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CONCEPT AND PROSPECTS OF COMPUTER AIDED DIAGNOSIS (CADx) FOR NIGERIAN VETERINARIANS

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SUMMARY

The importance of computers in all works of life need not to be overemphasized. However, in Nigeria, the application of computers in veterinary medicine has not been fully utilized. Computer aided diagnosis is a process that has significantly improved the practice of veterinary medicine in other parts of the world. This paper throws light on the area and gives examples of relevant software packages. The paper also highlights the significance, advantages and limitations of the process, and its prospects for the country's veterinarians. Recommendations are made on how best the Program can be inculcated into the Nigerian veterinary practice.

Key words: Computer, diagnosis, Veterinarians, Nigeria

INTRODUCTION

Computers are arguably the greatest invention of modern times as they have revolutionised many occupations and industries. This is because computers can do some aspect of a job faster, more efficiently and conveniently than humans. Computers are more efficient at handling volumes of data and repetitive tasks whereas humans are better suited for decision making.

Efficient use of computers in veterinary practice may improve the service to the animal owning public and provide adequate return on investment of time and money. Computers in veterinary practice are commonly used for accounting, drug and supply inventory management, client communication, hospital management, computer assisted diagnosis (CADx) programs as well as other practice related programs (McCurning, 1998; Hassan *et al.,* 2004). The capacity for computers to aid the diagnostician is growing. The computer aided laboratory and clinical diagnosis programs which are the focus of this write up are mostly based on artificial intelligence. They will enable veterinarians to be more accurate in their diagnosis and reduce the amount of information that must be memorized. The accuracy of diagnosis determines the success of intervention, even in the absence of treatable disease. Computers can keep track of more things and perform more computations in a given amount of time thereby overcoming ignorance by calculating all possibilities in less time than the brightest of humans. If the common sense of humans can be combined with the computational capacity of the computers, the best of both can improve the accuracy, speed or efficiency (reduce the cost) of diagnosis. The combination of the Veterinarian and the computer provides value in the practice of veterinary medicine (Bushby, 1992-1994; Stevens, 1992). Apparently, computers are becoming an indispensable instrument in almost all professional endeavors. It is therefore, imperative for veterinarians in Nigeria to understand the full potentials of computers as an aid for the improvement of veterinary practice in the country. This is what informed the attempt of the authors of this paper to give an insight into the concept of computer aided diagnosis for the Nigerian veterinarian.

CONCEPT OF COMPUTER AIDED DIAGNOSIS (CADx)

The size of the veterinary medical knowledge domain by which we diagnose and prescribe is substantial and growing in size. No veterinarian can diagnose what he or she does not remember. Computer aided diagnostic software can manage the large volume of information that is involved in the diagnostic process. CADx programs are developed to aid in tasks such as medical diagnosis and more to teach us about the use of our intelligence than it did to replace it. The information used by diagnosticians as input to CADx programs is referred to as findings or manifestations. The clinician must be aware of each finding and each disease and also the association between signs, causes and problems (Bushby, 1994). The earliest works of artificial intelligence implemented by computers captured and took advantage of this structure (Bushby, 1985).

Veterinary CADx programs developers like Stevens (1992) is of the view that in limited areas such as veterinary medicine where the meaning and significance of terminology is precise, and where specific findings and test results have predictable interpretations, computer can unleash its special abilities. Diagnostic algorithms, interpretive rules, and patterns machine analyses are usually programmed in common languages to provide intelligent, expert analysis and recommendation faster and more reliably than any humans (Weed, 1982; Steward, 2002).

Various models abound for the development of CADx programs. Some examples include the following:

Production rule model

In this type of model the structure of information is in the form of rules composed mainly of two major parts: a "premise" or "if" and a conclusion or "then" clause. Each major component can be composed of any number of constituent. The premise may be a conjugation of conditions while the conclusion may be simple or compound. The conclusion may also be a potential premise. As a result, computer may search all the rules and 'fire' or reckon as true all conclusions of rules for which the premise is known to be true. A subsequent run through the rules data base allows the programs to fire any rules with premises now known to be true because of the first round of conclusions. The second round of conclusion may be once again used to search the data base, and so on, until there cease to be rules which 'fire'. The components of the program which administrates this application of embedded logic is called 'inference engine' and the software using this methodology are said to be employing "production" rules. The main draw back to this model is that the intricate complexities where humans put clues together to reach a diagnosis is lacking here. On the other hand, the main advantage of this model is to explain reasons to the users. Examples of software packages built on this model include ASSICIATIATE, CARDIO, HEMO and PROVIDE among others (Long, 1991; Stevens 1992).

IF (patient's PCV< LoNorm PCV) or (patient's RBC < LoNorm RBC)
Store 'Anaemia' to message.

IF (patient's MCHC < LoNorm MCHC)
Store 'Hypochromic' + message to message

IF (Hb test done and MCHC in normal range)
Store 'Normochromic' + message to message

IF (PCV and RBC test done and MCV is in normal range)
Store 'Normocytic' + message to message

IF (PCV and RBC test done and MCV > HiNorm MCV)
Store 'Macrocytic' + message to message

IF (PCV and RBC tests done and MCV < LoNorm MCV)
Store 'Microcytic' + message to message

IF (MCV not elevated and no polychromasia or anisocytosis, and RPI < 1.2)
Store message + '- Non-responsive' to message

IF (NRBC present and polychromasia and macrocytosis present or RPI > 1.5)
Store message + '- very responsive' to message
ELSE
IF (macrocytosis or polychromasia or RPI > 1.2)
Store message + '- responsive' to message

Figure 1: Production Rules from HEMO (Stevens, 1994).

Causal model

Another model used by CADx developers is the causal model. These are designed based on the architecture of cause effects networks which explain the present findings and suggest measures which could be taken along with the outcomes of these measures. A CADx program built on this model include CASNET (Weiss, 1974) which builds a network of relations between dysfunctional states and thereby addresses what is wrong with the patient apart from diagnosing a disease or gives differential list. Each dysfunctional state node has an associated weight and status values. The weight reflects likelihood derived from the association with nearby state nodes. The status value reflects the result of test associated with the node whether that test is a physical finding, historical question response or laboratory findings measurement(s). The network output is an assortment of serial, parallel and over lapping connectives between starting states and final states. While intermediate nodes representing dysfunction which are either confirmed or denied by the process? A user can select from the various paths to explain current conditions, identify primary disorders, choose therapies or prognosticate.

A clustering algorithm based on the notion that symptoms do not occur in isolation but often observed in groups and this paradigm may also be applied to diseases and diagnosis of physiologic states that also occur in groupings. Ranking the potential cluster compositions of the presenting signs and then testing hypotheses concerning individual and combined clusters of physiologic changes can also be conducted much the same way as the production rule protocol (Wu, 1990).

Other models that are used for the development of CADx programs include the simple association model, case based reasoning model etc.

Some veterinary CADx software packages and their concepts are described below.

Provides
This software compare or 'couples' specific bodies of medical information or compares information pertaining to a specific medical problem to the information entered by the veterinarian concerning the patient. The pathway required by the input to this program illustrates the complexity of the diagnostic process that must be performed and which must be emulated for the automation of the diagnostic process.

The list of diseases suggested as possibilities are often ranked in some fashion putting the more likely candidates in limelight. Specificity and sensitivity ratios are usually used to rank the result of the computer searches. The number of expected findings associated with the disease gives the specificity ratio while the number of findings accounted for by a candidate disease divided by total number of patient findings gives the sensitivity ratio.

Vetcad
This uses a model called simple association model. It is merely a table based storage of findings and disease entities from which the software is able to produce diagnostic suggestions. It is mainly used in clinical chemistry and electrocardiography. It can be maintained by updating the field contents in the table as new disease information is made available. This software needs major revision only when vastly divergent association models for diagnostic reasoning are developed.

Consultant
This software package is driven by "case based reasoning" where signs for the patient are pattern-matched with previous cases. Database of several thousand published literature serve as the knowledge base of cases to which the veterinarian encoded set of symptoms is compared. This interchange is accomplished by online modem connections and is dynamically updated as more cases are recorded (White and Lewkowicz, 1987).

Internist
This involves the ranking of calculation of 'evoking strength' or prior probability' of a disease (i.e. probability of disease before knowing any test result) and the 'frequency' or posterior probability (the probability of a patient with the diseases having the given test result or symptom. These ranking calculations are taken from epidemiological publications and/or expert opinions and illustrate the probabilistic nature of the signs/symptoms as well as the laboratory tests.

Present illness program
This has a sophisticated knowledge representation (Pauker *et al.,* 1976; Szolovits and Pauker, 1976, 1978). The program characterizes each disease hypothesis as being composed of a number of structural elements. The concept of this Program is based on relationship between findings and hypothesis. The structure recognizes the relationship a hypothesis has with certain findings and other hypothesis as well as a 'likelihood' estimator. A hypothesis relation to findings includes being triggered by a finding as distinct from merely being associated with findings. Relations between disease hypotheses can be classified as either complementary or competing. Complementary hypotheses are those which together can account for more findings on the patient than either of the hypotheses alone, while competing hypotheses are those that either of which can explain the same set of hypotheses. Specific relations which are considered complementary might be "caused by", "cause of", "complicated by", "complication of" or "associated with" relationships between diseases. Hypotheses which are competing are those normally enumerated on a differential diagnostic list. The likelihood estimates or scores are derived from the number of patient findings explained by the hypothesis relative to the total number of findings the patient has, or the disease that can be potentially accounted for. The knowledge

base in this case consists of disease frames upon which the inference engines can compare findings of the patient to generate hypotheses. The hypotheses can be active, semi active, or inactive in nature. Active hypotheses are used to suggest further testing or query. Semi active are not justification for further action while inactive means no hypothesis. The flaws in this package are that the probabilistic reasoning components lack discoveries that are to be made in ensuring years. The Program has features allowing hypothesis of clinical and physiologic states apart from specific disease.

Heart failure diagnosis program

This program expands the concept of causal model to a large domain and integrates the approach with other approaches to knowledge representation and inference (Long, 1990). It combines the use of casual model with probabilistic reasoning for diagnostic purposes and further integrates pharmacodynamic physiological models to reason about the effect of pharmaceutical intervention as well as employing a library of cases to compare and qualify its results. In this case, the objective can be to find therapies which can break causal chains of dysfunctional state connectives which are producing undesirable effects in the patient. In so doing, the program extends beyond CADx and enters the domain of computer aided medical management.

SIGNIFICANCE OF COMPUTER DIAGNOSIS (CADx)

Computer aided diagnosis (CADx) must garner the advantages of machines' computation to provide improved outcome for the veterinary patient. This can be achieved by improving the sensitivity of diagnostic processes by pointing out diagnostic hypothesis that would otherwise be missed or delayed. Alternatively, improvement can be in the specificity of active diagnostic hypotheses, thereby reducing the number of testing processes endured by the patient or the budget. Other means by which the diagnostic process can be improved include structuring the process for better organizational features to facilitate record keeping or documentation and exchange for purposes of pharmacological, epidemiological, sociological market research or regulatory demand. The process can also be improved for the sake of the patient by any qualitative means which lessens stress on the diagnostician. If no other improvements are made other than this, the patient will benefit from a clinician who is less likely to commit error in the human roles directing and overseeing the process, more effectively communicate with the owner, staff and patient. The clinician will also be more sensitive to the other needs of patient and owner and more patients will be able to receive this attention. In particular, machine computation has the potential to take over tedium and allow the clinicians more freedom to do what they do best (Steward, 2002).

ADVANTAGES OF COMPUTER AIDED DIAGNOSIS (CADx)

One of the advantages of CADx is to expand the list of considerable disease candidates and subsequently the diagnostic pathways. One thing computer aided diagnosis is also good at is the prevention of omissions. The aspect directly combats the feeling of insecurity of not remembering something when nothing fits. The expansion of the differential is a reliable tool and serves as a safeguard.

Computer aided diagnosis will highlight sub goals that can be undertaken to further pursue a definitive diagnosis. All tools currently available in the practice provide statements as part of their output with laboratory tests which would be useful in ruling in or out currently active disease hypothesis. Some packages provide immediate links to references and others provide internal abstracts on diseases while some such as the CONSULTANT provide immediate opportunity to have reprints forwarded. If the full extension of this concept is ever implemented, linked references could be used to access information on incidence of disease, signs or disease outcomes. Other advantages of CADx include provision of links to publications regarding relevant clinical trials, specific physiologic and/or dysfunctional states that are part of the patient's current status and pathogenesis of current disease hypothesis either leading to or proceeding from the current state of affairs. Other advantages of the links include timely and convenient access to literature. The formalism of organizing the input to the diagnostic process is another advantage of CADx. The structured input enables exhaustive search and structuring of the diagnostic input suggesting further queries even before primary history taking is over. Also the codification of the patients signs grants insight prior to CADx access.

It should however be noted that the CADx programs were not intended to narrow the diagnostic differential list or considerable disease hypothesis, rather they capitalize on quick and exhaustive searches of complex domains to produce a list of disease that should not be overlooked. Also even with development of the CADx software the specialist veterinarians are also required to explore approaches and intervention as well as to provide and substantiate parameters required by these information management tools. Specialists are also required to educate the practitioners with necessary insights by which they can play their roles as overseers and diagnostic quality controllers. The oversights of inputs and intermediate ascertations require the intellect and common sense of human veterinarians to succeed.

LIMITATIONS OF COMPUTER AIDED DIAGNOSIS (CADx)

Following are some of the limitations of CADx:

1. CADx does not guarantee a diagnosis rather it applies all the knowledge it contains in arriving at the differential diagnosis list or disease hypothesis according to its inference engine.
2. CADx cannot make a specific diagnosis.
3. There is the high price of initial investment required for the purchase of such programs.
4. The largest demand on this technology is the cost of maintenance of the knowledge or the rule base.
5. There is the difficulty in making comparative clinical performance trials in making validations of results.
6. The potential distrust and discrediting of expert system as unqualified by board experts or specialists also hinders the development CADx.

Like any other technologically advanced instruments, CADx is of little importance until it is adopted for use as common practice. As development of CADx in veterinary medicine depends on the wiliness of the user to adopt it, then the user interface which is the means by which input data is solicited and is the platform for presentation of information and knowledge that results from computation, becomes an integral part of the advancement of CADx. The user acceptance is largely determined by appearance, access, speed and convenience. The interface and performance of the technology must be able to convince the user of the benefits for the adoption of the technology (Steward, 2002).

Reliability

The power of the computer is not that it is easier to be correct, with a single task; rather it is the power to do enough tasks correctly. It is also easy to generate mounds of garbage as it is to generate mounds of useful information. This underscores the burden upon the veterinary user of CADx to think well before selecting input to be fed into the diagnosis process, as the quality of result depends on the quality of input.

As of present, the reliability, quality control and oversight of both the implementation of knowledge base and inference engine require professional human element.

PROSPECTS OF COMPUTER AIDED DIAGNOSIS (CADx)

The current level of CADx software development does not exhaust the full potentials of artificial intelligence technology. Therefore, research into "machine learning" will allow more rapid generation of deductions from large volumes of data which may be difficult to investigate. Electromagnetic managements of data and information provide some advantages that contribute to such improvements. Indeed the hardest knowledge to incorporate in this age is the oldest knowledge, but technology in this area advances as well.

Means to be sure/confidence support

CADx is already a means to be sure of oneself as a diagnostician. As a result, power will increase as long as the knowledge base is updated. CADx can also be utilized to support the confidence level of the diagnostician. With the advent of wireless technology and mobile computing the information highway is rendered less obstructive.

Serves as a means to understand the structure of diagnosis and/or an individual's set of findings

Even if the CADx program in use does not have sensitivity analysis features, the user can perform some informed experiments by selectively including and discluding findings and observing how the differential list is affected. This may be useful where the certainty of the finding in question or its manifestation is on borderline. This thoughtful exploitation of the diagnostic input allows more direct approach to the root of the problem.

Serves as tool to guide client-clinician interaction

Systematization of the diagnostic process can influence the reliability of that process just as systemic approach do physical examination findings. CADx will help in making presentation easier than the preparation of any form of audio-visual aide. With the advent of colour multimedia networked computer, the storage and logistical requirements of this application may be fascinating. Routine use of CADx may also facilitate the resolution of unanticipated outcomes from previous visits.

Serves as a means to understanding diagnostic process

The more we attempt to capture for expert diagnostician reasoning process, the more we learn about that process. This will be helpful in training additional experts as well as training of practitioners to cases and referrals and thus contributing to primary and continuing education. As a result, research in CADx can improve valuable insight to every level of veterinarian.

Integration of CADx with other information processes

CADx and other artificial intelligence tools are usually integrated into other processes. HEMO seems to be the most frequently used in this respect because of its simplicity, narrow domain and utilitarian approach. CADx can be integrated with medical records, laboratory results, anaesthetic machine and respirators. This makes logistics of veterinary practice easier. Packaged with instruments, convenience and speed may be provided by strategically incorporating artificial intelligence diagnostic for small domains to trap and rectify dysfunctional state in all sorts of circumstances.

Improvements in hardware will continue to potentate advantages of computer where speed and broad computation will continue to improve. As CADx is dependent on the tractability of computation in larger domains of knowledge, growth may have a direct impact. Current limitations of CADx include the computational barriers seen in programs like PRESENT ILLNESS PROGRAM, CASNET and HEART FAILURE DIAGNOSTIC PROGRAM. Adleman (1994) has demonstrated the capacity to utilize nucleotide sequencing of DNA strands to perform computation. This discovery suggests the possibility of computational speeds a thousand fold faster than supercomputer with trillion fold decrease in storage space. This DNA based computing may provide computational feasibility that may break the current combinatorial bounds and results in nucleic acid computers that will assist in searching the vast space of diagnostic hypothesis for better understanding and treatment of medical cases.

As we embrace the future of veterinary diagnostics, it is always better to understand the natural process well in order to facilitate the processes and avail the patient with the advantages by bringing them in contact with the beneficial factors.

CONCLUSION

It is now evident that computer is an indispensable tool in all works of life. And owing to the importance of computers in aiding diagnosis in many parts of the world, it has become imperative for Nigerian veterinarians to acquit themselves with the potentials of CADx as a tool for improving their efficiency as veterinarians. Nevertheless, the CADx programs can never replace a veterinarian, the basic broad based veterinary knowledge is still important to be able to use the CADx programs.

RECOMMENDATIONS

1. The veterinary council of Nigeria should in its continued education Program include the training of veterinarians on the use of CADx software.

2. The CADx facilities should be provided in all the Nigerian veterinary teaching hospitals so as to be included in the curriculum of training future veterinarians.

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