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TIDE: An Intelligent Home-Based Healthcare Information & Diagnostic Environment

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Abstract. The 21st century promises to usher in an era of Internet based healthcare services—*Tele-Healthcare*. Such services augur well with the on-going paradigm shift in healthcare delivery patterns, i.e. patient centred services as opposed to provider centred services and wellness maintenance as opposed to illness management. This paper presents a Tele-Healthcare info-structure *TIDE*—an 'intelligent' wellness-oriented healthcare delivery environment. TIDE incorporates two WWW-based healthcare systems: (1) *AIMS* (Automated Health Monitoring System) for wellness maintenance and (2) *IDEAS* (Illness Diagnostic & Advisory System) for illness management. Our proposal comes from an attempt to rethink the sources of possible leverage in improving healthcare; vis-à-vis the provision of a continuum of personalised home-based healthcare services that emphasise the role of the individual in self health maintenance.

1. Introduction

Healthcare in the 21st century is deemed as an 'extended enterprise'—a global enterprise that is experiencing a paradigm shift towards a preventative, managed and self-care, client-focused approach to the delivery of healthcare services [1] [2]. Emerging healthcare concepts and philosophies are reflective of innovative Information Technologies (IT)—Innovations such as computer-based patient records, hospital information systems, computer-based decision support tools, image processing, data compression, community health information networks, Telemedicine and new ways of distributing health information to consumers are beginning to affect the cost, quality and expanded access to healthcare information and services. Whilst this paradigm shift in the definition of healthcare is due in part to the powerful functionality of available IT technologies, it can be argued that IT, for our case the field of Artificial Intelligence (AI), is both being pulled by and helping to draw a new agenda about how healthcare will be practised in the future. Here, concepts and technologies are impacting on each other.

This paper discusses the synergy between AI and the new trends in the healthcare delivery system [3] [4], i.e. the delivery of healthcare via the Internet/WWW. The efficacy of AI towards healthcare is demonstrated by discussing an on-going in-house Tele-Healthcare project *TIDE—Tele-Healthcare Information and Diagnostic Environment*. TIDE aims to ensure a continuum of healthcare throughout the life-time of the individual. This is to be achieved by the delivery of *Personalised, Pro-active, Persistent, Perpetual* and *Present* healthcare maintenance *Information* services, coupled with *Diagnostic* services to the community via the Internet. Technical realisation of TIDE involves a confluence of information technologies—AI (expert systems, case-based and common-sense reasoning), medical informatics, multimedia, Internet and database technologies. This unique confluence of technologies within TIDE gives rise to an efficacious

'intelligent' info-structure that has the potential to re-think the modalities and mediums in which medical information is retrieved, disseminated and exploited.

2. TIDE: An Overview

TIDE is a manifestation of the emerging trends in modern healthcare practices, i.e. more person-centred as opposed to provider-centred together with an emphasis on wellness maintenance as opposed to illness management [5] [6] [7].

In the realm of TIDE we present two AI-based healthcare systems: (1) *AiMS (Automated Health Monitoring System)* and (2) *IDEAS (Illness Diagnostic & Advisory System)*. During the lifetime of an individual, he/she is likely to remain in the wellness cycle for most of the time yet there would be instances when the individual will fall in the illness cycle. To cater for the above two eventualities, TIDE aims to provide individuals an opportunity to maintain their own health and respond to illness episodes on a day-to-day basis from the confines of their home/workplace.

The objective of AiMS is to promote wellness maintenance, ensuring individuals remain healthy for prolonged periods of time. AiMS will provide personalised healthcare services, i.e. simplified *Personalised Lifetime Health Plans (PLHP)*, to assist individuals to manage and interpret their own healthcare needs. Put simply, a PLHP 'intelligently' integrates existing illness records (the past health perspective) with wellness plans (the future health perspective) to guide the individual in healthcare planning. A PLHP comprises a merged set of *Health Expectations* and *Health Tips*. Health expectations are evidence based health events that require planning. Health tips are lifestyle recommendations to ensure a healthy life.

The focus of IDEAS is illness management—to provide timely medical advice whenever an individuals fall in the illness cycle. IDEAS is an AI-based consultation package that is adept to provide primary health-care for non-critical illnesses: it would make a diagnosis, prescribe a treatment plan and direct the patient to the nearest pharmacy.

When an individual is in the wellness state, his/her health will be regularly monitored by AiMS so as to ensure that the individual remains healthy for prolonged periods. Whenever the individual falls ill, control of the PLHP is passed to IDEAS—IDEAS will conduct a 'virtual consultation session' with the patient, perform a diagnosis based on the patient's current symptoms/signs and finally prescribe a treatment plan.

3. The Wellness Perspective: Automated Health Monitoring Services (AiMS)

AiMS is a personalised health monitoring system that helps to keep track, manage, interpret an individual's health history and offer health maintenance advice. Each session with AiMS entails several important functions: (a) it collects an individual's current health data—a dynamic and pro-active web-based questionnaire is generated to acquire specialised information; (b) it interprets the acquired information and explains to the individual medically relevant facts; (c) it monitors the individual's health status based on his/her personalised health plans and it subsequently renders medically-relevant advice to maintain a healthy lifestyle; (d) it provides reminders for scheduled therapy and appointments and can electronically schedule medical appointments; (e) it also alerts healthcare agencies whenever an emergency situation is detected. Being in the prototype stage, AiMS currently provides monitoring services for depression, hypertension, diabetes and cardio-vascular related diseases. Functionally, AiMS comprises two main components:

*Personalised Health Monitoring***:** AiMS incorporates personalised health monitoring routines that are formulated based on an individual's current health profile. For each

'virtual consultation session', AiMS extracts the medical history of an individual from the centralised EMR database. Next, AiMS proceeds to 'intelligently' ask pertinent questions to the user to determine the user's current health profile (as shown in Figure 1). Intelligence derives from the fact that the questions posted to the user are dynamically generated (on the fly) after analysing the answers furnished by the user to previous questions. Typical responses of AiMS are shown in Figure 2 and are:

- An advice in the form of a list of *do and don't* activities.
- An advice to monitor certain health indicators such as cholesterol and glucose levels and perhaps suggest procedures to monitor these indicators.
- An advice for a detailed medical examination or to see a healthcare professional.
- An advice for a particular therapy or treatment programme.

General 'Personalised' Health Tips and Facts (PHTF): To ensure a continuum of healthcare and dissemination of health information, AiMS incorporates the PHTF module that provides general health tips, customised to an individual's health requirements. PHTF builds on the individuals PLHP to provide a variety of WWW-based services such as: an *immunisation planner*, a *dietary guide* , an *exercise/fitness monitor,* a *stress level indicator, body mass index (BMI) guides*, *personalised health information.*

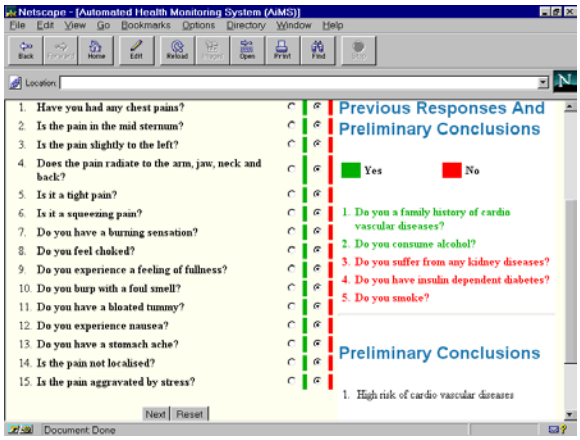

Figure 1: A typical screen for a consultation session with AiMS for monitoring diabetes

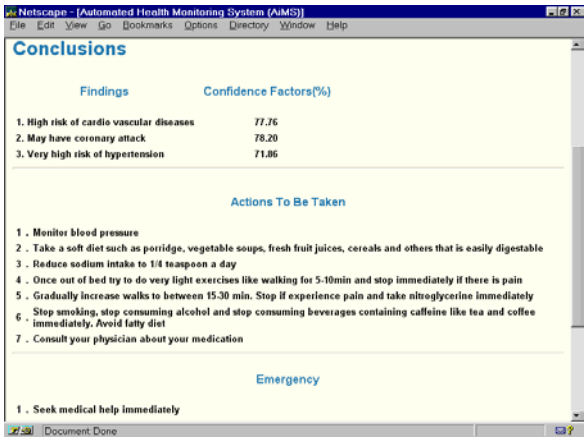

Figure 2: Suggestions rendered by AiMS at the conclusion of the consultation session

4. The Illness Perspective: 'Intelligent' Diagnostic & Treatment Advisory Services (IDEAS)

IDEAS aims to provide the community quality 'virtual' medical consultation for non-critical illnesses over the WWW. IDEAS, being in the prototyping stage, minimally covers the following medical conditions: cough, cold, sore throat, diarrhoea, abdominal pain, chest pain, dizziness and earache.

Functionally, IDEAS will conduct a web-based 'virtual consultation session' comprising *dynamically* generated questionnaires for the collection of relevant patient's health information (see Figure 3). Next, based on the collected information and the patient's health record (i.e. centralised EMR), IDEAS would come up with a diagnosis and treatment plan (see Figure 4). In a Tele-healthcare environment, IDEAS serves as a patient screening agent—screening patients in need of just primary healthcare as opposed to patients in need of tertiary health-care. IDEAS is intended to be the community's initial point of contact for non-critical diagnostic and treatment services.

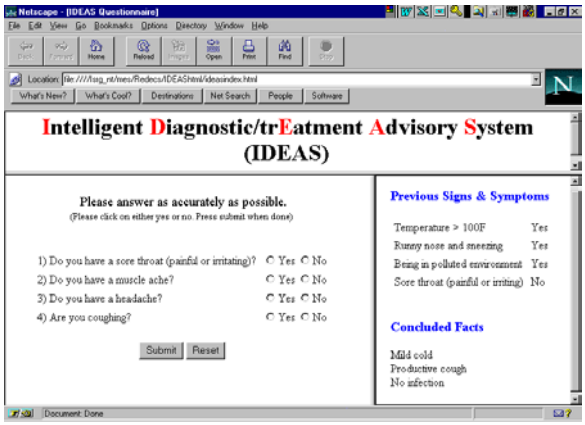

Figure 3: Snapshot of an IDEAS screen used for the collection of signs from patients

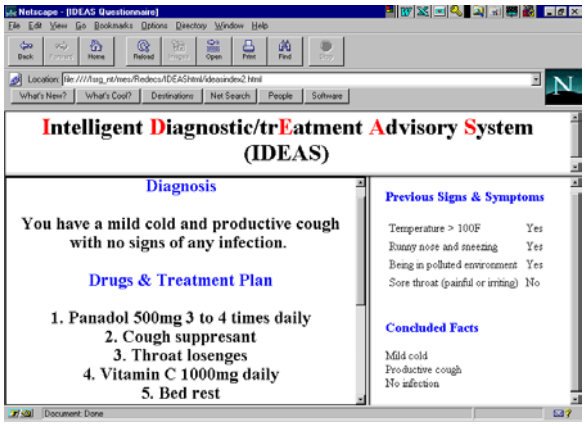

Figure 4: Snapshot of the IDEAS diagnosis screen, depicting both the diagnosis and the treatment plan.

5. TIDE: Design and Implementation Issues

TIDE manifests an info-structure that provides a seamless synthesis of AI-based decision-making systems (the expert systems embedded within AiMS and IDEAS), databases storing the EMRs and web-based programs and protocols.

At the heart of AiMS and IDEAS are two individual expert systems, encapsulating medical knowledge and reasoning techniques. For inferencing purposes we have devised a hybrid of forward and backward chaining strategies. In addition, the inference engine is also responsible for the 'intelligent' generation of subsequent questionnaires (i.e. web-pages) that may contain only the next set of pertinent questions—questions derived from the previous responses and in support of the multiple hypothesis active at that stage of the consultation and accompanying information. Both AiMS and IDEAS feature a friendly web-based interface for the collection of platform-independent person/patient data.

Expert medical knowledge, in particular the Malaysian medical procedures, is represented using typical *if ...then ... else* statements, with additional HTML text to output. TIDE's knowledge base—referred as the Decision Guide—partitions the rules into various modules, each addressing a particular scenario. Conceptually, the rule structure itself is divided into three constructs: *Question Constructs* address the questions to ask the user for a value for a fact; *Rule Constructs* represent pure knowledge that can be inferred over during the reasoning cycle; and finally *Rule-Answer Constructs* representing HTML-based information that is presented to the user (as part of the output) when the rule is satisfied (shown in Figure 5). Operationally, the rules combine in a dynamic manner, during inferencing, to address the defined diagnostic scope of TIDE. Dynamic web-pages are prepared to present the conclusions of the expert systems, together with hyperlinks to various information-related Web documents (as shown in Figure 6).

TIDE has been implemented using the Prolog, more specifically *LPA Prolog 3.5*. Both the TIDE expert systems reside on a server. Interactions between the client (the users) and TIDE is conducted over the WWW and is accomplished by using *ProWeb*—a Prolog-Web interface toolkit supplied by LPA. The web-based user-interface is developed using HTML and Java Script and the graphical charts are derived from Java applets. The functionality of TIDE demands frequent access to patient's EMR that may be stored in a centralised server-based database. Database connectivity is implemented by using the *ProData* (supplied by LPA) toolkit that provides a tight coupling between LPA Prolog and

all DBMS which support ODBC. Here, we will like to point out that TIDE is one of the few successful Prolog based AI applications that reside on the WWW.

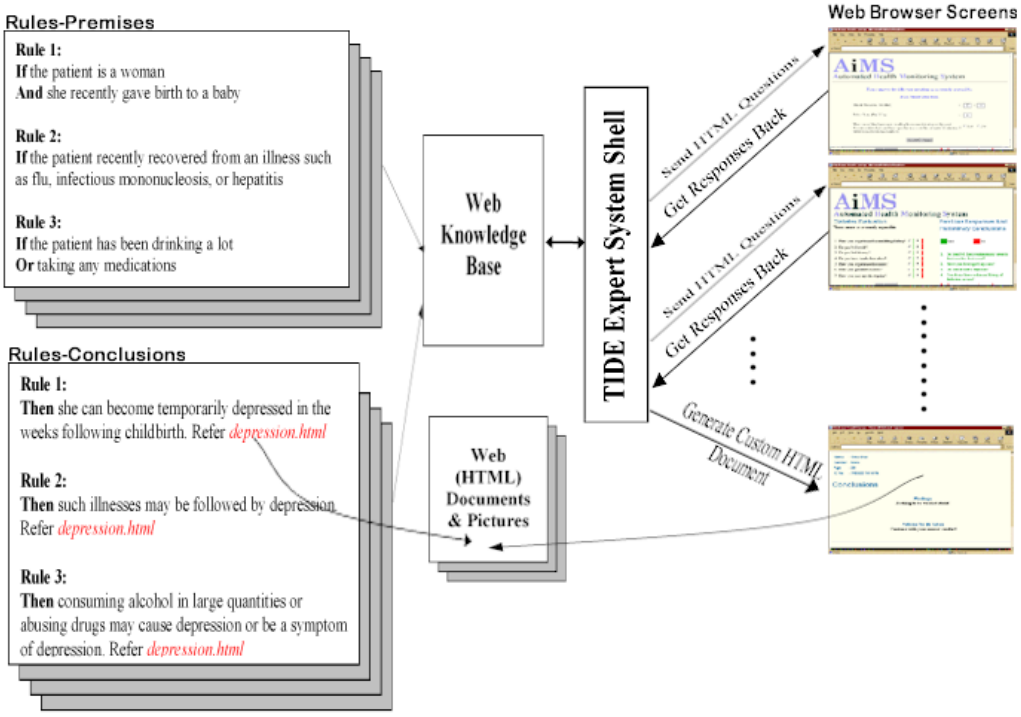

Figure 5: Illustrating the Rule Constructs—The top box shows the question construct and the bottom one the rule-answer construct. The right hand-side of the diagram shows the transactions involved in the generation of the dynamic HTML pages during the consultation session.

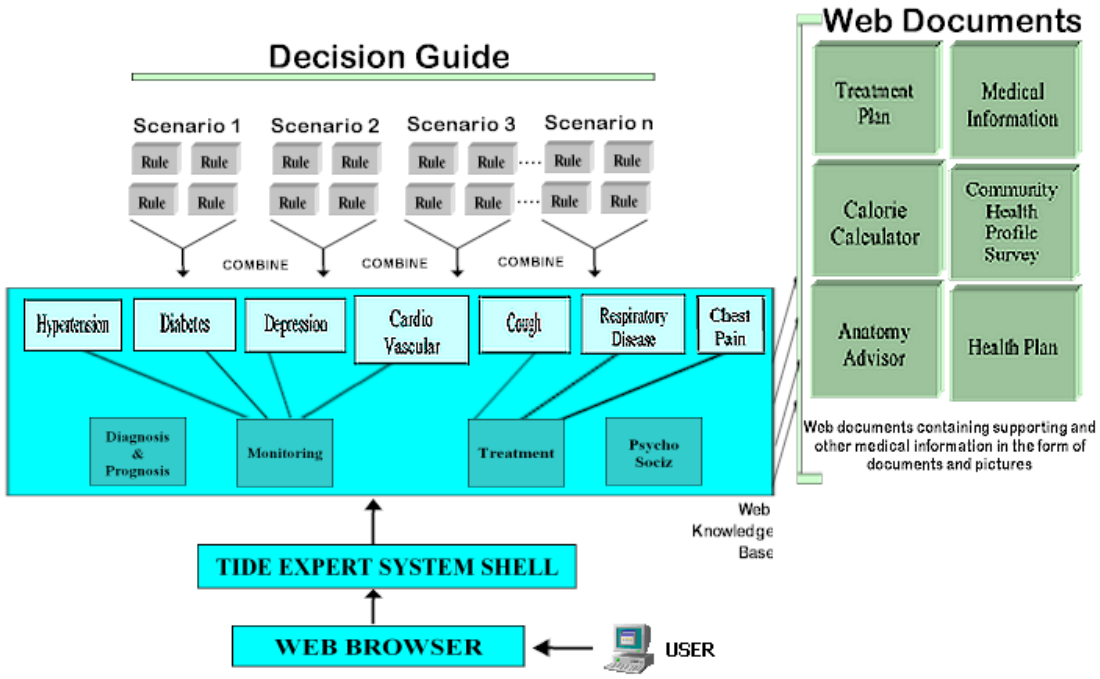

Figure 6: The functional architecture of TIDE.

5.1. Generation of Dynamic Web-Based Questionnaires

User's interaction with the TIDE applications is via a *Dynamically* generated HTML user interface comprising highly pertinent questions. This strategy is a step forward from the 'static' web user-interfaces in which pre-determined, yet at times irrelevant, questions are presented to the user.

Dynamic generation of web-based questionnaires is achieved by first designing a layout of the questionnaire and storing it in a template file. Throughout the consultation session, this template file is repeatedly modified and posted by the expert systems to the user. After every interaction with the user, the expert system modifies the contents of the template file as per the earlier answers, i.e. it writes the next set of questions to the template file. The updated template file is then posted to the user as the next web pages. The response of the user is passed via the web-pages back to the expert system for the updating of the template file. This process is transparent to the user as it is repeated throughout the web-based consultation session. Figure 7 shows a simple functional diagram to elucidate process of dynamically generating web pages.

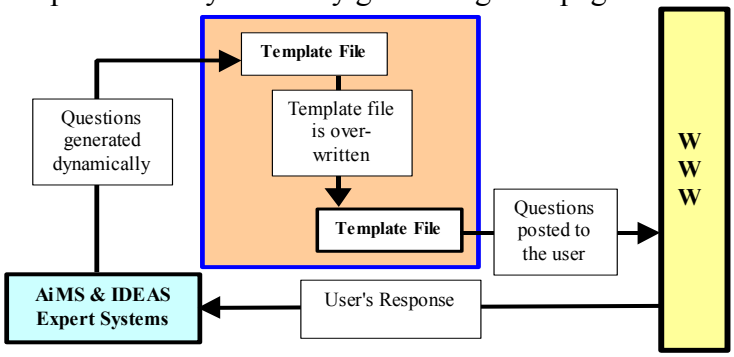

Figure 7: Functional diagram depicting the process of dynamically generating web-pages.

6. Concluding Remarks

In conclusion, we emphasise that the conception of TIDE has identified opportunities to improve healthcare delivery through increased use of information technology, in particular AI. Each interaction with TIDE is an active process, with an intelligence bias, that performs several important functions: it collects patient data; it checks, interprets, and explains to the subject medically-relevant facts and plans; it adapts its advice based on the subject's prior experiences and stated preferences; it performs "sanity checks" on both medical efficacy and cost-effectiveness of diagnostic conclusions and therapeutic plans; it monitors wellness progress and it helps to educate and encourage individuals towards health maintenance.

Finally, the TIDE info-structure is a showcase application demonstrating the efficacy of AI concepts and functionality on the WWW. The TIDE project is still in progress and more sophisticated and extended services are expected to evolve.

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