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Expert system in extension

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Abstract
Agricultural extension services are essential for enhancing farming techniques and productivity. Nevertheless, obstacles such as a shortage of available specialists, fluctuating guidance, and accessibility problems hinder the delivery of effective advisory services. AI-powered expert systems present a hopeful alternative by delivering immediate, data-informed suggestions for diagnosing and overseeing agricultural practices. This research investigates the usability, efficacy, and influence of an expert system designed to assist farmers through extension advisory services. A systematic interview framework gathered information from farmers with diverse backgrounds regarding system usability, accuracy of recommendations, user motivation, risk propensity, and technical abilities. To evaluate the influence of essential factors on the adoption and effectiveness of expert systems, we employed Multiple Linear Regression (MLR). The MLR model facilitated the assessment of how variables like farmers' education level, agricultural experience, system usability, and risk perception affected their utilization of the specialist system. The findings reveal that the majority of farmers regarded the expert system as user-friendly, efficient in delivering timely advice, and very precise in identifying agricultural problems such as soil health oversight, crop choice, and pest management. The MLR assessment suggested that educational background and prior experience with technology notably influenced adoption rates. Farmers possessing limited technical expertise required additional training to maximize the advantages of the system. Although the feedback was generally positive, several apprehensions were expressed regarding the system's capability to adjust to local circumstances and the need for continuous updates to tackle immediate agricultural issues.

This research underscores the capabilities of AI-based expert systems to revolutionize agricultural extension services. By reducing dependence on human consultants and delivering reliable, scalable, and precise guidance, these systems can significantly enhance

agricultural efficiency. Nonetheless, advancements are required in interface design, region-specific content, and training programs for farmers to ensure broader implementation. Subsequent studies should concentrate on improving machine learning models, integrating adaptive learning techniques, and expanding access for smallholder farmers to widen the effect.

Keywords: Specialized system, Agricultural outreach, Artificial intelligence in agriculture, Support for decision-making, Targeted farming, Multiple Linear Regression (MLR), Agricultural advisory services

Introduction

Farmers require assistance from specialists in a range of agricultural disciplines, including entomology, pathology, extension services, and tractor mechanics. An expert system, or knowledge-based system, can be utilized in these domains whenever human expertise is needed. It has proven to be effective in various problem areas that typically necessitate human-like reasoning. An expert system is a software that initiates with the collection of data on a particular issue. It offers one or more solutions, or at the very least, some parts of an answer (Ermine, 2001) [1]. The gathering and organization of knowledge play a vital role in expert systems (Waterman, 2003) [20]. These systems find application in diverse fields such as extension, agriculture, animal husbandry, biology, engineering, medicine, communication, marketing, and banking. They comprise programs that utilize encoded knowledge to address challenges in a specific domain. The knowledge for expert systems is derived from specialists and is formatted for the system's use in reasoning. The knowledge of experts must be collected from various sources, including specialists, libraries, academic journals, and databases. This knowledge often necessitates considerable training and experience in sectors like agriculture, extension, and engineering. Once sufficient knowledge is collected, it can be encoded, stored in a knowledge base, and subsequently tested and enhanced.

Expert systems in extension can support decision-making and tackle significant challenges across various sub-disciplines by utilizing knowledge and analytical guidelines established by experts in the field. Although numerous resources, such as books and manuals, hold extensive knowledge, individuals must read and interpret this data for effective application. Consequently, a small number of extension agents frequently find it difficult to manage the intricate and varied problems encountered by millions of farmers, given the differences in education and comprehension levels. Nevertheless, they have the capability to develop expert systems in extension that combine human insight and knowledge to address specific issues. Acknowledging the significance of this subject, this paper will examine the concept, origins, aims, features, objectives, classifications, design, components, benefits, and drawbacks of expert systems.

Concept of Expert System

The concept of creating expert systems originates from artificial intelligence (AI) and stands apart from conventional computing and programming techniques. A traditional application adheres to a sequential approach to reach a defined result. In contrast, an AI application is composed of a knowledge base and a method to derive conclusions. Expert systems can deliver quantitative data, much of which is derived from fundamental and practical research, including economic thresholds, crop development frameworks, and pest population models, as well as heuristics for interpreting qualitative information. A key strength of expert systems is their capability to elucidate their reasoning. As the system records its logical processes, a user can seek clarification for a recommendation concerning various crops and technologies, and the system will outline the factors it considered for that advice. This aspect enhances user trust in the recommendation and boosts the acceptance of the expert system.

Origin of Expert System

The age of the computer revolution that led to the emergence of expert systems, indeed started in the early seventies (Waterman, 2003) [20]. Only a handful of leading U.S. universities possessed research laboratories originating in the 1960s and 70s that generated expert systems. The input from more than 40 AI researchers, each of which added to the quantities Building Expert System, managed to shed light on (Hayes, 19983). They developed specialized solvers that depended on knowledge instead of on algorithms and overarching search. This method represented a significant shift from traditional artificial intelligence applications, which relied on several heuristic guidelines instead of a set of specialized information. This deviation from the norm proved to be a wise choice, it resulted in the creation of a novel category of effective systems and unique system design.

DENDRAL was the initial expert system were ten by the Stanford University in the late 60's. And then came MYCIN at Stanford University. Another pioneering expert system, POSPECTOR, assists geologists in locating mineral resources and Rl (also referred to as XCON), which was utilized by the Digital Equipment Corporation to assist in selecting and setting up components for complex computer systems. Extension Expert System Extension expert systems were initially created at the Indian Agricultural Research Institute, New Delhi within the Department of Agricultural Extension

Who is Expert?

Specialists are not merely people who have skimmed some guides or attended a few courses—they are individuals whose extensive education and practical experience distinguish them. Their expertise goes beyond mere ability; it involves performing duties with a degree of sophistication and effectiveness. that the majority of individuals are unable to equal. What truly sets experts apart is their ability to sift through unnecessary information and focus on the essence of a problem. They possess a diverse toolkit of specialized insights, effective techniques, and awareness of typical traps. When confronted with a difficulty, they swiftly identify recognizable patterns and implement the appropriate solution, nearly instinctively. Under lyingall of this constitutes a profound pool of practical knowledge—what we refer to as expertise. It follows that if we aim to comprehend or portray this expertise, seeking insights from those who possess it is a sensible approach. After all, who is more qualified to shed light on the intricacies of expert behaviorior than the experts them-selves.

What is Expert System?

An expert system is fundamentally a web-oriented software application created to address issues and deduce solutions similarly to a human specialist. Advances in artificial intelligence have resulted in the creation of methods that represent information at higher levels of abstraction, departing from the inflexible frameworks characteristic of traditional programming. These methodologies are integrated into specific programming languages, allowing for the development of applications that reflect human thought processes and reasoning—rendering these systems not just more intuitive but also simpler to create and maintain. Expert systems, often referred to as such, mimic human knowledge in particular, clearly outlined fields of problems.

In comparison, conventional languages such as FORTRAN and C were mainly designed for procedural data handling—managing numbers, arrays, and similar elements. Nonetheless, humans often approach intricate problems through more abstract, symbolic means, which these traditional languages find challenging to support. Expert systems fill this void, offering a structure that aligns reasoning more closely with human thought processes. The definitions that come next will further clarify what defines an expert system. An "Expert System" is a sophisticated software application that utilizes knowledge and reasoning methods to address challenges that are complex enough to necessitate human expertise for their resolution. The understanding required to operate at this level along with the reasoning methods employed can be regarded as a representation of the skill of the top professionals in the industry (Daniel Hunt, 1986) [19].

What is Agriculture Expert System?

An agricultural expert system functions as a dedicated decision-support tool for extension officers, aiding them in developing suggestions for farmers. These systems allow agents to deliver precise and prompt advice, which farmers can then implement as specific actions in the field. Importantly, such expert systems promote the direct conveyance of scientific information from researchers to farmers, significantly reducing the misrepresentation or degradation of information that frequently arises when numerous intermediaries participate in traditional technology transfer methods. This guarantees that farmers obtain trustworthy and unmodified recommendations, thus improving the effectiveness of agricultural extension services.

In essence, an expert system is a software application that utilizes specific, qualitative knowledge to solve issues in a defined area—reflecting the abilities of a human specialist (Doran, 1988).

An Expert System (also known as a Knowledge Based System, KBS) is a software application designed to replicate the decision-making methods of a specialist in a specific area. In in the realm of agriculture, such frameworks combine the shared knowledge from multiple fields—plant pathology, extension services, entomology, horticulture, and agricultural meteorology—into a cohesive structure that addresses the specific, immediate requirements of farmers. Expert systems integrate research outcomes and hands-on expertise with the intricate reasoning of various experts, thus assisting farmers in making knowledgeable choices for their crops.

Objectives of Expert System

Essentially, expert systems are software applications created to replicate the decision-making skills of a human specialist, albeit solely within a narrowly defined scope. The area of interest must be distinctly organized and well comprehended—there's no space for uncertainty in this case. Developing such a system goes beyond mere programming skills; it requires specialized knowledge in that particular domain to address the specific challenges encountered there. An expert system typically comprises a knowledge base (which contains essential facts, heuristics, and specialized information), an inference engine (which formulates conclusions and tackles problems by evaluating that knowledge), and a user interface (enabling users to engage with the system—entering inquiries and receiving responses). The method of creating expert systems is quite different from conventional programming. It requires a unique perspective and approach, concentrating more on acquiring and utilizing expert-level knowledge rather than merely coding.

Uses of Expert Systems

Expert systems are progressively becoming popular in multiple fields, such as decision-making, planning, design, and diagnostics. Significantly, their implementation in agricultural extension has been growing among both extension workers and farmers. As highlighted by Rao, specialized systems fulfill various important roles within this framework.

- Unique decision moments, like organizing tasks.
- Structuring procedures—for instance, establishing the arrangement of an irrigation setup.
- Selection activities, such as determining the best crop type or selecting an ideal market channel.
- Diagnostic activities, including the detection and classification of particular livestock ailments.
- Reevaluation of data, such as examining collections of financial statements.
- Predictive evaluations, such as anticipating severe weather occurrences like thunderstorms or frost.
- A sequence of strategic choices made during the production cycle, including choices about crop protection, nutrition, and livestock feeding methods.

Characteristics of Expert System

According to the Patterson (2003), the following are the characteristic of expert system:

Expert systems are unique because they emphasize knowledge rather than just data when addressing problems; the idea that “knowledge is power” truly forms the foundation of their structure. Instead of integrating knowledge directly into the control software, these systems utilize a distinct knowledge base. This division is advantageous: it permits modifications or enhancements to the knowledge base without the need to recompile the entire software. In some cases, the same control software can even operate with different knowledge bases, resulting in specialized expert systems for various tasks. These adaptable structures are referred to as “expert system shells,” as they can accommodate an array of knowledge bases as needed. Expert systems are capable of explaining how a particular conclusion was reached and why requested information is needed during a consultation. This is significant as it allows users to evaluate and comprehend the system’s reasoning capabilities, consequently enhancing the user's trust in the system.

Expert systems utilize symbolic representations for knowledge (rules, networks, or farms) and carry out their reasoning via symbolic computations that are similar to the manipulations of natural language. (An exception to this is the specialized system built on neural network frameworks.)

Expert systems frequently deduce conclusions with metaun derstanding; that is, they think critically with awareness of themselves, along with their own knowledge boundaries and potential.

Purpose of Expert System

Expert systems are created to solve intricate, real-life issues that would usually necessitate the knowledge of experts, like healthcare professionals or farming advisors. The first step in developing an expert system entails methodically collecting and structuring pertinent knowledge from domain specialists—individuals who possess significant hands-on experience in areas like agriculture or extension services. The focus is placed on knowledge-based approaches rather than alternative formal representations or analytical methods, mainly because they can offer quick, easily accessible solutions to end-users, such as technicians and field agents, who may not consistently have ready access to expert guidance.

In reality, expert systems that are integrated with extensive, domain-specific knowledge—like that pertaining to agricultural extension—allow users to utilize years of gathered expertise to tackle urgent challenges. These systems not only aid frontline personnel but also help supervisors and managers in evaluating circumstances and participating in strategic planning. A variety of specialized expert systems are available, each targeting specific concerns with concentrated and thorough understanding, thus showcasing the practicality and significance of larger expert system endeavors.

Throughout the last ten years, the implementation of expert systems has greatly improved efficiency in various fields, such as business, science, engineering, agriculture, and the armed forces. The presence of commercial expert system software featuring intuitive interfaces has additionally supported their integration. Furthermore, continuous research and hands-on application persist in honing these systems, with each new usage offering important knowledge about their efficacy in particular situations.

Types of problems solved by Expert Systems

Expert systems signify a notable progress for businesses that depend on specialized knowledge that is difficult to convey or share among individuals. Essentially, these systems encapsulate and systematize the understanding and thought processes of experienced professionals, rendering this information broadly available throughout the organization for efficient resolution of issues.

Types of problems solved by Expert Systems

Expert systems signify a major breakthrough for organizations that depend largely on specialized knowledge that is challenging to convey or share among individuals. Essentially, these systems document and structure the insights and thought processes of experienced experts, rendering this knowledge broadly available within the organization for efficient problem resolution.

In the realm of agricultural extension, expert systems show significant worth. They enable the distribution of vast, specialized information to a large number of farmers and extension workers across extensive areas, frequently impacting millions. These systems offer users advice and remedies for a wide variety of agricultural issues—from crop ailments and pest problems to more comprehensive decision-making tasks—mimicking the insights of seasoned subject matter experts.

Furthermore, agricultural expert systems are used for diagnostic functions, helping to recognize and tackle problems such as pest infestations, plant ailments, and weed management. Their usage goes beyond just crops to embrace areas like livestock farming, veterinary care, poultry, aquaculture, apiculture, and numerous other agricultural businesses. Typically, expert systems are especially beneficial in situations where issues do not have a clear, straightforward answer, relying on the intricate knowledge of experts to guide effective decision-making.

Types of Expert Systems: Several writers have presented various kinds of expert systems as outlined below:

Rule based

In rule-based systems, knowledge is not merely kept as fixed information—similar to an unending inventory you might encounter in a textbook. Rather, these systems are organized around a series of IF-THEN statements, which direct reasoning or decision-making in different contexts. You possess a collection of facts, a repository of rules, and an interpreter that identifies which rules are relevant based on the existing facts. The emphasis is more on establishing a foundation for reaching conclusions or making decisions according to particular circumstances, rather than solely on possessing knowledge.

Object-Oriented

"In computer programming, object-oriented refers to a programming paradigm. Numerous programming languages facilitate object-oriented programming. Several programming frameworks, such as the Java platform and the NET Framework, are founded on object-oriented concepts. Object-oriented programming is frequently shortened to OOP."

Eriksson (1996) has mentioned three more types as Logic-based

In this method, coding is organized utilizing predicate calculus—consider PROLOG as a traditional instance. The logic of the system fundamentally outlines the pathway for the program's execution, establishing regulations and connections that direct its reasoning procedure.

Induction-based & Hybrid systems

Induction-focused systems, conversely, derive patterns and rules from instances—similar to deducing general concepts from particular examples. Hybrid systems seek to merge both logic-oriented and induction-oriented approaches, fusing analytical reasoning with learning abilities to enhance adaptability and address challenges.

Information versus Knowledge-oriented systems

To elaborate, information denotes raw data—facts and figures that are pending interpretation or application. A knowledge-based system, on the other hand, is intended to handle this information, converting it into structured rules and practical knowledge. In essence, although information serves as the initial stage, the knowledge-based system functions as the mechanism that enhances and applies it, facilitating the realization of particular objectives. The illustration below visually differentiates these concepts for additional understanding.

The DENDRAL

DENDRAL is notable as one of the first systems that used specialized knowledge for problem-solving in the field of artificial intelligence. Created at Stanford University in the late 1960s, with Lindsay playing a significant role, DENDRAL sought to infer the structures of organic compounds based on their chemical makeup—a challenge that would be virtually unmanageable to accomplish manually or by consulting textbooks, due to the vast number of potential molecules. DENDRAL's uniqueness lay in its capacity to integrate the heuristic techniques of skilled chemists, effectively transforming human knowledge into computational methods for examining molecular configurations.

The MYCIN

MYCIN, developed by Buchanan and Short liffat Stanford in the mid-1970s, marks an important landmark in the realm of medical artificial intelligence. Fundamentally, MYCIN operated as a digital advisor, replicating the diagnostic and therapeutic practices of a doctor, especially for ailments like spinal meningitis and bacterial bloodstream infections. What set MYCIN apart was its ability to reason with uncertain or partial information, an innovative characteristic at the time. Moreover, the system was distinguished by its capability to offer users coherent, rational justifications for its decision-making procedures, thereby increasing both its trustworthiness and usefulness in medical environments.

Why Expert system in Agriculture Extension

Historically, research-oriented information has been shared with local farmers mainly through extension agents, typically government personnel responsible for engaging with rural populations. Esman (1983) [14] noted that this duty primarily resides with these field agents; nevertheless, their quantities are often inadequate to uphold significant and steady interaction with the families they are meant to serve. Continued to evaluate the system, highlighting that numerous extension specialists undergo excessively specialized education, concentrating mainly on technology and its implementation. This limited perspective leads to overlooked chances for aiding their clients as well as for interacting with the wider, more dynamic elements of rural extension, especially the possibilities for transformative communication.

Schultz (1981) [18] added to this discussion by asserting that economic growth cannot depend exclusively on natural resources, physical assets, and labor. Rather, effective socio-economic progress necessitates a wide array of human capabilities. In the framework of globalization, it is becoming more evident that outreach strategies need to advance beyond traditional methods like demonstrations, training workshops, and media broadcasts through radio or television. A more holistic, flexible strategy is now essential to address the intricate issues encountered by rural communities. Extension system should be very fast, based on farmer's requirements, their assets, existing market, and cost-effectiveness ratio. In the age of fast growing electronic information system, best combination Collaboration between humans and technology is essential to address the socio-economic and informational requirements of farmers and to promote sustainable agriculture. Taking these factors into account, a Specialist System of Extension is essential and connecting 558 Krishi Vigyan Kendras through net to serve the agricultural community in the most effective manner in the new millennium.

Design of Expert System

There must be a acknowledged human specialist—someone clearly skilled in the specified area. This person's expertise should arise from specialized understanding, good judgment, and considerable experience. In addition, the expert needs to be able to express not just their knowledge and experience, but also the rationale and techniques they use to tackle specific issues. Finally, the task at hand ought to be placed within a distinctly outlined and restricted area, guaranteeing that the system's range stays feasible and well-organized.

Steps in Design Techniques

There are four (module) essential component of a full-fledged expert system:

1. The knowledge-acquisition module.
2. The knowledge base.
3. The inference engine.
4. The Explanatory interface.
5. The Knowledge Acquisition Module.

The knowledge-acquisition module acts as a fundamental element of an expert system. In computational language, "knowledge" pertains to data that allows a computer tofunction thoughtfully. This understanding includes information, convictions, and experiential guidelines, which collectively create an organized assembly able to provide effective results when utilized. Assessing the extent and range of understanding, whether in an individual or a software program, generally entails assessing their capability to adapt and thrive in multiple scenarios. The knowledge-gathering procedure itself is the approach by which a knowledge engineer collects data from specialists, academic literature, and other credible sources. This data is subsequently transformed into a format suitable for computer systems, often utilizing encoded rules. Within in the context of agricultural expert systems, the knowledge-acquisition module gathers information not solely from groups of subject matter experts—each focused on specific crops or agro-enterprises—but also from textbooks, technical bulletins, and research results. Therefore, the module combines both expert heuristics and verified factual information, guaranteeing that the system's suggestions are both trustworthy and rooted in evidence.

The Knowledge Base

The second element is the knowledge base. It serves as the fundamental part of any expert system because it holds the information gathered from specialists in the relevant area. Typically, a knowledge engineer is tasked with collaborating with an expert to develop the knowledge base for the system. The knowledge engineer must perform a detailed analysis of the inference process and develop the prototype knowledge base. The tasks associated with creating the knowledge base encompass knowledge gathering, representation, coding, and refinement. Although the term "knowledge representation" can be employed in a broad context to denote all forms of depicting issues, remedies, and information in a set of rules, it is this final application that the majority closely captures the meaning that is associated with the word "knowledge". A knowledge repository for the programming domain documents two essential categories of knowledge - the link from a piece of source code to a general explanation of what that piece of code "produces". It also encapsulates causal relationships from one state (or perhaps several states) to another (outcome) state. This represents the traditional "antecedent-consequent" structure of a rule. A rule base expert system must offer a collection of tables that enable a clear differentiation between rule antecedents and rule consequents. Consequently, a rule base configuration that includes a distinct table for antecedent source code segments is favored. This table will serve to supply antecedents to the abstract state descriptions contained in the main consequent.

The Inference Engine

The third most crucial element is the reasoning mechanism or "inference engine". The reasoning engine processes the input statements of the problem statement document. This input is typically submitted to the reasoning engine in a tree format held in memory, having first been processed by a lexical analyzer and parser. The main task of the reasoning engine is to take a problem statement, for instance a goal statement, and to match the collection of characteristics of the objective compared to a collection of characteristics in the rule base within a rule consequent table. The reasoning engine utilizes the outcomes of this alignment to begin obtaining the relevant rule antecedents. There may be multiple "parallel" antecedents for a given goal, and/or there may be multiple antecedents that will form a "chain" of state description records as they are retrieved. The reasoning engine works together with the code generator to the effect that all necessary source code fragments are retrieved and combined to create a more extensive target program segment, which is recorded in an output program file.

Feasibility of its use in remote areas

A question is frequently posed by the developers of expert systems regarding how this system could be used in remote areas where there is scarcity of electricity, telephone connectivity and now-how? In order to address this inquiry, it can be observed that a few years ago there were no STD and PCO booths in remote and grassroots areas. But due to economic crisis and unemployment problem, a number of educated youths opened STD and PCO booths in remote areas also. The illiterate farmers and labourers come to the booth and get their telephone number linked through the booth operator, enabling communication with their sons or brothers employed in metropolitan areas within a matter of minutes.

The act of composing letters and utilizing post offices for sending and receiving mail has significantly diminished. Likewise, when the internet-based electronic system is implemented in rural areas, as the government has already outlined, the expert system will also be easily accessible to the illiterate farmers in even remote areas.

Since several national and international organizations are currently establishing their networks in rural areas and investing money in India, a day is not far to get the Internet connectivity in isolated communities as well. Consequently, this service will be readily available to every onein both city and countryside settings.

Advantages

- Provides consistent answers for repetitive decisions, processes and tasks.
- Holds and maintains significant levels of information.
- Encourages organizations to clarify the logic of their decision-making.
- Never "forgets" to ask a question, as a human might
- Disadvantages.
- Lacks common sense needed in some decision making.
- Cannot make creative responses as human expert would in unusual circumstances.
- Domain experts not always able to explain their logic and reasoning.
- Errors may occur in the knowledge base, and lead to wrong decisions.
- Cannot adapt to changing environments, unless knowledge base is changed.

Conclusion

At present, only larger institutions like medical institutions, railways, air ways, oil companies etc. can afford to purchase cybernetic expertise, but we may soon see the day when "smart assistants" are available on store shelves for personal computers designed for farming and allied areas as well. As we know that Indian agriculture is transforming from traditional to contemporary, farmers require precise information on the necessary technologies. They also need to take decision about what to grow/do? This is not possible by conventional system of extension. Furthermore, it is not achievable because of the limited number of extension agents and minimal investment in extension. Consequently, it is neither feasible nor practical to provide guidance and disseminate the required information based on the needs of the farmers with existing extension framework. The expert system for extension was conceived and structured in a way that way that it will provide the demand based information to the millions of the farmers efficiently through website even in the remote corners of the country at the same time. This system is entirely different from the conventional system of extension in terms of efficiency, accuracy, precision, decision-making and also considering the cost and benefit.

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