Trends and Insights on Tools Used for the Development of Expert Systems: A Systematic Review of Research Articles (2018-2022)

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TRENDS AND INSIGHTS ON TOOLS USED FOR THE DEVELOPMENT OF EXPERT SYSTEMS: A SYSTEMATIC REVIEW OF RESEARCH ARTICLES (2018-2022)

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Abstract— **Expert systems, a branch of artificial intelligence, have seen tremendous growth over a long period of time. The application of technology has cut across different sectors of society and made possible by using various software tools. This article critically reviewed the application of software tools in the development of an expert system for use in different sectors. Key issues of focus included tools used, application areas, and the implementation environment. A structured approach to the systematic review was adopted that involved formulation of research questions, establishment of criteria for inclusion & exclusion, undertaking a search, selection of articles to be reviewed, assessment of the quality of articles, extraction of data, and analysis of the data. Articles published in English from 2018 to 2022 from journals, conference proceedings, and book series were reviewed. Findings from the review pointed to a widespread application of expert systems globally, developed using several tools. CLIPS, Prolog, Jess, and MATLAB emerged as the preferred tools for the development of expert systems. The implementation of the expert systems involved the independent use of the tools and their integration with other software environments. The different software integration pathways used with the tools have also been highlighted. This review provides insights into the state of research relating to the development of expert systems and their applications.**

Keywords: **Expert systems, knowledge-based system, CLIPS, Prolog, Jess, MATLAB**

I. INTRODUCTION

The emergence and growth of artificial intelligence (AI) has brought with it many new interests. The field has evolved over a long period, with studies pointing that it remained an emerging area in regional science but contributed immensely to the identification of future research interests (Lazzeretti et al., 2022). While affirming the diverse application areas of AI in civic engineering, Dede et al. (2019) defined the area as the development of "machine elements that analyze the human's thinking system and reflect the same to reality" pp.1. AI is now considered an essential component of business models in addition to playing a key strategic role in planning for many sectors globally (Dwivedi et al., 2021). It is also viewed as a branch of computer science that focuses on understanding the intelligence of humans (Hakim et al., 2020b).

Expert systems (Dede et al., 2019; Mirmozaffari, 2019; Salehi & Burgueño, 2018), fuzzy logic (García et al., 2019; Dede et al., 2019; Mirmozaffari, 2019; Salehi & Burgueño, 2018), Artificial neural networks, swarm intelligence (Dede et al., 2019), metaheuristic algorithm (Mirmozaffari, 2019), machine learning (Mirmozaffari, 2019; García et al., 2019; Salehi & Burgueño, 2018), Computer Vision, Natural Language Processing (García et al., 2019) and pattern recognition (Salehi & Burgueño, 2018) are some of the notable branches of AI. Additionally, Galbusera et al. (2019) used a schematic diagram to illustrate the three main branches of AI that included symbolic (chat bots, expert systems), evolutionary algorithms and machine learning made up of support vector machines, artificial neural networks, decision trees, & statistical based methods. Despite the varied approaches adopted in categorizing branches of AI, it is evident that there is agreement on their existence.

One branch of AI that has been very impactful in providing solutions to real life problems in society is expert systems. Such systems have been relevant by providing advice on existing problems based on accumulated knowledge (Sotnik et al., 2022). Expert systems have been viewed as those that solve problems that ordinarily would be handled by human specialists/experts (Salehi & Burgueño, 2018; Hakim et al., 2020b). According to Jabbar & Khan (2016) and Rachna (2022), such systems have also been referred to as knowledge – based systems, while Mirmozaffari (2019) argued that they depend on knowledge that is specialised provided to them as a methodology for solving problems. The choice of the term knowledge-based despite being general is attributable to the approach used to provide solutions to problems. Kendal & Creen (2007) provided clarity on the use of the two terms through a proposal that classified knowledge - based systems into a number of categories, including expert systems, neural networks, case-based reasoning systems, genetic algorithms, intelligent agents, and data mining. The application of expert systems has targeted specific domain areas (Tavana & Hajipour, 2019), by depending on knowledge obtained from different sources, such as human experts, books, and magazines (Hakim et al., 2020b). The purpose of this systematic review is to provide trends and insights on the tools used for developing expert systems in addition to the targeted application areas.

II. BACKROUND

Advances in software tools for developing expert systems have a direct influence on the efficiency of solutions offered. Provision of up to date information on existing tools for developing experts is crucial in informing future research direction. This systematic review sought to examine tools used for developing expert systems through studies conducted from 2018 to 2022. Special attention was given to application areas and their implementation environments. An evaluation of past reviews of expert systems preceded this review.

Summary of previous reviews

A comparative study by Jabbar & Khan (2016) based on nine parameters to determine the suitability of tools recommended resource constraints both computational and financial in addition to domain specific requirements as key in influencing the choice.

Similarly, Yurin & Dorodnykh (2020) based their comparison on several factors which included support for non-programmers, facilitating modelling that is visual, generation of code, checking of code, ability to generate expert systems, integration with CASE-tools and availability of other sources of information. Embeddability, Forward Chaining, Backward Chaining, Extensibility, Open Source, Development Tools & Developer Support have also been used as a criterion for assessing the abilities of tools/shells for developing expert systems (Pithadia, 2021).

While Jabbar & Khan (2016) compared MATLAB, Scilab, Prolog and Lisp; Yurin & Dorodnykh (2020) focused their comparison on Expert system designer, Expert system creator, Exsys Corvid, ClipsWin, ES-Builder Web, VisiRule, Generic knowledge base editor and their proposed tool Personal knowledge base designer (PKBD). PyClips, Jess, Clips, Pyke and Eresye were the basis of the comparison done by Pithadia (2021).

Open source and free tools for the development of expert systems were examined in a review undertaken by Rachna (2022) that listed the Java Expert system shell (JESS), Jboss. Drools, Euler Proof Mechanism, Info Sapient, JLog, JEOPS, FOCL, BABYLON, MIKE, WindExS, RT-Expert, CLIPS 6.0, Fuzzy CLIPS and some of the main ones.

Additionally, Liu (2018) explored potential resources for developing expert systems categorising based on associated programming language or on arbitrary details.

Tavana & Hajipour (2019) comprehensively reviewed the application of fuzzy expert systems, establishing that the tools used for their development were categorised into either commercial or non-commercial.

Objectives of the systematic review

The key objectives of the review included:

1. Identification of tools used in the development of expert systems
2. Examination of the key application areas of the systems developed
3. An assessment of the implementation environments used to develop the expert systems.

III. REVIEW METHOD

The systematic review was conducted through a protocol developed based on existing guidelines (Dybå & Dingsøyr, 2008; Higgins et al., 2019) that informed stages and specific activities in each of them.

The inclusion and exclusion of articles in the review was primarily informed by the area of focus, which was expert systems, use of the English language, and more critically the year of publication; the target being those done between 2018 and 2022. Additionally, details on tools used, application area, and implementation details were factors in deciding which articles were to be included or left out.

Articles and papers considered for inclusion in the systematic review were sought from different sources facilitated through the academic social network Mendeley and search engine Google Scholar. Online scholarly databases used for searching for articles included ProQuest, SpringerLink, ScienceDirect, and Wiley. Types of items considered during the searching process were theses, books, conference papers, and journal articles.

Efficiency of the strategy for searching was informed by the choice of keywords such as expert system and knowledge-based system together with the respective software tools used for their development as informed by previous reviews. Articles selected initially were further filtered through a process that first considered the title followed by contents of the abstract and technical implementation details provided as illustrated in figure 1.

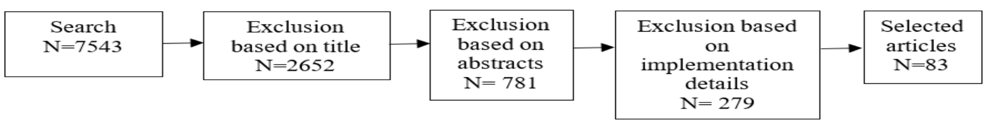

Figure 1: Selection of articles at different stages

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List of references selected for the systematic review were stored in a Google Scholar account that facilitated the generations of citations. Generation of bibliography for the citations based on the APA format was performed using Zotero, a reference management tool for organizing and sharing research sources.
An assessment of the quality of selected articles informed the final selection for the review. Guidelines for assessing the quality of research (Stenfors, Kajamaa & Bennett, 2020) provided the basis for the selection with a focus on a detailed explanation of the problem, objectives, methodology used, implementation environment and the discussion of the findings. Data was extracted from the final list of selected articles using a form-based table (Dybå & Dingsøyr, 2008) that captured among other the authors, type of publication, country/continent, application area, implementation environment and key findings.

IV. RESULTS

Software tools used in the development of expert systems
This section explored some popular tools used in the development of expert systems in the period from 2018 to 2022. They included expert system shells, Prolog – an AI-based language, Python libraries, and conventional programming languages. A brief description of each tool is given in the section that follows.

Prolog
According to Körner et al. (2022) Prolog has evolved for over 50 years with the completion of the first version in 1972 and now boasts of a large body of research. It is a fifth-generation AI logic programming language (Sajja & Akerkar, 2010; Subarna, 2018) and supports the development of expert systems (Liu, 2018; Chen & Lin, 2021; Mukhoid et al., 2018). Reasoning in Prolog is through backward chaining using an inbuilt inference engine (Mukhoid et al., 2018; Che-Chern & Chia-Heng, 2020). Being one of the popular logic programming language, it has many implementations that though different support most core features that include being open source, support for non-standard data types, modules, interfaces for foreign languages, constraint programming, constraint handling rules, improvement of program efficiency by reusing results (tabling), support for multiple cores (parallelism); indexing of rule & facts, typing of interfaces, tools for testing & debugging, support for global variables, use of mutable terms and coroutining – the writing of reversible predicates (Körner et al., 2022). Mukhoid et al. (2018) argued that considering different factors for selecting software tools for developing expert systems, Prolog emerged as a good option among a group of others. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis of the tool pointed to the huge potential that it has going into the future (Körner et al., 2022).

Expert System Shells
a) CLIPS
CLIPS, which stands for 'C' Language Integrated Production System, was developed between 1985 and 1996 as a rule-based programming language at the Johnson Space Center in NASA and made available as a public domain software (Riley, 2023a). Written using C (Konyeha & Imouokhome, 2018; Ananthapadmanaban & Karthik, 2019; Riley, 2023a), the shell has been touted as a suited table tool for developing expert systems (Liu, 2018; Sayed, 2021) and other programs where heuristics offer better solutions than algorithmic approaches (Riley, 2023a). According to Mukhoid et al. (2018), CLIPS competitive advantage over other tools is largely because of several aspects, including syntax that is explicit, ability to call functions programmed in other languages, access of its modules by other languages, and a performance that is acceptable. The support for different programming paradigms including object-oriented, rule-based, and procedural (Savage et al., 2019; Ananthapadmanaban & Karthik, 2019) in addition to portability and low cost (Savage et al., 2019) placed the tool in a better position for consideration in the development of solutions. Inferencing in CLIPS is done through forward chaining (Konyeha & Imouokhome, 2018; Lodhi et al., 2018) with a rete algorithm being used for pattern matching (Riley, 2023b). Improved versions have been released in the recent past. Version 6.4 has been enhanced through a C Application Programming interface that is redesigned, inclusion of wrapper classes for Java and. NET, and provision of an integrated development environment that supports Unicode for Java and Windows (Riley, 2023b).

b) Java expert system shell (Jess)
Another popular tool for the development of an expert system shell is JESS (Java expert system shell). Developed in the late 1990's in California at the Sandia National Laboratories as both a scripting and rule-based language (Hill, 2003). Pithadia (2021), while comparing JESS with other tools, established that despite the code not being open source it could embed with other languages, supported both forward and backward chaining, offered an option for extending the code, development tools exist, and avenue for support of developers exists. It has been recommended for the development of expert systems (Liu, 2018: Mikulić, Lisjak, & Štefanić, 2021) with a core of its design as a language derived from CLIPS (Hill, 2003). The Rete algorithm for pattern matching is one of the design aspects of Jess derived from CLIPS (Mukhoid et al., 2018).

c) VisiRule
This is another expert system shell developed by Logic Programming Associates (LPA) Limited. It is among the popular tools for the development of expert systems that uses forward chaining (Mikulić et al., 2021). VisiRule facilitates non-programmers to develop solutions by combining powerful

features that include expert systems, rapid prototyping, flowcharts, decision trees, and automation of documentation (Easy-to-use Rapid Prototyping Software Tool | VisiRule, n.d.-b). Mikulić et al. (2021) asserted that VisiRule uses nodes as the main constructs representing expressions, functions, or questions.

d) ES-Builder Expert System shell

McGuinness (n.d.) described the ES-Builder expert shell as a teaching tool for students at different levels, compatible with the Windows operating system that supports the development of expert systems through graphical interfaces in addition to the creation of decision trees. The tool also provides a platform for developing web-based expert systems (Mhlongo et al., 2019). Yuri & Dorodnykh (2020), through a comparison with other tools, established that it supported visual modelling through decision trees, code checking, and the generation of expert systems.

Python libraries

A few Python libraries have been created to facilitate the development of expert systems and are highlighted below.

a) Python Knowledge Engine (PYKE)

PYKE is among the few python libraries used in the development of expert systems.
It was inspired by PROLOG and introduced logic programming for the Python community (Bruce, n.d.; Zarca et al., 2019). PYKE is written purely in Python (Ug, 2022; Bruce, n.d.) and has been recommended for use in the development of expert systems (Liu, 2018; Mikulić et al., 2021).
Key strengths of the tool are that it easily integrates with Python programs (Markéta, 2022), supports both forward and backward chaining (Zhang et al., 2018) and enables the utilisation of multiple fact and rule bases in addition to initialisation of several inference engines (Shetty et al., 2020). Facts, rules and questions are the three knowledge bases supported by PYKE with its own source file (Markéta, 2022).

b) PyCLIPS

Another Python library that support development of expert systems is PYCLIPS. It is described as a module for extending the Python language by embedding the functionality of CLIPS expert system shell (PyCLIPS Python Module | Python and CLIPS Integration, n.d.).

c) Clipspy

CLIPSPY is another to tool that facilitates the incorporation of CLIPS capabilities in Python. This is possible through a bidirectional translation between Python and C language Foreign Function Interface (Ghanem et al., 2023; Basile et al., 2022). The tool has been used to develop expert systems (Vajda, 2020).

Nature of publications

Publications selected for the review were of three types with their distribution illustrated in figure 2.

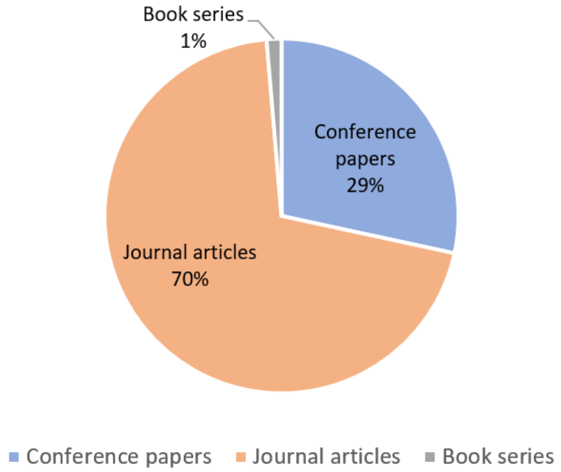

Figure 2. Types of publications

Journal publications were the majority at 70% with a total of 44 different ones used to disseminate findings on the studies relating to expert systems.

The frequency of the publications in the journals is illustrated in figure 3.

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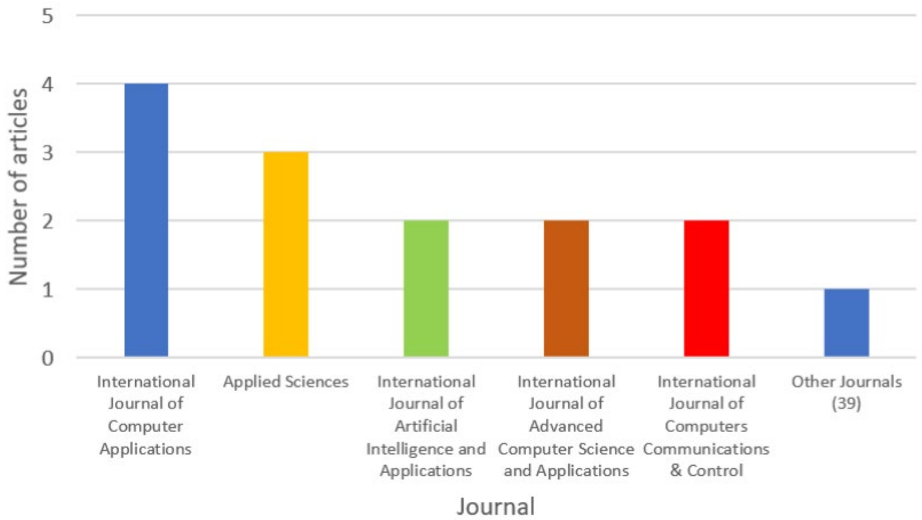

Figure 3. Frequency of publications in journals

Research interests by region

Research interests on expert systems were spread globally with findings reported from all the continents. Figure 4 compared interests among the continents with Asia leading with twenty-seven (27) articles followed closely by Europe with twenty-three (23) and Africa eighteen (18).

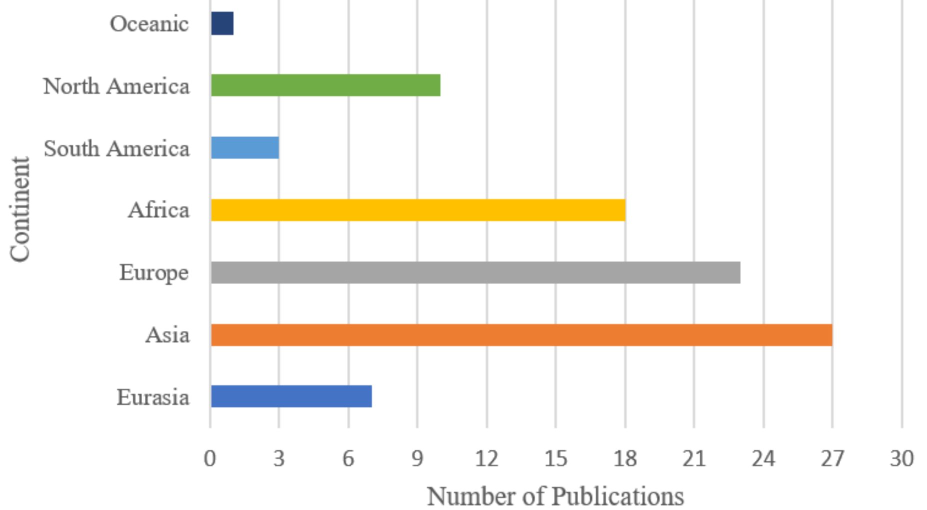

Figure 4: Publications per continent

The distribution of the publications per country is illustrated in figure 5. The leading countries in research on expert systems include Nigeria at position one with India, USA and Russia tied at second position with six (6) articles each. A total of thirty-seven (37) countries contributing to the body of knowledge under the period of the systematic review.

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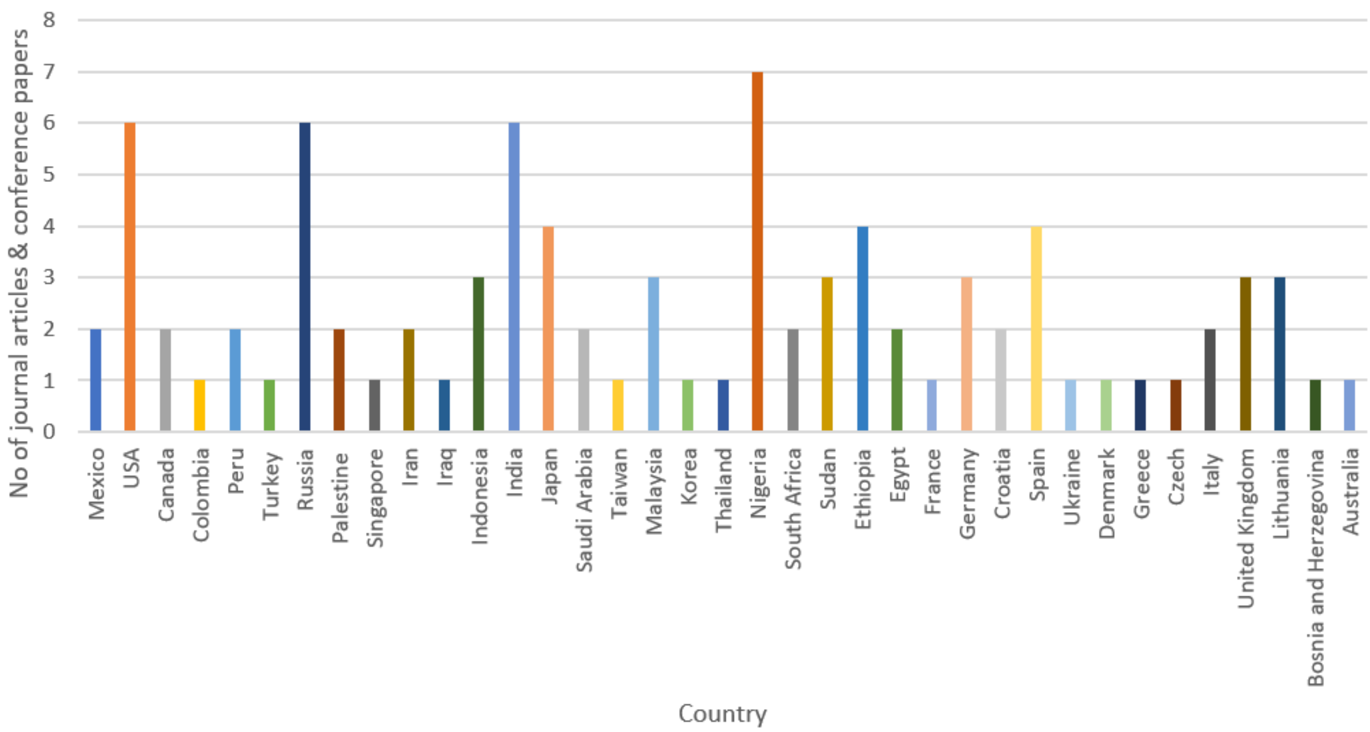

Figure 5. Publication per country

The application areas for the expert systems developed using specific tools were varied. From the reviewed articles twelve (12) broad application areas emerged with the distribution of publications in each shown in figure 6.

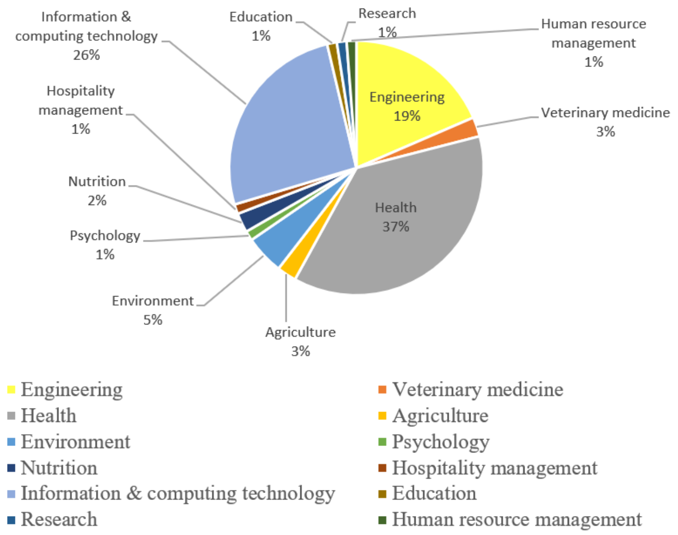

Figure 6. Application areas of expert system development tools

Applications in the health sector were the majority at 37%, followed closely at 26 % by the Information & computing technology that included all related fields such as Computer Science, Information Technology, Artificial intelligence, Software engineering among others. Application in engineering were also significant at 19% with all other areas recording usage frequency of the technology at below 6 %.

The nature of applications in the different field was broadly categorized into four areas as shown in figure 6, with a dominant application in diagnosis at 46%.

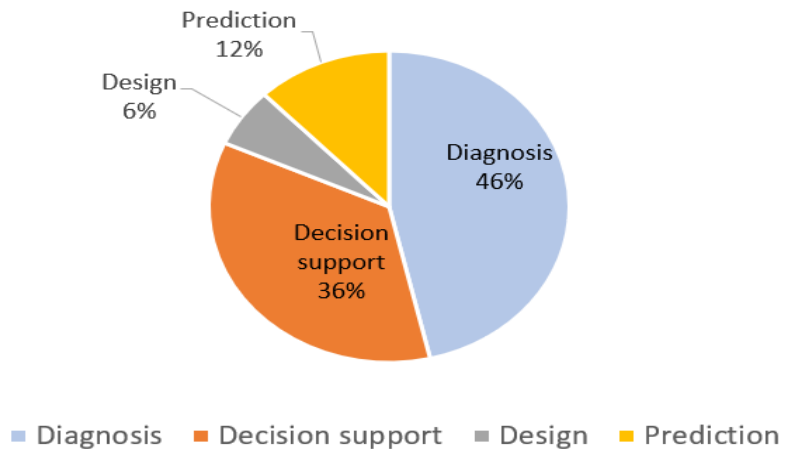

Figure 6. Nature of applications of expert system tools

Usage of tools

Different software tools have been used in the development of expert systems. Table 1 illustrates the usage of the tools in the different studies reviewed.

TOOL	REFERENCES
Prolog	Ahmed & Mahmoud (2014); Chen & Lin, 2021); Agizew (2019); Al-Hajji et al. (2019); Huang et al. (2021); Che-Chern & Chia-Heng, 2020); Muhamad & Rahim (2019); Torres et al., 2021); Burnashev et al. (2019); Ceyda & Çilgin (2022); Pradiawati et al. (2019); Seipel et al. (2018); Al-Hajji et al. (2019); Adane (2020); Das et al. (2018)
CLIPS	Savage et al. (2019); Salman & Abu-Naser (2019); Ananthapadmanaban & Karthik (2019); Konyeha & Imouokhome, 2018) ; Nine et al. (2021); Massel et al. (2019); Mazloom et al., 2018); Sitanggang et al. (2018); Rivas-Perez et al., 2019); Kravchenko at al., 2020); Lodhi et al. (2018); Yurin et al. (2018); Harradi et al., 2021); Mishra et al. (2018)
Jess	Vitkus, Salter, Goranin & Čeponis (2020); Vitkus, Steckevičius, Goranin, Kalibatienė & Čenys (2020); Akanbi & Masinde (2018); Motlagh et al. (2018); Mulyani & Sahal (2019); Vitkus, Jezukevičiūtė & Goranin (2020); Akinpelu et al. (2019); Mostafa et al., 2018); Ogheneovo et al. (2018); Lopez-Santana et al. (2018); Sitdhisanguan et al. (2018)
MATLAB	Nkamgang et al. (2018); Ukaoha et al., 2020); Singla et al. (2020); Nuhu et al. (2021); Gupta & Ahlawat (2019); Casal-Guisande et al. (2020); Alade et al. (2018); Montaña et al., 2018); Tehseen et al. (2020); Carreño et al. (2019)
PYKE	Markéta (2022); Zhang et al. (2018); Shetty et al. (2020); Zarca et al. (2020); Zarca et al. (2019); Dinh et al. (2018); Damrongrat et al., 2018)
VisiRule	Mikulić et al. (2021); Muraina & Adeleke (2021); Chrimes et al. (2021); Abranches et al. (2019); Mikulić et al. (2021)
ClipsPy	Basile et al. (2022); Fitzke et al. (2020); Malec et al. (2022); Taneja et al. (2022)
ES-Builder	Mhlongo et al. (2019); Abduljabbar et al. (2020); Nasr et al. (2018); Marzouk & Zaher (2020)
PyClips	Capolei et al. (2019); Aivazoglou et al. (2020);
Clips & ClipsPy	Ghanem et al. (2023); Vajda (2020)
Delphi XE	Yurin & Dorodnykh (2020)
VB.NET	Psyrras & Sextos (2018); Eyasu et al. (2020)
Jess & Clips	Aguayo-Canela et al (2019)

Python	Mujawar et al. (2018)

Table 1. Expert systems tools usage

Analysis of the utilization of the tools is illustrated in Figure 7, with Prolog, CLIPS, Jess and MATLAB emerging as the dominant ones in that order

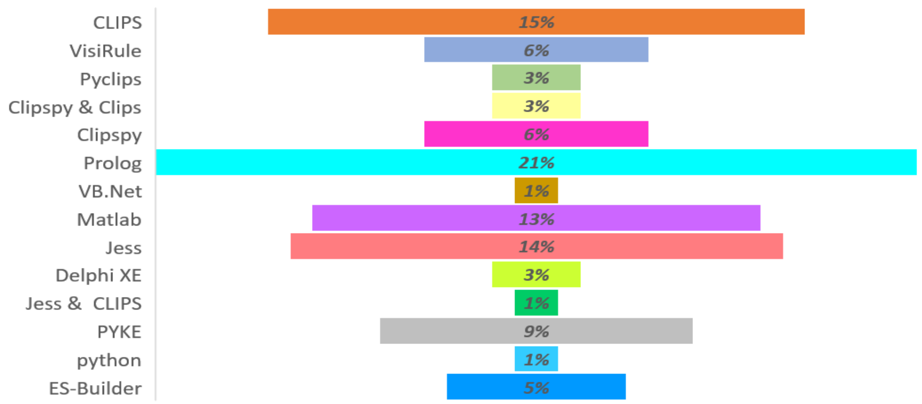

Figure 7. Usage frequency of tools for developing expert systems

CLIPS was used dominantly in engineering, while Prolog was popular among health applications followed closely by MATLAB. In the field of Information and computing technology, PYKE a python library was the tool of choice, closely followed by Jess and Prolog. Additionally, it was established that CLIPS was used across six (6) application areas that included environment, veterinary medicine, agriculture, health Information & computing technology and education. On the other hand, Jess was applied in five (5) areas while Prolog, VisiRule and ClipsPy were each applied in four (4) application areas.

Implementation alternatives for developing expert systems

The usage of software tools in the development of expert systems has varied with different alternative implementation strategies being selected. This section examined the implementation approaches adopted by researchers while using the tools.

The CLIPS expert system shell has been used to undertake different projects with the implementation taking different forms. CLIPS has been used independently to develop expert systems for nutritional planning (Mazloom et al., 2018), control of desalination process (Rivas-Perez et al., 2019), and in code generation using fish bones diagrams (Yurin et al., 2018). The shell has also been integrated with other software tools while developing expert systems. They include Delphi XE 10.2 (Salman & Abu-Naser, 2019), C++ (Ananthapadmanaban & Karthik, 2019), Java through the NetBeans Integrated environment (Kravchenko et al., 2020), Java using a native interface wrapper for the shell known as CLIPSJNI (Lodhi et al., 2018), and ontology management tools (Massel et al., 2019).

A web-based expert was also developed using CLIPS by integrating web technologies that include phpMyAdmin for managing MySQL databases and XAMPP, a package that combined Apache, MySQL, PHP, and Perl (Konyeha & Imouokhome, 2018). Hardware-based projects that incorporated CLIPS have also been undertaken by integrating the shell with specialised tools.

Harradi et al. (2021) used both CLIPS and Ardupilot, an autopilot software to control drones.

Additionally, the shell has been used together with microcontroller development tools in controlling a robot arm that is teleoperated in a dynamic environment (Capolei et al., 2019).

Prolog as an AI – based programming language has also been used extensively in developing knowledge – based systems. It has been used independently in construction of systems for different purposes key among them the diagnosis and management of viral hepatitis (Agizew, 2019), representation of knowledge from experts using languages that are domain-specific (Seipel et al., 2018), diet recommendation for diabetes (Ahmed & Mahmoud, 2014), mitigation of insider threats that are unintentional within financial institutions (Adane, 2020) and facilitating efficient query & extension of existing knowledgebase for medical diagnosis with minimal programming skills (Das et al., 2018). The language has also provided avenues for integration with other existing software tools, as was the case with CLIPS.

Integration done with Prolog includes web technologies (Al-Hajji et al., 2019; Ceyda & Çilgin, 2022; Burnashev et al., 2019; Torres et al., 2021); Muhamad & Rahim, 2019; Al-Hajji et al., 2019). Prolog has also been integrated with Java (Chen & Lin, 2021; Huang et al., 2021; Che-Chern & Chia-Heng, 2020). Interfacing of prolog and Bayesian networks has helped in addressing disruption challenges in the train systems (Pradiawati et al., 2019). Similarly, the integration of the two was used by Torres et al. (2021) in automating the process of symptom consultation among patients.

Jess

Another expert system shell used extensively is the Java based expert system shell (Jess). It has been used as a stand-alone tool for developing expert systems (Akanbi & Masinde, 2018; Mulyani & Sahal, 2019; Vitkus, Jezukevičiūtė & Goranin, 2020; Akinpelu et al., 2019). Additionally, it has been integrated with Java (Motlagh et al., 2018; Lopez-Santana et al., 2018), eXtensible Markup Language (Vitkus, Salter, Goranin & Čeponis, 2020), languages for web ontologies (Vitkus, Steckevičius, Goranin, Kalibatienė, & Čenys, 2020), JADE – a multiagent environments (Mostafa et al., 2018), WEKA – a data mining & machine learning tool (Sitdhisanguan et al., 2018) and with the android studio (Ogheneovo et al., 2018).

MATLAB

There are also been cases where MATLAB like many other software tools has been used independently in developing Expert systems. Gupta & Ahlawat (2019) developed a system for predicting how usable an application software is based on a model that is generalized. Additionally, MATLAB has been used as a standalone tool for the development of expert systems for monitoring the process of treating pressure ulcers (Casal-Guisande et al., 2020), Parkinson's disease detection (Montaña et al., 2018), assessing the structural health of buildings (Nuhu et al., 2021), diagnosing chronic kidney diseases (Singla et al., 2020), COVID 19 (Ukaoha et al., 2020) and parasitic diseases in human intestines (Nkamgang et al., 2018). Alade et al. (2018) integrated MATLAB and JavaScript in diagnosing different types of diabetes, while Tehseen et al., 2020) developed a system for diagnosing pulmonary diseases together with asthma using the same tool with Java, Android development environment and PHP. An expert system to support the formulation of designs for for installation of IOT systems based on blockchain technology was also developed by integrating MATLAB and Zig, a smart online chatting tool (Carreño et al., 2019).

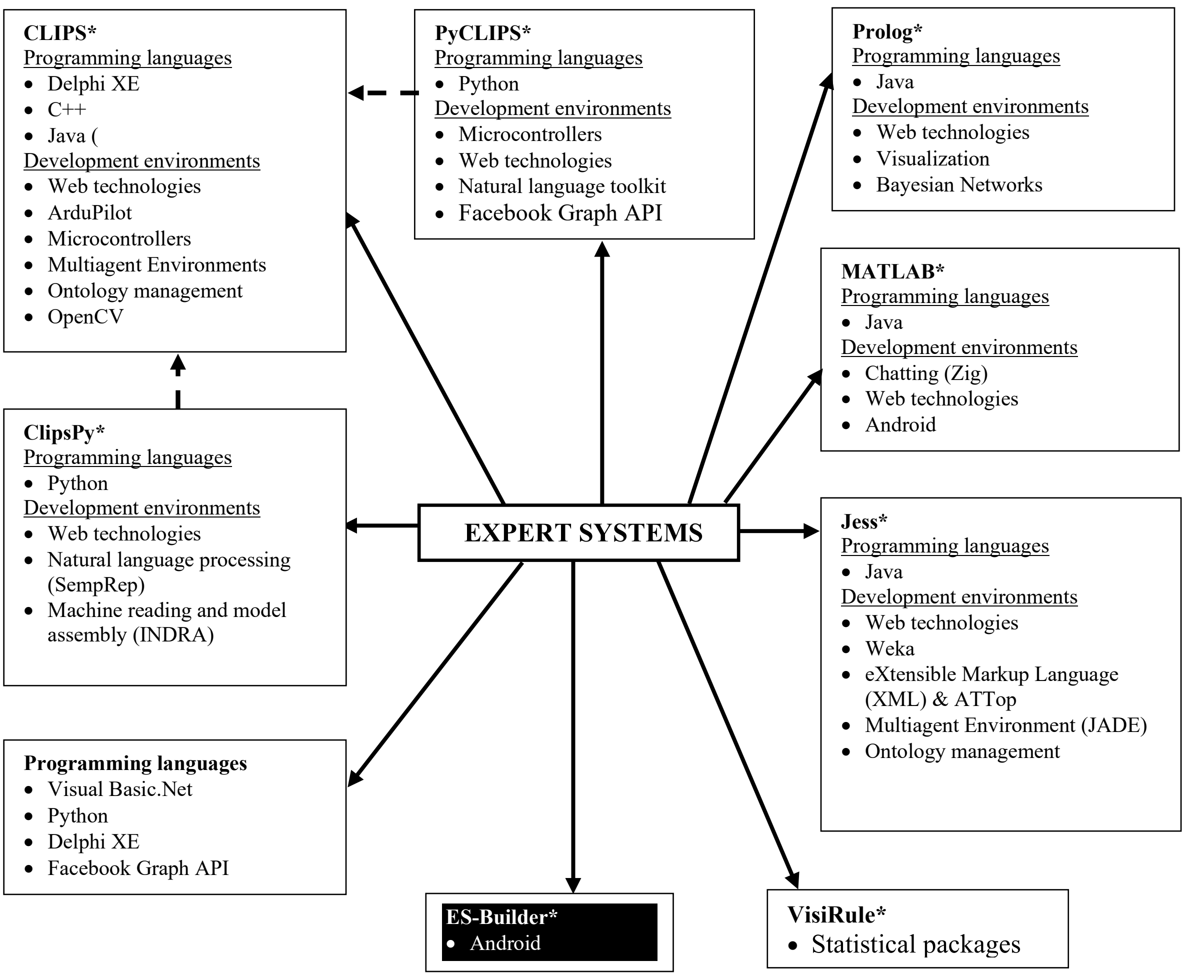

Figure 8. Software implementation alternatives for developing expert systems

ClipsPy

The development of expert systems has also seen the use of ClipsPy, the python interface for CLIPS with other software tools. Through the interface the python language has utilized CLIPS functionalities in optimizing security compliance activities (Ghanem et al., 2023), automating decision making for aircraft navigation (Vajda, 2020), refining computer networks security policies (Basile et al., 2022) and deploying AI-based radiology in veterinary practice (Fitzke etal., 2021). Python and ClipsPy have also incorporated other tools key among them SemRep – a natural language processing tool and INDRA – an assembler for dynamic reasoning (Malec et al., 2022; Taneja et al., 2022).

PyCLIPS

Libraries to interface Python with expert system shells have also been to develop expert systems.

PyCLIPS has been used together with a Microcontroller development environment to develop an expert system for operating a robot arm (Capolei et al., 2019). Additionally, Aivazoglou et al., 2020) developed a recommender system for social networks using the python interface, a Toolkit for Natural Language processing and an Application Programming Interface (API) for interacting with data on Facebook. On the other hand, PYKE another Python library has been integrated with Python's Support Vector Machine to detect extremist content on websites (Markéta, 2022) and also with Kivy – an open source Python App development framework in forecasting flooding (Zhang et al., 2018). PYKE has also been integrated with Django-rest & Falcon Python frameworks (Zarca et al., 2020), JSON & XML (Zarca et al., 2019), Hadoop – a distributed storage ecosystem & Java (Dinh et al., 2018) and with Multi-Agent Evolutionary System Architecture (MESA) – a tool for building agent-based models (Damrongrat et al., 2018).

ES-builder system shell has mostly been used as a standalone tool when developing systems (Abduljabbar et al., 2018; Mhlongo et al., 2019). However, Marzouk & Zaher (2020) integrated it with android development environment while developing a expert system to assist in the classification of elements as either electrical, mechanical or plumbing in a given facility.

The VisiRule expert shell has also been used independently in the developing of expert systems for use in different sectors. They include selection of a research design (Muraina & Adeleke, 2021), assessment of severe COVID (Chrimes et al., 2021), management of pressure ulcers (Abranches et al., 2019) and in human performance evaluation (Mikulić et al., 2021). An expert system for inspection of vehicle was however developed by integrating VisiRule with a statistical package (Mikulić et al., 2018).

Other notable platforms for use in the development of expert systems include a combination of Python, HTML, CSS, JavaScript, the REST API and Flask – a framework for developing web applications (Mujawar et al., 2018). Microsoft Visual Basic.net has also been integrated with Common Lisp- a general purpose programming language to develop a system for diagnosing diabetes (Eyasu et al., 2020). Additionally, Psyrras & Sextos (2018) used Microsoft Visual Basic.NET and OpenSees – a freeware for analysis of seismic structure to develop an expert system for assessment of 3D buildings. Delphi XE, an object-oriented programming language was used to development of expert systems for design of knowledge bases without any form of integration with existing software (Yurin & Dorodnykh, 2020). Figure 8 illustrates the different software implementation alternatives when developing expert systems.

V. DISCUSSION

Research on application of expert systems, a branch of Ai in different sectors of the society continues to grow globally with studies being conducted in different countries. Key sectors that have adopted the technology included health, engineering, Information & computing technology, environment, nutrition, veterinary medicine, agriculture, education, human resource management, hospitality management and psychology. Health emerged as the sector that largely applied the technology followed closely by Information & computing technology and engineering. The nature of applications in the fields were categorized as either diagnosis, decision support, prediction and design.

Tools that facilitate the implementation of such systems have also been varied. Expert systems shells, AI based programming languages and libraries for conventional programming languages emerging as the categories of tools for use when implementing solutions. Expert system shells used to implement solution included CLIPS, Jess, VisiRule and ES-Builder. Prolog, an AI-based language and MATLAB, a specialized language has also adopted in the implementation of expert systems. Implementation of expert systems using conventional languages has been achieved through libraries and interfaces. Python integration with CLIPS was made possible through PyClips and ClipsPy while Java utilized CLIPSJNI in accessing functionalities provided by the same expert system shell. VisiRule and ES-Builder also emerged as tools of choice when implementing expert system-based solutions. The usage of the tools took many forms ranging from independent use to integration with other development environments. Majority of the tools facilitated their independent use in formulating solutions which included CLIPS, Prolog, Jess, MATLAB, VisiRule, PYKE and ES-Builder. Java, C++ and Python were integrated with CLIPS using libraries or interfaces with CLIPS. PyClips and ClipsPy were utilized for interfacing Python with CLIPs while CLIPSJNI provided the same for Java. The Integration of Java and Jess was done without the need for libraries given that the shell was implemented in the same language.

CLIPS offered many alternatives for integrating with other software environment which included conventional programming languages like Java, C++ &Delphin XE, web technologies, Multiagent environments, AI environments for natural language processing & computer vision, microcontroller development platforms, speech recognition and finally ontology management tools. Different integration options have been availed by Prolog and this included with web technologies, Java and Bayesian networks. Interfacing Jess was achieved with Java web technologies, JADE- a multiagent environment and WEKA – a data mining & machine learning tool. MATLAB has been integrated well with JavaScript, Zig- a chat tool and with Java together with the android environment. Other notable integrations included ES-builder with android and VisiRule with statistical packages.

VI. CONCLUSION

Expert systems continue to provide valuable opportunities to address problems in different sectors of our society. Many tools are available for use in the implementation of such solution. The choice of the tool for used must be guided by the nature of the problem being address but importantly the ability to integrate with other software environment. CLIPS, Prolog, Jess and MATLAB emerged as suitable tools for selection, however other tool such as ES-Builder and VisiRule also offered viable alternatives for consideration. The availability of interfaces makes the integration of Java, C++ and Python with expert system shell a viable option for developers. Special attention should also be given to PYKE, a python module that supported the development of experts in Python.

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VII. REFERENCES

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