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A Medical Multimedia Expert System for Heart Diseases Diagnosis & Training

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ABSTRACT. Multimedia (MM) is an increasingly important tool in training and development for high-technology medical techniques and education. This paper investigates at a broad range of methods for incorporating multimedia expert system (ES) services into the world of heart diseases diagnosis, training, and education. Then, a multimedia expert system for heart diagnosis is presented. The proposed ES is implemented using Visual Prolog having into consideration the heavy use of multimedia services to implement system data bases and friendly intelligent multimedia user menus and interfaces. The system is constructed of several phases including knowledge acquisition for heart disease diagnosis and symptoms, knowledge representation using rules and semantic networks. These phases work together achieving patient symptoms detection, investigation, and diagnosis, respectively. A working prototype model of the system is then built and tested. Doctors and physicians who work in the field of heart diagnosis diseases can use the system. It also helps for training beginner's doctors and medical students and workers who work in the field of heart diagnosis.

1. Introduction

Expert systems (ES) are artificial intelligence-based computer programs that have received a great deal of attention during years. These programs have been used to solve an impressive array of problems in a variety of fields. The part of the expert system that stores the knowledge is called the knowledge base. The part that holds the specifics of the to-be-solved problem is called the global database. The part that applies the knowledge to the problem is called the inference engine. Expert systems typically have friendly user interfaces to enable inexperienced users to specify problems for the system to solve and to understand the system's conclusions.

Many of our present and future ES applications will necessitate technology integration because of the various information forms that users will require in their work, recreation, and entertainment worlds. Within the domain of microcomputer technology, information media exist in various multimedia (MM) forms, including text, data, graphics, images, animation, motion video, and audio. Various MM integrated platforms, which make microcomputer-based MM information presentations possible, include various media hardware and software systems.

Although, there are many computer based diagnosis systems are developed for medicine[1-3], however the number of expert systems exist for human heart diagnoses domains are still very few[4]. Even most existing systems are not mainly based for providing multimedia services and they lack flexibility. These systems are usually designed using traditional software methodologies[5,6]. They do not gain complete benefits of multimedia services[7-9]. Integrated expert systems (ES) and MM have the potential to address many unresolved issues by providing new synergies, "intelligent" user interfaces, additional informational dimensions, and interesting, beneficial application solutions, as explained in Section 3 in this paper. These applications are made intelligent by the embedding of reasoning capabilities provided by an ES through knowledge-based representation and inference features. As a result, intelligent MM systems enable a wide range of users to interact in a nonlinear, seamless, context-sensitive manner with varying types of complex applications, including information classification, retrieval, assimilation, and learning. Synergistic integration of ES and MM technologies requires architectural designs that offer advantages over conventional systems[10,11]. The development of medical expert systems brings with it many formidable technical, behavioral, legal, and ethical problems that must be addressed by the researchers in this field[12-14]. These include acquiring and representing medical knowledge, validating the systems, getting physicians and patients to accept them, and deciding the responsibility for clinical decisions made with the help of these systems. Some of these problems will be dealt with in the proposed design in this paper.

The next sections of the paper cover the following topics: section 2 describes objectives of medical expert systems; Section 3 shows the comparative analysis of multimedia expert systems, Sections 4 and 5 show the architecture of a proposed design for multimedia expert system for heart diseases diagnoses, and Sections 6 and 7 show results and conclusions, respectively.

2. Objectives of Medical Expert Systems

Because complex medical decisions are often made when major uncertainties; as explained in Section 5.2 in this paper; are present and when the stakes are extremely high, expert systems are ideally suited for decision analysis. Motivations for the development of expert systems in medicine have been numerous. Assisting physicians in making diagnoses and treatment recommendations is the most commonly found application of expert systems in medicine. A physician may have knowledge of most diseases, but, due to the extensive number of diseases, a physician could benefit from the support provided by an expert system to quickly isolate the disease. Specifically, the goals of developing expert systems for medicine are as follows:

- To improve the accuracy of clinical diagnosis through approaches those are systematic, complete, and able to integrate data from diverse sources[15].

- To improve the reliability of clinical decisions by avoiding unwarranted influences of similar but not identical cases[16].

- To improve the cost efficiency of tests and therapies by balancing the expenses of time, inconvenience against benefits, and risks of definitive actions[17].

- To improve our understanding of the structure of medical knowledge, with the associated development of techniques for identifying inconsistencies and inadequacies in that knowledge[18].

- To improve our understanding of clinical decision-making, in order to improve medical teaching and to make the system more effective and easier to understand[19, 20].

Most of these objectives will be taken care of in the following sections of this paper.

3. Integration Models of ES and MM Comparative Analysis

Figure 1 illustrates a continuum of software architecture possibilities for achieving ES and MM integration. They are (1) stand-alone, (2) transnational, (3) loose coupling, (4) tight coupling, and (5) full integration. Table 1 identifies the level of integration and predominant features, and it summarizes advantages and disadvantages of these software design integration variations. The system proposed in this paper is implemented using the full integration model, and will be explained in detail in Section 4.

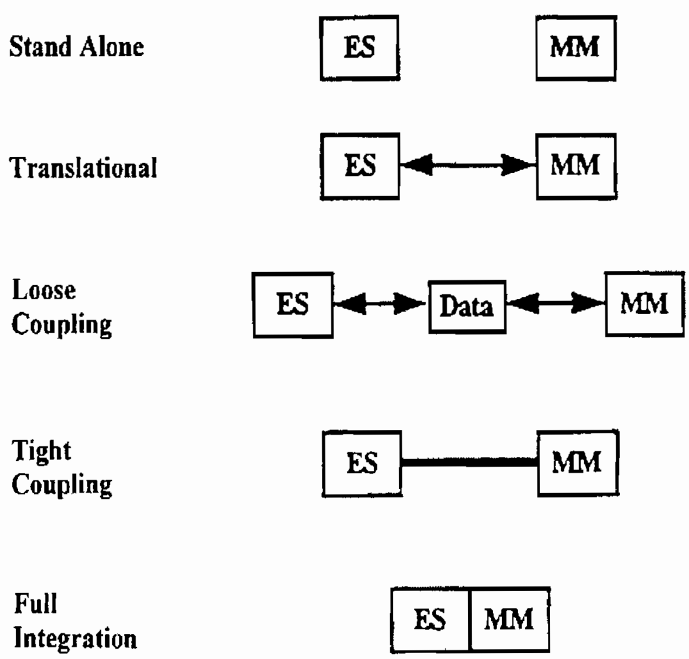

Fig. 1. Integration models of expert systems and multimedia.

4. Medical Multimedia Expert System Proposed Design

In this section, a new medical multimedia expert system (MMES) is proposed. The system can work as an electronic expert technical library for operators training and diagnosis of heart diseases. It diagnosis's heart diseases and locates patient heart failure positions and supplies other needed information through the use of different system databases and libraries. The system has different types of heart multimedia data to support complete benefits to physicians who work in heart disease field. It contains an accurate system knowledge base representation; heart sound manipulation, heart images library, and catalogs that can be retrieved based on the disease name and image format type. The system has a friendly multimedia graphic user interface. The system information is stored in Arabic and English languages; "help menus" and system description become easy to understand by users. The knowledge base (KB) of the system is dynamic and can be modified by system designer. The evaluation process of the system is performed practically by domain experts. Figure 2 shows a block diagram for the architecture of the proposed design. The following sections describe the functions of each unit of the system and the system objectives.

Table 1. Predominant features of ES and MM software architectures.

Software Architectures and Their Properties				
Architecture	Integ. level	Features	Advantages	Disadvantages
Stand-alone	1	Independent modules Independent construction No interaction	Commercial tools available Ease of development Speed of development Independent systems maintenance	No integration Double maintenance No synergy
Translation	2	Independent development Development and delivery Emphasis Begin with either system	Commercial tools available Deliver best system Independent systems Maintenance Speed of delivery	Redundancy in development Accurate translation may be difficult Retranslating may be Required limited synergy
Loose coupling	3	Application decomposition Inter-module communication via data Many variations	Commercial tools available Ease of development Synergy possible Simplicity of design Reduced data maintenance	Overlap in inputs and processing High communications overhead Speed of operations Poor maintainability Ripple effect of error
Tight coupling	4	Application decomposition into separate independent modules Inter-modular communication via parameter or data passing	Reduced communications overhead Improved run-time performance Retention of modularity Flexibility in design Improved robustness	Lack of commercial tools Increased development and maintenance complexity Redundant parameters and data processing Validation and verification issues
Full integration	5	ES and MM share data and knowledge representation Communications via dual nature of structures Cooperative reasoning	Robustness Runtime performance and Resource utility No redundancy in parameter and data processing potential for improved problem solving	Specification and design issues Development time No commercial tools Validation and verification Maintenance compatibility

4.1 Objectives and Advantages of the Proposed Design

4.1.1 Support to the Development Environment

Providing Knowledge. Knowledge for ES is acquired from two major sources: undocumented (experts) and documentation (e.g., manuals, procedures, databases, video/films, and textbooks). In many ES developments, multiple sources of undocumented and documented knowledge are used in the same application. Undocumented knowledge may be in various MM forms such as taped interviews (audio), interview transcripts (text), and knowledge structures and mental models (diagrams). Documented knowledge sources include an even larger variety of MM forms, including text, illustrations, still pictures, and motion film, video, and audio recordings. It is becoming common for these analog and digital forms of knowledge to be stored magnetically and optically (MM1 in Fig. 2). If documentation knowledge is represented in one of these media forms and storage formats, it is easier to use than if it is resident in people who may not be available when needed or at all.

Acquisition of Knowledge. One of the most difficult tasks in building ES is to acquire knowledge from human experts. Knowledge acquisition is a discovery activity that has been widely used to transfer knowledge from a source of expertise to a representational form. MM technologies have the potential to support this process (MM2 in Fig. 2) and include:

1- Knowledge diagramming, it is a top-down graphical description of domain knowledge. This method uses graphic techniques to define scope, enhance understanding, and define modules of knowledge.

2- Knowledge acquisition, an example would be the educational MM tools, which is used to teach the knowledge acquisition process with the use of hypertext (HT) [21] and video clips related to knowledge elicitation.

3- General MM supports during the knowledge acquisition process.

Representing the Knowledge Base. While traditional ES mainly use rules in their knowledge base, newer systems are venturing into the use of MM devices for knowledge-base rules and media storage and retrieval (e.g., CD-ROM) , (MM3 in Fig. 2). The system stores rules and current specifications on a CD-ROM disk. Other knowledge representation such as frames and semantic networks may be stored as MM schema and object-oriented programming formats (e.g., icons [MM3 in Fig. 2).

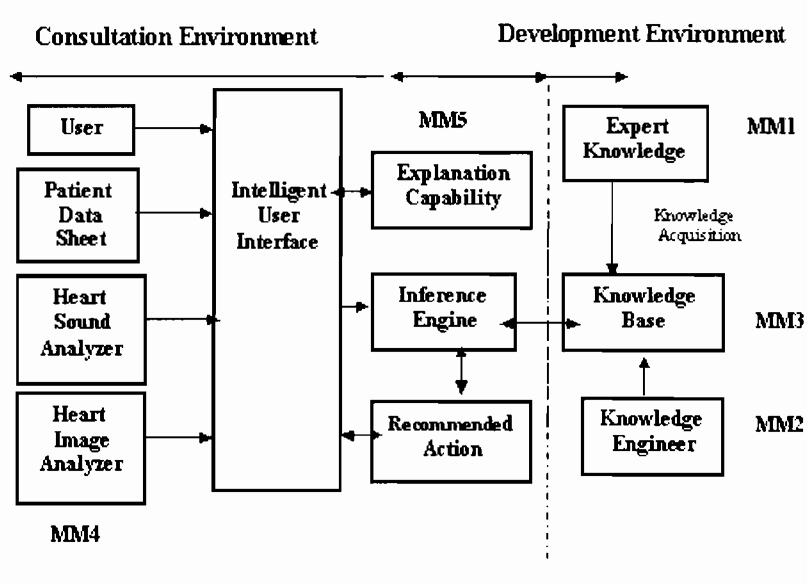

Fig. 2. A medical multimedia expert system for heart diagnosis proposed.

4.1.2 Support to the Consultation Environment

Improving User Dialogue. In most ES, the dialogue between the system and the user is done via the keyboard with the system asking questions (frequently by showing menus and prompting questions) and the user providing answers. MM enhances this dialogue (MM4 in Fig. 2).

Displaying Results. ES primarily provide advices to users. This includes diagnoses and suggestions on ways to heart medical treatment; for example, appropriate treatment procedures can be identified and displayed during a diagnosis dialogue. When complex patient case is involved, the advice will be supported either individually or in combination with schematics, drawings, still and full-motion pictures and audio instructions (MM4 in Fig. 2). Another way to display results is by developing special interface designs that are enhanced by MM; this will provide effective means of accessing MM database information. These types of support are also very important for intelligent computer-based training systems.

Providing Explanations. While displaying results and providing recommendations are essential features of ES, MM supplements explanations of "why?" "why not?" and "what if?" user questions (MM5 in Fig. 2). Examples include supporting graphs (e.g., trend lines), display of pictures (still and motion), or graphical comparisons of alternatives. This functionality provides HM explanations for knowledge-based heart diagnosis applications. The HM user interface includes template-based text, graphics, and icons that represent linked objects. These objects communicate by messages and use a standard, object-oriented programming approach. Another advantage of MM-enhanced explanation capabilities is the potential to increase user system acceptance.

4.1.3 Complementary Integration

In the previous configurations, either the ES played the major role or MM supported it, or vices versa. However, the two technologies can be used *independently* to perform different tasks of the same job. Thus, instead of supporting each other as in previous software architectures, they complement each other. Such a combination is likely to occur in complex systems where the ES itself is integrated with other computer-based information systems (e.g., databases or complex applications). In these systems, the MM can be part of the application itself (e.g., displaying MM educational material) while the ES performs some advisory or monitoring task (e.g., determining student learning style preference and identifying the best type of presentation material or providing redemption guidance). In this complementary manner, ES/MM integration will be expanded to include other computer-based and database-oriented information systems.

5. System Architecture and Implementation

The system consists of three main stages. At the first stage, the types of heart diseases will be classified, then the link between them will be figured out. Data acquisition will be done using data sheets which contain complete data about heart sounds, curves and diagrams, cholesterol and sugar analysis, and patient illness history. At the second stage, the code to build the system using visual prolog will be written and then tested on line. The following sections describe implementation stages.

5.1 Medical Problem domain Knowledge

Diagnosis is one of the main categories of applications suitable for expert systems. In this paper, heart diseases are classified into 25 different ones[22]. The semantic networks for left and right-sided heart failure diseases are constructed as shown in Fig. 3 and 4, respectively. There are different symptoms between left and right sided heart failure. Symptoms of Hypertension, Orthopnea, Cough and Hemoptysis can be caused of left-sided heart failure and not found in the right-sided heart failure as shown in Table 2. Patient data are divided into demographic data and clinical data. The demographic data is such as patient age and sex. Clinical data are such as laboratory results and physical findings detected by a physical examination of the patient. A diagnosis basically consists in relating patient data with corresponding diseases. Diagnosis of heart disease is based on the clinical data of the patient. The doctor should perform complete examinations including palpation and auscultation and then he may ask for an electrocardiogram (ECG) for the patient's heart.

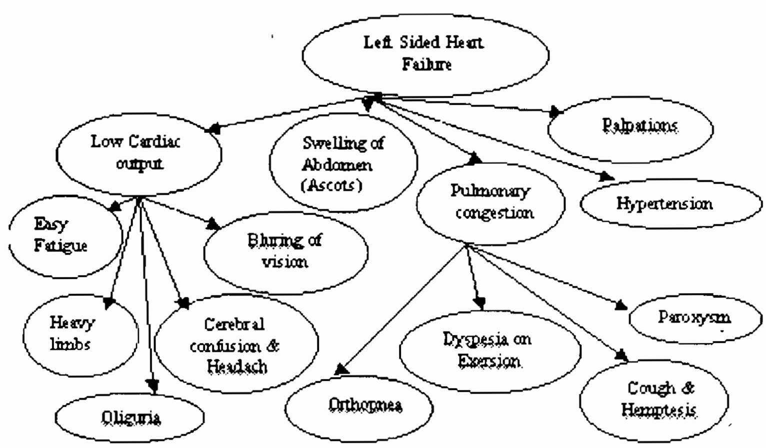

Fig. 3. Left-sided heart failure semantic net.

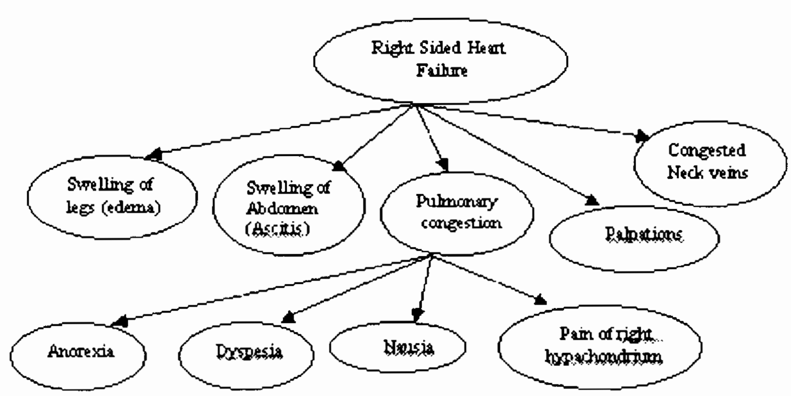

Fig. 4. Right-sided heart failure semantic net.

5.2 Knowledge Representation

The most popular type of knowledge representation techniques is the production rule[23]. In our case, there are a number of symptoms (*i.e.*, patient data) that all contribute in diagnosing a disease. IF-THEN rules are used for representing of heart disease. However, not all of the symptoms have the same significance.

Uncertainty in expert systems can be handled in a variety of approaches, among which are Certainty Factors[24], Dempster-Shafer theory[25], Bayesian network[24], and Fuzzy logic[26]. Fuzzy sets deal with propositions that have inherently vague meaning[27]. Certainty factors can be shown to be a special case of the Dempster-Shafer theory. Model uncertainty based on a range of probabilities, rather than a single probabilistic number. In this paper, we use Certainty Factors approach for handling vague medical terms.

Certainty Factors are used as a degree of confirmation of a piece of evidence. Mathematically, a certainty factor is the measure of belief minus the measure of disbelief. Certainty Factors outperforms Bayesian reasoning in areas such as diagnostics and particularly medicine[24]. It is used in cases where probabilities are not known or too difficult or expensive to obtain. Evidential reasoning can manage incrementally acquired evidence conjunction and disjunction of hypotheses evidences with varying degree of belief, and provide better explanations of control flow. In addition , CF has many advantages like:

- simple computations propagate uncertainty in system,
- easy to understand, and
- clearly separated belief from disbelief.

Table 2. Heart diseases symptoms' clustering template.

Symptoms Disease	**Left Sided Heart Failure**	**Right Sided Heart Failure**
Dyspnea	Strong	--------
Cough	Moderate	--------
Haemoptosis	Strong	--------
Orthopnea	Strong	--------
Dyspepsia	--------	Moderate
Pain of Hypochondrium	--------	Strong
Swelling of left leg	--------	Strong
Syncope	Strong	Mild
Oliguria	Strong	Mild
Ascitis	--------	Strong
Blurring of vision	Mild	Mild
Pallor & Coldness	Mild	Mild
Chest pain	Mild	Mild
Palpitation	Mild	-------
Fever	Mild	-------
Nausea	--------	Mild
Anorexia	--------	Mild
Easy fatigue	Moderate	--------
Heavy legs	Moderate	--------

Certainty theory requires the assignment of a number between 0 and 100 that reflects belief in an answer. In the Decision Maker expert system, the user assigns a certainty factor (CF) to one or more question responses (facts). The minimum CF of the facts becomes the CF of the solution, unless multiple rules arrive at the same solution. In such cases, the certainty of the solution is calculated according to the formula A + B - A*B/100, where A and B are the CF of solutions reached by separate rules. This definition was first used in the expert systems developed MYCIN[28] for combining evidence. A certainty factor uses both the premise (IF) and conclusion (THEN). Portions of a rule, or assigned to the premise portion only and conclusion portion, is being calculated. We make a scale starting from absolute certainty 100 to absolute uncertainty or falsity 0. A threshold level is assigned using the expert's advice. Symptom diseases are classified into strong, moderate and mild as shown in Table 2. This table shows clustering of symptoms' facts to avoid repetition. We can use *AND / OR* to connect a premise clauses in compound rule as shown in Fig. 5.

IF *there is symptom(s) Dyspnea* (Strong)
AND *symptom(s) Easy Fatigue* (Moderate)
AND *symptom(s) Heavy Limbs* (Mild)
AND *symptom(s) Oliguria* (Moderate)
AND *symptom(s) Bluring of vision* (Mild)
AND *symptom(s) Palpitation* (Mild)
OR *symptom(s) Hypertension* (Mild)
OR *symptom(s) Cerebral confusion & Headach* (Strong)
OR *symptom(s) Orthopnea* (Strong)
OR *symptom(s) Paroxysmal Nocturual dyspnea* (Strong)
OR *symptom(s) Cough & Hemoptysis* (Moderate)
THEN *the Disease is left sided Heart Failure*

Fig. 5. An example for production rule.

6. System Practical Results

Doctors and physicians who work in the field of heart diagnosis diseases can use the proposed system for training beginner's and medical students who work in the field of heart diagnosis. Additional benefits for the proposed system are illustrated in previous Sections 2 and 4 with some details. The system is implemented using visual prolog for windows, which is a prolog inference engine with simple graphical user interface and empty knowledge base. Knowledge base composes of rules implied from the Table 2. Symptoms' facts are encoded in rules. A rule interpreter compares the IF portions of rules with the facts, when the current problem situation satisfies or matches the IF part of a rule, the action specified by the THEN part of the rule is performed. So the inference chain formed from successive execution of rules. This inference chain indicates how the system used the rules to infer the disease of the patient. Our system's inference used the backward chaining technique to infer the rules as the system starts with what it wants to prove.

Figure 6 shows project main screen. Figures 7 and 8 show the system input patient data screens for heart diagnosis. The system asks a doctor (user) about the demographic data concerns information such as patient; age, sex cardiology risk factors, clinical data symptoms and signs through different dialogues and store answers in its knowledge base. After finishing the questions concerning the symptoms dialogue, the results appear as shown in Fig. 9. Figure 10 shows a sample case used for training and education. Figure 11 shows output sample slide for heart diagnosis patient case. Figure 12 displays a video show output for heart diagnosis patient case and training case.

7. Conclusion

This paper described a prototype model of a multimedia expert system for diagnosing heart diseases. The system uses the rule-based reasoning technique through simple querying of symptoms, signs and investigations done to the patient. The system can be used for diagnosing heart disease patients. It gives therapeutic advice, and it serves as an educational and training tutor. In addition, it helps undergraduate and postgraduate medical students working in the field of heart diagnosis.

Fig. 6. Main screen.

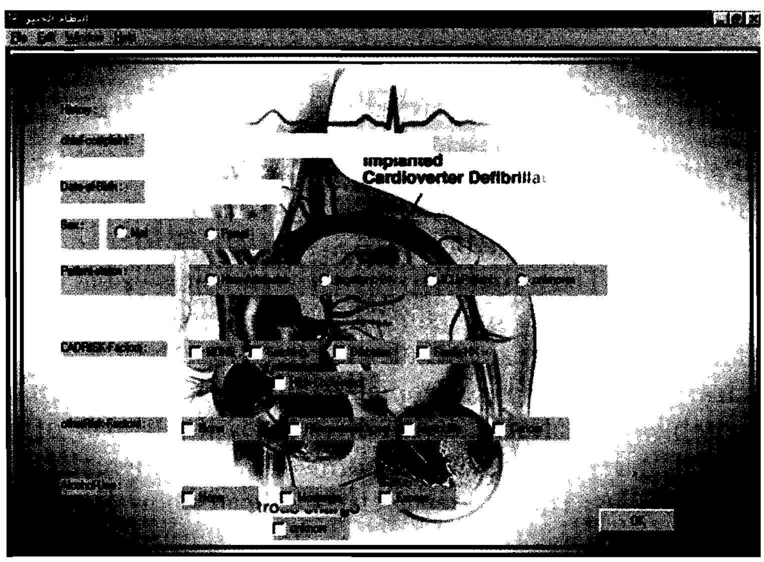

Fig. 7. Input patient data for heart diagnosis-first screen.

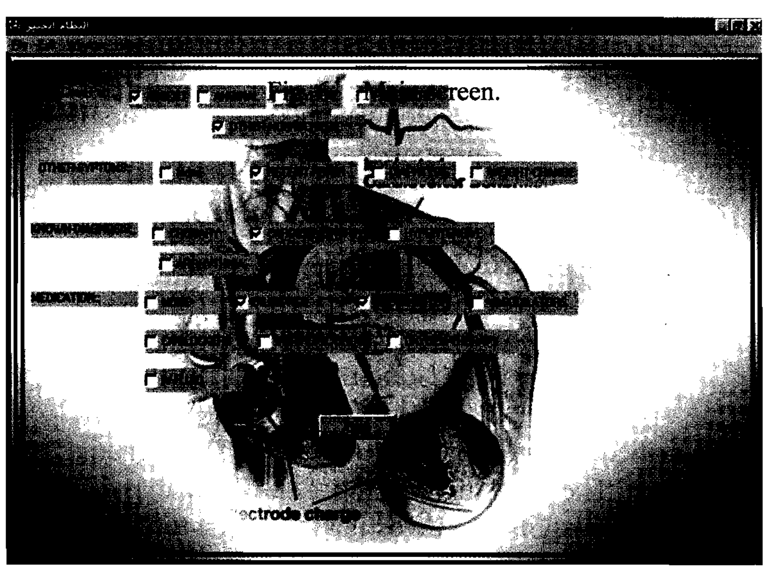

Fig. 8. Input patient data for heart diagnosis-second screen.

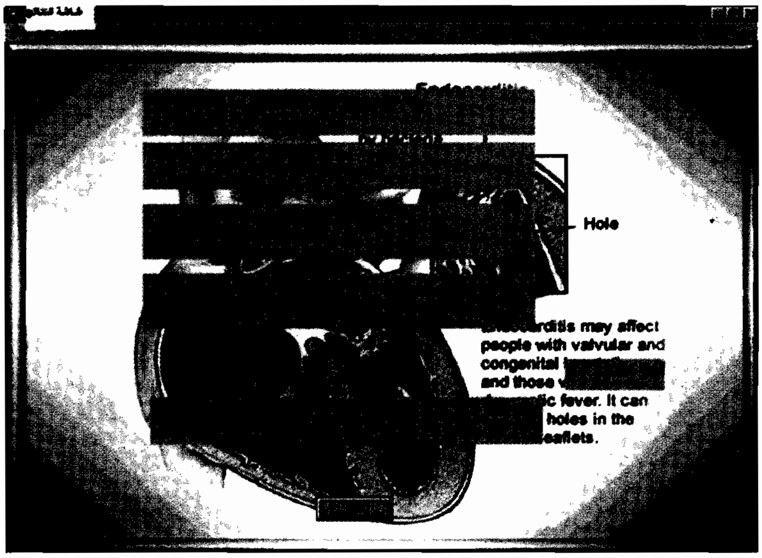

Fig. 9. Output heart diagnosis results screen.

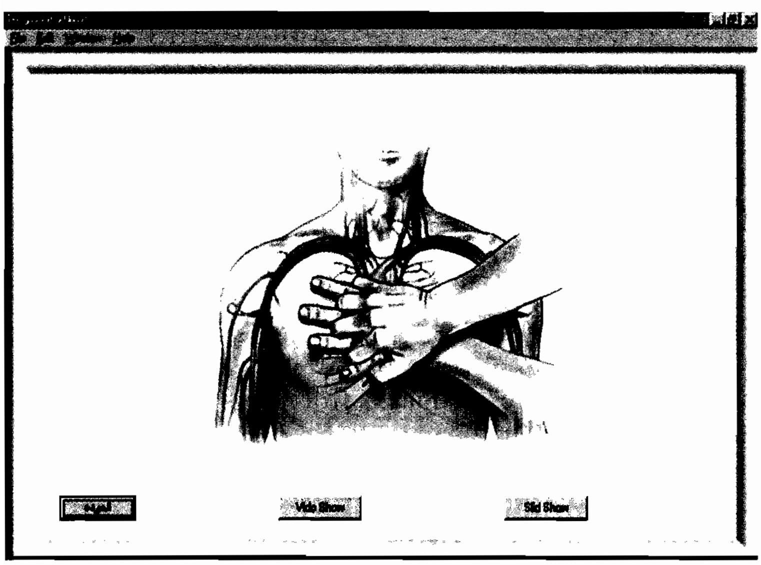

Fig. 10. Output screen – for training and education.

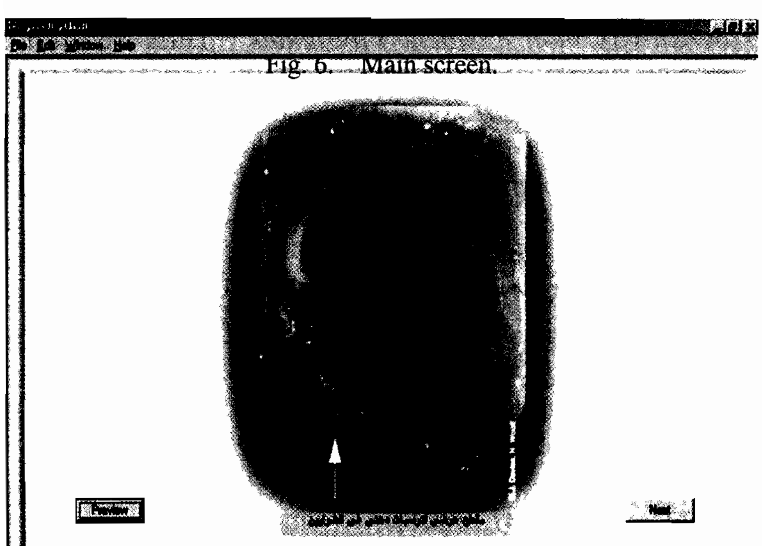

Fig. 11. Slides show output for heart diagnosis screen.

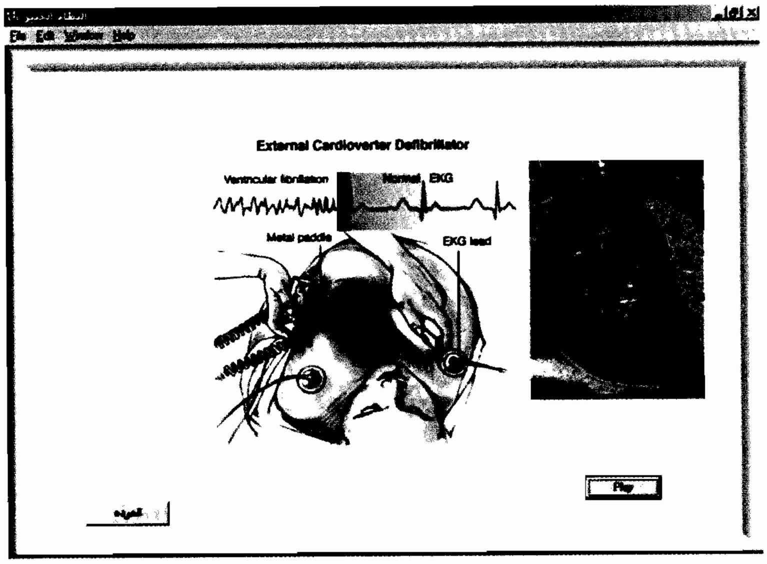

Fig. 12. Video show output for heart diagnosis.

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المستخلص. تعتبر الوسائط المتعددة من التكنولوجيا المتطورة التي يتزايد استخدامها في مجال التدريب والتعليم وخاصة في النظم الطبية ، وذلك لما تقدمه مـــن خـــدمات صوتية ومرئية مثل الفيديو والرسومات المتحركة والتصوير . كمـــا تعتبـــر الـــنظم الخبيرة من الوسائل التقنية المتقدمة الناجحة التي تستخدم بفاعلية وكفاءة فـــي تقـــديم حلول المشاكل الصعبة التي تعتمد على تراكم المعرفة من خبرات سابقة وخاصة في مجال الطب والعلاج وتشخيص الأمراض. ويقدم هذا البحث المقترح تصميمًا جديـــدًا مبتكرًا لدمج تكنولوجيا وخدمات الوسائط المتعددة مع تقنيات النظم الخبيـــرة لبنـــاء وتنفيذ نظام طبي خبير متعدد الوسائط يستخدم بفاعلية وكفاءة في التدريب وتشخيص أمراض القلب للإنسان. ويعتمد البحث المقترح على اســـتخدام وســـائل البرمجيـــات الحديثة المتوفرة حاليا بالأسواق بأسعار زهيدة ، مما يقلل من النفقات. ويـــشمل ذلـــك استخدام لغات الذكاء الاصطناعي مثل لغة برولوج المرئي ، بالإضـــافة إلـــي بنـــاء وحدات المواجهة بين النظام الخبير والمستخدمين بواسطة تكنولوجيا الوسائط المتعددة المرئية والمسموعة . ويتكون النظام المقترح من مجموعة من الوحدات التي تتعـــاون فيما بينها لتقديم الحلول الطبية المناسبة لمرضى القلب ، وذلك بعـــد أن يـــتم تحميـــل النظام الخبير وتدريبه بالمعلومات والأسس والقواعد الضرورية اللازمة التـــي تعـــين النظام الخبير على تحديد نوع المرض. ثم يقدم النظام بعد ذلك الإرشادات العلاجيـــة الموثوق فيها ، ويقترح العلاج المناسب للحالة المرضية التـــي يـــتم استـــشارته فـــي علاجها. ويستخدم النظام الخبير المقترح من قبل أساتذة في مجال طـــب القلـــب ، وكذلك بواسطة طلاب كليات الطب في الجامعات في مجال تـــدريب وتعلـــيم طـــب القلوب.