City University London
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INM358 – Knowledge Management in Healthcare

TES
Tuberculosis Diagnosis Expert System
An Expert System built in the ESTA Expert System Shell

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Knowledge Management in Healthcare Coursework
Tuberculosis Diagnosis Expert System (TES)
Report

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Introduction

The author of this coursework is working for the Newham Primary Care Trust, East London, in a busy IT department. Tuberculosis "(TB) is more common in Newham due to local patterns of deprivation amongst communities with a history of travel to and from other high incidence areas throughout the world. The World Health Organisation estimates that two thirds of the world's population have been exposed to TB." [LBN, 2005].

Alexander has for that reason chosen to use the disease Tuberculosis (ICD-10 A15.-A19.) [I] as project to model a knowledgebase for this assignment.

Knowledge acquisition methods

It was not possible to arrange a face-to-face interview with a Tuberculosis expert from the Health Protection Agency due to a lack of time. Therefore, Alexander Beisser has used the following online resources to acquire the necessary knowledge of Tuberculosis to successfully develop a knowledgebase for the ESTA Expert System Shell:

- Health Protection Agency, London, UK
- Center for Disease Control, Atlanta, USA
- World Health Organisation, Geneva, CH
- National Institute for Health and Clinical Excellence, London & Manchester, UK
- TB Alert, Brighton, UK
- Netdoctor UK, netdoctor.co.uk
- Wikipedia Online Encyclopaedia, wikipedia.org

[I] Source: Wikipedia; available on http://en.wikipedia.org/wiki/Tuberculosis

These resources provided a good and very comprehensive base of information to build an expert system for Tuberculosis. It should be noted that Alexander has had a short discussion about the disease with a member of staff in the Public Health department of the Newham Primary Care Trust. She has been able to direct him into the right direction for the knowledge acquisition and confirmed that he used the right references for this coursework.

A full list of references will be given at the end of this report.

Knowledge structures

The developer of the TES Knowledgebase has chosen to use a data driven, forward chaining approach, where the search strategy begins with facts as start data and rules that are applied to the facts to find new facts that then lead to the goal state [Roudsari, 2007].

The start data in the TES system is that the patient presents a cough as symptom. This symptom can be associated to several illnesses like common cold, asthma, smoker lung and Tuberculosis (just to mention a few). Rules need now to be applied to find the correct way through the structure of the knowledge base to get to the correct diagnosis, which is in our case Tuberculosis.

The goal state in TES is to diagnose the user / patient correctly with the disease Tuberculosis. Questions are being asked in relation to the symptoms and behaviour of the patient to differentiate between the possible findings of smoker lung, asthma or common cold so that the goal state is been reached.

It was planned for the TES system to allow a level of backtracking, but due to unexpected results when using it, it has been decided to limit this functionality on sub-sublevel only. A future system shall have a complete backtracking utilisation included. Backtracking allows the expert system to resume the search on a previous (higher) level to find and follow alternative ways, if a dead end in the knowledgebase has been reached [Roudsari, 2007].

The following questions have been used in the planning / development process to determine the rules for the knowledgebase in the TES system:

1. Does patient smoke?
2. How many cigarettes does the patient smoke?
3. Is patient asthma sufferer?
4. How long does the patient have the cough?
5. Does patient present a raised temperature?
6. Did the patient receive any antibiotics within the last 21 days?
7. Which antibiotics did the patient receive?
8. Did patient receive a BCG vaccination?
9. Did the patient travel or visit family members abroad?
10. Did a family member travel abroad or visit a family member abroad?
11. Where did the patient or family member travel to?
12. Does the patient cough up any sputum?
13. Does patient's sputum contain blood?
14. Does the patient have a lack of appetite and lost weight?
15. Does patient suffer from fever and night sweats?
16. Has a chest x-ray been requested?
17. Does x-ray show any abnormalities?

The questions let to the development of the following sections within TES:

advice_non_tuberculosis	Advice of non Tuberculosis diagnosis
chest_xray	See if chest x-ray examination determines diagnosis
eating_habits	Did eating habits change
give_asthma_advice	Advice of possible Asthma condition
give_inconclusive_result_advice	Advice patient that results are inconclusive
give_low_tb_advice	Advice patient that he or she is not likely to suffer from TB.
give_medication_resistance_advice	Check for antibiotics resistance
give_short_advice	Give advice to patient with short breath
give_stop_smoking_advice	Advice patient to stop smoking
give_tuberculosis_medication	Advice patient of Tuberculosis medication to be given
give_tuberculosis_treatment_advice	Advice patient about Tuberculosis result
low_risk_tuberculosis	Questions to check if patient has low risk of tuberculosis

	infection
medication	Check for previous use of tuberculosis medication
patient_check_eyes	Check for yellow eyes
patient_examine_xray	Check x-ray for Tuberculosis
patient_not_travel	Section for patients that did not travel
patient_send_xray	Send patient for x-ray examination
patient_smoker_lung	Try to identify if patient has smoker lung
patient_smokes	Check if patient does or does not smokes
patient_travel_area1	Patient travelled to area 1 or area 2.
patient_travel_area3	Patient travelled to area 3
patient_travel_area4	Patient travelled to area 4
patient_travel_destination	Allow selection of travel destination
patient_travelled	Set section depending if patient did travel or not
patient_tuberculosis	Test to see if diagnosis is tuberculosis
start	The start of consultation. Get patient name.

Table 1: Sections used in TES

The sections of the TES system use the following parameters.

asthma	Diagnosis could be asthma(?)
condition_cough	Patient has cough(?)
inconclusive_result	Result is inconclusive(?)
medication	Tuberculosis medication(?)
medication_resistance	Tuberculosis medication resistance(?)
patient_appetite	Does lack of appetite and weight loss exists(?)
patient_asthma	Patient suffers from asthma(?)
patient_breath	Patient suffers from shortness of breath(?)
patient_eyes	Are the eyes of patient yellow(?)
patient_fever	Does patient suffer from fever(?)
patient_medication	This medication is used to treat latent TB(?)
patient_name	The name of the patient(?)
patient_night_sweats	Does patient suffer from night sweats(?)
patient_pain	Has patient abdominal pain(?)
patient_skin	Is skin yellow(?)

patient_smoker	The patient is / is not a smoker(?)
patient_smokes_amount	Amount of cigaretts or cigars smoked per day(?)
patient_sputum	Does patient cough up sputum(?)
patient_sputum_blood	Does sputum contain blood(?)
patient_travel	Did patient travel(?)
patient_travel_destination	Destination of patient travel(?)
patient_vacination	Patient received BCG vacination(?)
patient_vomit	Does patient vomit regularly(?)
risk_low	Patient has low risk of Tuberculosis infection(?)
short_breath	Patient might suffer from shortness of breath(?)
tuberculosis	Result is Tuberculosis(?)
xray_examination	Has an x-ray examination been performed(?)
xray_result	Does x-ray examination indicate Tuberculosis(?)

Table 2: Parameters used in TES

The worth on using an expert system for Tuberculosis - the problem that the system tries to resolve

The Tuberculosis Diagnosis Expert System (TES) is trying to assist a medical professional in the correct diagnosis of the disease called Tuberculosis. The system can also be used by patients. It tries to help the healthcare professional to distinguish between the following diagnoses

- Tuberculosis
- Smoker lung
- Common cold
- Asthma

TES is asking questions relating to the patients lifestyle and his or her travel habits to determine if the patient falls within a risk group for having a Tuberculosis infection and advices the professional on the method of treatment or it refers to secondary resources (i.e. guideline published by the Health Protection Agency). TES shall be understood as an expert system that supports and enhances the work of the medical professional and not to replace him or her.

Expert systems do not have any conscience and can therefore not act upon it. This could be stated as a positive factor as bias or other subconscious influences do not have an impact in the treatment of patients, but in many cases doctors using their conscience and previous experiences for the good of their patients. It can be stated without doubts that humans are better in learning and acting on past experiences than machines and computers, even in our highly advanced technical world.

The worth of using an expert system for Tuberculosis lies in the functionality to guide (less experienced) healthcare professionals through the diagnosis process and procedure of a Tuberculosis infection and to give advice in distinguish it from other illnesses that can show similar symptoms (i.e. patient with the Gilbert's-Syndrome[II] for example can show the symptoms of yellow skin or yellow eyes similar to Tuberculosis sufferers) and it is therefore important to check for the accurate symptoms to get the correct diagnosis (goal state).

Functionality, design and construction

The TES system has been developed using the Visual Prolog tool called ESTA (Expert System for Text Analysis). This freeware tool allows the definition of parameters (as shown in Table 2). These parameters are then referred to in the developed sections (as shown in Table 1). Sections can call other sections to create a chain of rules / procedures to guide the user through the created system.

The section "fire" rules that call other sections or giving advice to the user. The functionality of given advice can be compared with displaying warning or information displays in other applications like Internet or medical IT applications.

Systems that are developed in the ESTA expert system shell are similar to dialogue or chat applications, but are different from them in one fundamental point. Expert systems are acting on user input by applying underlying rules to determine the displayed output, whereas Internet chatting tools are solely displaying what the user enters into the application.

[II] Gilbert's syndrome on Wikipedia: http://en.wikipedia.org/wiki/Gilbert%27s_syndrome

ESTA creates a knowledgebase that depends on the provision of parameters and sections and the "calling", referencing of sections. This builds the backbone of the application and determines its usefulness of the advice provided by the system.

It allows the user to check the created knowledgebase for errors, which is a very useful tool in bug-fixing the application when it provides an unexpected output. Another helpful function within ESTA is the visualisation of the section tree. It lets the developer choose which section he or she wants to use as starting point for drawing the section tree.

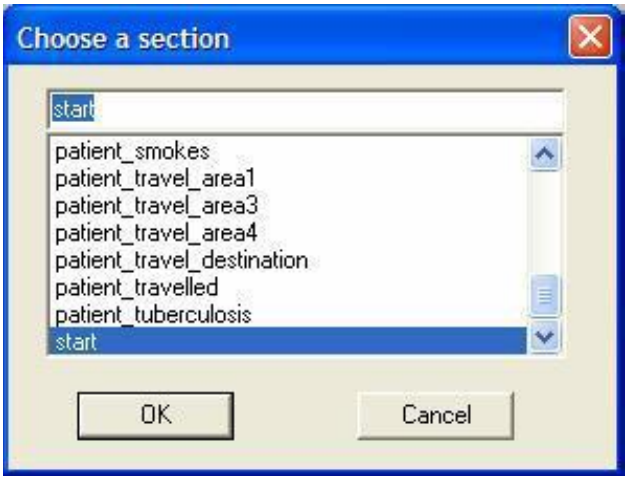

Figure 1: Selection option for start point of drawing the section tree for TES

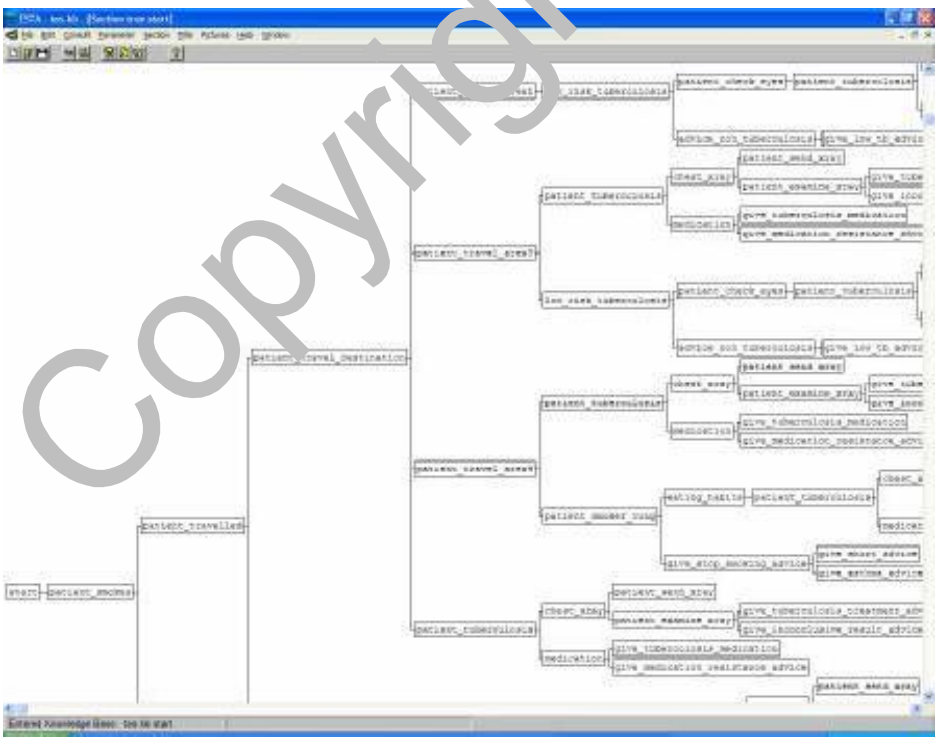

Figure 2: Part of the section tree diagram for TES

The development of TES has included the use of images. Figure 3 shows the welcome screen that is displayed when the user opens the TES knowledgebase.

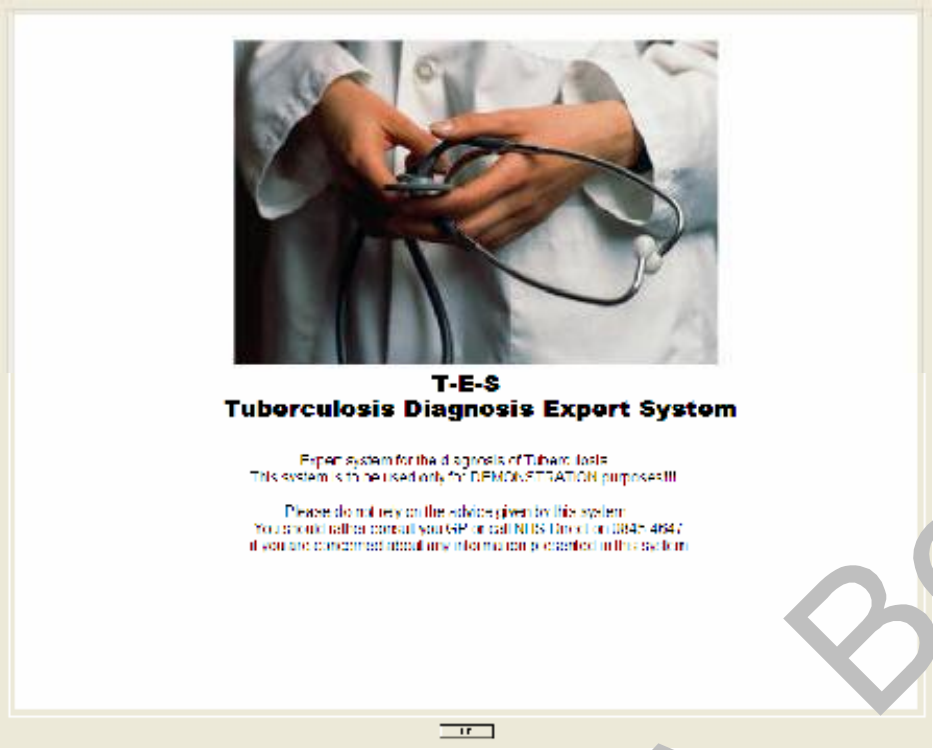

Figure 3: TES welcome screen

This welcome screen has been designed as a Microsoft Windows Bitmap image (bmp), which welcomes the user to TES. It also provides a warning message that patients shall not rely on the information given in this system. The warning message has been included to advise users to seek professional advice through their healthcare provider. It also intends to protect the developer from any claims made against him on the ground of information / advice given by this prototype system.

Figure 4 shows the use of an image – in this case an x-ray image – to help answering the question given.

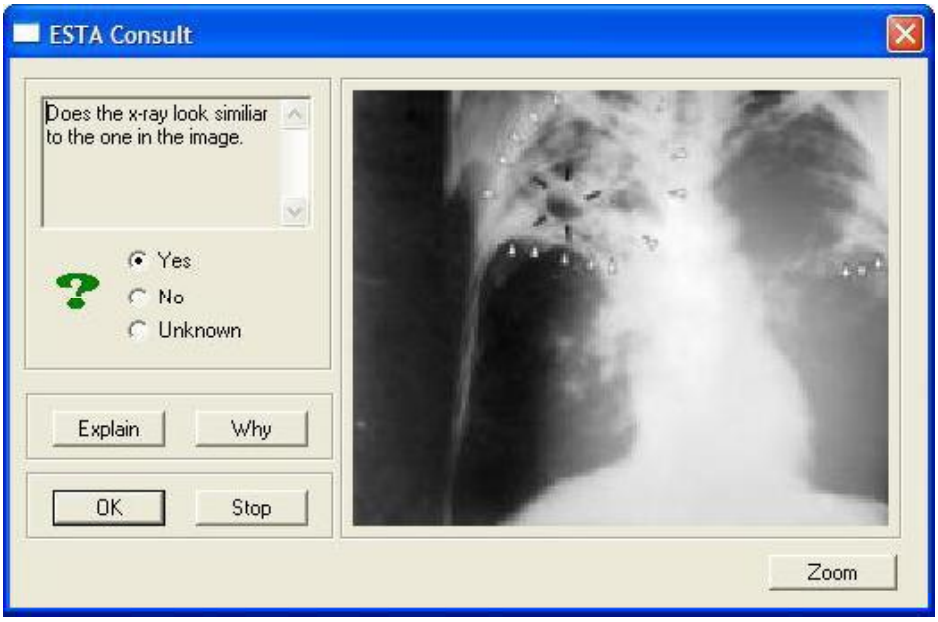

Figure 4: Image of a chest x-ray used in TES dialogue.

Figure 5 illustrates the functionality of giving advice to user of TES system within the ESTA development shell. The advice given in the screen dump is the advice given by the gold state.

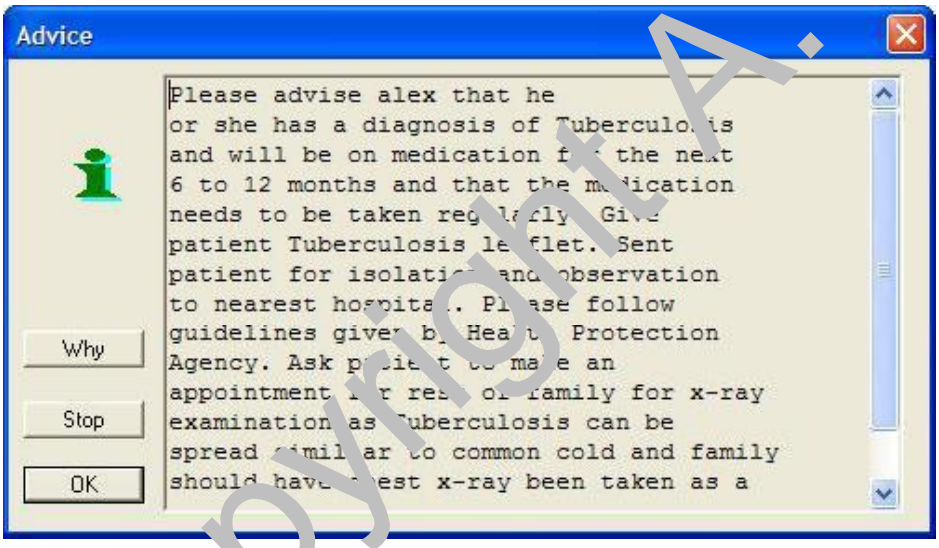

Figure 5: Advice screen in TES.

The user of the system can get explanations of most of the questions at the point when TES asks the user for input. Figure 6 demonstrates one of the questions with an explanation option attached to it.

Figure 6: Question with explanation available.

The following explanation will be displayed if the user clicks on the "Explain" button.

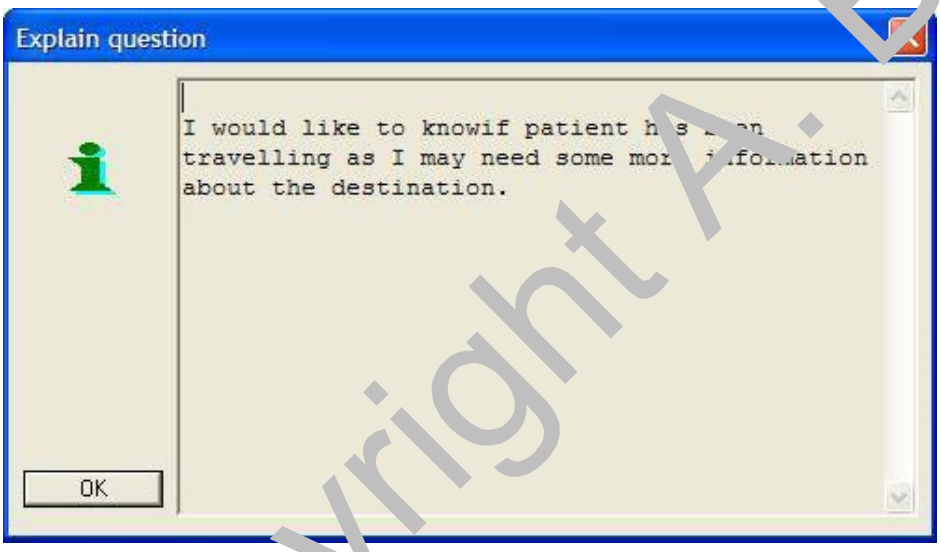

Figure 7: Explanation given by TES to user.

A click on the "OK" button will bring the user back to the question / interaction state (as shown in Figure 6).

Testing

Extensive testing has taken place after the development of the initial version of TES. The testing involved some form of a Black-White-Box testing regime. A complete testing report has not

been enclosed into this report due to report word limitation as well as due to time constrains in developing the system.

Several errors that have occurred in the first version made it necessary to change the structure and approach to the development of the TES knowledge system. A different section inter-linking approach has been utilized. This move forwards involved the splitting of sections into many smaller ones that link more heavily with each other and the provision of more frequent advice to the user of TES.

The second version followed the correct chain of rules and provided the correct outcome. Nevertheless, it still acted in an undesired way at the end of a consultation by looping through processes or linking to unexpected, often irrelevant sections. The developer of the TES system decided therefore to perform further fine tuning of section development and rule management. This process let to the deletion and merger of a few sections, but also to a new distribution of advice given to the patient / user. The inclusion of exit functions rounded up this redevelopment of the knowledgebase for the TES system.

Alexander Beisser can state that the final redesign has fixed all errors that he encountered during the development and testing of the system and it is currently running in a stable manner. The outcome and advice given by TES is as expected.

Strengths and weaknesses

TES has its strengths and weaknesses. It is a prototype for an expert system in Tuberculosis diagnostic on General Practise level. It does not claim to have complete knowledge of the disease and can therefore only act as a model or case-study for further development.

The developer had no previous experience in using the ESTA Expert System Shell and he has encountered several difficulties in the early stages of development of TES. Alexander Beisser has limited knowledge of Prolog from his undergraduate studies that gave him a better understanding of creating the underlying logic and rules to build a stable system.

Time constraints played a major role in the development of the system as he is working full-time and also needed to prepare another piece of coursework for university. He therefore decided at

some point before the Easter break to stop enhancing the system in the fear that unexpected error would put him under too much stress.

He would have liked to include more questions, rules and advice into the system as well as the provision to cope with unexpected patient symptoms input to create a more robust tool. However he is happy with the outcome of this development and is glad to be able to hand-in this coursework in on time.

Value of prototype

The Tuberculosis Diagnosis Expert System has been developed as a prototype to demonstrate the positive value an expert system can demonstrate on the treatment of patients with a specific, unknown condition.

The value of TES can be seen in the assistance it gives to medical professions and healthcare providers. Another worth of it is the knowledge the systems developer gained not only about the disease, but also about the field of knowledge representation and implantation into a “real-life” application.

Conclusion

The development of the TES system has proved to be a challenging task for Alexander. There have been frustrating times when the system did not work as intended or just suddenly jumped backwards to a point of irrelevance. On the other hand, there have been many happy and enjoyable moments, especially when TES worked finally as intended and the goal state was reached. He can admit that he was proud of developing TES to such a state that it runs stable and in the expected way. The praise he had been shown by his colleagues, to whom he presented the system, has been encouraging.

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