LEGAL ASPECTS OF ARTIFICIAL INTELLIGENCE

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Abstract

Artificial intelligence is a branch of computer science dealing with computer programs that exhibit the characteristics we associate with intelligence in human behavior. An artificial intelligence program has the ability to "learn" or infer more knowledge from that which it already knows and can therefore perform functions similar to a human expert in a particular field. Legal aspects of protecting the ownership of artificial intelligence technology and minimizing the risk of liability for harm caused by use of artificial intelligence technology are explored in this presentation.

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By Haynes and Boone

I. INTRODUCTION

This presentation is directed to those whose greatest resource is their intellect and, particularly, their ability to generate wealth in the form of intellectual property relating to the field of artificial intelligence technology.

Generally, the owners of any form of technology are vulnerable to those who may seek to use the legal system to extract profit generated by commercialization of the technology, based on physical or economic harm caused by use of the technology. Owners are also vulnerable to those seeking to usurp the technology and use it for their own benefit. The legal system is capable of being used both as a sword against the technology owner and as a shield to protect him, depending on the circumstances. A basic understanding of the law in this area is therefore essential to the technology owner wishing to hedge his position in the marketplace.

The law evolves by adapting traditional legal principles to fact scenarios which change continuously with the development of new technology. Because of rapid advancements in technology, the state of the law often lags behind, meaning that lawyers and judges must struggle with the then-current legal principles to best apply them to serve competing interests. This has been especially true with the federal patent and copyright laws as applied to computer software technology. Contract and tort law as it relates to injury caused by computers and computer software has also lagged technological development.

Uncertainty in the law exists as applied to artificial intelligence technology because the technology has unique characteristics and is relatively new in its commercial application. The broad categories of legal uncertainty include the allocation of liability for losses due to artificial intelligence or expert system errors, and artificial intelligence technology ownership rights in the context of contract and licensing arrangements and patent and copyright principles. With respect to liability, to date there has been no tort law precedent developed that directly involves any artificial intelligence or expert system program.

The discussion which follows is intended to give those working in the artificial intelligence field a familiarity with pertinent legal principles. Practical pointers are provided for maximizing the protection of artificial intelligence technology.

II. FUNDAMENTALS

A. ARTIFICIAL INTELLIGENCE

Artificial intelligence is the part of computer science concerned with designing computer systems that exhibit the characteristics we normally associate with intelligence in human behavior.

1. Ordinary Computer Programs Distinguished

Ordinary computer programs transform inputs to outputs based on an algorithmic process, that is by implementing clearly defined steps based on factual knowledge. Ordinary programs assume a perfect domain of factual knowledge where all states are known, giving an illusion of certainty in the outcome.

Artificial intelligence programs use heuristic processes involving factual and procedural knowledge. Imprecise methods based on rules with less than 100% probability are applied to produce a reasoned result or best "guess" solution to a problem. Heuristic processes work with imperfect domains where all outcomes are not known (as in the real world) and attempt to achieve a goal condition by reasoning an answer when only incomplete information is available. Artificial intelligence programs can also "learn" by changing their reasoning process based on previous solutions.

The ability to infer a result or "reason" based on incomplete information is simultaneously the strength and the weakness of artificial intelligence programs.

2. Types of Artificial Intelligence Systems

a. Expert Systems - Also referred to as knowledge-based systems. The provision of programs designed to act as a human expert within a particular domain (area of expertise).

b. Robotics - The provision of programs to enable robotic devices to perform a variety of tasks emulating human performance.

c. Computer Vision - The provision of programs to enable computers to understand and react to their surroundings through visual input.

d. Speech Recognition - The provision of programs to enable computers and humans to communicate through speech as opposed to reading and writing.

e. Natural Language Processing - The provision of programs to enable computers to communicate with people in human language rather than in a computer language.

f. Computer Assisted Instruction (CAI) - The provision of programs to create intelligent computerized tutors that adapt to the learning patterns of the student.

g. Automatic Programming - The provision of programs for assisting a programmer in designing, testing or writing other programs.

B. COMPONENTS OF AN EXPERT SYSTEM

The function of an expert system is to give reasoned solutions or advice about a particular domain (area of expertise) based on a knowledge base of facts and rules, emulating the reasoning processes of human experts.

1. The principal components of an expert system are a knowledge base, an inference engine and a user interface. The expert system may also include other input or output means.

a. Knowledge Base - The knowledge base contains knowledge about the particular domain. It contains (1) factual knowledge about objects, events or situations and (2) procedural knowledge about courses of action, which may be in the form of rules.

b. Inference Engine - The inference engine directs the use of knowledge in the knowledge base and effectively "runs" the expert system by deciding how and when the rules in the knowledge base are to be applied to the problem, given the input, to achieve an acceptable solution. The inference engine is sometimes referred to as the control structure or rule interpreter.

c. User Interface - The user interface is a component of the expert system that provides for bidirectional communication between the user and the computer. The user interface may be, for example, a screen display and keyboard.

d. Input/Output Means - Other input means may comprise part of the expert system for receiving external information or data from the environment. Other output means may also be provided for performing some action.

2. Examples of Expert Systems

a. Medical Diagnosis Expert System - An expert system used to assist physicians in diagnosing a patient's illness based on the symptoms of the patient. See: "A neural network expert system for diagnosing and treating hypertension", IEEE Computer (March 1991).

b. Geology Expert System - An expert system used for assisting geologists in locating mineral deposits. See: "Model Design in the PROSPECTOR Consultant System for Mineral Exploration", Expert Systems in the Microelectronic Age (1979) at 153.

c. Financial Planning Expert System - Expert systems used for stock and tax planning applications. See: "Financial Expert Systems", Proceedings of the Fifth National Conference on Artificial Intelligence (1988) at 1150.

d. Expert System for Air Traffic Control - An expert system used for the control of air traffic by monitoring and controlling aircraft until turned over to the tower for final approach. See: "Air Traffic Control: A Challenge for Artificial Intelligence", AI Expert (Jan. 1987) at 59-66.

III. <u>LEGAL LIABILITY</u>

Legal liability can result for physical or economic harm caused by the use of artificial intelligence technology. The potential for harm increases with the commercialization of expert systems developed to solve complex problems or perform difficult tasks.

A. POTENTIALLY RESPONSIBLE PARTIES

Because of the nature of the development process for expert systems, persons may be subject to blame when an expert system causes harm.

1. Vendor of Expert System
2. Vendor of Hardware
3. Supplier of Supplemental Software
4. Developer of Inference Engine
5. Knowledge Engineer
6. Human Experts
7. User

B. SOURCES OF LIABILITY

Potential sources of liability derive from the following circumstances that may give rise to harm involving an expert system:

1. The expert system provided an incorrect response.
2. The user relied on the expert system response and should not have done so.
3. The responsible party should have consulted the expert system but did not do so.

C. THEORIES OF LIABILITY

1. Contract
    a. Breach of Contract
    b. Breach of Warranty

2. Tort

a. Strict Liability

b. Negligence

c. Professional Malpractice

d. Fraud or Misrepresentation

3. Texas Deceptive Trade Practices Act

IV. CONTRACT

Many types of contracts may exist which govern the relationships between the various parties involved with the development and use of an expert system. Among them are agreements governing the sale or lease of the expert system by a vendor to a user, software licenses, employment agreements and nondisclosure agreements.

A. PRIVITY REQUIRED

The party seeking remedies in contract must be in privity with the breaching party in order to be entitled to relief. This means the party seeking damages must be a party or intended beneficiary to the contract. A third party suffering harm therefore would not be able to bring a contract action. An exception to this rule is where the Uniform Commercial Code (U.C.C.) applies. Under the U.C.C. a seller's warranty liability will extend to any third party if it is reasonable to expect that party to use the goods and that use results in personal injury.

B. THE UNIFORM COMMERCIAL CODE (U.C.C.)

1. Effect of the Uniform Commercial Code

The U.C.C. provides rules which govern transactions in goods and is in effect, with minor variations, in all states except Louisiana. It is important to determine whether a contract involving an expert system is governed by the U.C.C. because the U.C.C. (a) expands breach of warranty remedies to third parties not in privity; (b) supplies missing contract terms as a matter of law based on explicit rules; and (c) imposes a heightened requirement of good faith and fair dealing on contracting parties.

2. Applicability of the Uniform Commercial Code

Article 2 of the U.C.C. deals only with the sale of goods. A contractual arrangement involving an expert system must be analyzed to determine if the U.C.C. applies.

"Sale" - A lease or license of an expert system arguably is not a "sale," meaning the U.C.C. should not apply to the transaction. See General Hospital Leasing, Inc., 578 S.W.2d 877 (Tex. Civ. App. 1979). However, the structuring of a contract in the form of a lease or license of expert system software will not necessarily mean that the transaction is not a "sale" for purposes of applying the U.C.C. The courts will look to the essence of the transaction. Office Supply Co. v. Basic/Four Corp., 532 F.Supp. 766 (E.D. Wis. 1982).

"Goods" - Generally, packaged software is considered a "good" and custom software is considered a "service", although courts have reached differing results on this issue. Compare: Data Processing Services v. L.H. Smith Oil Corp., 1 U.C.C. Rep. Serv. 20.29 (Ind. Ct. Ap. 1986) (custom software provided by software developer did not constitute "good" under U.C.C. since developer was retained to design, develop and implement computerized system to meet user specific needs); RRX Industries v. Lab-Con, Inc., 772 F.2d 543 (9th Cir. 1985) (software considered good under U.C.C. even though employee training, repair services and system upgrading were provided).

C. BREACH OF CONTRACT

1. What Constitutes Breach

A breach of contract occurs where a party to a contract having an absolute duty to perform an obligation under the contract fails to perform.

Minor Breach - If the breach is minor so that the nonbreaching party still obtains the substantial benefit of the contract, the nonbreaching party must still perform his obligations under the contract. He may seek remedy for the breach.

Material Breach - If the breach is so severe that the nonbreaching party is denied the substantial benefit of his bargain under the contract, the nonbreaching party can treat the contract as at an end and his duty of counterperformance is discharged.

2. Remedies for Breach

a. Compensatory Damages

The purpose of compensatory damages is to compensate the nonbreaching party for loss directly relating to breach.

b. Consequential Damages

The U.C.C. provides that a party may recover consequential damages arising from a breach of contract. U.C.C. § 2-715(2). The purpose of consequential damages is to compensate the nonbreaching party for further losses from breach that were reasonably foreseeable at the time the contract was made. Consequential damages may include lost profits and other damages proximately resulting from the breach.

c. Limitation of Damages

The U.C.C. states that consequential damages may be limited or excluded by agreement unless the limitation is unconscionable. U.C.C. § 2-719(3). Generally, a disclaimer of personal injury damage is considered unconscionable and unenforceable. RRX Industries v. Lab-Con., Inc., 772 F.2d 543 (9th Cir. 1985).

D. BREACH OF WARRANTY

The following types of warranties are provided under the U.C.C.:

1. Warranty of Title and Against Infringement

A seller warrants he has title to the goods being sold and that they were free of patent, trademark or copyright infringement claims. U.C.C. § 2-312.

2. <u>Implied Warranty of Merchantability</u>

A seller warrants that the goods are fit for ordinary purposes for which they are used and will pass without objection in trade. U.C.C. § 2-314.

3. <u>Implied Warranty of Fitness for a Particular Purpose</u>

If seller has reason to know of a particular purpose for which goods are to be used, the buyer may rely on the seller's skill or judgment in selecting the particular goods. U.C.C. § 2-315.

4. <u>Express Warranties</u>

Affirmative statements made by the seller. U.C.C. § 2-313.

V. <u>STRICT TORT LIABILITY</u>

The doctrine of strict liability allows for special liability of sellers of a product for physical harm to a user or consumer. Under a theory of strict liability, recovery may be had against a seller for personal injury without regard to privity of contract and without regard to fault.

A. RESTATEMENT (Second) OF TORTS § 402A (1965)

1. One who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property is subject to liability for physical harm thereby caused to the ultimate user or consumer if:

a. the seller is engaged in the business of selling the product, and

b. it is expected to and does reach the consumer without substantial change in the condition in which it is sold.

2. The rule in subsection 1 applies though (i) the seller has exercised all possible care in the preparation and sale of his product, and (ii) the user or consumer has not bought the product from or entered into a contract with the seller.

B. APPLICABILITY TO EXPERT SYSTEMS

A strict product liability cause of action involving an expert system must meet the following elements to apply: (a) the expert system must be a product; (b) the defendant must be a seller of the expert system; (c) the expert system must reach the injured party without substantial alteration and (d) the expert system must be defective.

1. Whether an Expert System is a Product

a. Criteria for determining whether the expert system is a product include:

(i) whether the expert system is mass marketed or uniquely designed for each customer, and

(ii) whether the service or sale portion of the transaction dominates.

2. Whether Defendant is a Seller of the Product

The provision of application building tools such as expert system skills, editors, compilers or the like or other components can be distinguished from the provision of the integrated computer program or hardware/software of the expert system. Many expert systems may not be provided from one source but integrated by the customer.

3. Whether the Expert System is Altered Before Reaching the End User

The end user may change the programming in the inference engine or modify the knowledge base. The argument of alteration is strengthened also by virtue of the expert system being constructed with the ability to learn and hence alter itself.

4. Whether the Expert System is Defective

Whether the expert system is defective depends to a large extent on what the expectations of the system are and to what extent the user can reasonably allow himself to rely on the expert system; unlike algorithmic programs, expert systems do not always guarantee successful outcomes but make the best possible decisions using inference techniques based on incomplete information.

VI. NEGLIGENCE

The tort of negligence imposes liability for conduct imposing an unreasonable risk to another resulting in damage. In order for a cause of action to exist for negligence, the following elements must be present: (1) the existence of a legal duty of care owed to the injured party; (2) a breach of that duty; (3) actual and proximate cause of the injury by the breach of the duty; and (4) damages.

A. BREACH OF DUTY OF CARE

The general standard of care examined in negligence actions is that of a "reasonable man of ordinary prudence." A higher standard of care is owed by professionals, as will be discussed below. With respect to developers of expert systems, the following standards of care may apply:

1. Duty to Provide a System Based on a Responsible Design

The developer may have a duty to design a system which reasonably contemplates problems that may result from its intended use. In evaluating the reasonableness of the design process a court will be likely to weigh the utility of the design against the risks associated with its use. The court would also evaluate the feasibility of safer alternatives that may be involved in the design to avoid risk of harm.

2. Duty to Supply Information with Reasonable Care

The providers or developers of expert systems may have a duty to use reasonable care in compiling the information for use by the system. This would include reasonable care in developing the facts and rules in the knowledge base.

B. CAUSATION

Causation may be difficult to prove in expert system cases since it is likely that the harm will be caused in some way by human intervention. In order to establish proximate cause for the purposes of negligence, the courts will determine whether the type of harm suffered was reasonably foreseeable under the circumstances.

C. DAMAGES

A person sustaining personal injury or physical damage to property may recover all damages, direct, indirect or consequential, that are proximately caused by the injury. However, many jurisdictions will not allow recovery under a negligence theory of economic losses in the absence of personal injury or injury to property. See, e.g. Cargill Inc. v. Products Engineering Co., 627 F.Supp. 1492 (D. Minn. 1986); Copiers Typewriters Calculators, Inc. v. Toshiba Corp., 576 F.Supp. 312 (D. Md. 1983).

VII. PROFESSIONAL MALPRACTICE

Professional malpractice is the imposition of liability for negligence where the standard of care owed to the injured party is greater than that of a reasonable man of ordinary prudence. Professionals owe a greater duty of care and are held to a standard of an average practitioner in the profession.

A. APPLICABILITY OF COMPUTER MALPRACTICE ACTION TO AN EXPERT SYSTEM DEVELOPER

The developer of an expert system would potentially owe a heightened duty of care if the court applied the standard of a professional to the developer. This would ease the plaintiff's burden of proof for a showing of negligence.

The courts in the past have declined to embrace the tort of computer malpractice. Chatlos Systems v. National Cash Register Corp., 479 F.Supp. 738 (D.N.J. 1979). (Computer malpractice claim dismissed.)

One reason for this is there are no legislative standards which apply to the profession of computer science, and the field is changing so rapidly that if standards were adopted they would be quickly outmoded.

More recent cases indicate that liability might be found based on a computer malpractice theory of recovery. See Data Processing Services, Inc. v. L.H. Smith Oil Corp., 493 N.E.2d 314 (Ind. Ct. App. 1986) (where a programming firm was held liable for professional malpractice). See also Diversified Graphics Ltd. v. Groves, 868 F.2d 293 (8th Cir. 1989) (in which a professional standard of care was applied to computer system consultants).

VIII. MISREPRESENTATION

Liability may exist for misrepresentation or fraud when the seller of an expert system makes misrepresentations about the system which induce reliance by the buyer.

A. STRICT LIABILITY

If the seller is engaged in the business of marketing expert systems, strict liability for false representations would exist, even if the seller was not at fault.

B. INTENTIONAL MISREPRESENTATION

For an intentional misrepresentation liability, it must be shown that the seller made false representations knowingly or with reckless disregard for the facts.

C. NEGLIGENT MISREPRESENTATION

For negligent misrepresentation liability, it must be shown that the seller should have known the representations were false.

IX. DECEPTIVE TRADE PRACTICES ACT

The Texas Deceptive Trade Practices Act (DTPA) provides a remedy for consumers who are victimized by false, deceptive and misleading business practices as well as breaches of warranty. The DTPA is a consumer protection act so that a competitor who is not a consumer cannot bring a DTPA action.

A. PROHIBITED ACTS

The DTPA proscribes the following activities:

1. passing off goods or services as those of another;

2. causing confusion or misunderstanding as to the source, sponsorship, approval or certification of goods or services;

3. representing that a guarantee or warranty confers or involves rights or remedies which it does not have or involve; and

4. the failure to disclose information concerning goods or services which was known at the time of the transaction if such failure to disclose such information was intended to induce the consumer into a transaction into which the consumer would not have entered had the information been disclosed.

B. REMEDIES

1. Consumer Protection Division

a. temporary restraining orders, temporary injunctions, permanent injunctions; and

b. $2,000.00 per violation not to exceed $10,000.00.

2. Consumers

a. actual damages, treble damages available if acts committed knowingly;

b. injunction;

c. court costs; and

d. attorneys' fees.

X. MINIMIZING THE RISK OF LIABILITY

The potential liability for harm caused by malfunctioning, improperly designed or improperly used expert systems is great but may be minimized considerably by contractual limitations agreed to between the parties. An expert system developer should attempt to limit liability for actual damages and for consequential damages to the extent permitted under the U.C.C. or applicable common law. Under the U.C.C., the parties may agree to exclude or limit liability for consequential damages and to substitute other remedies, such as repair and replacement, for actual damages.

A. CONTRACTUAL LIMITATION OF REMEDIES

1. Substitute Damages Instead of Actual Damages

The parties to a contract may agree that instead of the possibility of receiving actual damages, an injured party will instead have only the right to some type of "substitute" damages. The most common type of substitute damages is repair or replacement of the goods.

Substitute remedies (such as repair or replacement) under U.C.C. § 2-719 which are intended to provide relief in place of actual damages are only enforceable to the extent they are meaningful. Farris Engineering Corp. v. Service Bureau Corp., 276 F.Supp. 643 (D. N.J. 1967), aff'd, 406 F.2d 519 (3rd Cir. 1969). Consequential damages may be recoverable if there is a failure of the substitute remedy. RRX Industries v. Lab-Con, Inc., 772 F.2d 543 (9th Cir. 1985).

2. Exclusion of Incidental and Consequential Damages

Incidental and consequential damages may be excluded provided the limitation or exclusion is not unconscionable under U.C.C. § 2-719(3).

B. DISCLAIMER OF WARRANTIES

Courts will uphold disclaimers of implied warranties of title, noninfringement, merchantability and fitness for a particular purpose if they are in writing and conspicuous and otherwise are reasonable under U.C.C. § 2-316. Earman Oil Co. v. Burroughs Corp., 625 F.2d 1291 (5th Cir. 1980).

1. Express Warranties

Specifications, samples, descriptions and statements relied upon during the bargaining process by the purchaser of an expert system may create express warranties even if not contained in the final contract. U.C.C. § 2-313. The parole evidence rule (inadmissibility of verbal statements) may serve to prevent nonwritten proof of express warranties inconsistent with the written language of the integrated contract, but courts may nonetheless allow parole evidence depending on the circumstances. A merger clause can avoid this problem by stating the final contract represents the complete understanding of the parties. Investor's Premium Corp. v. Burroughs Corp., 389 F.Supp. 39 (D.S.C. 1974).

2. Warranty of Title and Noninfringement

A disclaimer of warranty of title must clearly indicate that the transferring party does not possess full title and must therefore be explicit and express. Sunseri v. RKO Stanley Warner Theatres, Inc., 374 A.2d 1342 (Pa. Super. Ct. 1977) (insufficient disclaimer where contract "transferred only that interest Seller has").

If components of expert system are licensed from others and incorporated into the system, the developer-vendor should properly disclaim such warranties.

3. <u>Warranty of Merchantability and Fitness for a Particular Purpose</u>

These implied warranties may be disclaimed provided the appropriate contract language is used. It is important to draft the language of the contract clearly so that there is no misunderstanding as to the purposes for which the expert system is to be used and the degree to which the user can rely on its performance. The developer should avoid unnecessary "marketing" of the system in the recitals or definitions. Warning labels and instructions which limit scope of use are also advisable.

4. <u>Disclaimer of Warranties Must Be Reasonable</u>

Under U.C.C. § 2-316, warranty disclaimers are inoperative if considered unreasonable. Circumstances of unreasonableness are most likely to arise where the parties are not dealing in good faith.

5. <u>Consistency in Contract Language is Required</u>

Where there are conflicts between express and implied warranty language or disclaimers in a contract, U.C.C. § 2-317 offers guidance as to construction. Exact or technical specifications displace general language and express warranties displace inconsistent implied warranties, except for the implied warranty of fitness for a particular purpose. <u>Chatlos Systems v. National Cash Register Corp.</u>, 479 F.Supp. 743 (D.N.J. 1979).

C. NOT ALL LIABILITY CAN BE "CONTRACTED AWAY"

1. Limitations on liability as to actual damages in the form of repair and replacement clauses which "fail in their essential purpose" may be unenforceable. <u>Ford Motor Co. v. Mayes</u>, 575 S.W.2d 480 (Ky. App. 1978).

2. Limitations on contractual liability will not shield the developer from personal injury tort claims because such limitations may be considered unconscionable or unenforceable due to public policy.

3. Limitations on contractual liability will not shield the developer from tort claims or fraud, misrepresentation or negligent design. Siviero Bros. Contracting Corp. v. City of New York, 142 N.Y.S.2d 508 (1st Dept. 1955).

D. GLOBAL RECOMMENDATIONS FOR EXPERT SYSTEM CONTRACT DRAFTING

1. The rights and obligations with respect to ownership of use of the expert system should be clearly defined. The expectations of the parties concerning the expert system project should be reduced to writing early in the relationship.

2. Performance limitations and intended uses of the expert system should be well defined.

3. Mechanisms should be provided in the contract for resolving disputes and handling unexpected events which may arise between the parties over time.

XI. PROTECTING THE OWNERSHIP OF ARTIFICIAL INTELLIGENCE TECHNOLOGY

Artificial intelligence technology may be embodied in computer software and in systems having both computer hardware and mechanical hardware. Protection of hardware aspects is relatively straightforward under the trade secret and patent laws. The computer software aspects of artificial intelligence as may be employed in expert systems and in other forms are more difficult to define and protect under the law.

The nature of computer software is such that its value lies both in its form of expression and in its function. The expression aspects, such as program code, are traditionally best suited to copyright protection. The functional aspects, which would include the ideas and techniques employed by the program, are better protected under the patent laws.

The law relating to the protection of computer software is in a state of evolution, and it is true that the copyright, trade secret and patent law each may serve to protect computer software relating to artificial intelligence, albeit in different ways. These forms of legal protection are not mutually exclusive.

A. TRADE SECRET PROTECTION

Trade secret law protects information meeting the definition of a "trade secret" against use or disclosure by others. The protection accorded a trade secret holder is against the unauthorized disclosure or use of the trade secret by those subject to an express or implied restriction of nondisclosure or nonuse. The law protects the trade secret owner when the trade secret is gained by improper means. Kewanee Oil v. Bicron Corp., 416 U.S. 475 (1974).

1. Defining a Trade Secret

A trade secret includes any information used in one's business which provides a competitive advantage and is reasonably maintained as a trade secret. While many definitions may apply depending on the jurisdiction, four basic elements are common to the various definitions of trade secret and confidential information (see Restatement of Torts § 757 Comment b):

a. there must be some minimal novelty in the matter that is not generally known;

b. the information must be of some competitive value;

c. the information must be the result of some minimal investment or expense; and

d. the information must be maintained in relative secrecy.

Software as a whole or in its constituent parts can constitute a trade secret protectable under the trade secret law. Cybertek Computer Prods. Inc. v. Whitfield, 203 U.S.P.Q. 1020 (Cal. Super. Ct. 1977).

2. When Trade Secret Liability Arises

a. breach of confidential relationship

b. use of improper means to discover trade secret

c. breach of express contractual obligation of nondisclosure

3. Importance of Secrecy Agreements

Secrecy agreements in software licenses, nondisclosure agreements and employment agreements have increasingly been upheld in finding liability for trade secret misappropriation. See Electronic Data Systems v. Kinder, 497 F.2d 222 (5th Cir. 1974). Express confidentiality obligations can survive the termination of the underlying license or other agreement. Com-Share, Inc. v. Computer Complex, Inc., 338 F.Supp. 1229 (E.D. Mich. 1971), aff'd, 458 F.2d 1341 (6th Cir. 1972).

B. COPYRIGHT PROTECTION

1. What is Copyright?

Copyright law as embodied in Title 17 of the United States Code is a traditional "right to exclude" having its origins in the Constitution. Art. I, § 8, cl. 8. Copyright offers protection for "original works of authorship fixed in a tangible medium of expression."

2. Copyrightability of Computer Programs

Computer programs, including artificial intelligence programs, constitute copyrightable subject matter under the U.S. copyright law. 17 U.S.C. § 102(a). The definition of "computer program" was expressly added to the list of literary works qualifying for copyright protection in the 1980 Act amendments. See 17 U.S.C. § 101.

As with other types of computer programs, artificial intelligence programs will typically evolve through various levels of development and forms of expression, all of which represent copyrightable subject matter:

a. flow charts and other program descriptions

b. source code

c. object code

d. microcode

e. program documentation and user manuals

3. Limitations of Copyright Protection for Computer Programs

Copyright law only prevents copying of protectable expressions and does not protect the use of ideas. Ideas, procedures and processes are unprotectable under the copyright law. 17 U.S.C. § 102(b).

An "algorithm" (procedure for solving a mathematical problem) constitutes an uncopyrightable idea or procedure under § 102(b) of the copyright law. Gottschalk v. Benson, 409 U.S. 63 (1972).

4. Scope of Copyright Protection

a. Data Bases

Although a data base often constitutes a collection of unoriginal facts, it is well settled that computerized data bases constitute copyrightable subject matter under 17 U.S.C. § 103(a) which provides for protection of "compilations" (including collective works).

b. Literal Code Language

Original program code is protectable whether it is in the form of higher level language (source code) or in the form of machine language (object or microcode). Apple Computer, Inc. v. Franklin Computer Corp., 714 F.2d 1240 (3rd Cir. 1983), cert. dismissed, 464 U.S. 1033 (1984); NEC Corp. v. Intel Corp., 645 F.Supp. 590 (N.D. Cal. 1986), vacated, 835 F.2d 1546 (9th Cir. 1988).

c. Program Structure, Sequence and Organization

Nonliteral elements of a computer program are protectable. The court in Whelan Associates, Inc. v. Jaslow Dental Laboratory, Inc., 797 F.2d 1222 (3rd Cir. 1986) held that copyrightable protection extends beyond the literal program code and protects the "structure, sequence and organization" of the program. This means the "logic," or arrangement of a computer program's modules and subroutines, including its data files, is protectable.

d. Program User Interface (so-called "look and feel")

The screen display is the principal interface with the user of a computer program. The appearance and arrangement of the screen output displayed on a computer terminal, sometimes referred to as the "look and feel" of a software product, can have great commercial value and is protectable under the copyright law. The important case holdings on this issue are:

(i) Broderbund Software, Inc. v. Unison World, Inc., 648 F.Supp. 1127 (N.D. Cal. 1986) (screen display of program for generating customized greeting cards was held infringed);

(ii) Digital Communications Associates v. Softklone Distributing Corp., 2 U.S.P.Q.2d 1385 (N.D. Ga. 1987) (arrangement and design for main menu (status screen) of Crosstalk XVI Program was held infringed);

(iii) Lotus Development Corp. v. Paperback Software Int'l, 740 F.Supp. 37 (D. Mass. 1990) (menu structure of Lotus 1-2-3 Spread Sheet, including choice of command terms, structure and presentation was infringed by Defendant's "VP-Planner"); and

(iv) Apple Computer, Inc. v. Microsoft Corporation and Hewlett-Packard Co., 709 F.Supp 925 (1989) (on motion for partial summary judgment) No. C-88-20149-RPA (case pending to decide whether unlicensed elements of Macintosh visual displays in combination with licensed visual displays are infringed by Windows 2.03).

5. <u>Mechanics of Copyright Protection</u>

a. <u>When Is a Copyright Created</u>?

It is important to know that copyright protection begins immediately when a work is fixed and it is not necessary to place a copyright notice on a work or register it to establish a copyright.

b. <u>Copyright Legend</u>

The U.S. copyright laws have been modified to conform with the international copyright treaty known as the Berne Convention. Works publicly distributed no longer require a copyright legend; however, a copyright notice is recommended because omission of notice can give an infringer a defense of innocent infringement.

The copyright legend consists of (1) the word "Copyright" or "©"; (2) the year the work was created and (3) the name of the copyright owner. For software, copyright notice is recommended for (1) floppy disk labels, (2) development documentation, (3) source code listings, (4) user screen at boot-up or as a continuous status line and (5) user manuals and related material.

c. <u>Registration</u>

A copyright registration is a formal recognition of copyright protection. While not required, it is a prerequisite to filing an infringement action in federal court.

If a registration is filed within 3 months of creation of a work or before infringement, <u>statutory</u> damages (damages absent proof) and attorneys' fees are available to a copyright plaintiff.

C. PATENT PROTECTION

Artificial intelligence technology is patentable provided it meets the statutory requirements for patentability. This is true without regard to whether the technology is embodied in computer software. The patent law will protect computer processes provided they do not "wholly preempt the use of a mathematical algorithm." In re Grams, 888 F.2d 835 (Fed. Cir. 1989).

1. What is a Patent?

A patent is the right to exclude others from making, using or selling a claimed invention in this country for 17 years from the date of issuance.

2. Requirements for Patentability

The subject matter in question must meet the following statutory requirements in order to be patentable:

a. it must be useful under 35 U.S.C. § 101;

b. it must be novel under 35 U.S.C. § 102; and

c. it must be nonobvious under 35 U.S.C. § 103.

3. Exploitation of Patent Rights

A patent holder may exploit its patent, which generally has the attributes of property, in a number of ways.

a. Restrict Competition

The patent holder may exclude others from practicing the invention and thereby seek to recover increased profits from the legalized monopoly position.

b. Assignment

The patent holder may sell or assign its rights under a patent to a third party in exchange for whatever consideration may be negotiated by virtue of the leverage of the monopoly power.

c. License

The patent holder may license the patent by granting limited exclusive or nonexclusive rights to others to practice the claimed invention in exchange for negotiated consideration.

XIII. CONCLUSION

Precautionary measures should be taken to protect the ownership of artificial intelligence technology and to limit the potential risk of liability from its use. A well-reasoned, organized approach in this regard should be implemented early in the development of the technology. The legal interests in an artificial intelligence project will differ for each participant and according to the particular circumstances. Independent counseling is therefore advised to best serve the needs of each participant. A generalized checklist follows which may be helpful in implementing certain precautionary measures consistent with the concerns addressed in the presentation.

A. EXECUTIVE CHECKLIST FOR THE PROTECTION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY

1. <u>Protect the Confidentiality of the Technology</u>

    a. Use Confidentiality Notices on all Documentation
    b. Limit the Disclosure of the Technology
    c. Maintain Facility Security
    d. Exit Interviews

2. <u>Use Written Agreements</u>

    a. Nondisclosure Agreements
    b. Employment Agreements
    c. Consulting Agreements
    d. Development Agreements
    e. Systems Agreements (sale/lease/license)
    f. Software Licenses
    g. End User Licenses
    h. Warning Labels

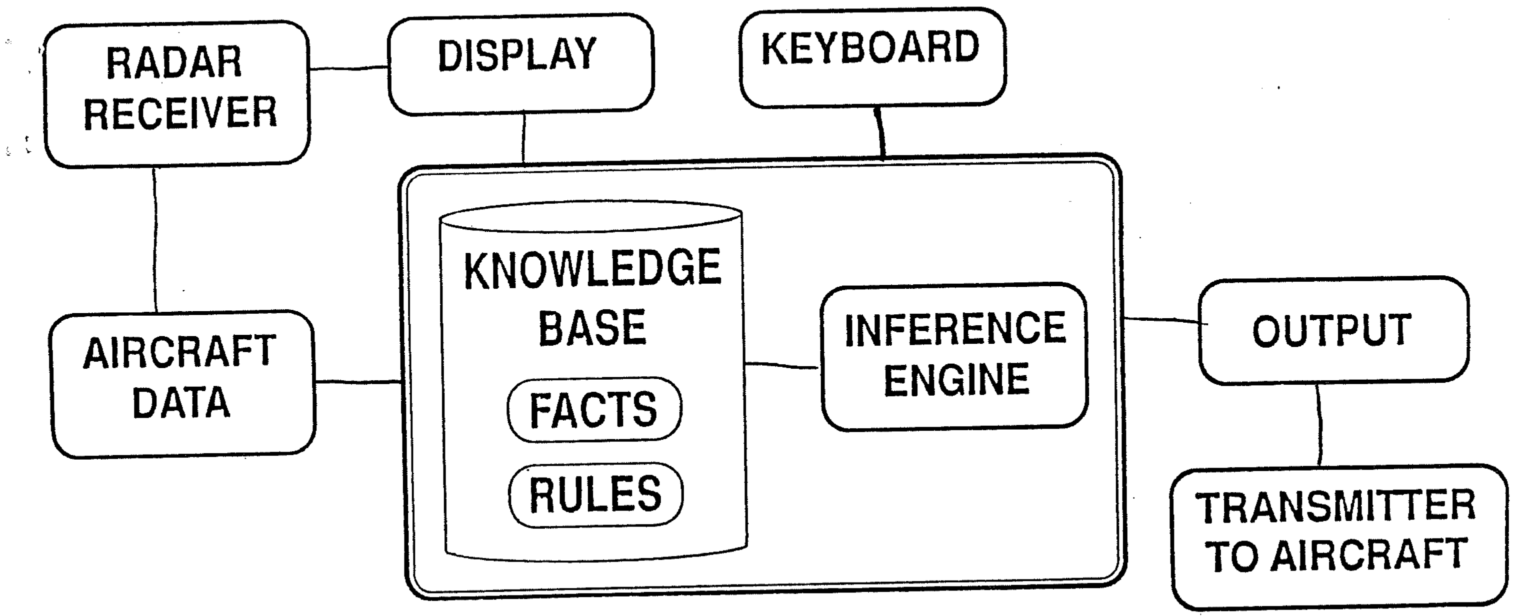
3. <u>Preserve Copyright Interests in the Technology</u>

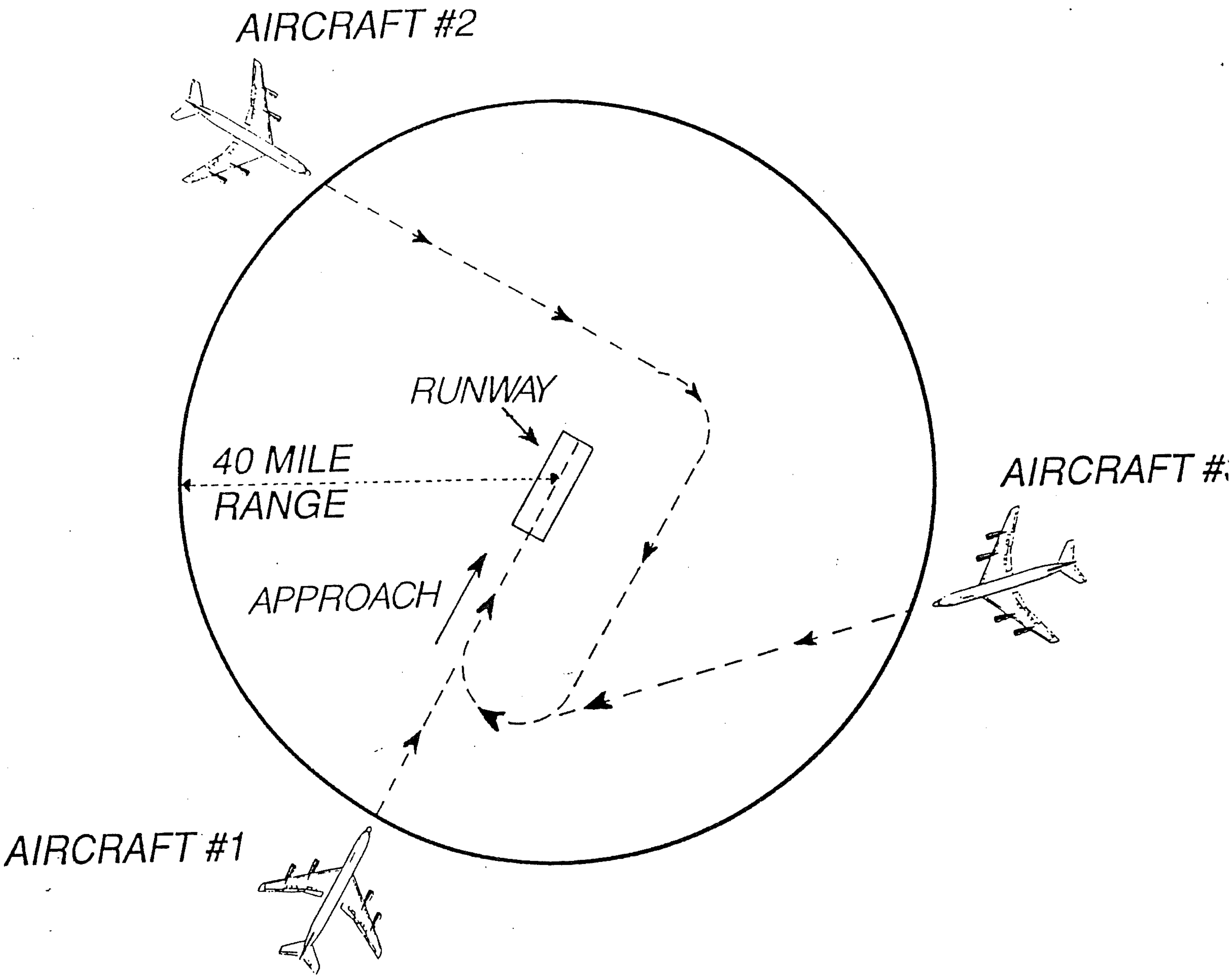
    a. Use Copyright Notices
    b. Register Copyrights

4. <u>Patent the Technology</u>

    a. Perform Right to Use Searches
    b. Perform Patentability Searches
    c. Timely File Patent Applications to Preserve both U.S. and Foreign Patent Rights

2d-1179I


RADAR RECEIVER
DISPLAY
KEYBOARD
KNOWLEDGE BASE
FACTS
RULES
INFERENCE ENGINE
AIRCRAFT DATA
OUTPUT
TRANSMITTER TO AIRCRAFT


AIRCRAFT #2
RUNWAY
40 MILE RANGE
APPROACH
AIRCRAFT #1

HARDWARE VENDORS

EXPERT SYSTEM

USER

EXPERT SYSTEM VENDORS

HUMAN EXPERTS

SOFTWARE SUPPLIER

INFERENCE ENGINE DEVELOPER

KNOWLEDGE ENGINEER

SOURCES OF LIABILITY

1. Incorrect Response Provided by Expert System
2. Undue Reliance on Expert System
3. Failure to Use Expert System

THEORIES OF LIABILITY

1. CONTRACT
   a. Breach of Contract
   b. Breach of Warranty
2. TORT
   a. Strict Liability
   b. Negligence
   c. Professional Malpractice
   d. Fraud or Misrepresentation
3. STATUTORY

STRICT TORT LIABILITY

RESTATEMENT (SECOND) OF TORTS § 402A (1965)

1. ONE WHO SELLS ANY PRODUCT IN A DEFECTIVE CONDITION UNREASONABLY DANGEROUS TO THE USER OR CONSUMER OR TO HIS PROPERTY IS SUBJECT TO LIABILITY FOR PHYSICAL HARM THEREBY CAUSED TO THE ULTIMATE USER OR CONSUMER IF:

   A. THE SELLER IS ENGAGED IN THE BUSINESS OF SELLING THE PRODUCT, AND

   B. IT IS EXPECTED TO AND DOES REACH THE CONSUMER WITHOUT SUBSTANTIAL CHANGE IN THE CONDITION IN WHICH IT IS SOLD.

2. THE RULE IN SUBSECTION 1 APPLIES THOUGH (A) THE SELLER HAS EXERCISED ALL POSSIBLE CARE IN THE PREPARATION AND SALE OF HIS PRODUCT, AND (B) THE USER OR CONSUMER HAS NOT BOUGHT THE PRODUCT FROM OR ENTERED INTO A CONTRACT WITH THE SELLER.

PROTECTING OWNERSHIP

A. TRADE SECRET PROTECTION

A TRADE SECRET HAS THE FOLLOWING CHARACTERISTICS:

1. AT LEAST MINIMAL NOVELTY
2. COMPETITIVE VALUE
3. AT LEAST MINIMAL INVESTMENT
4. RELATIVE SECRECY

B. COPYRIGHT PROTECTION

1. THE COPYRIGHT LAW PROTECTS "ORIGINAL WORKS OF AUTHORSHIP" INCLUDING COMPUTER PROGRAMS
2. THE COPYRIGHT LAW PROTECTS "EXPRESSIONS" NOT IDEAS
3. THE SCOPE OF COPYRIGHT PROTECTION ENCOMPASSES
   A. DATA BASES (COMPILATIONS OF INFORMATION)
   B. LITERAL CODE
   C. PROGRAM STRUCTURE, SEQUENCE AND ORGANIZATION
   D. PROGRAM USER INTERFACE

C. PATENT PROTECTION

A PATENT GRANTS THE RIGHT TO EXCLUDE OTHER FROM MAKING, USING AND SELLING AN INVENTION FOR A PERIOD OF 17 YEARS. FOR AN INVENTION TO BE PATENTABLE IT MUST BE:

1. USEFUL,
2. NOVEL, AND
3. NONOBVIOUS

EXECUTIVE CHECKLIST FOR THE PROTECTION OF ARTIFICIAL INTELLIGENCE TECHNOLOGY

1. PROTECT THE CONFIDENTIALITY OF THE TECHNOLOGY

   A. USE CONFIDENTIALITY NOTICES ON ALL DOCUMENTATION
   B. LIMIT THE DISCLOSURE OF THE TECHNOLOGY
   C. MAINTAIN FACILITY SECURITY
   D. EXIT INTERVIEWS

2. USE WRITTEN AGREEMENTS

   A. NONDISCLOSURE AGREEMENTS
   B. EMPLOYMENT AGREEMENTS
   C. CONSULTING AGREEMENTS
   D. DEVELOPMENT AGREEMENTS
   E. SYSTEMS AGREEMENTS (SALE/LEASE/LICENSES)
   F. SOFTWARE LICENSES
   G. END USER LICENSES
   H. WARNING LABELS

3. PRESERVE COPYRIGHT INTERESTS IN THE TECHNOLOGY

   A. USE COPYRIGHT NOTICES
   B. REGISTER COPYRIGHTS

4. PATENT THE TECHNOLOGY

   A. PERFORM RIGHT TO USE SEARCHES
   B. PERFORM PATENTABILITY SEARCHES
   C. FILE TIMELY PATENT APPLICATION TO PRESERVE BOTH U.S. AND FOREIGN PATENT RIGHTS

United States Patent [19]

Gerstenfeld

[11] **Patent Number: 4,827,418**

[45] **Date of Patent: May 2, 1989**

[54] **EXPERT SYSTEM FOR AIR TRAFFIC CONTROL AND CONTROLLER TRAINING**

[75] Inventor: **Arthur Gerstenfeld**, Newton, Mass.

[73] Assignee: **UFA Incorporation**, Newton, Mass.

[21] Appl. No.: **931,867**

[22] Filed: **Nov. 18, 1986**

[51] **Int. Cl.⁴** **G06F 15/48**

[52] **U.S. Cl.** **364/439**; 364/578

[58] **Field of Search** ... 364/200 MS File, 900 MS File, 364/300 MS File, 513, 578, 439

[56] **References Cited**

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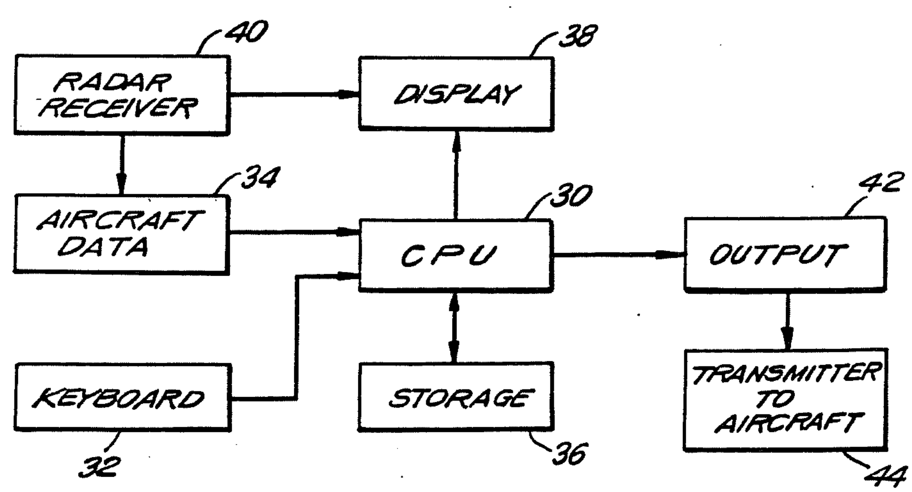
Primary Examiner—Parshotam S. Lall
Assistant Examiner—Thomas G. Black
Attorney, Agent, or Firm—Joseph S. Iandiorio; Michael L. Sheldon

[57] **ABSTRACT**

A expert system form of artificial intelligence for control of air traffic which may also be utilized for air traffic controller training. The expert system receives input data representing the altitude and heading of all aircraft in the control area. The aircraft data is compared with the data of the other aircraft. Sequencing and local flow control is optimized and if a potential conflict arises between two aircraft, clearances are transmitted to the aircraft to resolve the conflict. The aircraft data is also compared with a knowledge base of air traffic control rules for the particular airport involved. An inference engine written in LISP (or another AI language) allows real time access to the knowledge base. The position and heading of each aircraft is monitored and controlled until turned over to the tower for final approach. The expert system may also be used for air traffic controller training and be used as a intelligent tutor. The air traffic controller trainee's clearances are input and compared to those generated by the system. If the trainee's clearances are in error, or can be improved, the expert system prompts the trainee and coaches him in a way so that he learns from his past errors.

2 Claims, 10 Drawing Sheets



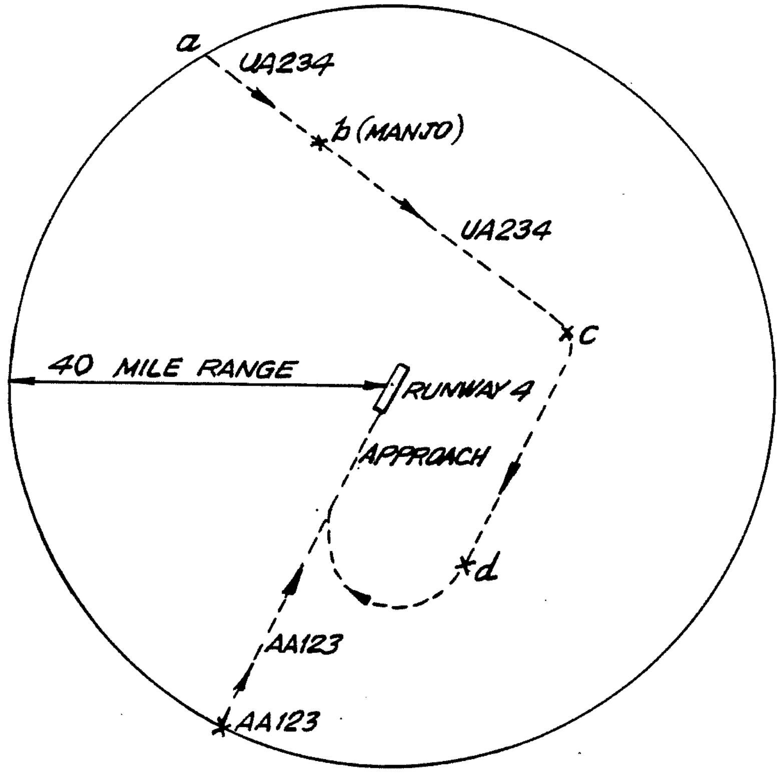

a
UA234
b (MANJO)
UA234
c
40 MILE RANGE
RUNWAY 4
APPROACH
d
AA123
AA123

FIG.1

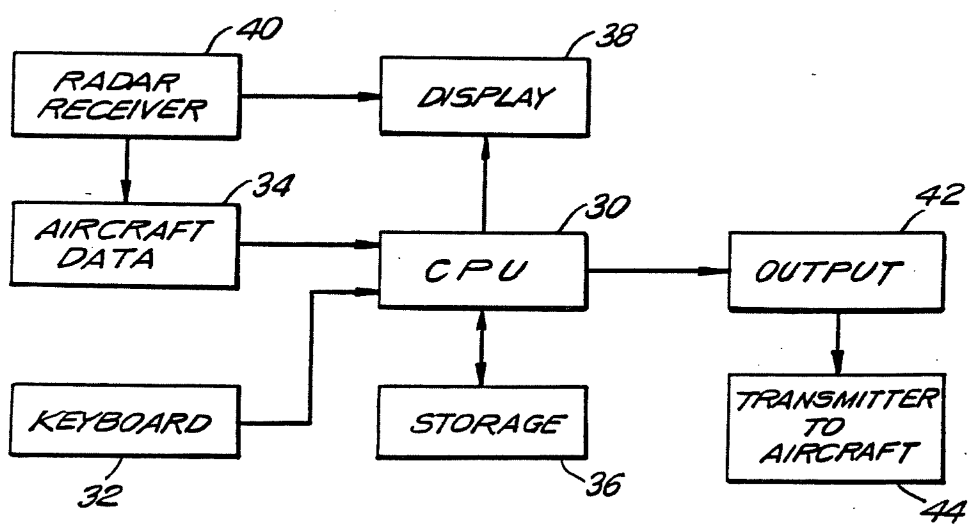

40
RADAR RECEIVER
38
DISPLAY
34
AIRCRAFT DATA
30
CPU
42
OUTPUT
KEYBOARD
STORAGE
TRANSMITTER TO AIRCRAFT
32
36
44

FIG.2

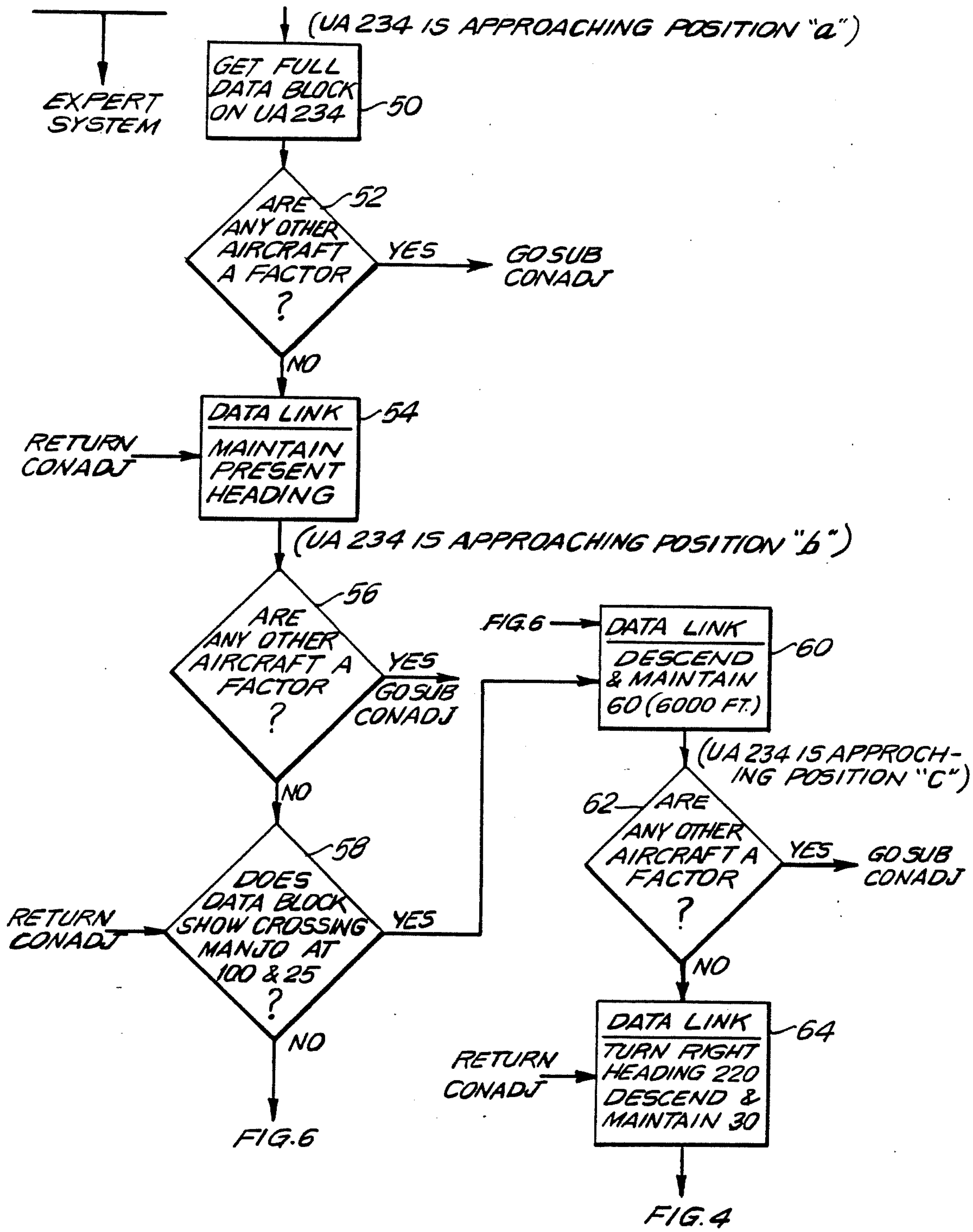

(UA 234 IS APPROACHING POSITION "a")
EXPERT SYSTEM
GET FULL DATA BLOCK ON UA 234
50
ARE ANY OTHER AIRCRAFT A FACTOR ?
52
YES
GO SUB CONADJ
NO
DATA LINK
MAINTAIN PRESENT HEADING
54
RETURN CONADJ
(UA 234 IS APPROACHING POSITION "b")
ARE ANY OTHER AIRCRAFT A FACTOR ?
56
YES
GO SUB CONADJ
NO
DOES DATA BLOCK SHOW CROSSING MANJO AT 100 & 25 ?
58
RETURN CONADJ
YES
NO
FIG.6
FIG.6
DATA LINK
DESCEND & MAINTAIN 60 (6000 FT.)
60
(UA 234 IS APPROCH-ING POSITION "C")
62
ARE ANY OTHER AIRCRAFT A FACTOR ?
YES
GO SUB CONADJ
NO
DATA LINK
TURN RIGHT HEADING 220 DESCEND & MAINTAIN 30
64
RETURN CONADJ
FIG.4

FIG.3

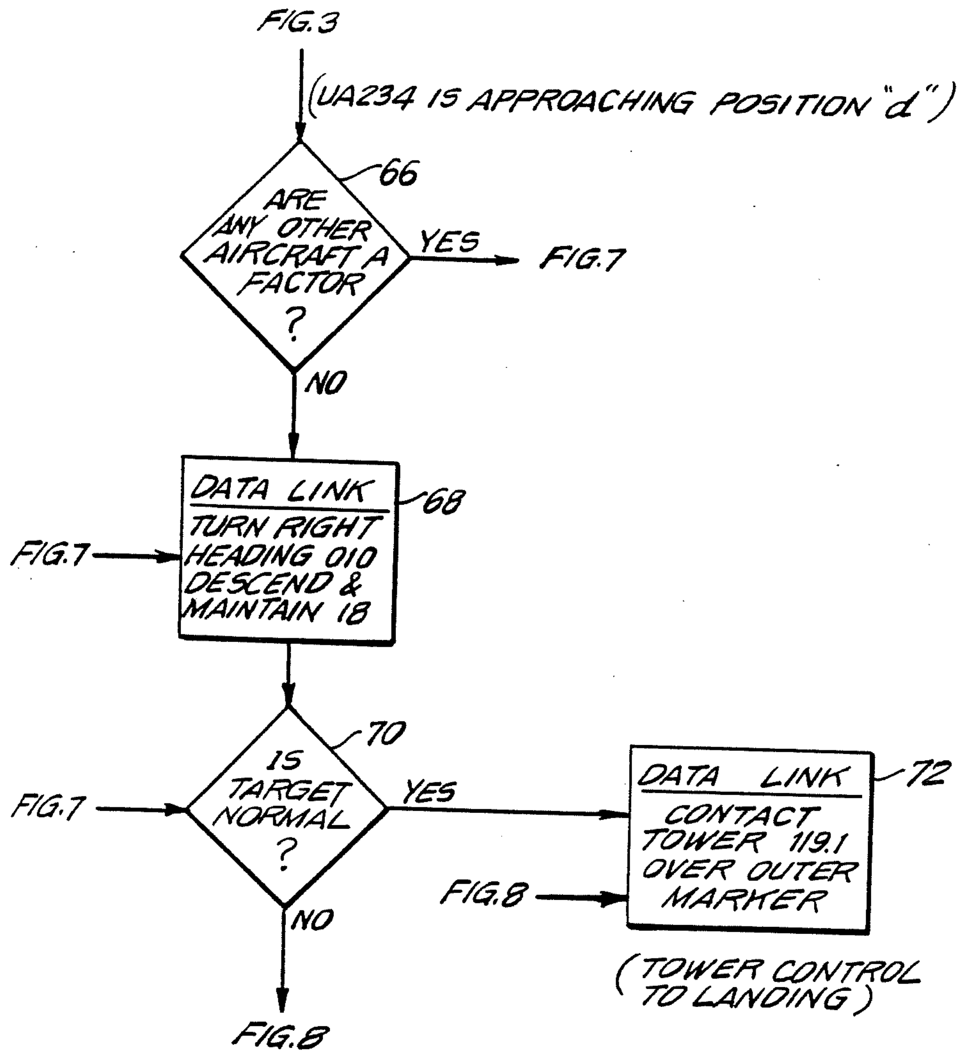


FIG.3
(UA234 IS APPROACHING POSITION "d")
ARE ANY OTHER AIRCRAFT A FACTOR ?
66
YES
FIG.7
NO
DATA LINK
TURN RIGHT HEADING 010 DESCEND & MAINTAIN 18
68
FIG.7
IS TARGET NORMAL ?
70
FIG.7
YES
DATA LINK
CONTACT TOWER 119.1 OVER OUTER MARKER
72
FIG.8
NO
FIG.8
(TOWER CONTROL TO LANDING)

FIG. 4

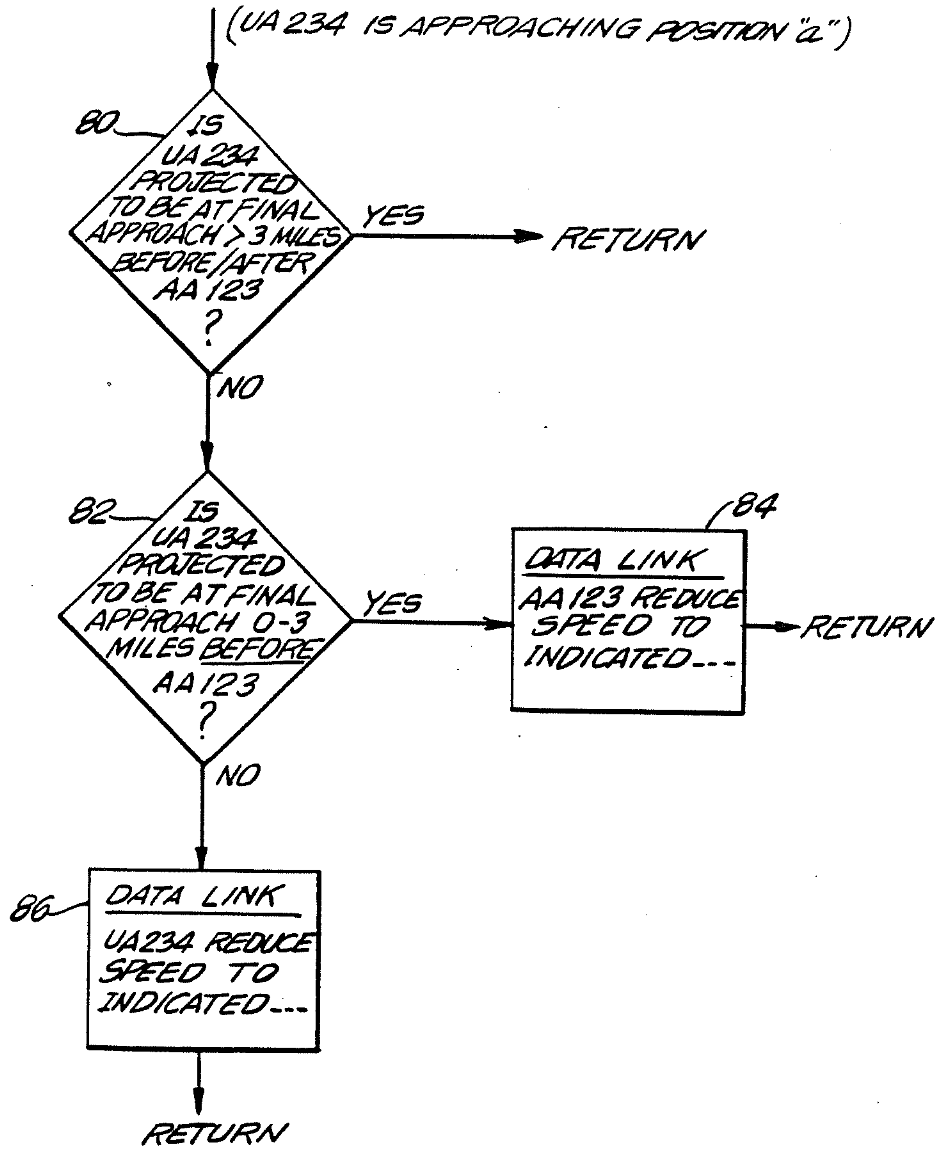

(UA 234 IS APPROACHING POSITION "a")
80
IS UA 234 PROJECTED TO BE AT FINAL APPROACH > 3 MILES BEFORE/AFTER AA 123 ?
YES
RETURN
NO
82
IS UA 234 PROJECTED TO BE AT FINAL APPROACH 0-3 MILES BEFORE AA 123 ?
YES
84
DATA LINK
AA 123 REDUCE SPEED TO INDICATED---
RETURN
NO
86
DATA LINK
UA234 REDUCE SPEED TO INDICATED---
RETURN

FIG. 5

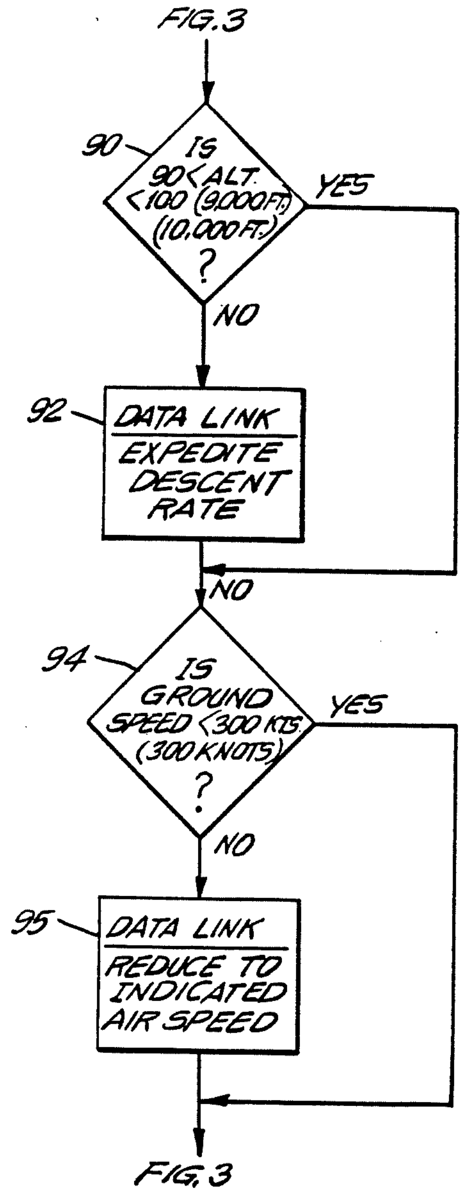


FIG. 3
90
IS 90<ALT. <100 (9,000FT.) (10,000FT.) ?
YES
NO
92
DATA LINK
EXPEDITE DESCENT RATE
NO
94
IS GROUND SPEED <300 KTS. (300 KNOTS) ?
YES
NO
95
DATA LINK
REDUCE TO INDICATED AIR SPEED
FIG. 3

FIG. 6

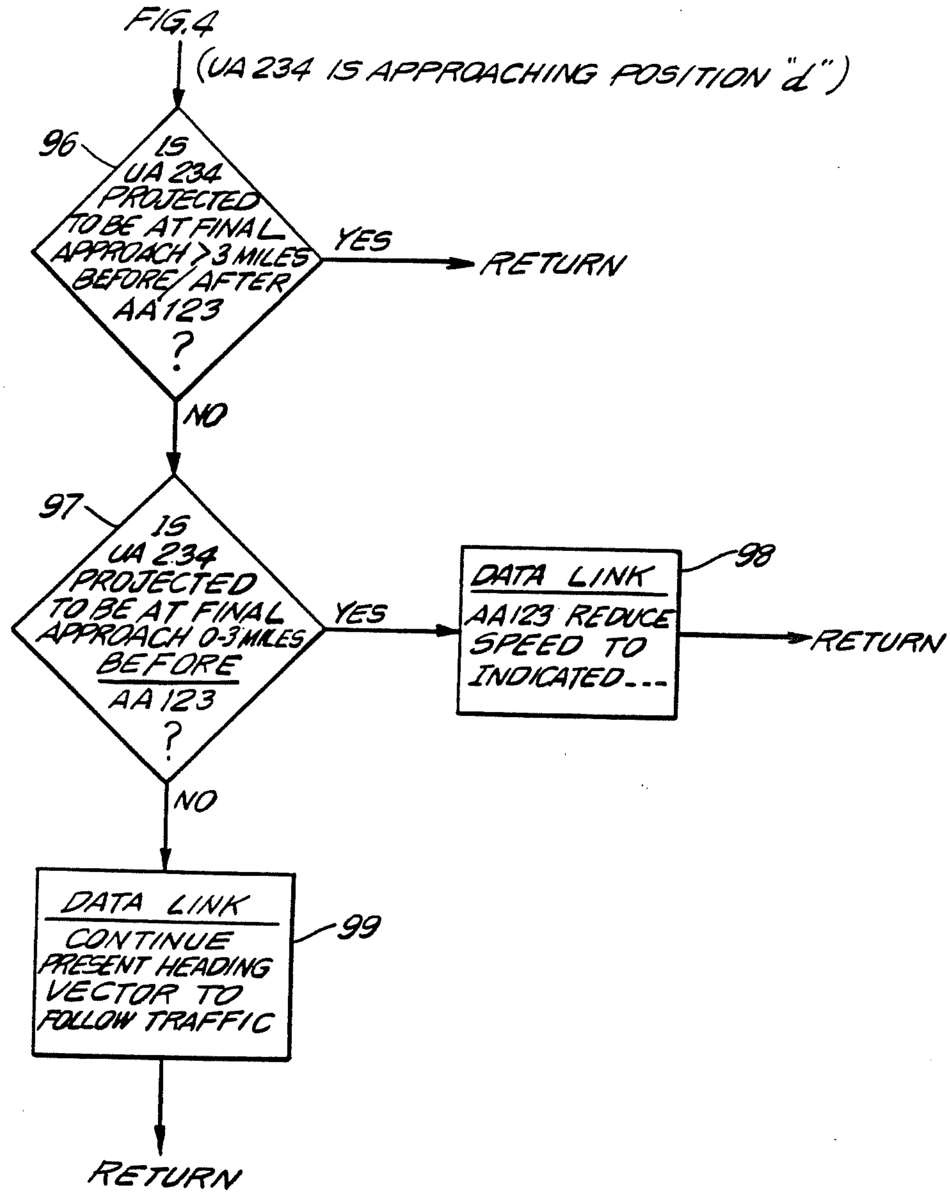


FIG.4
(UA 234 IS APPROACHING POSITION "d")
96
IS UA 234 PROJECTED TO BE AT FINAL APPROACH > 3 MILES BEFORE/AFTER AA123 ?
YES
RETURN
NO
97
IS UA 234 PROJECTED TO BE AT FINAL APPROACH 0-3 MILES BEFORE AA 123 ?
YES
DATA LINK
AA123 REDUCE SPEED TO INDICATED...
98
RETURN
NO
DATA LINK
CONTINUE PRESENT HEADING VECTOR TO FOLLOW TRAFFIC
99
RETURN

FIG.7

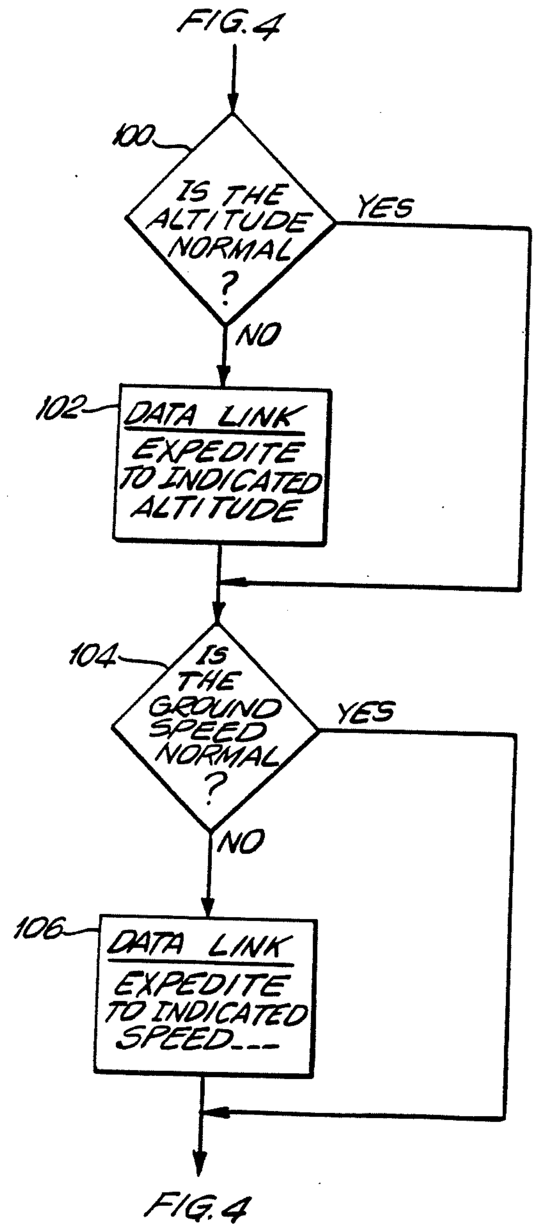


FIG. 4
100
IS THE ALTITUDE NORMAL ?
YES
NO
102
DATA LINK
EXPEDITE TO INDICATED ALTITUDE
104
IS THE GROUND SPEED NORMAL ?
YES
NO
106
DATA LINK
EXPEDITE TO INDICATED SPEED---
FIG. 4

FIG. 8

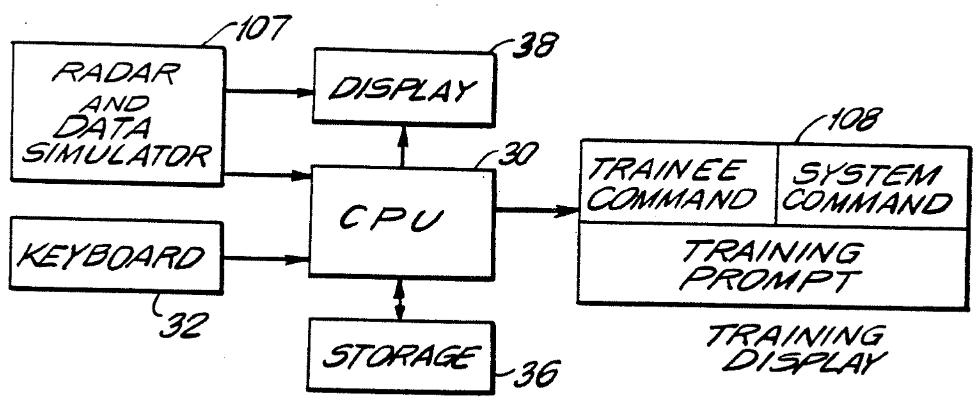

107
RADAR AND DATA SIMULATOR
38
DISPLAY
30
CPU
KEYBOARD
32
STORAGE
36
108
TRAINEE COMMAND
SYSTEM COMMAND
TRAINING PROMPT
TRAINING DISPLAY

FIG.9

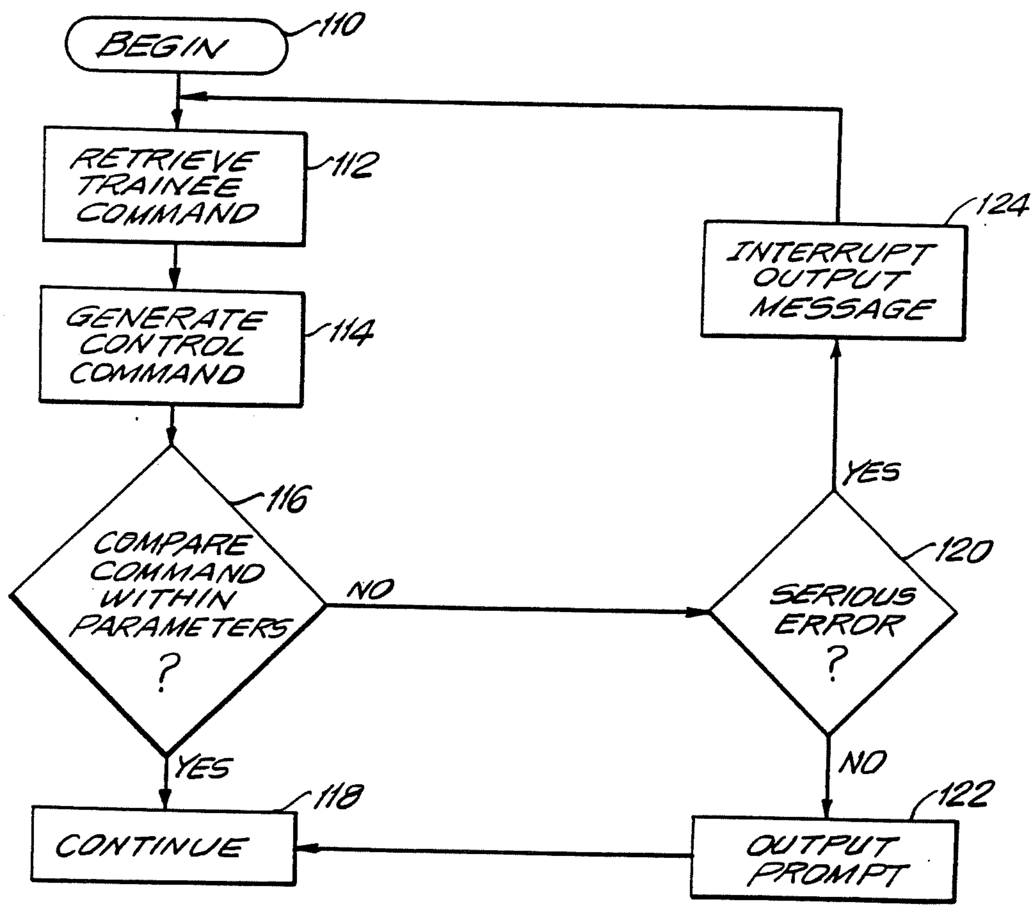
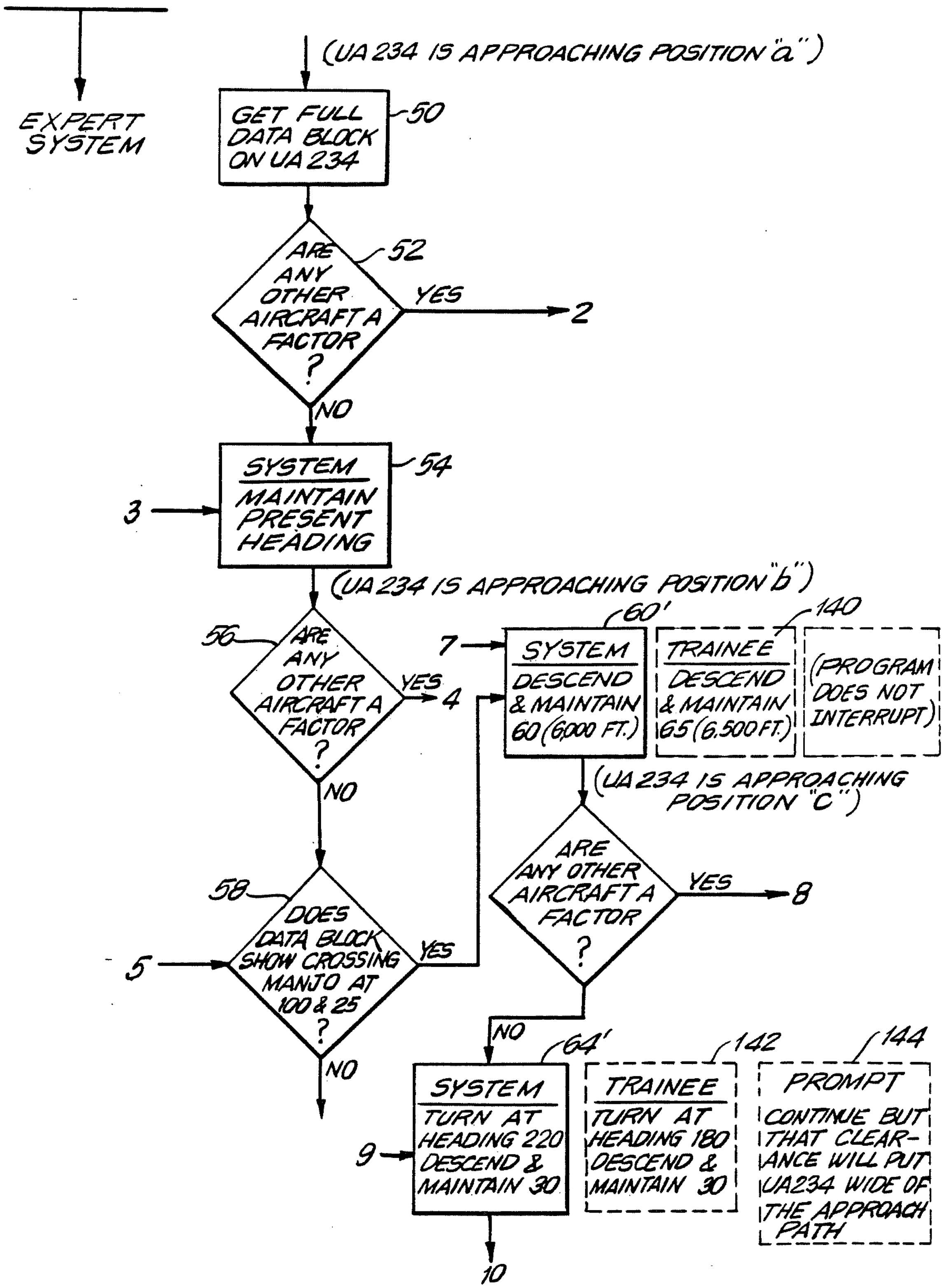

BEGIN
110
RETRIEVE TRAINEE COMMAND
112
GENERATE CONTROL COMMAND
114
COMPARE COMMAND WITHIN PARAMETERS ?
116
NO
YES
CONTINUE
118
SERIOUS ERROR ?
120
YES
NO
INTERRUPT OUTPUT MESSAGE
124
OUTPUT PROMPT
122

FIG.10



EXPERT SYSTEM
(UA 234 IS APPROACHING POSITION "a")
GET FULL DATA BLOCK ON UA 234
50
ARE ANY OTHER AIRCRAFT A FACTOR ?
52
YES
2
NO
3
SYSTEM
MAINTAIN PRESENT HEADING
54
(UA 234 IS APPROACHING POSITION "b")
56
ARE ANY OTHER AIRCRAFT A FACTOR ?
YES
4
NO
7
60'
SYSTEM
DESCEND & MAINTAIN 60 (6,000 FT.)
140
TRAINEE
DESCEND & MAINTAIN 65 (6,500 FT.)
(PROGRAM DOES NOT INTERRUPT)
(UA 234 IS APPROACHING POSITION "C")
ARE ANY OTHER AIRCRAFT A FACTOR ?
YES
8
58
5
DOES DATA BLOCK SHOW CROSSING MANJO AT 100 & 25 ?
YES
NO
NO
64'
142
144
9
SYSTEM
TURN AT HEADING 220 DESCEND & MAINTAIN 30
TRAINEE
TURN AT HEADING 180 DESCEND & MAINTAIN 30
PROMPT
CONTINUE BUT THAT CLEARANCE WILL PUT UA234 WIDE OF THE APPROACH PATH
10

FIG. 11

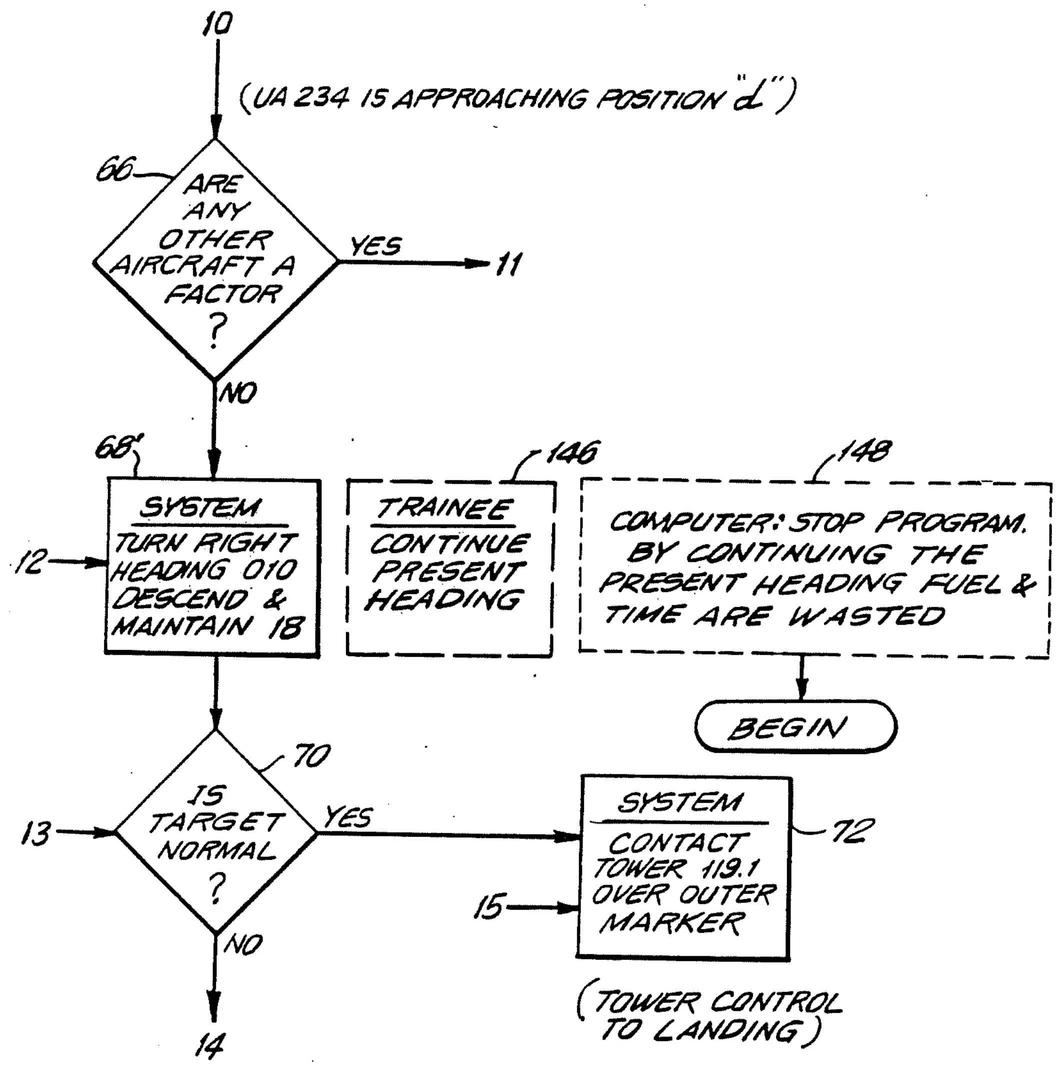

10
(UA 234 IS APPROACHING POSITION "d")
66
ARE ANY OTHER AIRCRAFT A FACTOR ?
YES
11
NO
68'
SYSTEM
TURN RIGHT HEADING 010 DESCEND & MAINTAIN 18
12
146
TRAINEE
CONTINUE PRESENT HEADING
148
COMPUTER: STOP PROGRAM. BY CONTINUING THE PRESENT HEADING FUEL & TIME ARE WASTED
BEGIN
70
IS TARGET NORMAL ?
13
YES
NO
14
SYSTEM
CONTACT TOWER 119.1 OVER OUTER MARKER
72
15
(TOWER CONTROL TO LANDING)

FIG. 12

EXPERT SYSTEM FOR AIR TRAFFIC CONTROL AND CONTROLLER TRAINING

BACKGROUND AND SUMMARY OF THE INVENTION

This invention relates generally to data processing systems and particularly to a data processing system for controlling air traffic. The data processing system may also be used to provide automated air traffic controller training.

The control of approaching and departing aircraft at busy airports is a stressful occupation with potentially disastrous results should error occur. The air traffic controller is required to monitor dozens of arriving and departing flights on the radar screen. The controller must be aware of each air craft's heading, altitude and speed and be cognizant of the aircraft's future flight path to insure that no aircraft are on a collision course and to sequence aircraft efficiently to help traffic flow and save fuel. The demands of the profession have led to a shortage of qualified air traffic controllers. Accordingly, it is desirable to be able to automate air traffic control with an advanced data processing system. It is further desirable to be able to have a data processing system capable of training air traffic controllers. The present invention is directed towards meeting these objectives.

An experienced air traffic controller intuitively applies many hundreds of "rules" in directing aircraft. Such rules include minimum safe distance, minimum and maximum altitude, proper heading and local rules such as noise abatement guidelines and geographic hazards. A data processing system for controlling aircraft must therefore also be capable of drawing on and acting upon the applicable air traffic control "rules" for the particular airport involved. These rules must be part of the "knowledge base" which is drawn on by the air traffic control system. The present data processing system includes a knowledge base representing the knowledge of the most experienced air traffic controllers. The knowledge base is able to grow incrementally so that as new knowledge is gained it may be readily added to the data base.

The present data processing system integrates the knowledge base of the air traffic control rules into an automated system for the control of aircraft. The system receives as inputs data relating to the altitude, heading and configuration of all aircraft in the control area. The system simultaneously compares the position of all aircraft to determine if any conflict will arise. If any conflict is imminent the headings and altitude of one or more of the aircraft will be adjusted until the conflict is resolved. The aircrafts' positions are continually monitored and as the aircraft reach a predetermined position, the aircraft will be cleared, via appropriate instructions transmitted automatically to the aircraft, to proceed to the next position in the control sequence. The air traffic control data processing continues until the aircraft is turned over to the tower on final approach.

The air traffic control data processing system is also Particularly suitable for air traffic controller training. For training, the system is utilized with simulated radar and aircraft data. The air traffic controller in training inputs suggested aircraft clearances based upon the simulated data appearing on a radar display. The trainee's clearances are compared with the optimum clearances generated by the data processing system. If the trainee's clearances are sufficiently close to the optimum clearances, the simulation proceeds. If the trainee's clearances are less than optimum, the system will output a prompt to the trainee suggesting how the clearance could be improved and the simulation will continue. If the trainee's clearance is seriously in error, the simulation will be interrupted, the trainee informed of the error and the simulation restarted. In this manner the trainee will gain the expertise necessary for the control of aircraft at commercial airports.

Accordingly, it is an object of this invention to provide a data processing system for air traffic control.

It is another object of this invention to provide a data processing system for air traffic controller training.

The system utilizes artificial intelligence in the form of a knowledge base system or expert system so that heuristics or "rules of thumb" are used by the computer just as is now being used by air traffic controllers.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to better understand the invention, reference is made to the following drawings which are to be taken in connection with detailed specification to follow, in which:

FIG. **1** illustrates a radar display of the flight paths of two aircraft in a landing control sequence;

FIG. **2** is a block diagram of the hardware used to implement the data processing system for the control of the aircraft of FIG. **1**;

FIGS. **3**–**8** are flow diagrams of the data processing system used for air traffic control;

FIG. **9** is a block diagram of the hardware for implementing the data processing when used in air traffic controller training;

FIG. **10** is a flow diagram of the data processing system as used in air traffic controller training; and

FIGS. **11** and **12** are flow diagrams corresponding to FIGS. **3** and **4**, of the data processing as used for air traffic controller training showing the trainees suggested control clearances and the system's prompts to the trainee.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a typical radar display showing two aircraft (United Airlines Flight 234 "**UA234**" and American Airlines Flight 123 "**AA123**") approaching a single runway ("Runway 4") for landing. The radar display shows a radius of approximately 40 miles from the airport with the approach paths for the two aircraft shown in dotted lines. As shown, **UA234** is on an approach that will require a 90° turn followed by a 180° turn, various positions along its projected flight path are labeled a, b, c and d. Point b is named "MANJO" which is an arbitrary name given by air traffic control to a specific checkpoint. **AA123** is making a direct approach to Runway 4. In actuality, many more planes would be located within a 40 mile radius of a major airport. However, two aircraft are sufficient to describe the operation of the present data processing system.

FIG. **2** illustrates, in broad overview, the hardware for implementing the data processing arrangement of the instant invention. The hardware includes a standard stored program controlled central processing unit (CPU) **30**, connected to a keyboard **32** and to a standard data/program storage means **36** such as magnetic disk or tape. CPU **30** is also connected to a display **38**, generally in the form of a standard radar display similar to that illustrated in FIG. 1. Display 38 is connected for input from a radar receiver 40 and CPU 30 and displays the standard radar "blips"illustrating the aircraft within the control area, the radar transponder data for each aircraft and also displays the commands output to the aircraft by the data processing system.

Connected for input of data to CPU 30 is an input device 34 for the data relating to the aircraft to be controlled as received from radar receiver 40. The aircraft data is transmitted to receiver 40 by the radar transponder of the aircraft and includes the aircraft's speed, heading, altitude and identification. Also connected to CPU 30 is an output device 42 for output of the direction commands to the aircraft. The clearances may be transmitted as data or as voice synthesized verbal commands. Accordingly, output device 42 may be in the form of a voice synthesizer or a data translator. Output device 42 is connected to a transmitter 44 for radio transmission of the directional commands to the aircraft.

FIG. 3 is a flow diagram of a portion of the data Processing arrangement of the present invention. The data Processing of FIG. 3 is based on the aircraft control display shown in FIG. 1 in which UA234 is approaching position a which is at the outer periphery of the radar coverage. At block 50 the data processing will retrieve a full data block on UA234. The data block includes the aircraft's altitude, speed and heading as well as other appropriate identifying information on the aircraft such as whether it is a "heavy" aircraft (i.e., a "jumbo jet"). The data block is received from radar receiver 40 and input into the CPU 30 via input device 34 which may be a standard interface for translating the data into a form capable of being processed by CPU 30.

The artificial intelligence allows the system to access knowledge as it is needed using an inference engine. The means that information is not retrieved sequentially but rather the information is retrieved just as a human retrieves information.

After retrieval of the data at block 50 data processing Proceeds to block 52 where a test is made to determine if any other aircraft are a factor which will affect UA234. This test is made by comparing the data received at block 50 with the data on any other aircraft in the control area as illustrated in FIG. 1. Initially, we will assume that no other aircraft are presently a factor in the approach of UA234 so that the test made at block 52 is negative. Under this assumption, data processing proceeds to block 54 which is labelled "data link" to indicate an output of the data processing system to the aircraft to be controlled. The output comprises the control commands that are to be transmitted to the aircraft. The CPU 30 outputs the commands to output device 42 which, in turn, is connected to transmitter 44 for transmission to the aircraft either in the form of data or by voice synthesized commands. At block 54 the output clearance is "maintain present heading" which informs the pilot of UA234 that he is cleared to proceed to point b on FIG. 1. Alternatively, the aircraft clearances may be transmitted by a human air traffic controller who simply transmits by radio to a pilot the clearance output by the data processing system and displayed on display 38.

As the aircraft approaches MANJO (point b), data processing proceeds to block 56 where, again, a test is made to determine whether any other aircraft will affect UA234. If the result of the test is negative, that is, no other aircraft are affecting UA234's flight path, processing proceeds to block 58 whereby the data block being received from UA234 is compared to the expert system knowledge base of appropriate positioning data for the aircraft. At block 58 the data received from UA234 is read to determine if UA234 crossed MANJO at 100 & 25. That is, did UA234 cross MANJO at an altitude of 10,000 feet (100) at an air speed of 250 knots (25). If at block 58 UA234 has the correct air speed and altitude, the expert system proceeds to block 60 where the clearance to the aircraft to "descend and maintain 60" (i.e., reduce altitude to 6,000 feet) will be output to UA234.

Data processing thereafter continues to block 62 where another test is made to determine if any other aircraft will affect the flight path of UA234. At this time UA234 will be approaching point c of FIG. 1. If no other aircraft are a factor, the expert system continues to block 64 for output of the clearance to UA234 to turn right at a heading of 220 and to descend and maintain a 3,000 foot altitude.

After communication to the aircraft of the clearance of block 64, data processing proceeds to block 66 of FIG. 4 where, again, a test is made to determine if any other aircraft will affect UA234 which is now approaching position d of FIG. 1. If no other factor aircraft are affecting UA234, at block 68 a clearance is output to UA234 to turn right at a heading of 10° and to descend and maintain an 1800 foot altitude. The expert system will thereafter proceed to block 70 to determine whether the data received from the aircraft is normal. If so, processing proceeds to block 72 where UA234 is instructed to contact the tower at a frequency of 119.1 Mhz when the aircraft is over the outer runway marker. At this point, control of the aircraft is turned over to the airport's tower control for the final landing. The above-described expert data processing system was directed to the approach of UA234 where no other aircraft were a factor. We will now consider the situation where other aircraft are affecting the approach of UA234.

The expert system includes a conflict adjustment subroutine ("CONADJ") to adjust the arrival of the aircraft should either aircraft be a factor with respect to the other. If the tests made at blocks 52, 56 and 62 are answered in the affirmative, that is, that another aircraft (AA 123) is a factor with respect to UA 234, the expert system branches to the conflict adjustment subroutine shown in FIG. 5. In the conflict adjustment subroutine of FIG. 5 processing begins at block 80 where the expert system will calculate the distance between the conflicting aircraft at final approach to determine if UA234 will be at its final approach more than three miles either ahead or behind AA123. If the test of block 80 is answered affirmatively, there is no conflict between the approach of the flights because both flights are sufficiently far apart. Accordingly, processing returns from the conflict adjustment subroutine to the appropriate point in FIG. 3.

If at block 80 it is determined that UA234 will arrive at final approach less than three miles either before or after AA123, the expert system proceeds to block 82. At block 82 a determination is made as to whether UA 234 will arrive first so that the trailing flight (AA 123) may be slowed down so that the aircraft arrive more than three miles apart. If at block 82 UA234 will be at final approach before AA123, the expert system proceeds to block 84 where AA123 is cleared to reduce its speed to an indicated amount so as to arrive more than three miles after AA123. Thereafter, the expert system returns out of the subroutine to the next data block of FIG. 3. If at block 82 UA234 will not arrive before AA123, data processing proceeds to block 86 where UA234 is cleared to reduce its speed so that it arrives more than three miles after AA123. Thereafter, the expert system returns from the subroutine of FIG. 5 to the appropriate data block of FIG. 3.

We will now turn to the data processing which occurs if UA234 has not crossed MANJO at 10,000 feet at 250 knots i.e., the test made at block 58 of FIG. 3 is negative). The expert system thereupon calls upon to block 90 of FIG. 6 where the data block is examined to determine if UA234's altitude is between 9,000 and 10,000 feet. If the altitude of UA234 is not within these parameters, the expert systems calls upon block 92 where UA 234 is cleared to expedite its descent rate so as to place it within the desired altitude parameters Alternatively, if at block 90 UA234 is determined to be within the altitude parameters, the expert system calls upon block 94 where the speed of UA234 is checked. At block 94 the data block retrieved from UA234 is examined to determine if UA234's air speed is less than 300 knots. If air speed is less than 300 knots, the expert system returns to block 60 of FIG. 3. If UA234's air speed is greater than 300 knots, the expert system proceeds to block 95 wherein UA234 is cleared to reduce its air speed to the indicated speed. The expert system thereafter returns to block 60 of FIG. 3.

Turning now to block 66 of FIG. 4 in which UA234 is approaching position d and where other aircraft are a factor, the expert system proceeds to FIG. 7 which is a frame similar to the conflict adjustment frame of FIG. 5 but which differs slightly in clearances due to AA234's proximity to final approach. FIG. 7 begins at block 96 where a determination is made if UA234 will be at final approach more than 3 miles either before or after AA123. If so, there will be no conflict and the expert system may return to block 68 of FIG. 4.

If the test made at block 96 is negative, the expert system contacts block 97 to determine if UA234 will be at final approach within 0–3 miles before AA123. If so, the expert system contacts block 98 where AA123 is cleared to reduce its speed to remove the conflict and the expert system thereafter returns to block 68 of FIG. 4. If UA234 at block 97 is not projected to be at final approach within three miles of AA123, the expert system proceeds to block 99 wherein UA234 is cleared to maintain its present heading and is vectored to follow traffic (i.e., AA123). Thereafter, the expert system contacts block 70 of FIG. 4 to determine if UA234's altitude and air speed are normal for landing. If UA234's altitude and air speed are normal, the expert system contacts block 72. If UA234's altitude and air speed are not normal, the expert system proceeds to FIG. 8.

FIG. 8 verifies the altitude and air speed of the aircraft on final approach and is similar to FIG. 6. At block 100 the altitude of UA234 is read from the data block to determine if it is normal for final approach. If it is not, the expert system contacts block 102 whereby UA234 is cleared to adjust its altitude to normal approach altitude. If at block 100 the altitude of UA234 is normal or has been adjusted at block 102, the expert system contacts block 104 for determination if the air speed of the approaching aircraft is normal. If the air speed is normal, the expert system returns to block 72 of FIG. 4 to turn over the aircraft to tower control. If at block 104 the air speed of the approaching aircraft is not normal, the expert system proceeds to block 106 where UA234 is cleared to adjust its speed to appropriate approach speed. Thereafter the expert system returns to block 72 of FIG. 4 to turn over the aircraft to tower control for landing. It is to be noted the expert system may be used to control departing aircraft as well.

As noted previously, this new expert system may also be utilized in air traffic controller training. In such a configuration the air traffic controller trainee will review a simulated radar display and input his clearance via keyboard 32 based on the simulated data. The simulation has been written in the highly efficient computer language C. The inferences engine and knowledge base are written in the AI language LISP to permit elegant manipulation of symbols and decision rules. The clearance input by the air traffic controller will be compared to the clearance by the expert system. If the trainee controller's clearances are within a predetermined range of the clearances by the expert system the trainee air traffic controller is providing proper approach control instructions and the expert system will continue. If, however, the air traffic controller's clearances are not within a predetermined range of the expert system the trainee will be prompted by the expert system to correct his clearances.

The invention has been built on a LISP Machine (Symbolic) linked to a VAX AI Workstation through an Ethernet network. FIG. 9 illustrates appropriate hardware for use of the expert system for air traffic controller training. As is seen FIG. 9 corresponds to FIG. 2 with the same reference numerals used to depict the same hardware. FIG. 9 includes a radar and simulator 107 outputting a simulated air traffic control problem to CPU 32 and radar display 38. The output of CPU 30 is connected to a training display 108, such as a CRT, which is divided into three "windows" for the display of the trainee's suggested control clearances as input via keyboard 32, the clearances generated by the air traffic control data processing via the data processing arrangement described above and a Prompt to the trainee if the trainee's command is at variance with the command generated by the system.

FIG. 10 is a flow chart of the expert system used in the training mode for comparing the trainee's clearances with the clearances generated by the expert system. In FIG. 10 we will assume that the simulated control problem involves the same two flight paths as shown in FIG. 1. From the beginning at block 110 the expert system proceeds to block 112 where the clearance input by the trainee in response to the simulated data is retrieved. At block 114 the optimum control clearance generated by the expert system arrangement of FIGS. 3–8 is retrieved. The trainee's clearance is compared to the expert system clearance at block 116 and if the trainee's clearance is within an appropriate range of the optimum clearance the simulation continues to block 118. If, however, the trainee's clearance is outside of the optimum parameters the expert system contacts block 120 where it is determined from the knowledge base if the clearance is seriously in error. If the trainee's clearance is not seriously in error, the expert system contacts block 122 whereby a message will be output to the prompt window of display 108 suggesting how the trainee's clearance may be improved. This computerized intelligent tutor is "taught" when to interrupt and what form the interruption is to take. Thereafter the simulation continues. If the trainee's clearance is seriously in error, the expert system contacts block **124** where the simulation will be interrupted and an error message output in the prompt window of display **108**. The system thereafter returns to the beginning of the sequence so that the simulation may be repeated until the trainee learns the optimum control clearances.

FIGS. **11** and **12** correspond to the expert system of FIGS. **3** and **4** with the same expert system blocks labeled with the same reference numerals. As shown in FIGS. **11** and **12**, the expert system operation is essentially identical to that of FIGS. **3** and **4**. However, FIGS. **11** and **12** also illustrate the clearance input by the trainee and any prompts generated by the expert system to instruct the trainee. The "data link" blocks **60**, **64** and **68** of FIGS. **3** and **4** are replaced by system clearance blocks **60'**, **64'** and **68'** of FIGS. **11** and **12**. The system clearances, rather than being transmitted to an aircraft, are displayed in the system clearance window of display **108** and are compared by the expert system with the trainee's clearances Next to each system control command **60'**, **64'**, **68'** are shown the clearances **140**, **142** and **146** input by the trainee which are displayed in the trainee clearance window of display **108**.

At block **60'** the clearance generated by the expert system is "descend and maintain 6,000 feet". The trainee has input a clearance at block **140** to descend and maintain 6,500 feet. The trainee's clearance is compared to the optimum clearance of the data expert system as shown in FIG. **10**. However, in this case the trainee's clearance is within a predetermined range of the expert system clearance so that no interruption is made and the simulation proceeds.

Turning now to block **64'** where the clearance generated by the expert system is to turn right, descend to 2,200 feet and maintain 300 knots. The clearance input by the trainee at block **142** is to turn right at a heading of 180° and to maintain 300 knots. The trainee's clearance is compared to that of the expert system. In this case the trainee's clearance is sufficiently at variance from the expert system's clearance so that the trainee should be informed of the optimum command but the simulation can continue. Accordingly, at block **144**, the expert system will output in the training prompt window of display **108** a prompt **144** that will inform the trainee that the heading suggested for **UA234** will place it wide of the approach path. Thus, the trainee is informed that his proposed command is less than optimum. This is the essence of the computerized intelligent tutor thereafter, the expert system proceeds to FIG. **12**.

At block **68'** of FIG. **12** the optimum clearance generated by the expert system at block **68'** is for **UA234** to turn right at a heading of 10° at an altitude of 1,800 feet. The trainee at block **146** has input a clearance that **UA234** continue its present heading. The trainee's clearance is compared to the expert system's optimum clearance and is found to be seriously in error so that the trainee should be informed and the simulation interrupted. This too is an important part of the computerized intelligent tutor. The computer will interrupt the simulation and output in the training prompt window of display **108** a Prompt **148** informing the trainee that the command was in error and that continuing present heading will waste time and fuel. Thereafter, the simulation may be repeated so that the trainee may learn from previous mistakes.

The symbolic languages used in "artificial intelligence" applications, such as LISP or PROLOG, with the language C used for the simulation portion are particularly suitable for this application. In order to illustrate the expert system previously described by reference to flow charts note the following lines of LISP code:

```
(defun atc2 (AA123)
1    (cond ((eq AA123 'no-other-aircraft-a-factor)
           'maintain-present-heading)
2          ((eq AA123 'other-aircraft-approaching-at-zero-
           degrees) 'go-to-frame-101)
3          ((eq AA123 'other-aircraft-approaching-at-180-
           degrees) 'go-to-frame-101)
4          ((eq AA123 'aircraft-in-front) 'go-to-frame-103))).
           for front
```

The system is divided into "frames". The first line of the above frame (frame ATC 2) constitutes the "are any other aircraft a factor" test undertaken at blocks **52**, **56** and **62** of FIG. **3**. The frames that are to be branched to constitute the "conflict adjustment" subroutine similar to that of FIG. **5**. If at line 1 of the above frame no other aircraft are a factor the command "maintain-present heading" is output to the aircraft. Lines 2 and 3 contact frame 101 if other aircraft are approaching at either 0° or **180°** (due North or South). Line 4 is directed to the situation where another aircraft is in front of **AA123**, in this case line 4 calls up frame 103.

Frame **101** provides for conflict adjustment when branched to from the above frame and reads as follows:

```
(defun frame 101 (AA123)
1    (cond ((eq AA123 'other-air-est-arrive-within-3-mi-
           before) 'decrease-speed-AA123)
2          ((eq AA123 'other-air-est-arrive-more-than-3-mi-
           before) 'maintain-speed-AA123)
3          ((eq AA123 'other-air-est-arrive-more-than-3-mi-
           after) 'maintain-speed-AA123)))
```

Line 1 considers the situation where the other aircraft will arrive within 3 miles before **AA123**, if so, **AA123** will be told to decrease its speed, which will increase the distance between the aircraft and thus resolve potential conflict. Lines 2 and 3 of the frame consider the situation if the other aircraft will arrive more than 3 miles before or after **AA123**. In such a situation there is no potential conflict and thus no change in **AA123** air speed is required, thus **AA123** is cleared to maintain its present speed.

Frame 103 is contacted from line 4 of frame ATC 2 where there is an aircraft in front of **AA123** and reads as follows:

```
(defun frame 103 (AA123)
1    (cond ((eq AA123 'front-aircraft-speed-eq-AA123)
           'maintain-speed)
2          ((eq AA123 'front-aircraft-speed-   -AA123)
           'maintain-speed)
3          ((eq AA123 'front-aircraft-speed-   -AA123)
           'decrease-speed)))
```

This frame adjusts the speed of **AA123** so that **AA123** will not gain on the aircraft in front. Lines 1 and 2 determine if the speed of the aircraft in front is either equal to or greater than that of **AA123**. If either is the case then **AA123** is ordered to maintain its speed. Line

3 controls the situation where the speed of the aircraft in front is less than that of AA123. If so, AA123 is told to decrease its speed so that it will not close on the aircraft in front.

As is seen each "frame" comprises both the "knowledge base" which is used to control the approach of incoming aircraft and the means to control program flow in response to the data received from the aircraft. The inference engine determines what frames to call upon. Such frames may be readily modified, added or deleted to modify the control of approaching aircraft. Certain frames may only become active under certain conditions such as at night or in poor weather.

The above-described arrangement is merely illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. An expert data processing system to act as an intelligent tutor for air traffic controller training comprising:

means for simulating data transmitted from the aircraft that are to be controlled, said simulated data representing the position and heading of the aircraft;

means for input of air traffic control clearances by an air traffic controller trainee;

a stored program controlled computer having data input means for input of said simulated aircraft data and output means for output of control clearances;

data processing means for accessing the simulated aircraft data from a first aircraft and comparing said data to simulated data from another aircraft, means for comparing the data of said first and second aircraft with a knowledge base of aircraft control data, means for branching within said knowledge base based on said comparison, means for outputting control clearances based on a comparison of the simulated aircraft data with said knowledge base, means for comparing the control clearance generated by said data processing with said trainee's control clearance and means for output of said control clearance, said trainee's clearance and said comparison.

2. The system as claimed in claim 1 further including display means connected to said output means, said display means displaying said control clearance, said trainee's clearance and said comparison in juxtaposition to each other.

* * * * *