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Patentability of mathematical modelling and simulation methods

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Summary. "Patentability" refers to conditions laid down by law to what can be patented and what cannot. In this study, changes in the patentability of simulation methods are compared with the rapid development of computational science since 1970s. Although technological progress has caused computational simulation and modelling methods to grow to an everyday tool of technology, these methods have traditionally been excluded from patentability as "non-technical subject matter" or "abstract ideas". We describe the changes in patentability criteria in Europe and in the USA, and illustrate the development of patenting activity in this field during the last decade. Practisers should be aware of these changes, and investigate the possibilities they might offer.

Key words: patentability, modelling, computer-implemented simulation

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Description

Law changes over time, and across the world, and so does the patent law. We may assume that revisions of patent law somehow reflect the technological development, but with a delay. In this article, we study the development of computational modelling and simulation and its impact on patenting in the field of mechanics. Does this development also show in patenting activity?

A patent is a set of exclusive rights granted for an invention for a limited time period in exchange for a detailed public disclosure of the invention. The purpose of this reward is to enhance the development of technology, but without limiting scientific research. Therefore, scientific theories as such are excluded from patentability. Additionally, a patentable invention shall meet the legal requirements of novelty, inventiveness and industrial applicability. Evaluation of these criteria is performed in a centralized manner by patent offices, under the guidance of courts' interpretations.

The scientific system, on the other hand, is based on debate and discussion: no result is final, but can be improved, corrected, or even replaced. No exclusion right is associated with scientific results. In this way, publishing is a central part of the scientific method. Contrary to the patent system, scientific results are accepted or denied in a de-centralized

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manner, among "peers". Because engineering is more business-related, engineers may be more reluctant to publish their results, mainly to avoid helping competitors.

In view of patenting activity, the relation between academic research and engineering is closer than it would seem at first sight. For instance, the Technology Licencing Office (TLO) of MIT received, in the fiscal year 2017, 794 invention disclosures (including 84 from Lincoln Laboratory), filed 271 US patent applications, had 298 US patents issued, executed 137 licenses and options, had 25 companies formed using MIT intellectual property, and received $53.6 million in total licensing revenue [3].

Purely mathematical methods are scientific by nature and therefore, in one way or another, excluded from patentability. In Europe, they are considered "non-technical", and in the USA, "abstract ideas". Simulation methods typically deviate from pure mathematics by computer implementation and by motivation. Should then computer-implemented simulation of technical systems be regarded as abstract mathematical methods or technical inventions? Recent case law in Europe and in the USA give differing answers to this fundamental question.

Patentability of modelling and simulation methods in European practice

According to Article 52(2) of the European Patent Convention (EPC) [5], mathematical methods as such are excluded from patentability. However, if there is a technical apparatus involved with the mathematical method, the invention is not a mathematical method as such. In addition, the computer implemented mathematical method may be a part of a technical process. From the point of view of the mathematical method, the question is then what is the role of the mathematical method in this context. Does it have a technical effect, for example, in controlling a technical system or a process, or by affecting the internal functioning of the computer? This question relates to inventive step, not whether the invention as a whole is technical or not.

Because claims directed to methods of simulation, design or modelling typically comprise features which fall under the category of mathematical methods, the question of patentability of mathematical simulation and modelling methods, too, mostly relates to inventive step, and only indirectly to EPC 52(2). More specifically: does the mathematical method contribute to the solution of a technical problem?

The case law of the EPO gives examples when this is and when this is not the case.

Modelling and simulation methods are used to produce concrete results, like building structures or electrical circuits design processes. Advances of computational methods and hardware have enabled engineers to reduce expenses by using computational models. For example, continuum-based structural finite elements were invented in the aircraft industry at Boeing already during the early 1950's to solve plane stress problems arising in the design and analysis of delta wing panels [1, 2].

By hindsight, it is therefore easy to accept that these concrete results could comprise patentable technical inventions in the sense of the EPC, and, furthermore, form a basis for inventive step. However, the historical development has been far from straightforward.

As late as in 2012, the official Policy of the European Patent Office on patentability of modelling and simulation methods was very limited (Guidelines of Examination of the European Patent Office, chapter G.II.3.3, [4]):

"A mathematical method for designing electrical filters is not patentable; nevertheless filters designed according to this method would not be excluded from patentability by Art. 52(2) and (3)."

The Guidelines represent the official policy of the EPO, and it is mostly based on selected individual decisions of the Boards of Appeal of the EPO. Each individual decision of the Boards of Appeal (BoA) represents the case under appeal only, and if the decision becomes part of the EPO practice, its reasoning is included in the Guidelines.

Therefore, decisions like T 0605/93 (1995), T 0110/98 (1999) and T 0078/92 (1994) [6], which seem to contradict the first part of the above cited text passage of the Guidelines, still did not represent the official policy of the EPO, in general. This was even the case with the landmark decision T 1227/05 dated 13.12.2006, [6]. The above cited text passage ("A mathematical method for designing electrical filters is not patentable") was removed from the Guidelines in the 2013 edition [7], and the reasoning of T 1227/05 was added to the Guidelines as late as in 2017 [8], and even then in a slightly modified form (Example 4 in chapter G.VII, 5.4.2.4).

However, decision T 1227/05 appeared to be very influential, and many later decisions adopted its reasoning. Because the Guidelines were amended as late as 2013 [7], we may speak of a transition period in the official policy of the EPO around 2006 - 2013.

The EPO published recently a new version of the Guidelines (November 2018), in which the section relevant to mathematical methods, modelling and simulation (GL G-II 3.3) has been thoroughly rewritten. In the 2018 edition, section G.II.3.3 was redrafted to clarify the assessment of claims comprising mathematical methods in general, and a new section G.II.3.3.2 on simulation, design, and modelling was added to illustrate them as basic examples of mathematical methods in view of patentability.

As said in G.II.3.3, mathematical methods play an important role in the solution of technical problems in all fields of technology. Examples of technical applications which serve a technical purpose are given. Furthermore, the claims shall be functionally limited to the technical purpose. This can be achieved by specifying how the input and output of the sequence of mathematical steps relate to the technical purpose so that the mathematical method is causally linked to a technical effect. Decisions T 2035/11, T 1029/06, T 1161/04 are cited as examples.

Modelling and simulation methods as basic examples of mathematical methods are further illustrated in Example 4 of chapter G.VII.5.4.2.4. The logic is roughly as follows:

Example 4 relates to a computer-implemented method for simulating electric circuits under $1/f$ noise.

Simulation in the example is based on stochastic differential equations. Stochastic differential equations are, as such, mathematical methods, which are excluded from patentability. However, computer implemented simulation of electric circuits under $1/f$ noise is not a mathematical algorithm as such because it is computer implemented and has a technical purpose in the industrial process of circuit design. The algorithm is furthermore limited to this purpose as the claim features define how the numerical simulation is performed.

Therefore, example 4 differs from a simulation study of the behaviour of an unnamed technical system. A "meta-specification" of this kind indicating no functional link between the technical system and the simulation method would result in an excessive scope of protection (T 1227/05).

As for patentability of mathematical simulation methods in general, Headnote II of T 1227/05 crystallizes the reasoning by saying that specific technical applications of computer-implemented simulation methods are themselves regarded as modern technical methods, which form an essential part of the fabrication process and precede actual production, mostly as an intermediate step. Furthermore,

"such simulation methods cannot be denied a technical effect merely on the ground that they do not yet incorporate the physical end product".

The reasoning then proceeds to give argumentation that in the appeal case (computer implemented simulation of electric circuits under $1/f$ noise) there is indeed a technical effect, and the invention considered as a whole is technical.

To further illustrate the transition period around 2006 - 2013, examples citing T 1227/05 but ending at a negative conclusion are, for example T 0531/09 (3.5.2012, Security checkpoint simulation) and T 2331/10 (15.12.2017, Operating wind turbines). In T 0531/09, tasks at the checkpoint are modelled as probabilistic events, each taking a certain time to perform, which may depend on what happens in preceding tasks. However, probabilistic delays in the invention are deemed non-technical as they relate to passenger queuing, which is administrational rather than technical. In T 2331/10, the invention addressed the problem of handling deficiencies in electric power delivered to a local region where a wind farm is embedded due to variations in the electric power output of such wind farms. Clarity issues were raised. Producing a more accurate production forecast was regarded as an intellectual activity, and relating to a non-technical problem.

Decision T 1227/05 clarified that simulation methods which were functionally limited to a well-defined technical purpose could be patentable. However, the decision left open the question how to assess the technical effect of mathematical differences between the models describing the same technical system. Further questions on decision T 1227/05 were recently posed in decision T 0489/14 (22.2.2019) illustrating the greyness is still present in the area. In Example 4 in [8], the difference was in the algorithm producing the random numbers to be used as a noise term. Because the algorithm required less computer resources in its contribution to the technical purpose than the one used in the prior art documents, the algorithm was deemed to produce a technical effect.

It should be noted that mathematical simulation methods have been an issue at European national courts, as well. The decision [9] ("Logikverifikation"), which is a predecessor to the logic in T 1227/05, was from year 1999. National legislations usually allow researchers to further develop a patented simulation method and employ the result in their scientific publications. Patent protection usually relates to professional or commercial exploitation of the invention only.

Patentability of modelling and simulation methods in USA and China

In Europe, patents are granted for inventions which solve a technical problem in a technical way. What is patentable depends on what one considers a technical problem and what kinds of solutions are considered technical. As discussed above, the current EPO policy requires that the relation of the model and the subject of modelling be defined in a sufficiently detailed way (establishing a sufficient link between the technical purpose and the mathematical method steps). As the meaning of sufficiency is ambiguous, modelling and simulation field still lies in no-man's-land, or the "grey area" of patentability.

In the USA, patents may be granted for inventions which are new and useful (35 U.S.C. §101). Although no position is taken on the technicality of the invention, laws of nature, natural phenomena, and abstract ideas have been excluded from patentability [10] by the case law. A motivation for such an exclusion is to prevent too broad a scope of protection [11].

A situation where a patent might be regarded as barring rather than enhancing inventiveness was addressed in the decision of the Supreme Court of the U.S (SCOTUS)

Bilski v. Kappos (2010) [11]. "The concept of hedging, described in claim 1 and reduced to a mathematical formula in claim 4, is an unpatentable abstract idea, [...]. Allowing petitioners to patent risk hedging would pre-empt use of this approach in all fields, and would effectively grant a monopoly over an abstract idea" (p. 15 of the decision).

For this reason, hedging was regarded as an abstract idea which is not patent-eligible. Other court decisions have specified that also mathematical methods are examples of abstract ideas [12]. One of the problems that remained after the Bilski decision was that an abstract idea was claimed in the Bilski case without any reference to technical entities (like computers). Computer implementation of abstract ideas like hedging algorithms was left open.

The next major decision of the Supreme Court regarding abstract ideas was Alice v. CLS Bank [13], in 2014. The Court held that abstract ideas must be "genuinely" linked to technical equipment. In this, the decision comes close to the reasoning of T 1227/05 of the EPO, and the concept of meta-specification. According to the Supreme Court, the invention must be significantly more than an abstract idea. The decision did not give any definition what "significantly more" means, but it stated, as an example, that an instruction to apply the abstract idea of intermediated settlement using some unspecified, generic computer is not enough to transform the abstract idea into a patent-eligible invention. The question what is exactly meant by "significantly more" has been clarified by the United States Court of Appeals for the Federal Circuit (CAFC), but there is still much greyness left.

How would this reasoning apply to the case of mathematical simulation and modelling? As mathematical methods, mathematical simulation and modelling are regarded as abstract ideas. According to the patent eligibility test of the Alice decision, one first investigates whether the claim is directed to ineligible subject matter (laws of nature, natural phenomena and abstract ideas). After that, one asks, whether the invention recites elements (either in isolation or in combination) in addition to the patent ineligible elements, which provide "significantly more" than the abstract idea itself. The most recent refinements and additions to these basic steps were published by the USPTO in January 2019 [14].

There are a number of US court decisions which might be tentatively compared with the EPO decision T 1227/05 that deals with modelling and simulation inventions. According to decision Enfish LLC v. Microsoft Corp. et al. [15] of the United States Court of Appeals for the Federal Circuit (CAFC), the second condition of the Alice test is fulfilled if the additional elements are directed to a specific improvement to the way computers operate. There are also subsequent decisions [16, 17] from the USPTO Patent Trial and Appeal Board where modelling related inventions have been found patent eligible on similar grounds as in the Enfish decision. Maybe the closest counterpart to the invention of the European decision T 1227/05 can be found in the USPTO patent eligibility examples [18] that were published in conjunction with the 2019 Revised Patent Subject Matter Eligibility Guidance [14]. One of the examples addresses a method for providing a digital computer simulation of an analog audio mixer. Among other features, the simulation involves generation of normally distributed random numbers. According to the USPTO analysis of the example, the method claim does not even recite any of the judicial exceptions enumerated in the revised guidance [14], and the claim is clearly patent eligible.

However, as the revised guidance [14] is quite recent, its future effect and extent cannot yet be fully anticipated. Therefore, it seems right to consider modelling and simulation

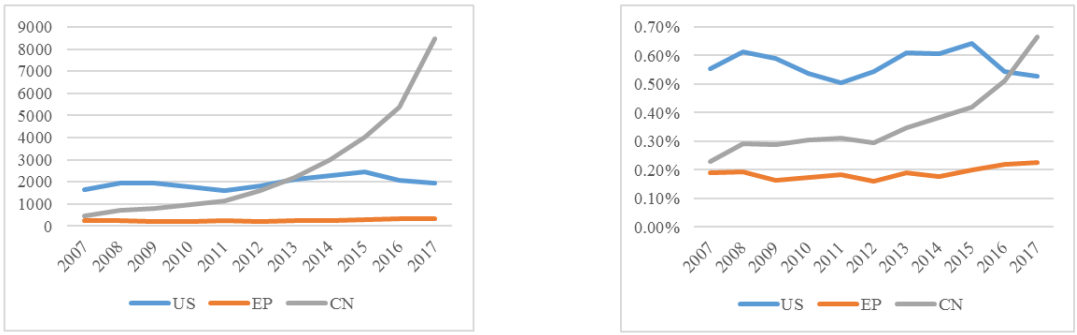

Figure 1. Number (left) and percentage (right) of patent applications in the largest patent offices in IPC subgroup G06F17/50 by year of publication.

related inventions still to lie in the "grey area" from the USA legislation point of view.

Note that the criterion of exclusions to patentability is much stronger in the USA than the corresponding criterion at the EPO. At the EPO, patentability analysis usually reduces to the question whether mathematical simulation steps can be considered to have a technical effect and thereby contribute to inventive step. In contrast, no difference is made at the USPTO between technical and abstract features in the assessment of obviousness, but the crucial question is typically patent eligibility, i.e., whether the claimed subject matter as a whole involves significantly more than an abstract idea.

The patent system in China comprises features from both of the above-mentioned systems. Therefore, there is a grey area of patentability also in China. Due to the rapidly growing economy and patenting activity in China and the number of Chinese applicants in Europe and in the USA, knowledge of the Chinese patent system becomes still more important. Traditionally, China has been more conservative in respect of software patenting. However, the patentability of computer programs has lately been revised along the lines of Europe and the USA.

Classification and statistics

Patents and published patent applications are classified according to the technical features of their content. The International Patent Classification (IPC) [19] is a hierarchical patent classification system used in over 100 countries to classify the content of patents in a uniform manner. Each classification symbol is of the form A01B 1/00. The first letter represents the "section" consisting of one of the letters A ("Human Necessities"), B ("Performing Operations, Transporting"), C ("Chemistry, Metallurgy"), D ("Textiles, Paper"), E ("Fixed Constructions"), F ("Mechanical Engineering, Lighting, Heating, Weapons"), G ("Physics"), and H ("Electricity"). Inventions related to modelling and simulation are classified into section G, more specifically, into subgroup G06F17/50 ("Computer-aided design"). The numbers of patent applications in the most important patent offices in subgroup G06F17/50 are shown in Fig. 1. The data have been retrieved from the EPODOC database.

It is apparent from Fig. 1 that the number of Chinese patent applications relating to modelling and simulation is growing extremely fast. However, this is also the case of the total number of patent applications in China. Fig. 1 shows also the change in share of all patent applications of those in IPC class G06F17/50. The percentage, too, shows a clear

Table 1. Applications in subgroup G06F17/50 in 2018.

	Applications in subgroup G06F17/50	Percentage of all applications
US	1987	0.53 %
EP	331	0.21 %
CN	10831	0.69 %

increase when compared with the other major offices. Unfortunately, the reason for this phenomenon can only be speculated. The tentative figures from year 2018 are given in Table 1. In any case, those who are working in this area should at least be aware of this trend.

Demonstrative examples

Simulation related patent application at the EPO and USPTO

The European patent application EP 3082055 A1 [20] and its U.S. counterpart US 2016300003 A1 [20] illustrate typical objections faced by simulation related inventions at the EPO and USPTO. As already noted, patentability analysis at the EPO usually reduces to the question whether mathematical simulation steps can be considered to have a technical effect and thereby contribute to inventive step. No difference is made at the USPTO between technical and abstract features in the assessment of obviousness, but the crucial question is typically patent eligibility, i.e. whether the claimed subject matter as a whole involves significantly more than an abstract idea. Application EP 3082055 A1 discloses a rotorcraft component simulation based upon finite element analysis (FEA) of three dimensional scan data and, in particular, upon structural analysis of physical rotorcraft components using three dimensional scan-based finite element analysis. The key steps of the method according to claim 1 of the application are as follows:

1. scanning the component and generating scan-based geometry of the component
2. comparing the scan-based geometry with the refined CAD-based geometry of the component to quantify geometric differences therebetween
3. generating scan-based FEA geometry of the component by meshing the scan-based geometry
4. performing finite element analysis on the scan-based FEA geometry to obtain scan-based FEA data
5. comparing the scan-based FEA data with the CAD-based FEA data of the component to quantify the effect of geometric difference therebetween.

According to the Examining Division of the EPO, the preamble of the claim indicates that the method is directed at "performing structural analysis", but emphasizes that it is unclear how the identified geometric difference is used in structural analysis. Structural analysis is customarily formulated in terms of concrete technical quantities like forces, stresses and strains. Therefore, difference between the two data sets as it was originally disclosed in the claim can be construed as a purely mathematical exercise, potentially resulting in no value that has a well-defined technical meaning.

The Examining Division then suggested amending the claim such that concrete technical effect would be achieved. As a response, the applicant amended the last method step to read as follows:

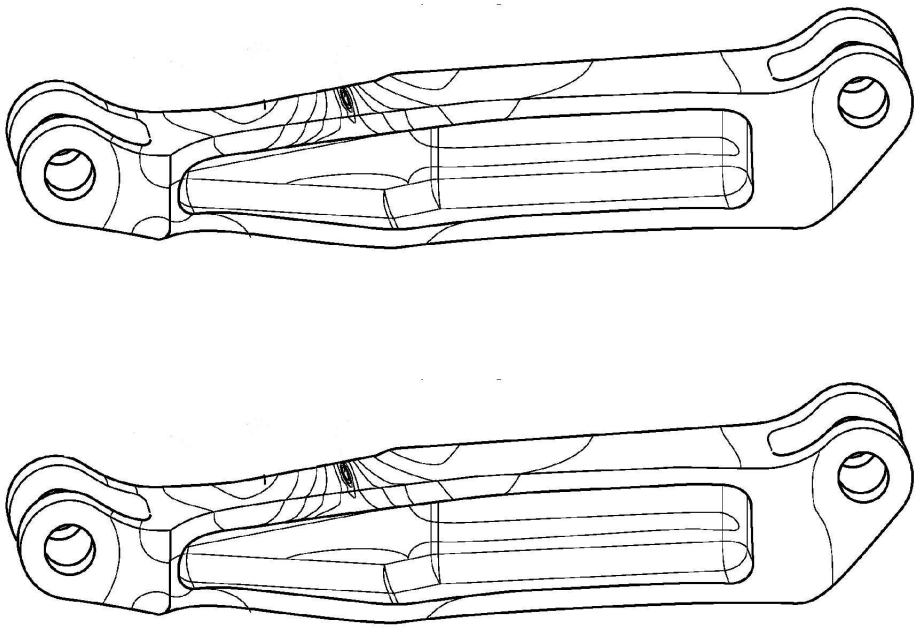

Figure 2. A rotorcraft component shown in the European patent application, EP 3082055 A1. CAD-based FEA data (top) and scan-based FEA data (bottom).

"comparing the scan-based FEA data with the CAD-based FEA data of the component to identify geometric difference therebetween to validate the scan-based FEA data".

The Examining Division considered the amendment sufficient, and furthermore, the claim was considered novel and non-obvious to a person skilled in the art, so patent was granted at the EPO (EP 3082055 B1, [22]).

The application US 2016300003 A1 filed at the USPTO had claims close to the European claims[2]. The first office action was issued on 28 June 2018. The examiner concluded first that the claims were directed to the abstract idea of computing scan-based geometry, and comparing scan-based FEA data with CAD-based FEA data and organizing and manipulating information through mathematical correlations. Independent claims were further deemed not to include additional elements that would be sufficient to amount to significantly more than the judicial exception because additional computer elements which are recited at a high level of generality provide only general computer functions that do not add meaningful limits to practicing the abstract idea. Dependent claims that provided additional features related to scanning systems and scan geometries were not considered to provide meaningful limitations to the abstract idea, either.

In subsequent communications between the applicant and the examiner, a significant question has been how to interpret the most recent patent eligibility guidelines at the USPTO. The examiner has maintained the patent ineligibility rejections also in the second office action. In a response, the applicant has argued that according to the 2019 revised guidance [14], the claims should be patent eligible.

It is possible that patent prosecution is still continued at the USPTO and, therefore, no exact conclusions can be drawn from the first two office actions. However, this example

[2]The scope of independent claim 1 in the EP application seems to be intermediate to independent claim 1 and dependent claim 2 in the US application.

demonstrates that U.S. patent ineligibility rejections are not always straightforward to overcome.

Simulation related to a scientific work

To further demonstrate the patentability of modelling and simulation, we cite a work in [23, 24, 25] and speculate if the model presented therein could have been patented. The model can regarded as a computer implemented mathematical method that is a part of a technical process, i.e. simulation of fatigue of metals. The question is then what is the technical effect achieved by the simulation? It has been mentioned that the model, compared to most of the preceding models, is able to accurately predict fatigue lives under complex and out-of-phase loadings. The proposed model can also be used for metals having different fatigue properties in different directions (e.g. forged steel). The model is simple and requires a reduced set of material parameters to be defined, which is why it is easy to implement and calibrate. Thus, the model has a technical effect and a technical purpose.

However, what is the technical problem and does the simulation contribute to the solution of this problem? Since the simulation results can be applied to the design of real material components, the simulation method then also solves a technical problem relating to industrial manufacturing. The simulation method can also be used to simulate the experimental tests.

The preceding questions related solely to the inventive step, and it must be further evaluated whether the invention as a whole is technical. Let us consider first the invention: a simulation method for prediction of the fatigue life of components made of forged steel. Since prediction of the fatigue life cannot be regarded as technical, the proposed invention as a whole is not technical. We then consider the invention: design and manufacturing of components made of forged steel using a simulation method for prediction of the fatigue life. Since the design and manufacturing of components can be regarded as technical, the proposed invention as a whole is technical, and we might expect the simulation method in this context to be patentable.

Summary and concluding remarks

Computational methods have developed from theoretical studies towards essential tools of industrial design. Recent changes in the practice of the European Patent Office (EPO) have made it possible to patent such methods alone, without referring to the end result of the design process. In contrast, changes in the patentability practice at the United States Patent and Trademark Office (USPTO) have restricted the scope of patent protection available to mathematical methods. In both offices, the changes leave a grey area of uncertainty.

A specific example of an invention with applications filed at both the EPO and USPTO was studied, and although no final decisions are available, the comparison seems to strengthen the picture that in the field of computational modelling and simulation, the practice of the USPTO has been stricter until present. The effect of the recently revised USPTO guidance [14] remains to be seen. A statistical survey showed that the number of patent applications in the field is growing, especially fast in China. There would certainly be a need for a survey of its own to explain this result. Another subject for further study could be the commercial exploitation of patents in the field of modelling and simulation.

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