4 I have presented a few examples to illustrate how the mathematical model may serve as a tool for assessing the logical consistency of current case law. I have also demonstrated that in the discussed situations the current case law is consistent with the mathematical model. This paper cannot endeavour to discuss all the particular situations of patent claim examination that are summarized in Table 1; however, I have applied the mathematical model to every type of situation addressed by case law until now and found that all the relevant current case law decisions can be fitted into the mathematical model. Based on this finding the mathematical model can be used to assist the systematic and automated evaluation of complex legal situations.

As demonstrated in Sect. 2, the possibility of claiming multiple priorities may result in extremely complicated situations if some of the prior art materials are published only after the earliest priority date. I will now illustrate the basic methodology of analysing a complex situation such as the case illustrated in Fig. 1 with the help of the proposed mathematical model.

The patent claim of the European patent application EP can be modelled as follows:

$$\mathbf{P} = \mathbf{A} \wedge \mathbf{B} \wedge (\mathrm{C1}\ \mathrm{xor}\ \mathrm{C2}).$$

When assessing the novelty of patent claim **P**, it has to be compared to the earlier patent applications P1, P2 and P3 in order to determine which patent claim variants are entitled to priority and to which priority. After this and in view of the validity of the priorities, the status of the second prior art PRA2 has to be decided, i.e. whether it can be used as public state of the art in respect of each claim variant. When the legal framework is thus clarified the actual novelty assessment can take place in the course of which all the patent claim variants are evaluated.

In view of the features disclosed in the documents of comparison (P1, P2, P3, PRA1, PRA2) feature **A** is a generic feature embracing specific features A1 and A2, feature **B** is a generic feature embracing specific features B1 and B2, thus features **A** and **B** are modelled by compound statements as explained in Sect. 4.2. Accordingly:

$$\mathbf{A} = \mathrm{A1}\ \mathrm{xor}\ \mathrm{A2}\ \mathrm{xor}\ (\mathbf{A} \wedge \neg\mathrm{A1} \wedge \neg\mathrm{A2})$$

$$\mathbf{B} = \mathrm{B1}\ \mathrm{xor}\ \mathrm{B2}\ \mathrm{xor}\ (\mathbf{B} \wedge \neg\mathrm{B1} \wedge \neg\mathrm{B2})$$

Footnote 21 continued
term or formula, or otherwise, encompasses feature A as well as feature B". (G2/98, Reasons of the decision, point 6.7).

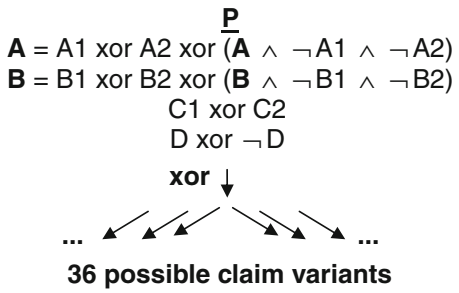

Fig. 7 Representation of European patent claim P

C1 and C2 are alternative features having no common generic feature or any specific sub-features within any of the objects of comparison; hence these features are modelled by basic statements (atomic propositions).

The omission of the feature D from the final European patent application EP will be treated by including a tautology in the form of the compound proposition (D xor ¬D) as explained in Sect. 4.3. Similarly, (E xor ¬E) can be formally inserted in order to compare the patent claim with PRA1. The resulting patent claim P is illustrated in Fig. 7.

It is easy to see that the patent claim representation illustrated in Fig. 5 results in 36 claim variants ($3 \times 3 \times 2 \times 2$). It is practically impossible to correctly assess such a complex situation in ones head. Moreover, patent practitioners have currently no tool or methodology for systematically evaluating a plurality of priority claims as a prerequisite to assessing novelty when some of the prior art material have been published only after the earliest priority date of the examined patent. My mathematical model provides an easy-to-follow methodology which clearly sets the guidelines for distinguishing and expressing basic and compound statements and which allows for the precise mathematical evaluation of the resulting claim variants.

This easy-to-follow methodology with its clear and simple rules could serve as the basis of a tutoring system that could be developed to teach law students, patent practitioners and patent examiners how to tackle legally complicated patent situations.

Furthermore, the mathematical model allows for developing an expert system or decision support software that may aid both patent authorities and applicants in assessing patentability. The software can assist the users to identify the basic statements which are then evaluated by the user. After this the determination of the resulting claim variants and the calculation of the truth evaluation of each claim variant can be performed by the software in a fully automated way.

For example in the present situation the user need only evaluate the basic statements A1, A2, B1, B2, C1, C2, D and E (albeit in respect of all the documents of comparison) which would allow the software to calculate the truth evaluation of all the 36 patent claim variants based on the simple logical rules of the mathematical model. We have seen in Sect. 2 that if any of the patent claim variants is lacking novelty then the patent claim cannot be allowed, hence, in practice patent examiners will be content to point out a single patent claim variant, which is not novel and refuse the patent application as a whole based thereon. However, it would be more

helpful for the applicants to present the novelty analysis of all the patent claim variants (which is currently not carried out by the EPO) this way the applicants would have more information when considering their patent strategy as to which claim variant (sub-invention) should or should not be pursued. In the present example the patent claim variants as well as their truth evaluation can be easily obtained in view of Sects. 4 and 5 and will therefore not be discussed here.

Such a software system is currently under development by the author and will hopefully provide an efficient tool for patent offices and courts in delivering more accurate and detailed decisions as well as for patent practitioners in delimiting patent claims from the prior art or in drawing up expert opinions in connection with the patentability of inventions.

7 Related work

Various attempts have been made to computerise legal reasoning and legal decision making by applying artificial intelligence to the field of law. Some of the most promising research projects are directed to providing case-based reasoning, expert systems and mathematical models such as neural networks or fuzzy logic.

Case-based reasoning uses existing case law to provide or predict future decisions, for example Ashley's HYPO system (Ashley 1990) comprises a knowledge base of over thirty judicial opinions in the field of trade secret law and allows for establishing similarities between a new case and the precedent cases forming the knowledge base with respect to given factors (e.g., whether plaintiff adopted security measures, whether plaintiff and defendant make competing products, etc.). HYPO compares the factors and determines the most helpful cases to the defendant's or plaintiff's position. This approach is particularly suitable for alleviating the work of legal practitioners operating in a common law system.

Expert systems on the other hand aim to offer the skills of an expert by providing legally relevant questions for generating a legal opinion as Tyree's FINDER (Tyree 2004) or by assisting the formulation of legal argumentation as McCarty's TAXMAN (McCarty 1997). Expert systems are often combined with knowledge based systems, for example deductive knowledge based systems are based on pre-defined IF–THEN rules for solving specific tasks in a limited legal field.

Neural networks simulate the functioning of a biological network of neurons, in particular that of the human brain. The neural networks comprise a number of interconnected neurons (nodes) some of them serving as inputs and outputs the others forming hidden layers. The structure of the neural network is adaptive, the behaviour of the neurons is defined by mathematical functions and the interconnections can be modified whereby the network can be trained to produce a desired output in response to a given input. Once the learning phase has ended the neural network can be used to find an input pattern similar to a completely new input and produce the learned output of the similar input. This is practically the scheme of reasoning by analogy (for proposed application see for example Hollatz 1999).

Fuzzy logic is another mathematical model that can be used to obtain an exact value in situations characterised by a certain level of indeterminacy—this being

often the case in legal decision making (see Philipps and Sartor 1999). For example the exact amount of compensation needs to be decided by a judge based on indeterminate terms such as the degree of negligence.

Artificial Intelligence models of the above kinds are directed to performing intelligent autonomous behaviour. This goal has only been accomplished to a very limited extent in legal applications—the complexity of the legal situations, the omnipresent human factors, and the discretional powers of judges render the full automation of legal decision-making practically unattainable.

Other Artificial Intelligence approaches seek only to assist the legal practitioner in argumentation. One of the applied tools is mathematical logic that has been reduced to practice in the form of argument assistants—software applications implementing the rules of logic for supporting argumentative tasks for lawyers. The classical logical argumentation model of Toulmin (see Toulmin 1958) dates back to the 1950 s and allows for drawing conclusions from given premises and warrants (inference licences) taking into account any counter argumentation in the form of a rebuttal. The possibility of rebuttals results in a defeasible argument, new information (counter-reasons, exceptions to a rule, etc.) can overturn a conclusion. Complex logical systems have been developed such as Verheij's Deflog (see Verheij 2003) to model further important phenomenon in legal argumentation such as reinstatement, which occurs when an overturned conclusion is held valid again on account of additional information. Argument support software traditionally involve graphical representation of arguments usually consisting of boxes corresponding to the propositional content of the arguments and of arrows expressing the relations between the arguments (see Schweers and Verheij 2007), while other argumentation management systems such as ArguGuide offer a content-oriented tool incorporating laws, precedents, facts and arguments for supporting legal argumentation tasks such as writing a plea (see Verheij 2007).

Turning to patent law, Nitta et al. have developed an expert system focusing on the procedural aspects of patent law (see Nitta and Nagao 1986). The KRIP system (Knowledge Representation System for Laws relating to Industrial Property) provides a tool for checking the legality of each patent procedure. In order to achieve this, the procedures defined by patent law need to be identified as well as the relationships between the procedures and the conditions for starting/ending any such procedure. In proceedings before the EPO the legality checking is carried out in the course of the formalities examination which is performed by formalities officers.[22] The formalities examination precedes the so-called search[23] (prior art search) and the substantive examination[24] relating to questions of patentability. The work load in connection with formalities examination as well as the responsibility of applicants have been greatly reduced by the online filing tools offered by national and international patent offices. The EPO, for example, offers the Online Filing

[22] See Guidelines for Examination in the European Patent Office: Part A, Guidelines for Formalities Examination (see supra note 4).

[23] See Guidelines for Examination in the European Patent Office: Part B, Guidelines for Search (see supra note 4).

[24] See Guidelines for Examination in the European Patent Office: Part B, Guidelines for Substantive Examination (see supra note 4).

software[25] which performs legality checking of nearly all data and intended procedural steps in connection with the filing of the patent application as well as certain procedural steps taken during patent proceedings. If the user omits required data or enters contradicting data, the program will warn the user; in case of serious deficiencies the online filing is not allowed by the program at all. However, in the case of substantive examination the questions of patentability are—for the most part—linked to the patent claims and neither KRIP nor any of the latest patent software offer any tool for examining and comparing patent claims. Moreover, patent claims vary from case to case and are by nature complicated both in a linguistic and in a technical sense; hence, it is not possible to simply apply the formalism of KRIP—which has been designed to describe limited number of rules and relationships prescribed by legal texts—to the substantive examination phase of patent proceedings.

The complexity of patent claims—defining the scope of legal protection—has also attracted some interest among researchers of the interdisciplinary field of Artificial Intelligence and Law. Current approaches are of a linguistic nature directed to simplifying patent claim sentences in order to paraphrase and summarise the contents of patent claims. A single claim sentence is segmented into clausal discourse units, transformed into complete sentences, co-reference relations are established and a discourse structure is built between the discourse units (see Bouayad-Agha et al. 2009b). Paraphrasing and multilingual summarisation of patent claims are but a few aspects of semantics-based patent processing techniques. These and other applications are incorporated in PATExpert[26] which, as an overall scientific objective, strives to change the current patent processing paradigm of textual processing to semantic processing (see Bouayad-Agha et al. 2009a).

The present paper offers a new approach to assisting legal decision making and legal argumentation in the field of patent law. The proposed model is similar to the above mentioned logic based argument support software in that it applies mathematical logic to help establish logically correct conclusions and offers graphical representation of the decision scheme. However, the proposed model differs from existing software both in substance and form. It relies on conventional, human argumentation and judgement in deciding basic factual questions. The legal questions, on the other hand, are incorporated in the model itself whereby a complex legal finding can be obtained from the basic decisions.

8 Conclusion

In the present paper I have introduced a mathematical model for the legal examination of European patent claims and shown its application in three different fields (assessment of novelty, allowability of amendments, and validity of a priority claim). I have shown that while findings based on case law require the application of various decisions of the Boards of Appeal and Enlarged Board of Appeal, the

[25] See website of the EPO: http://www.epo.org/applying/online-services/online-filing/download.html.

[26] See website of the PATExpert project: http://recerca.upf.edu/patexpert/.

proposed mathematical model allows for a common approach in all three fields of patent claim examination.

The mathematical model is based on mathematical logic and yields—in the illustrated situations—the same result as case law would dictate. This indicates that current case law has evolved into a logically highly coherent system. I have shown a few specific examples where earlier case law has been overturned by more recent decisions reflecting the logical requirements that could have been revealed by the mathematical model in advance.

I have also demonstrated that by separating the binary type of questions of fact which are decided by the competent authority from the questions of law which are incorporated in the logical rules, it is possible to automatically evaluate complicated legal situations once a limited number of factual questions are answered.

In my view a mathematical approach to patent claim analysis would be desirable for reviewing current case law as well as for assisting future decision making in the form of a computerised expert system based on the mathematical model. I am currently working on the development of such a software which will hopefully provide an efficient tool for patent offices and courts in delivering more accurate and detailed decisions as well as for patent practitioners in drawing up expert opinions.

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