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NOTES

SOFTWARE PATENT PROTECTION: A PROBLEM-SOLUTION THEORY FOR HARMONIZING THE PRECEDENT

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INTRODUCTION

As the software industry has emerged from infancy, it holds a wealth of opportunities and vast potential for continued growth. The United States Commerce Department predicted in 1990 that the software industry would continue to grow by twenty to thirty-five percent each year throughout the 1990s. Furthermore, worldwide software sales could reach one trillion dollars by the year 2000. The numbers alone show the opportunities available for software companies, and, with the increasing amounts of revenue, protecting the valuable software assets of these companies will be critical in the global marketplace.

The United States is the dominant force in the software industry. In the United States, software companies have increasingly turned to the patent system for protection of their software programs. Patents provide a stronger and more well-defined method of protection when compared with other forms of protection such as copyrights. As the software market continues to grow and mature, patents will play a key role in allowing software companies to carve a niche in the market.

2. Burton, supra note 1.
3. Id.
4. United States software companies held sixty percent of the global software market in 1990. Id. It is estimated that United States companies develop seventy percent of the software sold in Europe and Fifty percent of the software sold in Japan. Id.
5. Busse, Patents Gain Favor with Software Firms; Vendors Slow to Adopt Old Weapon, INFOWORLD, Aug. 26, 1991, at 82. In 1990, 6500 computer patent applications were filed with the Patent and Trademark Office, compared with 3200 in 1987. Apple Computer, Inc. applies for about 50 patents each year. Id.
and, in particular, maintaining the dominance of domestic software companies by providing powerful software protection. This software patent protection will allow, for example, domestic software companies to bar the importation of pirated versions of their programs or potentially obtain preliminary injunctions against alleged infringers.

The law related to software patents, unfortunately, has not been crystal clear. Even though the Supreme Court has firmly established patent protection for software, the Supreme Court precedent related to computer-implemented inventions has been subject to various interpretations. As a result of the confusion and contradictions in the law, the courts may have provided inadequate guidance to the United States Patent and Trademark Office (PTO) regarding the type of software patents that the PTO should issue. To worsen the situation, the PTO feels a certain sense of external pressure due to emotionalism over the whole software patent debate and, as a result, may often make patentable subject matter an issue in software cases that are already within the boundaries encompassed by patentable subject matter. One cannot necessarily place the blame for this on the PTO, however,

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9. Bender, supra note 6, at 3.


14. G. GOLDBERG, TOTAL QUALITY MANAGEMENT; POSITION PAPER GROUP 230; CLAIM ANALYSIS & REVIEW 1 (1990) (this document was obtained from the PTO through Freedom of Information Act Request No. 92-116). "The Office, and our group have come 'under fire' for allowing applications that are perceived as being either well know [sic] (unpatentable) or claiming non-statutory subject matter[,]" Id. "The whole 'software' question is very sensitive. Congress and many members of the public are and will be watching what we do. If too many patents are issued that are borderline or are perceived as being borderline the unfriendly publicity could adversely affect us." Id. at 5. Mr. Goldberg is the director of Group 230 in the PTO, which group is responsible for examining many software patent applications. Mr. Goldberg distributed this position paper to the examiners in Group 230.


Claims that deal with "computer programs," equations or mathematical calculations, or methods which might be suspect under the Supreme Court exclusions—such as methods of doing business, abstract intellectual concepts, printed matter
since it may result from a combination of lack of guidance\textsuperscript{17} and intense pressure from a watchful public and those opposed to software patent protection.

It is important to determine the exact scope and meaning of the Supreme Court precedent related to computer-implemented inventions. This precedent in part establishes the legal basis for software patents. This Note analyzes the history of patent protection for software inventions. This Note also constructs a synthesized definition for "mathematical algorithm" and sets forth a problem-solution theory for harmonizing the cases related to computer-implemented inventions. Part I discusses the history of computer-implemented inventions as patentable subject matter. Part II explains a definition for "mathematical algorithm" and discusses the problem-solution theory.

I. HISTORY OF SOFTWARE PATENT PROTECTION

A. THE SUPREME COURT PRECEDENT


The invention\textsuperscript{18} at issue in \textit{Gottschalk v. Benson}\textsuperscript{19} related to number conversion. Benson had invented a method of converting binary coded decimal (BCD) numbers into the corresponding pure binary numbers.\textsuperscript{20} The binary system is a way of representing numbers using...
only the digits 0 and 1 in what is also referred to as the base-two system. In comparison, the standard base-ten number system uses ten numerals for representing numbers, and each position of the numeral represents a power of ten. In binary, each position of a numeral represents a power of two. For example, the number “4” in base-ten is equal to 100 in binary; the “1” in the third position represents $2^2$. In the BCD system, each base-ten numeral from 0 to 10 can be represented by any four-digit binary number. For example, the base-ten numeral 53 is represented in BCD as 0101 0011, with the first numeral (0101) representing 5 and the second numeral (0011) representing 3. In comparison, base-ten 53 equals binary 110101.

BCD is a convenient way of representing pure binary numerals. Even though computers operate on binary numbers, BCD is often used by peripheral computer devices. Seven segment decoders, for example, are a common and well-known device that operates on BCD numerals. A seven segment decoder is a device that displays characters or numerals. Calculators, for example, often use seven segment decoders for each element of the display, with a separate seven segment decoder displaying each numeral of a calculator output. As the name suggests, a seven segment decoder uses seven individual elements for displaying a numeral. A total of seven segments are required for displaying any numeral between 0 and 9. A seven segment decoder displays the numeral 8, for example, by illuminating or activating all seven of the segments.

Seven segment decoders typically receive BCD numerals as an input signal. Calculators, however, utilize electronics that operate on pure binary numbers. As the calculator user presses the buttons and instructs the calculator to perform various mathematical functions, the electronics inside of the calculator perform the various mathematical functions on pure binary numbers. The calculator may receive BCD input numbers and will then convert those numbers to binary for performing the mathematical calculations. When the calculator has obtained the final result for display, the pure binary number must be converted into the corresponding BCD numerals for display by the seven segment decoders. A conversion routine converts the pure binary

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22. Id.
23. Id. at 17.
25. MANO, supra note 21, at 151, 444.
26. Id.
27. Id.
number into the corresponding series of BCD numerals, and each BCD numeral is then input to the seven segment decoder for the corresponding position on the display. The series of activated seven segment decoders thus displays to the user the final result in base-ten.

Benson had attempted to claim an algorithm for BCD to binary conversion without regard to the purpose for which it was used. The Benson invention was not limited to calculators or seven segment decoders, nor was it limited even to display or input devices. Any computer, or computer-related device, implementing Benson's BCD to binary conversion algorithm would have been covered by the claim at issue.

Benson's claims were rejected by the PTO as directed to nonstatutory subject matter. The Court of Customs and Patent Appeals (CCPA), however, upheld the claims as statutory. The PTO then sought review in the Supreme Court to determine whether indeed the claims defined patentable subject matter contemplated by the statute.

It was well known even before Benson that mathematics per se are not patentable. It was also known, however, that a computer programmed to operate in a new way is a statutory invention. These two principles thus tend to conflict when a computer is operating to perform mathematical functions. The problem becomes deciding when a computer operating in a new way to perform mathematical functions does not violate the principle that pure mathematical formulas may not be patented.

The Court first recognized the basic principles underlying non-patentable subject matter classes. Abstract ideas, scientific principles, and laws of nature are not patentable subject matter. These principles have long been in existence and were even used in the days when

29. See Benson, 409 U.S. at 68.
31. Benson, 409 U.S. at 64.
35. See supra note 32 and accompanying text.
Samuel Morse developed the telegraph to hold that one of Morse's claims for telegraphy was directed to non-patentable subject matter. Morse had obtained many patents on telegraphy, and one of his claims defined the use of "electromagnetism, however developed for marking or printing intelligible characters, signs, or letters, at any distances." With this claim, Morse was covering not only the embodiments he had disclosed, but also any future, and at the time unknown, embodiments that would produce signs for telegraphy.

Morse's rejected claim may be viewed as fitting into the non-patentable category of abstract ideas. Specific hardware apparatus for performing telegraphy is certainly a statutory invention, because it is a machine. Morse, however, was attempting to patent the abstract idea of using electromagnetism for telegraphy, because his claim would have covered any system that performed the claimed function.

It was also well known at the time of Benson that laws of nature and scientific principles are not patentable. Einstein could not have patented his well-known formula that $E=mc^2$. Likewise, Newton could not have patented his law that $F=ma$. Laws of nature, and scientific principles, represent the common tools of science that are available for all to use. To allow one to patent scientific principles would be contrary to promoting scientific progress.

The Court then applied these well-known principles to Benson's invention. Like with Morse's rejected claim, Benson was attempting to patent any use of BCD to binary conversion. The Court recognized that Benson's claim would cover any known and unknown apparatus for performing the claimed number conversion. Furthermore, Benson had set forth no precise application of his invention. As stated by the Court, the end use may vary from the operation of a train to verification of drivers' licenses to researching the law books for precedents. Allowing Benson a claim for his number conversion would in effect have been allowing the claim for the pure mathematical steps involved. Benson's claim effectively pre-empted the mathematical formula used in the number conversion. The finding of pre-emption means that one

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37. Id.
38. Id.
40. Morse, 56 U.S. at 113.
44. Id. at 68.
could not use the mathematical formula without infringing Benson's claim.45

The Court appeared to create a new class of non-patentable subject matter: mathematical algorithms.46 The Court defined a mathematical algorithm as a "procedure for solving a given type of mathematical problem."47 Benson's claim fit into this category, since the mathematical problem presented was number conversion. The key to avoiding this class of non-patentable subject matter was to avoid pre-emption of the mathematical procedure or formula defined in a particular claim. Ambiguity arose in the scope of the Court's holding, because it was often difficult to determine exactly what is a mathematical problem, and determining what is a mathematical problem is a necessary prerequisite to determining if a claim contains a mathematical algorithm.48

Finally, the Court urged to Congress to address the matter.49 The Court expressly did not intend to preclude a patent for any computer program. However, the Court seemed hesitant to rush into a new area of technology without congressional approval.

2. Parker v. Flook: Using Obviousness to Determine Patentable Subject Matter

In 1978, the Supreme Court in Parker v. Flook50 added a new twist to the mathematical algorithm rule. The claimed invention at issue de-

45. See id. at 72.
46. Software algorithms in general—step-by-step computer-implemented processes—are ordinarily patentable subject matter if no mathematical algorithm is involved in the process. See In re Maucorps, 609 F.2d 481, 486 (C.C.P.A. 1979); In re Sarkar, 588 F.2d 1330, 1333 (C.C.P.A. 1978); In re Toma, 575 F.2d 872, 877 (C.C.P.A. 1978); In re Freeman, 573 F.2d 1237, 1245 (C.C.P.A. 1978); In re Deutsch, 553 F.2d 689, 693 (C.C.P.A. 1977); In re Chatfield, 545 F.2d 152, 158-59 (C.C.P.A. 1976), cert. denied, 434 U.S. 875 (1977). Accordingly, a common approach to demonstrating that a patent claim contains patentable subject matter is to demonstrate that a mathematical algorithm is not involved, Sarkar, 588 F.2d at 1333, that patentable subject matter remains if the mathematical algorithm is removed, In re Noll, 545 F.2d 141, 147 (C.C.P.A. 1976), cert. denied, 434 U.S. 875 (1977) (claim as a whole must be analyzed for patentable subject matter), or that the mathematical algorithm is not pre-empted but, rather, is applied to a statutory process or system. Diamond v. Diehr, 450 U.S. 175, 187 (1981); See Barrett, supra note 13, at 10 (interpreting Diehr).
47. Benson, 409 U.S. at 65.
48. The courts tend to analyze the underlying purpose of a claim so that the Benson, rule may not be avoided by ingenious ways of defining inventions. See Parker v. Flook, 437 U.S. 584 at 593 (1978) (broadly interpreting Benson). Therefore, for example, even if inventions are defined with means-plus-function clauses, 35 U.S.C. § 112, para. 6 (1991), a court may find that the claim is actually directed to the solution of a mathematical algorithm. See, e.g., In re Abele, 684 F.2d 902, 910 (C.C.P.A. 1982) (an apparatus included a mathematical algorithm because of the recitation of a "calculating means").
49. Benson, 409 U.S. at 72-73.
defined a process for updating an alarm limit. One of the steps to the process used a mathematical equation for calculating a new alarm base $B_1$. In comparison to Benson, however, the claim included more than simply a solution to a mathematical formula. The preamble of the claim specifically set forth an end use for the process—catalytic chemical conversion of hydrocarbons.

The Court considered whether the claim defined patentable subject matter. The Court more specifically considered whether the additional limitations in Flook's claim were sufficient material to avoid pre-emption of a mathematical formula. The analysis of whether it was patentable, unfortunately, also included determining whether it was both directed to patentable subject matter and novel.

Pre-emption was non-existent in Flook's claim. The Court initially followed the Benson analysis by determining whether Flook's claim entirely pre-empted the formula for updating an alarm limit. The Court quickly recognized that, while there may be many uses of the alarm limit formula in the petrochemical industry which would be covered by the claim, other uses of formula may exist which would not infringe the claim. Even though the claim would potentially have had a very broad scope, it would not have been in effect a claim on the formula itself. The claim at issue, therefore, did not pre-empt the formula. This conclusion alone should have been enough to avoid the mathematical algorithm rule of Benson and find that the claim defined patentable subject matter.

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51. Claim 1 reads:

1. A method for updating the value of at least one alarm limit on at least one process variable involved in a process comprising the catalytic chemical conversion of hydrocarbons wherein said alarm limit has a current value of $B_0 + K$

wherein $B_0$ is the current alarm base and $K$ is a predetermined alarm offset which comprises:

   (1) Determining the present value of said process variable, said present value being defined as PVL;

   (2) Determining a new alarm base $B_1$, using the following quotation:

   $B_1 = B_0(1.0-F) + PVL(F)$

   where $F$ is a predetermined number greater than zero and less than 1.0;

   (3) Determining an updated alarm limit which is defined as $B_1 + K$; and thereafter

   (4) Adjusting said alarm limit to said updated alarm limit value.

Id. at 596-97.

52. Id.

53. Id. at 588.

54. Id. at 586 ("[the claims] do not, however, cover every conceivable application of the formula").

55. Id.

The Court, unfortunately, then diverged into a discussion of novelty. The Board of Patent Appeals and Interferences in the PTO had determined that the novel element in the claim was the mathematical formula used by process. The formula was the critical element in distinguishing the claim over the prior art. The Court seemed persuaded to use novelty as a means for drawing a line to divide non-patentable scientific principles from patentable processes. This has often been called the "point of novelty approach."

In using the point of novelty approach, the Court assumes that the mathematical algorithm or formula involved is in the prior art. This follows from the basic principle that scientific principles, laws of nature, and abstract ideas are available for all to use. If these classes of non-patentable subject matter are the basic tools of scientific research, then whatever is in these classes must be assumed to be in the prior art. Since the formula involved in the claim was deemed to be in the prior art, the Court effectively was able to eliminate the only novel element from the claim. All that was left was in the prior art and thus the Court held the claim non-patentable.

Flook was also unsuccessful in arguing that post-solution activity made the claimed process patentable. As defined in the claim, after the process had operated on data by using the formula, additional steps are taken and operations performed on the result of the mathematical formula. These additional steps add limitations to the claim and arguably could avoid the mathematical algorithm rule. The Court did not agree.

The Court considered the post-solution activity argument to be a rule that could potentially have disastrous effects. If the Court were to allow post-solution activity to be a limitation that could bring a mathematical formula into the realm of patentable subject matter, a patent claim drafter could add post-solution activity to any scientific principle in order to potentially obtain a patent on such a process. As an example, the Court stated, as is not disputed, that the Pythagorean theorem is not patentable, since it is a scientific principle. However, a patent claim drafter could add additional post-solution activity steps to the result of the Pythagorean theorem. And, these additional steps would not create a process that defines patentable subject matter.

57. Flook, 437 U.S. at 594-95.
58. See, e.g., In re Freeman, 573 F.2d 1237, 1243 (1978) (rejecting the "point of novelty" approach).
60. Id.
61. Id. at 590.
62. Id.; see also In re Abele, 684 F.2d 902, 909 (C.C.P.A. 1982); In re Walter, 618 F.2d 758, 767-68 (C.C.P.A. 1980); In re Gelnovatch, 595 F.2d 32, 41 n.7 (C.C.P.A. 1979); In re
At the time it was decided, *Flook* contained two significant holdings. First, the Court reaffirmed the basic mathematical algorithm rule of *Benson*. Second, the Court introduced considerations of novelty and non-obviousness into the analysis under § 101 of whether a claim defines patentable subject matter. Once again, the Court urged Congress to address the matter and set forth policy as to whether computer programs should be eligible for patent protection. Once again, Congress would not take up the matter and the Court would be left on its own.

If *Benson* had confused the law regarding the patentability of computer-implemented processes, *Flook* made it even worse. *Flook* complicated the § 101 pre-emption analysis by including an analysis of non-obviousness, which has developed from an entirely different line of cases. Patentable subject matter and non-obviousness had been separable requirements for patentability.

3. **Diamond v. Diehr: Rejecting the Obviousness Approach and Clarifying the Fundamental Rule**

Three years after *Flook*, the Supreme Court in *Diamond v. Diehr* finally clarified the state of the law. The Court upheld as statutory subject matter a claim defining a process for curing rubber, which included a mathematical formula as one of the steps. The Court also reaffirmed *Benson* and overruled the point of novelty principle expounded in *Flook*.

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64. *Id.* at 594-95.
65. *Id.* at 596.
66. *See, e.g., id.* at 600 (Stewart, J., dissenting).
68. Claim 1 reads:
Diehr solved a problem that had plagued the industry. The Diehr invention utilized a thermocouple connected to the press to determine and monitor the temperature inside of the press. Using the known Arrhenius equation, Diehr was able to repeatedly calculate the equation using continually upgraded temperature variables. The Arrhenius equation provided a press operator with a precise calculation of how long to cure the synthetic rubber. By continually re-calculating the equation with upgraded temperature variables, the press operator would obtain a precise indication of when to stop the molding process.

The Court had to consider the mathematical pre-emption rule as applied to the Diehr claim. The claim at issue included a mathematical formula, which alone could not define patentable subject matter. Did the claim at issue include sufficient matter, beyond the Arrhenius equation, to become statutory and still allow anyone to use the equation without infringing the claim? Furthermore, the Court was also faced with the \textit{stare decisis} effect of the point of novelty approach set forth by the \textit{Flook} court. Was novelty an appropriate factor in a § 101 patentable subject matter analysis?

1. A method of operating a rubber-molding press for precision molded compounds with the aid of a digital computer, comprising:
   - providing said computer with a data base for said press including at least, natural logarithm conversion data (ln), the activation energy constant (C) unique to each batch of said compound being molded, and a constant (x) dependent upon the geometry of the particular mold of the press, initiating an interval timer in said computer upon the closure of the press for monitoring the elapsed time of said closure, constantly determining the temperature (Z) of the mold at a location closely adjacent to the mold cavity in the press during molding, constantly providing the computer with the temperature (Z), repetitively calculating in the computer, at frequent intervals during each cure, the Arrhenius equation for reaction time during the cure, which is \[ \ln v = CZ + x \] where \( v \) is the total required cure time, repetitively comparing in the computer at said frequent intervals during the cure each said calculation of the total required cure time calculated with the Arrhenius equation and said elapsed time, and opening the press automatically when a said comparison indicates equivalence.

\textit{Id.} at 179 n.5.

69. \textit{Id.} at 177-78.

70. \textit{Id.}
The Court began with a bit of legislative history.\textsuperscript{71} Even though the \textit{Benson} and \textit{Flook} courts had urged Congress to address the matter, Congress had not in response amended the statute and had remained relatively silent on the issue. Perhaps since Congress had not taken up the issue, the Court analyzed the legislative history behind the term "process" in the statute defining patentable subject matter. In view of a decision in the previous term, \textit{Diamond v. Chakrabarty},\textsuperscript{72} the Court recognized that courts should not read limitations and conditions into the statute defining patentable subject matter which Congress has not expressed.\textsuperscript{73} Congress had intended statutory subject matter to "include anything under the sun that is made by man."\textsuperscript{74} Aside from the traditionally known exclusions to the statute, such as laws of nature and scientific principles, the Court was not in a position to create new classes of non-statutory subject matter, since the Court would effectively be reading severe limitations into the statute without any congressional indication that such limitations were proper or appropriate.

In view of legislative history, the Court reaffirmed and clarified the \textit{Benson} rule.\textsuperscript{75} \textit{Benson} stood for the long established principle that abstract ideas, scientific principles, and laws of nature are not patentable, and \textit{Benson} stood for no more than this. The Court reaffirmed this basic proposition of \textit{Benson}, while limiting the holding of \textit{Benson} to those traditionally-recognized classes of non-patentable subject matter.\textsuperscript{76}

The mathematical algorithm pre-emption rule still controlled claims with suspect subject matter. As applied Diehr's claim, however, no pre-emption existed. Diehr claimed a specific process for curing rubber, and this process used, but did not pre-empt, a mathematical equation. The Court characterized the claim as having "industrial application." Since no pre-emption existed, the claim survived the \textit{Benson} mathematical algorithm rule.\textsuperscript{77}

The Court was still faced with the "point of novelty" approach set forth in \textit{Flook}. Instead of reaffirming this portion of \textit{Flook}, the Court effectively overruled this requirement and eliminated novelty and non-obviousness as requirements for patentable subject matter.\textsuperscript{78} \textit{Flook} had

\textsuperscript{71} \textit{Id.} at 182-84 (discussing the Patent Acts of 1793 and 1952).
\textsuperscript{72} 447 U.S. 303 (1980).
\textsuperscript{73} \textit{Diehr}, 450 U.S. at 182.
\textsuperscript{74} \textit{Id.} (quoting S. REP. NO. 1979, 82d Cong., 2d Sess., 5 (1952); H.R. REP. NO. 1923, 82d Cong., 2d Sess., 6 (1952), U.S. CODE CONG. & ADMIN. NEWS 2394, 2399 (1952)).
\textsuperscript{75} \textit{Id.} at 185.
\textsuperscript{76} \textit{Id.}
\textsuperscript{77} \textit{Id.} at 188.
\textsuperscript{78} \textit{Id.} at 188-89 ("The 'novelty' of any element or steps in a process, or even of the process itself, is of no relevance in determining whether the subject matter of a claim falls within the § 101 categories of possibly patentable subject matter."). The CCPA had consistently rejected the "point of novelty" analysis. \textit{See In re Chatfield}, 545 F.2d 152, 157
mandated that anything within the non-patentable subject matter classes, such as abstract mathematical formulas, were deemed to be in the prior art. With this in mind, the claims were then divided into old and new matter to determine if what remained, when the mathematical formulas were removed, was patentable subject matter. The Diehr court recognized that patentable subject matter is a distinct and separable requirement from novelty. Novelty has no place in a patentable subject matter analysis. The overruling of the point of novelty approach by the Diehr court avoids confusing an analysis of patentable subject matter with the often complex determinations of novelty and non-obviousness under sections 102 and 103.

B. LOWER COURT DEVELOPMENTS

1. Pre-Diamond v. Diehr

a. In re Freeman: The Two-Part Test

Six years after Benson, the CCPA in In re Freeman 79 explained the Benson rule by setting forth a two-part test 80 While Benson established that mathematical algorithms are not patentable subject matter, Benson did not provide a well-defined test for evaluating claimed inventions.81 The Freeman court, therefore, constructed a two-part test as a tool for analyzing claims under the fundamental rule announced in Benson 82

The invention in Freeman covered a computer-based method of typesetting information, including mathematical formulas 83 The method provided an advantage over prior typesetting methods by posi-

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80. Id. at 1245.
81. See In re Toma 575 F.2d 872, 877 (C.C.P.A. 1978) (creating classes of claims in a search for the meaning of Benson); In re Chatfield 545 F.2d 152, 158 (C.C.P.A. 1976), cert. denied, 434 U.S. 875 (1977) (interpreting Benson, to mean that steps for solving an equation constitute non-patentable subject matter); In re Waldbaum 559 F.2d 611, 617 (C.C.P.A. 1977) (interpreting Benson, to mean that a mathematical formula must not preempt an otherwise statutory algorithm); see also In re Johnston, 502 F.2d 765, 774 (C.C.P.A. 1974); rev’d, 425 U.S. 219 (1976) (Rich, J., dissenting and requesting that the Supreme Court set limits on Benson).
82. Freeman, 573 F.2d at 1245. The two-part test is effectively a summary of previous CCPA decisions which had interpreted Benson. See In re Deutsch 553 F.2d 689, 692 (C.C.P.A. 1977). In Deutsch, the court distinguished the appealed claims over Benson, by finding that the invention at issue, a process for operating multi-unit plants, was a specific application of a mathematical formula and that only those using the formula for this specific process would be barred from using the formula itself. Id. at 692.
83. Claim 1 reads:
tioning symbols in a mathematical formula according to their appearance, which created a more visually-appealing display. The claimed process included three steps: (1) building a tree structure of symbols based on input codes; (2) creating concatenation point positions of the symbols using a local positioning algorithm; and (3) generating an image of the collection of symbols, which comprise an expression, on an output device such as a monitor.

The Board of Patent Appeals and Interferences in the PTO appeared to have misconstrued the meaning of "mathematical algorithm." In affirming a rejection of the claims, the Board of Appeals seemed to equate "algorithm" in the Benson sense with any programmed computer. The CCPA in response focused part of the analysis of the appealed claims on the meaning of "mathematical algorithm." The Benson holding required that the CCPA first determine what is a mathematical algorithm and then decide if the claims pre-empted such an algorithm.

The CCPA devised a two-part test for analyzing claims under the Benson holding. The first part of the Freeman test simply involved determining if the invention at issue contains a mathematical algorithm as defined in Benson. If an invention contains a mathematical algorithm, then the invention triggers the second part of the test. Under the second part, a court analyzes an invention to determine, in a sense, whether the algorithm is the primary focus of the invention. If the claimed invention covers a patentable process that makes use of a mathematical algorithm, the invention is patentable subject matter. If the invention, however, focuses on solving a mathematical formula without

1. In a computer display system comprising
   (A) a display device for generating relatively-positioned symbol images in response to applied sequences of signals specifying the shape and position of said images,
   (B) a data processor comprising... the improvement comprising
      means for storing additional information specifying spatial coordinate positions, relative to a reference point on a corresponding symbol, of a plurality of concatenation points associated with said corresponding symbol, and
      means responsive to said control program for generating and transferring to said display device data signals specifying the coincidence of at least one specified concatenation points [sic] on adjacent symbols.

Freeman, 573 F.2d at 1240-41.
84. Id.
85. Id. at 1240.
86. Id. at 1245.
utilizing the formula for a particular application, the invention is not patentable subject matter.\(^8\)

In applying the test, the CCPA concluded that Freeman’s invention did not even contain a mathematical algorithm.\(^9\) The local positioning algorithm was a step-by-step process for achieving a result, which, while meeting the standard definition of an algorithm,\(^9\) was not a step-by-step process for solving a mathematical problem, which is a mathematical algorithm as defined by Benson.\(^9\) Since the invention did not contain a mathematical algorithm, the CCPA did not apply the second part of the test. Accordingly, the second part of the two-part test originated as mere dicta from Freeman.

b. In re Walter: Modifying the Freeman Test

In re Walter,\(^92\) decided two years after Freeman, modified the second part of the two-part test. Walter clarified the analysis for determining when an invention wholly pre-empts a mathematical formula.\(^93\) This analysis involves removing the mathematical algorithm from the claimed invention and then determining if what remains in the claim is patentable subject matter.\(^94\) If a mathematical formula or algorithm has completely pre-empted the invention, then removing the algorithm will leave nothing in the claim that is statutory subject matter.\(^95\)

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88. Freeman, 573 F.2d at 1245: The invention must not pre-empt the mathematical algorithm.
89. Id. at 1246.
90. A broad definition of algorithm is “a step-by-step procedure for solving a problem or accomplishing some end.” WEBSTER'S NINTH NEW COLLEGIATE DICTIONARY 70 (1989); see also In re Chatfield 545 F.2d 152, n.5 (C.C.P.A. 1976), cert. denied, 434 U.S. 875 (1977).
91. Freeman, 573 F.2d at 1246.
92. 618 F.2d 758 (C.C.P.A. 1980).
93. The court restated the second part of the Freeman test. In analyzing a claim as a whole, the claim must define a specific implementation on an invention in terms of either structural relationships or process steps in order for the claimed invention to be patentable subject matter. Id. at 767. A specific implementation of a mathematical algorithm is analogous to applying a mathematical algorithm to an otherwise patentable process, which the Supreme Court analyzed a year later in Diamond v. Diehr, 450 U.S. 175 (1981).
94. Walter, 618 F.2d at 767.
95. Methods of calculating, for example, are not patentable subject matter in and of themselves. In re Gelnovatch, 595 F.2d 32, 41-41 (C.C.P.A. 1979); see In re Richman, 563 F.2d 1026, 1030 (C.C.P.A. 1977) (calculating an aircraft’s velocity component); In re de Castelet, 562 F.2d 1236, 1244 (C.C.P.A. 1977) (solving equations to obtain a set of points along a curve); In re Christensen, 478 F.2d 1392 (C.C.P.A. 1973) (method of computing porosity of subsurface formations). The invention in de Castelet was implemented by specified hardware components that interfaced a drawing machine which produced the curves based upon calculations performed by the hardware. de Castelet, 562 F.2d at 1238. If the invention had been claimed as an application of the methods of calculating curves to the specific embodiment, i.e., a drafting machine, the patentee's claims would have been pat-
The invention in *Walter* was a method of unscrambling electronic signals in a seismic prospecting apparatus.\textsuperscript{96} The apparatus generated “chirp” signals, which were transmitted downward into the earth. Various subsurface features in the earth reflected these signals at varying depths. The apparatus received these reflected signals, which were scrambled since the apparatus received the reflections at different instants in time and may have received only a portion of the original chirp signal. The invention in *Walter* cross-correlated the reflected return signals with the original chirp signal in order to unscramble the return signals.\textsuperscript{97} The cross-correlation used mathematical techniques of comparing the return signals to the transmitted signals,\textsuperscript{98} and these techniques further included Fourier transforms, which are a mathematical method of analyzing the components of a signal.\textsuperscript{99}

The issue in *Walter* required the CCPA to refine the second part of the two-part test. The claims at issue unambiguously included a mathematical algorithm due to the mathematical computations that the claim defined. The claims met the first part of the two-part test. Applying the second part of the two-part test would be more difficult, however, since *Freeman* had not addressed the second part of the test. The *Walter* court, therefore, seemed to inquire how the *Freeman* court would have applied the second part of the two-test.

The *Walter* modification examines how an invention uses a mathematical algorithm.\textsuperscript{100} An invention is not *per se* non-patentable by simply incorporating a mathematical formula and using the formula as part of a calculation for a statutory process.\textsuperscript{101} An invention is, however,

\textsuperscript{96} The basic steps of the claim read:

   the improved method of correlating . . . that comprises
   a) converting said series of sample signals into an augmented series of sample signals . . .
   b) forming a Fourier transform FTS, of each respective series of signals . . .
   c) forming a combined segment of each segment \( C_j \) of said reference signals . . .
   d) forming a corresponding Fourier transform FTC\(_j\) of each said combined segment . . .
   e) forming the non-zero conjugate complex vector products of pairs of the respective Fourier transforms and adding them together . . .

*Walter*, 618 F.2d at 761.

\textsuperscript{97} *Id.*

\textsuperscript{98} *Id.* at 769.


\textsuperscript{100} *Walter*, 618 F.2d at 767.

\textsuperscript{101} See *id.* at 766; see also *Diamond v. Diehr*, 450 U.S. 175 (1981).
outside the scope of § 101 if it merely presents a method of solving a mathematical formula.

The court concluded that the claimed invention at issue did not define patentable subject matter. The claimed cross-correlation technique merely solved a "mathematical algorithm" in the Benson sense of the term.\textsuperscript{102} In applying the second part of the Freeman test, the court found that the invention pre-empted a mathematical algorithm because the algorithm essentially was the invention.\textsuperscript{103} If the mathematical steps were removed from the invention, nothing remained that was patentable subject matter.\textsuperscript{104} The court determined that even though a specific end use—seismology—was recited in the claim, the entire claim was directed to calculations and was thus nonstatutory.

The court also stated that the end-product of an invention is a factor to consider in the analysis. If the result is a pure number, as in this case, then the invention is not patentable subject matter. Throughout the opinion, the court used the end-product theme to distinguish the invention of Walter over cases in which the courts found inventions incorporating mathematical formulas to be patentable subject matter.\textsuperscript{105}

2. The Aftermath of Diamond v. Diehr

a. In re Abele: Clarifying the Freeman Test

In re Abele\textsuperscript{106} clarified and explained the second part of the Freeman two-part test as modified by Walter. The invention at issue in Abele related to computerized axial tomography (CAT scans). CAT scans involve rotating a radiation source and detector around an area of interest to be viewed. Generally, the x-ray or radiation source must subtend the entire body, which subjects the patient's body to a considerable amount of radiation. Abele's method of processing CAT scan data allowed the use of a much narrower x-ray beam, which subjected the patient to a decreased amount of radiation.\textsuperscript{107}

\begin{itemize}
  \item \textsuperscript{102} Walter, 618 F.2d at 769. The court reasoned that the invention (method) merely solved a mathematical problem of cross-correlation. "The calculations are the beginning and end of the claims [invention]." \textit{Id}.\textsuperscript{102}
  \item \textsuperscript{103} \textit{Id}. Even though the invention included the specific application to seismic prospecting, a court does not generally consider an end use to be a limitation of an invention when the invention is described in terms of a method. \textit{See id.; but see J. Landis, Mechanics of Patent Claim Drafting} 82 (2d ed. 1974).\textsuperscript{104}
  \item \textsuperscript{104} Walter, 618 F.2d at 769; \textit{see also} Parker v. Flook, 437 U.S. 584, 595 (1978). "[I]f a claim is directed essentially to a method of calculating, using a mathematical formula, even if the solution is for a specific purpose, the claimed method is nonstatutory." \textit{Id}. (quoting In re Richman, 563 F.2d 1026, 1030 (1977)).\textsuperscript{105}
  \item \textsuperscript{105} Walter, 618 F.2d at 769.
  \item \textsuperscript{106} 684 F.2d 902 (C.C.P.A. 1982).
  \item \textsuperscript{107} \textit{Id}. at 903-04.
\end{itemize}
In the broadest claim, Abele included two steps, calculating and displaying.\textsuperscript{108} The CAT scan data processing electronics used this method for displaying the resulting CAT scan data. The claim, however, was not limited to any particular type of data. Dependent claim 6 limited the method of claim 5 to x-ray attenuation data used in the CAT scan process.\textsuperscript{109}

The court had to decide whether either of these two broad claims pre-empted a mathematical algorithm processing CAT scan data. \textit{Walter} had modified the second part of the \textit{Freeman} test such that a mathematical algorithm must be implemented in a specific manner to define structural relationships or to limit or refine claim steps in order to be statutory.\textsuperscript{110} Considering the broad scope of the claims at issue, in particular claim 5, the court had to decide how far the \textit{Walter} modification could reach to define statutory subject matter without infringing upon the fundamental rule announced in \textit{Benson}.

The court broadened the \textit{Walter} analysis.\textsuperscript{111} Focusing on the theme of applied mathematical algorithms, the court stated that \textit{Walter} did not expressly require that the claim define, limit or refine structural relationships or process steps in order to be within the realm of patentable subject matter. On the contrary, the mathematical algorithm need only be “applied in any manner to physical elements or process steps.”\textsuperscript{112} Mere post-solution activity or field of use limitations, however, will not be sufficient, under \textit{Abele}, to meet the requirements of an applied mathematical algorithm.\textsuperscript{113}

The applied mathematical algorithm rule fits with the \textit{Benson} holding. \textit{Benson} basically stated that a claim must not pre-empt a mathematical algorithm.\textsuperscript{114} If the mathematical algorithm is applied to a specific process, the process arguably cannot pre-empt the mathematical algorithm, because mere use of the mathematical algorithm without the

\begin{itemize}
\item \textsuperscript{108} Claim 5 reads:
\begin{quote}
5. A method of displaying data in a field comprising the steps of calculating the difference between the local value of the data at a data point in the field and the average value of the data in a region of the field which surrounds said point for each point in said field, and displaying the value of said difference as a signed gray scale at a point in a picture which corresponds to said data point.
\end{quote}
\textit{Id.} at 908.
\item \textsuperscript{109} Claim 6 reads:
\begin{quote}
6. The method of claim 5 wherein said data is X-ray attenuation data produced in a two dimensional field by a computed tomography scanner.
\end{quote}
\textit{Id.}
\item \textsuperscript{110} \textit{In re Walter}, 618 F.2d 758, 767 (C.C.P.A. 1980).
\item \textsuperscript{111} \textit{Abele}, 684 F.2d at 907.
\item \textsuperscript{112} \textit{Id.}
\item \textsuperscript{113} \textit{Id.}
\item \textsuperscript{114} \textit{Gottschalk v. Benson}, 409 U.S. 63, 71-72 (1972).
\end{itemize}
process in which it is applied would not infringe a claim defining that specific process.

Abele's claimed invention included a mathematical algorithm. The calculating step of claim 5 was on its face a mathematical operation. A mathematical step alone was sufficient to find that the claim contained a mathematical algorithm, which required that one further analyze the claim under the second part of the Freeman test.115

The court set forth a statutory subject matter line between claims 5 and 6.116 Claim 5 merely presented and solved a mathematical algorithm for calculating a number. The step of displaying the result was akin to post-solution activity and thus not a sufficient limitation to pass the second part of the Freeman test. The mathematical algorithm of calculating, as presented in claim 5, was not applied to any specific process or further limited or defined in any way. The court thus held that claim 5 defined non-statutory subject matter.117

The court reached the opposite result with respect to claim 6.118 This claim did not pre-empt the mathematical algorithm for calculating a number, because claim 6 specified that the mathematical algorithm was operating on x-ray attenuation data produced in a CAT scan process. With this limitation, others would be free to use the algorithm, provided that it was not used in conjunction with CAT scanning. In comparing claim 6 to the improved rubber curing process of Diehr, the court found that Abele had invented an improved method of CAT scanning.119 Claim 6 thus defined statutory subject matter.

b. In re Grams: The Overbreadth Doctrine

In re Grams120 involved a method of testing for abnormal conditions in individuals. The method involved using data derived from clinical laboratory tests on the individual. The test data was compared with predetermined values to determine an abnormal condition. If this comparison indicated an abnormality, the method further successively tested different combinations of constituents of the individual in order

115. See In re Walter, 618 F.2d 758, 767 (1980); In re Freeman, 573 F.2d 1237, 1245 (1978).
116. Abele, 684 F.2d at 908-09.
117. Id. at 909.
118. Id. at 908.
119. Id. at 909. One may view the additional limitation, at least in part, as a data gathering step. The inclusion of data gathering steps with a mathematical algorithm, however, does not necessarily result in a statutory process. See, e.g., In re Meyer, 688 F.2d 789 (C.C.P.A. 1982); In re Sarkar, 588 F.2d 1330 (C.C.P.A. 1978); In re Richman, 563 F.2d 1026 (C.C.P.A. 1977); In re Chatfield, 545 F.2d 152 (1976), cert. denied, 434 U.S. 875 (1977); In re Christensen, 478 F.2d 1392 (C.C.P.A. 1973).
120. 888 F.2d 835 (Fed. Cir. 1989).
to effectively eliminate potential abnormalities and thus narrow the class of abnormalities which could apply to the individual.²¹

This claim was of the type that appeared on its face to be on the borderline of patentable and non-patentable subject matter. Once again, the court had to decide how little matter, or few limitations, could be added to a mathematical algorithm in order to produce a statutory claim.

The mathematical algorithm dominated Grams' claims.²² Each step, with the exception of the first step, involved a mathematical operation. These mathematical steps involved the computations of comparing data which produced a result in a finding of an abnormal condition. Only the first step, performing clinical laboratory tests, was deemed to be not within the mathematical algorithm included in the claim. The step of performing clinical laboratory tests, however, was not a sufficient limitation to produce a claim that defined the application of a mathematical algorithm to an otherwise statutory process. The first step was actually a data gathering step. The clinical laboratory tests provided data to the mathematical algorithm. The court characterized the mathematical algorithm as the focus of the claim and the data gathering step to be only incidental to the solution of the mathematical algorithm.²³ A data gathering step is similar to the post-solution activity or field of use limitations in that it was determined to be not a sufficient limitation to move a mathematical algorithm into the scope of patentable subject matter. Unlike the "improved" processes claimed by Diehr and Abele, the court did not consider Grams' claim an improvement over any known processes.²⁴

c. In re Iwahashi: The Elusive ROM

Four days after the Grams decision, the Court of Appeals for the Federal Circuit (CAFC) held a claim statutory in In re Iwahashi.²⁵

121. The basic steps in the method read:

1. A method of diagnosing an abnormal condition in an individual . . . the method comprising [a] performing said plurality of clinical laboratory tests on the individual to measure the values of the set of parameters; [b] producing . . . a first quantity representative of the condition of the individual; [c] comparing the first quantity to a first predetermined value . . . [d] upon determining from said comparison that the individual's condition is abnormal, successively testing a plurality of different combinations of the constituents of the individual by eliminating parameters from the set to form subsets corresponding to said combinations . . . and [e] identifying as a result of said testing a complementary subset of parameters . . .

Id. at 837 (emphasis and bracketed letters in original).

122. Id. at 840.

123. Id.

124. Id.

125. 888 F.2d 1370 (Fed. Cir. 1989).
Iwahashi had invented hardware apparatus for performing auto-correlation. The auto-correlation circuitry was intended for use in pattern recognition. Each element of the claim defined a mathematical function, except the element of a read only memory (ROM).\textsuperscript{126} The ROM performed the function of generating square values. A first adder performed the function of adding sample values and then applied the result to the ROM. In response, the ROM generated the square values of the inputs. Additional circuitry, coupled to the ROM, then performed additional mathematical computations to complete the auto-correlation algorithm.

The claim included a mathematical algorithm.\textsuperscript{127} Each of the claimed elements, with the exception of the ROM, defined a specific mathematical operation. The court considered whether the claim contained sufficient structural or apparatus limitations to avoid pre-empting the auto-correlation algorithm.

Computer hardware, such as that disclosed in Iwahashi, is patentable subject matter as a machine.\textsuperscript{128} Furthermore, a specific hardware apparatus for calculating a mathematical algorithm will in general not pre-empt the algorithm, since other hardware embodiments are available for calculating the algorithm. In cursory fashion, the court concluded that the claim defined an apparatus that would qualify as a machine and thus be patentable subject matter.\textsuperscript{129} The court analyzed

\begin{footnotesize}
\textsuperscript{126} The appealed claim reads:

An auto-correlation unit for providing auto-correlation coefficients for use as feature parameters in pattern recognition for \( N \) pieces of sampled input values \( X_n (n=0 \text{ to } N-1) \), said unit comprising:

- means for extracting \( N \) pieces of sample input values \( X_n \) from a series of sample values in an input pattern expressed with an accuracy of optional multi-bits;
- means for calculating the sum of the sample values \( X_n \) and \( X_n - Z \) (\( t = 0 - P, \ P < N \));
- a read only memory associated with said means for calculating;
- means for feeding to said read only memory the sum of the sampled input values as an address signal;
- means for storing in said read only memory the squared value of each sum, \( (X_n + X_n - Z)^2 \);
- means for fetching and outputting the squared values of each such sum of the sample input values from said read only memory when said memory is addressed by the sum of the sample input values; and
- means responsive to the output \( (X_n + X_n - Z)^2 \) of said read only memory for providing an auto-correlation coefficient for use as feature parameter according to the following formula . . . .

\textit{Id.} at 1373.

\textsuperscript{127} \textit{Id.}


\textsuperscript{129} \textit{Iwahashi}, 888 F.2d at 1375: "The claim as a whole certainly defines apparatus in the form of a combination of interrelated means and we cannot discern any logical reason why it should not be deemed statutory subject matter as either a machine or a manufacture as specified in § 101." The court's treatment of the apparatus claim that included a
the means-plus-function clauses in the claim in view of the specific hardware embodiment disclosed in the specification in accordance with the requirement of 35 U.S.C. § 112, ¶ 6. In this analysis, the claimed elements did not pre-empt the mathematical algorithm, since the means-plus-function elements are construed to cover the corresponding disclosed structure and their equivalents. Thus, each of these elements does not cover all hardware apparatus for performing the specified function.130

d. Arrhythmia Research Technology, Inc. v. Corazonix Corp.: Claims that Define a Solution to a Specific Problem

The CAFC in Arrhythmia Research Technology, Inc. v. Corazonix Corp.131 acknowledged the underlying premise in the Supreme Court precedent. Abstract ideas, laws of nature, and scientific principles may not be patented.132 Mathematical equations per se are outside the realm of patentable subject matter. Applications of abstract mathematics to a specific process, however, may be patented.

Arrhythmia Research sued Corazonix for infringement of U.S. Patent No. 4,422,459 (Simson patent).133 The district court granted Corazonix summary judgment, holding that the Simson patent was invalid for failing to claim patentable subject matter. Arrhythmia Research appealed. The CAFC reversed the district court, holding that the Simson patent claims defined patentable subject matter.134

The Simson patent related to the analysis of electrocardiographic signals. Heart attack victims are vulnerable to a type of heart arrhythmia, known as ventricular tachycardia, shortly following the heart attack. The system and process claimed by the Simson patent can determine which heart attack patients are at risk for ventricular tachycardia. A particular type of signal, called “late potentials,” appears in the QRS segment of electrocardiographic signals in patients vulnerable to ventricular tachycardia. The Simson invention detected these late potentials to determine which patients are at risk.135

130. Id.
132. See supra note 32 and accompanying text.
133. Arrhythmia, 958 F.2d at 1054.
134. Id.
135. Claim 1 is the broadest method claim.
The Simson invention used steps involving mathematical equations. The invention first performed an analog-to-digital conversion of the QRS signal segments. The digitized QRS segments were then applied in reverse time order, i.e., backwards, to a high pass filter. The filter output was averaged. Finally, a comparison of the average value to a predetermined level indicated if the patient was at risk.\footnote{1}

Corazonix argued that claim 1 merely defined an abstract mathematical algorithm that calculates a number. Arrhythmia Research countered by stating that the claimed invention is a specific method of analyzing electrocardiographic signals. The court was thus presented with the issue of whether the Simson patent claims defined patentable subject matter.\footnote{137}

The CAFC in \textit{Arrhythmia Research} first recognized that \textit{Diehr} superseded portions of the \textit{Benson} and \textit{Flook} holdings.\footnote{138} \textit{Diehr} explained that the algorithm rule of \textit{Benson} stands for the long-standing principle that laws of nature, scientific principles, and abstract ideas are not patentable.\footnote{139} This theory is a reasonable interpretation of \textit{Diehr} and places a severe limitation on the original mathematical algorithm exception set forth in \textit{Benson}.\footnote{140}

The CAFC then applied the \textit{Freeman-Walter-Abele} two-part test to the appealed claims. First, the method claim included a mathematical algorithm due to mathematical equations in the Simson patent specification which support some of the process steps. Under the second part

\begin{quote}
\begin{itemize}
\item A method for analyzing electrocardiographic signals to determine the presence or absence of a predetermined level of high frequency energy in the late QRS signal, comprising the steps of:
\begin{itemize}
\item converting a series of QRS signals to time segments, each segment having a digital value equivalent to the analog value of said signals at said time;
\item applying a portion of said time segments in reverse time order to high pass filter means;
\item determining an arithmetic value of the amplitude of the output of said filter;
\end{itemize}
and
\item comparing said value with said predetermined level.
\end{itemize}
\end{quote}

\textit{Id.} at 1055.

\footnote{136} \textit{Id.}

\footnote{137} \textit{Id.} at 1058.

\footnote{138} \textit{Id.} at 1057 n.4.

\footnote{139} Diamond v. Diehr, 450 U.S. 175, 185 (1981).

of the test, the court held that the claim defined an otherwise statutory process, since the equations are applied to a specific method for analyzing electrocardiograph signals.\textsuperscript{141}

At least two aspects of the court's reasoning are significant. The court placed emphasis on the claim preamble in determining what the claimed steps do. As recited in the preamble, the claim was a specific "method for analyzing electrocardiographic signals" and defined a solution to the problem of determining which heart attack victims are at risk for ventricular tachycardia.\textsuperscript{142} It was not an abstract method of solving a mathematical equation. The preamble seemed to indicate a "field of use," which is a specific application of the claimed method. In prior cases, arguing a field of use was not always successful in attempting to show that a claim was statutory.\textsuperscript{143} The court has, however, emphasized that one must analyze a claim "as a whole" to determine patentable subject matter.\textsuperscript{144} Accordingly, the claim preamble must not be ignored in analyzing what the claim defines.\textsuperscript{145}

The court also addressed Corazonix's argument that the claim merely presented and solved a formula, since the output was simply a number. This argument had been successful in previous cases to show that a claim did not define patentable subject matter.\textsuperscript{146} The court, however, rejected the argument. The output (end result) was not an abstract number; it represented a voltage that measured heart activity and indicated the risk of ventricular tachycardia.\textsuperscript{147} Number processing inherently forms a part of computer-implemented software algorithms. Whether the end result is a number is not even a factor in determining patentable subject matter.

The \textit{Arrhythmia Research} decision shows the increasing strength of software patent protection.\textsuperscript{148} The CAFC has repeatedly recognized that the \textit{Diehr} decision severely limited the far-reaching mathematical

\begin{footnotesize}
\begin{itemize}
\item \textsuperscript{141.} \textit{Arrhythmia}, 958 F.2d at 159-60.
\item \textsuperscript{142.} \textit{Id.} at 1059.
\item \textsuperscript{143.} See, \textit{e.g.}, Parker v. Flook, 437 U.S. 584, 595 (1978); \textit{In re Walter}, 618 F.2d 758, 769 (C.C.P.A. 1980).
\item \textsuperscript{144.} \textit{In re Noll}, 545 F.2d 141, 147 (C.C.P.A. 1976), \textit{cert. denied}, 434 U.S. 875 (1977).
\item \textsuperscript{145.} \textit{See Arrhythmia}, 958 F.2d at 1059.
\item \textsuperscript{146.} See, \textit{e.g.}, Parker v. Flook, 437 U.S. 584, 590 (1978); \textit{In re Abele}, 684 F.2d 902, 909 (C.C.P.A. 1982); \textit{In re Walter}, 618 F.2d 758, 770 (1980); \textit{In re Gelnovatch}, 595 F.2d 32, 41 n.7 (C.C.P.A. 1979).
\item \textsuperscript{147.} \textit{Arrhythmia}, 958 F.2d at 1060.
\item \textsuperscript{148.} Judge Rader wrote a concurring opinion in which he adopted a statutory construction approach, analyzing the language of § 101. He stated that \textit{Diehr} limited \textit{Benson} to three classes of non-patentable subject matter: laws of nature, natural phenomena, and abstract ideas. Since the mathematical algorithm rule of \textit{Benson} had failed, \textit{Diehr} mandated that one should consult the statutory language for determining patentable subject matter instead of using judicially-created tests. \textit{Id.} at 1066.
\end{itemize}
\end{footnotesize}
algorithm rule of Benson. It is only the highly abstract and non-specific claimed algorithms incorporating mathematical steps that are outside the realm of patentable subject matter. This follows from the basic premise that laws of nature, abstract ideas, and scientific principles may not be patented. Nearly all software programs are a solution to a specific problem and will, therefore, be within the scope of patentable subject matter.

II. ANALYSIS

A. SYNTHESIS OF THE BENSON-FLOOK-DIEHR TRILOGY

1. A Reasonable Meaning for "Mathematical Algorithm"

Determining the meaning of "mathematical algorithm" is critically important in a § 101 analysis of claims that incorporate mathematical formulas. It is a mathematical algorithm which cannot be preempted under the Diehr holding. The Supreme Court defined a mathematical algorithm as "a procedure for solving a given type of mathematical problem." Other courts have struggled with determining precisely the extent of this definition.

149. See, e.g., id. at 1057 n.4; In re Grams, 888 F.2d 835, 839 (Fed. Cir. 1989).
150. See supra note 32 and accompanying text.
152. Diehr, 450 U.S. at 191 (stating that abstract mathematical formulas may not be patented).
154. See In re Meyer, 688 F.2d 789, 794-95 (C.C.P.A. 1982); In re Pardo, 684 F.2d 912, 915-16 (C.C.P.A. 1982); In re Walter, 618 F.2d 758, 764-65 (C.C.P.A. 1980); In re Gelnovatch, 595 F.2d 32, 45 (C.C.P.A. 1979); In re Toma, 575 F.2d 872, 877 (C.C.P.A. 1978); In re Freeman, 573 F.2d 1237, 1245 (C.C.P.A. 1978); In re Chatfield, 545 F.2d 152, 156 n.5 (C.C.P.A. 1976), cert. denied, 434 U.S. 875 (1977).

The recitation of a solution to a mathematical problem is not always readily apparent from the claims. See, e.g., In re Grams, 888 F.2d 835, 836-37 (Fed. Cir. 1988) (method of diagnosing abnormal condition in an individual recited a mathematical algorithm); In re de Castelet, 562 F.2d 1236, 1239 (C.C.P.A. 1977) (indirectly reciting equations for generating curves); compare In re Waldbaum, 559 F.2d 611, 616 (C.C.P.A. 1977) (controlling a data processor was a mathematical problem) with In re Deutsch, 553 F.2d 689 (C.C.P.A. 1977) (controlling a system of multi-unit plants was not a mathematical problem).

The court in Waldbaum distinguished Deutsch by stating that the algorithms in Deutsch were applied to a specific method of operating manufacturing plants, Waldbaum, 559 F.2d at 617, and the claims at issue in Waldbaum covered any use of the algorithms for controlling a processor. Id. at 616.
The Supreme Court's definition, unfortunately, is both hopelessly vague and overly broad.\textsuperscript{155} The term "mathematical problem" creates a dichotomy in a determination of which algorithms are mathematical algorithms. A mathematical problem encompasses at least the solution to mathematical formulas. Mathematical problems, however, may also encompass many inventions which are indisputably patentable subject matter. Since mathematics describe the way things work, a mechanical invention could feasibly be a mathematical problem.

A reasonable definition for mathematical algorithm follows from the common theme of all § 101 cases. Abstract ideas, scientific principles, and laws of nature cannot be patented.\textsuperscript{156} These are the basic tools of research and historically have been excluded from patentable subject matter. When one applies this theme to computer programming,\textsuperscript{157} which was present in the issues of Benson, Flook, and Diehr, a more practical definition for mathematical algorithm becomes apparent.

A "mathematical algorithm" is a computer-implemented solution to an abstract scientific principle or law of nature. This workable definition of mathematical algorithm addresses both the issue of computer programming present in the cases as well as acknowledging the \textit{stare decisis} effect of the traditionally recognized non-patentable classes of subject matter. Abstract mathematical formulas are encompassed by this definition, since they would be within either the scientific principles or laws of natures classes of unpatentable subject matter.\textsuperscript{158} If a

\textsuperscript{155} See, e.g., \textit{In re} Pardo, 684 F.2d 912 (C.C.P.A. 1982). The claims at issue, which did not even contain a mathematical algorithm, covered a method of controlling the execution of program steps in a computer. The claimed process basically involved three steps: (1) examining formulas in a data storage area of a processor to determine which formulas could be designated as defined; (2) executing the designated formulas in the order in which they were designated as defined; and (3) repeating steps (1) and (2) for the undefined formulas until these formulas have been defined and executed. \textit{Id.} at 913.

The \textit{Benson} decision created havoc for the unfortunate patent applicant. During prosecution of the patent application, which was filed in 1970 and received a notice of allowance in 1972, the release of the \textit{Benson} decision reopened prosecution, removing the notice of allowance. The applicant's specification described part of the invention as an "algorithm." The PTO used that fact to state that the applicant made an admission that the invention covered a mathematical algorithm and was, therefore, not patentable subject matter. \textit{Id.} at 914. Ten years after the applicant had originally received a notice of allowance, the CCPA summarily disposed of the PTO's position by stating that the appealed claims did not even contain a mathematical algorithm. \textit{Id.} at 916.


\textsuperscript{157} The § 101 issues have revolved around claims for computer-related inventions that include mathematics. \textit{Walter}, 618 F.2d at 764 n.4.

\textsuperscript{158} See Diamond v. Diehr, 450 U.S. 175, 186 (1981); but see \textit{In re} Meyer, 688 F.2d 789, 794-95 (C.C.P.A. 1982). The court \textit{Meyer} first stated that laws of nature and scientific principles can be expressed in mathematical format. The court then stated that "some mathematical algorithms and formulae do not represent scientific principles or laws of na-
The Benson decision supports this definition. In particular, the facts of the Benson case reveal that the Benson invention was no more than the solution to an abstract mathematical formula. The following is the Benson claim 1 rewritten with the equivalent mathematical steps.

The method of converting signals from binary coded decimal form into binary which comprises the steps of

1. storing the BCD number in a reentrant shift register,
2. dividing the BCD number by at least 8,
3. logically ANDing the BCD number with 11012,
4. adding 1 to the BCD number,
5. multiplying the BCD number by 4,
6. adding 1 to the BCD number, and
7. dividing the BCD number by at least 8.

Each step of the rewritten claim, with the exception of the storing step, represents a pure mathematical function. The steps of shifting a number contained within a shift register represent a multiply or divide operation. Shifting the number in the shift register to the right performs division on the number by multiples of two, depending upon how many places the number is shifted. Shifting the number to the left performs multiplication of the number by multiples of two. For example, the number 10102 (1010) shifted to the right one position becomes 1012 (510) which is 10 divided by 2. Shifting the number 1012 one position to the left would result in a number 10102 (1010), which is 5 X 2. Shifting the number 10102 one more position to the left would result in the number 101002 (2010), which is 5 X 4.

The third step of masking out the second position of the register may be accomplished by ANDing the contents of the register with 11012 (1310). With a "1" in the first, third and fourth positions, the logical AND operation will simply result in a number already present in those
positions of the register, while the "0" in the second position ensures a "0" in the result of the AND operation.

With the claim written in this equivalent form, it is apparent that the claim actually defines no more than a solution to a pure mathematical formula. The step of storing simply defines computer memory capability, which is required in any computer programming. The equivalent claim shown above may furthermore be represented by a pure mathematical formula, using base-ten numerals, as follows:

\[ (((\text{BCD number} / 8) \times 13) + 1) \times 4 + 1 \] / 8 = binary number

This equation represents the solution defined by Benson's claim. The claim merely solved an abstract formula for number conversion.

A further significant aspect of the Benson holding is what it is not. The Court recognized that Benson's claim preempted a mathematical formula, and, as shown above, the claim defined no more than a solution to a mathematical formula. It was the attempt to patent an abstract mathematical formula which concerned the Court. Mathematics \textit{per se} are not patentable under the Benson holding. The Court, however, expressly made it clear that they did not intend to preclude patent protection for any computer-implemented invention. "It is said that the decision precludes a patent for any program servicing a computer. We do not so hold." The Benson holding, therefore, cannot preclude all patent protection for computer-implemented inventions.

Diehr also supports the definition of "mathematical algorithm" explained above. Diehr stated that Benson stood for no more than the long established principle that abstract ideas, scientific principles, and law of nature cannot be patented. Furthermore, the Diehr court, in discussing Flook, recognized that the claims at issue in Flook defined no more than the solution to a formula for calculating an alarm limit. Therefore, Diehr implicitly recognized that it is only processes for solving abstract mathematical formulas that are exempt from patent protection, which is based upon the traditionally recognized classes of non-patentable subject matter.

163. Gottschalk v. Benson, 409 U.S. 63, 71 (1972); See, e.g., Diamond v. Diehr, 450 U.S. 175, 187 (1981) (citing Benson for the proposition that "a claim drawn to subject matter otherwise statutory does not become nonstatutory simply because it uses a mathematical formula, computer program, or digital computer").


165. Id. at 71.

166. Diehr, 450 U.S. at 185.

167. Id. at 186-87.
2. A Problem-Solution Approach to Determining Mathematical Algorithm Pre-emption

Pre-emption is a key element in § 101 analysis. In order to be statutory, a claim must define subject matter that does not pre-empt a mathematical algorithm. Once it has been determined exactly what is a mathematical algorithm, one must analyze claims containing suspect subject matter to determine whether pre-emption exists. While the Supreme Court has focused primarily on pre-emption itself, the lower courts have devised tools of analysis for determining pre-emption, such as the Freeman-Walter-Abele two-part test.

The two-part test is not the only test for determining patentable subject matter. Furthermore, the Supreme Court in Diehr did not expressly adopt the two-part test. In fact, the Court did not even cite the Freeman or Walter decisions. In discussing the invention at issue in Diehr, however, the Court emphasized that the mathematical formula used by the invention was applied to a specific process and solved a problem that had existed in the industry. The Diehr decision, therefore, supports the proposition that a claim for an invention which includes a mathematical algorithm will not pre-empt the mathematical algorithm if the claim defines a solution to a specific problem, without regard to whether the solution is new or non-obviousness. Stated in another way, a claim that incorporates a mathematical algorithm and defines the solution to a specific problem, and not merely the solution to a mathematical formula, will define patentable subject matter. This is a problem-solution approach.

Fundamental Supreme Court precedent from the mid-1800s supports the problem-solution approach. The Supreme Court in the 1861 Le Roy v. Tatham decision, which the Diehr court cited, hinted at a problem-solution approach.

169. See cases cited supra note 168.
170. See cases cited supra note 168.
171. See In re Abele, 684 F.2d 902, 907 (C.C.P.A. 1982); In re Walter, 618 F.2d 758, 767 (C.C.P.A. 1980); In re Freeman, 573 F.2d 1237, 1245 (C.C.P.A. 1978).
172. Arrhythmia Research Tech., Inc. v. Corazonix Corp., 958 F.2d 1053, 1058 (Fed. Cir. 1992); In re Meyer, 688 F.2d 789, 796 (C.C.P.A. 1982). Furthermore, if a claim fails to meet the two-part test, it is possible that the claim could still define patentable subject matter. Arrhythmia, 958 F.2d at 1058; In re Grams, 888 F.2d 835, 839 (Fed. Cir. 1989).
174. 63 U.S. 132 (1861).
175. Diehr, 450 U.S. at 185, 188. Diehr, cited the earlier decision of Le Roy v. Tatham, 55 U.S. 156 (1853). The same fundamental principles of patentable subject matter are discussed in both Le Roy decisions.
using a problem-solution approach in holding that an improved method of making lead pipe defined patentable subject matter.\footnote{176} 

The patentee in \textit{Le Roy} discovered a principle of lead that allowed the invention to be possible.\footnote{177} Prior art techniques of making pipe had involved forming the pipe in a mold.\footnote{178} The patentee discovered that superior pipe could be developed from heat and constriction of the metal from a set or solid state.\footnote{179} In comparison to the prior art, lead pipe or pipe of other soft metals formed according to the improved method could be made in any required length, contained much fewer defects, and was capable of withstanding greater pressures.\footnote{180} 

One issue before the Court involved determining if this improved method defined patentable subject matter.\footnote{181} The patentee's invention operated according to a newly discovered principle of soft metals.\footnote{182} Principles in the abstract, however, had been traditionally excluded from patent protection.\footnote{183} The Court considered whether the patentee's use of the principle was the proper subject matter for a patent.

The Court recognized that the patentee's method of making lead pipe solved a problem.\footnote{184} The patentee had not simply discovered a new principle of metal that allowed the invention to be possible, but instead had applied the principle to a specific method to produce lead pipe. The invention solved the problem that had existed in the industry of reliably and consistently producing quality lead pipe.\footnote{185} The Court emphasized that scientific principles are not patentable and must be applied to a practical purpose to effectuate a result in order to define patentable subject matter. A specific problem defines a “purpose,” and a solution to that problem is the effectuation of a “result.”

\footnote{176}{Le Roy, 63 U.S. at 135-37.}
\footnote{177}{Id. at 137.}
\footnote{178}{Id. at 135.}
\footnote{179}{Id.}
\footnote{180}{Id. The claim read:}
The combination of the following parts above described is claimed, to wit, the core and bridge, or guide-piece, with the cylinder, the piston, the chamber, and the die, \textit{when used to form pipes of metal, under heat and pressure}, in the manner set forth, or in any other mode substantially the same. \footnote{Id. at 138 (emphasis added).}
\footnote{181}{Id. at 137.}
\footnote{182}{Id.}
\footnote{183}{Id. (quoting Househill Company v. Neilson, Webster's Patent Cases, 683): “It is quite true, that a patent cannot be taken out solely for an abstract philosophical principle—for instance, for any law of nature or any property of matter, apart from any mode of turning it to account”.}
\footnote{184}{Id. at 135.}
\footnote{185}{Id.}
By analogy to Le Roy, the Diehr court stated that the claimed invention had solved a problem.\textsuperscript{186} The invention of Diehr solved the problem that had existed in the industry of consistently obtaining quality cures of synthetic rubber.\textsuperscript{187} In setting forth its reasoning, the Diehr court did not adopt the Freeman two-part test, but instead cited fundamental patentable subject matter precedent stated in Le Roy.\textsuperscript{188} The Diehr holding is an extension of these basic principles and includes analyzing claims to determine what an applicant has invented. A claim that defines a solution to a specific problem evidences the application of scientific principles and is within the realm of patentable subject matter.

The Benson decision also supports the problem-solution approach to determining patentable subject matter. As described above, Benson's claim defined no more than the solution to a mathematical formula for performing number conversion. As recognized by the Court, Benson's invention for number conversion was not applied to any specific problem.\textsuperscript{189} One may argue that Benson's invention solved the problem of converting BCD numerals into binary numbers. A response, however, would be to ask why number conversion is useful in the first place. Benson did not claim the use of BCD to binary number conversion in a solution to a particular problem. Benson merely claimed the solution to a mathematical formula.\textsuperscript{190}

The problem-solution approach also harmonizes reasoning used within the post-Diehr lower court decisions. In Abele, the claimed invention solved the problem of displaying x-ray attenuation data received while using a CAT scan process that exposed the body to much less radiation than in the prior art.\textsuperscript{191} The non-statutory claim 5, however, was not directed to any particular technology and merely defined a method of displaying data using the mathematical step of calculating.\textsuperscript{192} An inspection of claim 5 does not reveal any particular problem solved by the mathematical algorithm incorporated into claim 5. Claim 6 further limited claim 5 to the display of x-ray attenuation data produced in a two-dimensional field by a computed tomography scanner.\textsuperscript{193} Claim 6 thus adds a limitation to claim 5 which makes it apparent a problem solved by the claimed invention: display of x-ray attenuation data obtained from a narrower x-ray beam.

\begin{itemize}
\item \textsuperscript{186} Diamond v. Diehr, 450 U.S. 175, 178 (1981).
\item \textsuperscript{187} \textit{Id.}
\item \textsuperscript{188} \textit{Id.} at 185, 188 (\textit{citing} the earlier decision of Le Roy v. Tatham, 55 U.S. 156 (1853)).
\item \textsuperscript{189} Gottschalk v. Benson, 409 U.s. 63, 68 (1972).
\item \textsuperscript{190} \textit{Id.} at 68, 71.
\item \textsuperscript{191} \textit{In re} Abele, 684 F.2d 902, 904 (C.C.P.A. 1982).
\item \textsuperscript{192} \textit{Id.} at 908.
\item \textsuperscript{193} \textit{Id.}
\end{itemize}
In *Grams*, the claimed method of diagnosing an abnormal condition focused on the solution to a mathematical formula. The claimed steps of the method, with the exception of the step of performing clinical laboratory tests, each constituted a mathematical operation. It is not apparent from the claim in *Grams* how the solution to the mathematical algorithm for identifying an abnormal condition is applied to any specific process for solving a particular problem. The specification of *Grams* even asserts that the mathematical algorithm may be applied to *any* complex system, whether it be electrical, mechanical, chemical or biological. The claimed method, however, did not solve a specific problem in any particular complex system; it merely solved a formula.

The *Iwahashi* invention presents more difficulty, but still fits within a problem-solution theory. One may argue that Iwahashi's claimed invention merely solved a formula for auto-correlation. At least two responses are possible to overcome this argument. First, Iwahashi's claimed method for performing auto-correlation may be viewed as solving the problem of increasing the speed of auto-correlation computations when compared with a general purpose computer. If Iwahashi's method had merely been implemented on a general purpose computer, the claim would have been non-statutory as pre-empting the mathematical formula. The specialized hardware included as limitations in Iwahashi's claim provided a distinct benefit. "*[T]his invention offers a highly cost-effective auto-correlation unit for pattern recognition with simple circuitry without the need to use an expensive multiplier, but which has comparatively high accuracy and can, moreover, calculate auto-correlation coefficients at high speed."

Under a problem-solution theory, Iwahashi's claimed method solved the problem of a need for specialized hardware that efficiently, accurately, and at high speed solves auto-correlation functions.

Second, Iwahashi's claim may be viewed as a statutory "machine." The claim included specific hardware and structural limitations which distinguished it over a general purpose computer. Even though a ROM is the only actual physical element in the claim, the means-plus-function clauses are construed to cover the disclosed structure and their equivalents. Therefore, even the means-plus-function clauses distinguish over a general purpose computer by covering only Iwahashi's particular hardware disclosed in the specification as well as the equivalents.

195. *Id.*
Finally, in *Arrhythmia*, the CAFC emphasized a problem solved by the claimed invention. The claimed method included mathematical steps, such as digital filtering and comparisons, in performing an analysis of electrocardiograph signals. The invention, however, was not simply a collection of mathematical steps; it solved a particular problem by using a specific method. The inventor, Dr. Simson, had sought a solution to the problem of determining which heart attack victims were at high risk for ventricular tachycardia. The court focused on the solution set forth in the claim preamble to hold that the claim was statutory and did not pre-empt abstract mathematical computations.

B. THE FUTURE OF SOFTWARE PATENT PROTECTION

Some commentators have either criticized *Benson* or argued that the decision should be overruled. The underlying premise of *Benson* is that scientific principles, law of nature, and abstract ideas may not be patented. *Benson* further refined these classes of non-patentable subject matter to hold that mathematical formulas *per se* may not be patented. Overruling *Benson* would mean tampering with long established principles and allowing at least some patent protection for mathematical formulas.

Presently, non-statutory computer-implemented inventions are fairly well discernable under *Diehr*. If mathematical formulas can be patented, developing tools of analysis for determining which formulas may be patented and which may not would be an exceedingly difficult task. One would have to determine when an abstract mathematical formula would become a statutory process, and this analysis would tend to conflict with the basic rule that scientific principles may not be patented, since abstract mathematical formulas may be viewed as falling within the scientific principles category.


200. *Id.*

201. *Id.* at 1059.


205. *See supra* note 158 and accompanying text.
Certain anti-software groups argue that software patent protection has a relatively weak legal basis.\(^{206}\) This is not true. *Diehr* firmly supports much patent protection for software,\(^{207}\) and *Benson* supports at least some software patent protection.\(^{208}\) Even without *Diehr*, though, most software inventions would not be subject to the *Benson* rule. Software inventions typically do not include a mathematical algorithm and thus could not pre-empt an abstract mathematical formula. These types of inventions include, for example, database structures,\(^{209}\) program algorithms,\(^{210}\) and user-interfaces.\(^{211}\) Even before *Benson*, the courts had established that a computer programmed in a new way is a statutory invention.\(^{212}\) The *Benson* court did not tamper with this principle and expressly did not extend the holding to pre-empt any patent protection for computer programming.\(^{213}\)

**CONCLUSION**

Patent protection for software inventions has been mired in controversy. The Supreme Court precedent related to software, and other


Those opposing software patent protection often also argue that allowing patent protection for mathematical algorithms will result in the PTO granting patents on "obvious" algorithms and basic building blocks of software. Schrage, *The Patently Absurd Way We Protect Software and Biotech Innovations*, *Wash. Post*, Oct. 25, 1991, at F3. The concern over the patenting of basic software building blocks hinges not on patentable subject matter, but on other statutory requirements for patentability, such as non-obviousness.

The Software Patent Institute is currently working on assembling a public database of issued software patents and related information, which could include fundamental algorithms, that would be made available to the PTO for prior art searching. Busse, *Software Floods the Patent Office*, *InfoWorld*, Sept. 30, 1991, at 39. The PTO is also taking steps to maintain pace with the increased filings of software patent applications. These steps include: (1) a revised classification system to help divide up software patents into more specific categories; (2) new training and specialization among examiners so that the examiners work on related applications instead of working on many unrelated software patent applications; and (3) a computerized search system to replace an outdated microfiche database. *Id.*; Burke, *U.S. Agency Revamps Software Patent System; U.S. Patent Office*, *PC Week*, May 27, 1991, at 145.


\(^{209}\) See, e.g., U.S. Patent No. 4,926,344 (entitled "Data Storage Structure of Garment Patterns to Enable Subsequent Computerized Prealteration").

\(^{210}\) See, e.g., U.S. Patent No. 4,791,583 (entitled "Method for Global Blending of Computer Modeled Solid Objects Using a Convolution Integral").

\(^{211}\) See, e.g., U.S. Patent No. 5,075,675 (entitled "Method and Apparatus for Dynamic Promotion of Background Window Displays in Multi-Tasking Computer Systems").

\(^{212}\) In re Prater, 415 F.2d 1393, 1403 n.29 (1969); In re Bernhart, 417 F.2d 1395, 1400 (C.C.P.A. 1969).

computer-implemented inventions, is subject to various interpretations. Lower courts have sometimes struggled with determining the scope of patent protection for computer-implemented inventions under the Supreme Court precedent. The PTO also seems to want more guidance regarding the types of software inventions that qualify as patentable subject matter.

A problem-solution approach effectively harmonizes and fits with the Supreme Court precedent. The courts have often inquired in a patentable subject matter analysis as to whether a claim at issue defines a solution to a particular problem. Under the Supreme Court precedent, a claim will be within the realm of patentable subject matter if it defines a solution to a specific problem, and not merely the solution to an abstract mathematical formula.