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EEGEXPERT
AN EXPERT SYSTEM INTEGRATED IN EEG AUTOMATIC DIAGNOSIS

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Summary - This paper describes an Expert System integrated in EEG Automatic Diagnosis. The features are acquired from an EEG'er by means of a user-friendly interface. These include characteristics (obtained by visual analysis) of background activity, sleep, paroxistic activities and others.

In the future, EEGExpert intends to be the last ring in the complete automatic EEG diagnostic chain.

INTRODUCTION

This paper intends to describe an Expert System for EEG Automatic Diagnosis, reasoning in a "data--driven" way, from data resulting of visual inspection of the EEG record.

The system, named EEGEXPERT, will integrate in the future a Feature Extraction System.

At present, EEGExpert can reach conclusions, make a report and provide explanation of its reasoning, only about EEG Background Activity. In the future, it will extend this to Sleep, Focal, Periodic and Paroxistic Activities.

The actual program has been written in OPS5 (a tool for building Expert Systems) plus Pascal. It is running on a μVAX-II under Operating System μVMS.

The primary structure of EEG classes and Diagnostic Rules has been built by a clinician. The authors are responsible by the implementation and knowledge reorganization.

EEGEXPERT STRUCTURE

1. Introduction

Such as any other Expert System (ES), the kernel of EEGExpert consists in essentially three parts (Fox, 1984) :

* a Knowledge Base (KE)
* a Data Base (DB)
* an Inference Engine (IE)

The IE uses Knowledge (based upon rules) to interpret the Data present in DB and reach conclusions.

The whole system can be divided in 4 main blocks:

* Acquisition of the Data obtained by visual inspection of the EEG;

* Loading of Data file into the WM, reorganization of Data, inference over the Data to achieve conclusions and file storing of OPS5 information about the sequence of firing rules and their actions over the WM. This last step is important to allow the system explaining its reasoning after the conclusions are presented;

* Natural Language Report of the main data present in WM. This doesn't yet include the explanation, which is only given in a structured form;

* Explanation utility, providing a backtrace of the rules which fired in order to produce a given conclusion.

The output of the system is a file with a patient identification header, the report and the conclusions.

2. The Data Base

We can distinguish in an Expert (or Rule Based, or Production) System two kinds of Data Bases:

* a "permanent" DB with long-term information, and powerful data-management;

* a "temporary" DB with short-term information, represented in OPS5 based systems by its Working Memory (WM).

Actually, we have one file by each patient EEG record with compacted information resulting from the visual analysis of the EEG. These files aren't yet organized in a real DB.

Anytime the system is requested to make a Report and Diagnostic about a patient, the corresponding Data File is loaded into WM and the inference begins.

The data stored in WM is structured in Attribute-Value Elements. Each Element has a **Class*** Name and a lot of **Attributes**, each with a **Value**.

Classes usually represent in EEGExpert, Activities (Alpha, Beta, Focal, etc.), Tests (Hyperpneia, Sleep, Intermitent Luminous Stimulation) and Assimetries.

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* a **Class** is a set of "objects" with similar properties.

3. The Knowledge Base

The knowledge Base consists on **rules** which contain knowledge about the subject.

There are in EEGExpert two kind of rules: rules for primary data reorganization and rules which conclude about the patient state: the domain rules.

In an OPS5 based system, rules consist of **Condition-Action pairs** in the form

IF <conditions> THEN <actions>.

Examples of rules are (in a readable format):

(ELECTROGENESIS SLOWNESS DEGREE 2
IF
(Context is Rules about Background Activity for adults)
(Alpha Rhythm has frequency in the range 7-8 c/s)
(Theta Activity is moderate)
THEN
(There is an Electrogenesis Slowness of Degree 2))

(POSTERIOR ALPHA ASSIMETRY
IF
(Context is Rules about Background Activity for adults)
(Alpha rhythm has smaller abundancy, frequency and amplitude in Hemisphere <HEM>)
THEN
(Posterior Alpha has a pathologic assimetry in Hemisphere <HEM>))

4. The Inference Engine

The IE (or Rule Interpreter) establishes the control of rules triggering. It is already implemented by OPS5.

Its main function is performing sequential **Recognize-Act Cycles**. Each of them evaluates the Left Hand Side (LHS or conditions) of the rules in order to construct a **Conflict Set**. This consists of the rules whose LHS matches the present WM state. Then, a built-in strategy decides which of the rules is triggered (Brownston, 1985).

Such a system reasons in a **bottom-up** (or forward inference, or data-driven) way, i. e., from the data to the conclusions.

This approach has been chosen because the primary data is well known and stable. There is no need for questions to the user, once he has introduced the whole information resulting from his (or her) visual analysis. Also, the conclusions can occur in a very wide space of possibilities.

5. Acquisition of Data Obtained by Visual Inspection of the EEG

The Data Acquisition is performed by a sequence of Displays.

The model used for the sequence results from several years of clinical experience and was made by a clinician (Dr. T. Paiva from Hospital de Santa Maria - Lisbon).

Each Display represents a Class (ex.: Alpha) and its attributes on the right side of the screen.

The user can walk through the attributes using a cursor. Everytime

he reaches an attribute, the list of possible values for that attribute appears on the left side of the screen. Then, he can choose the correct value. This will appear under the corresponding attribute name.

A Display lasts until all the attributes for the corresponding class get a value.

This mode of operation was carefully studied having in mind the goal of presenting to the clinicians an interface to the system as close as possible to their way of working and to acellerate the report generation process.

Also, the sequence of Displays is not "blind", but depends on the previous ones. For instance, if the conscience state was wakefullness, the system won't ask information about Sleep.

It is important keeping in mind that the whole lot of Class names, Attribute names and its possible values are stored in a special--purpose file, which can be easily edited if one wants to change any of those elements.

This feature makes the system more flexible and can function in the future as an interface between an automatic feature extraction system and EEGExpert, instead of the present Man-Machine Interface.

EXPLANATION

It is necessary for the complete acceptation of an automatic diagnosis system by an expert that this system provides an explanation of its reasoning process.

In EEGExpert, the explanation is presented as a backtrace of the rules which fired in order to reach a given conclusion. This backtrace is provided in a structured form, not yet in Natural Language.

There are two kinds of explanations: one, "user-friendly", for clinicians; another, OPS5-like, for debug of the program.

The way this explanation mechanism is implemented has the advantage of being applicable to any new rule which can be inserted (isolation from KB implementation). One disadvantage is that it can only be made after the inference process (after the presentation of the conclusions). However, this is not much relevant in this application, since the whole data for inference is present from the beginning.

NATURAL LANGUAGE REPORT GENERATOR

1. Introduction

The output of EEGExpert is a report of the EEG record. This includes a description of the main data present in short-term Memory (Alpha rhythm amplitude, abundance, topography and stability, existence and type of Artefacts, etc.) as well as the conclusions obtained by the Expert System.

For the data description goal, a flexible Natural Language Generator was built, once we want to extend it later to the conclusions and the explanation.

The basic components of the Generator are an ATN-like parser and some sentence constructors, each semantically bound to a particular class.

The generator uses a Dictionary of technical and common portuguese words and some procedures which provide syntactic concordance.

The whole generator is written in PASCAL.

2. Global Structure

This subsystem can be divided in 4 distinct parts:

i) Selection and Loading of WM elements which will be described;

ii) Acess to the sentence skeleton constructor for each kind of text class;

iii) Invocation of a Parser which validates and syntactically corrects the sentence passed from level ii);

iv) Sentence writing procedure, which controls line changing, tabulation, sentence continuation and paragraphs.

The text classes which are referred in ii) consist in major groups which join elements whose descriptive output text is similar.

At the present, there are two of these groups:

* ARTEFACTS
* BACKGROUND ACTIVITY, which describes in two separate subgroups Alpha Rhythm and Beta, Theta and Delta activities.

3. The PARSE procedure

PARSE is an important procedure which receives a sentence skeleton. Then, PARSE syntactically corrects the sentence, putting verbs in correct time and making concordances between sentence elements (adjectives and substantives as objects and subjects).

Translated examples of outputs from the procedures associated to each group and corresponding "parsed" sentences are:

a. OCULAR ARTEFACTS BE REGISTER.
OCULAR ARTEFACTS ARE REGISTERED.

b. ALPHA RHYTHM BE ABUNDANT, OF BIG VOLTAGE, STABLE FREQUENCY AND REGULAR MORPHOLOGY ; PRESENT ASSYMETRIC TOPOGRAPHY.

ALPHA RHYTHM IS ABUNDANT, OF BIG VOLTAGE, STABLE FREQUENCY AND REGULAR MORPHOLOGY ; PRESENTS ASSYMETRIC TOPOGRAPHY.

In the original portuguese version, as masculin is usually different from feminin, and plural from singular, there are substantives and adjectives which aren't yet correct at this stage. That cannot be seen with the translated examples!

4. The Dictionary

A Dictionary of common and technical portuguese words is used. All the possible values for attributes of classes are present there, but not only them. Verbs and some technical words were included too.

The Dicitionary is consulted by the PARSE procedure in order to assure correct sintax for the sentences, but can also be accessed by a special-purpose management program that can insert and/or delete words, make lists of words present and load/save the dictionary file to/from program memory.

During PARSE, only the sentence words present in the Dictionary are analysed and corrected.

CONCLUSIONS

Until now, EEGExpert was tested with closed sets of EEG cases. If we take into account the interactions within rules already implemented and others not yet present in the KB it doesn't make sense, at the present phase of the project, to realize sistematic tests using clinical records.

The above mentioned selected tests were performed to get some guidance for eventual reformulations in the system. They revealed the need for a refinement of the attributes quantification given by visual or computerized analysis, and perhaps for the implementation of Fuzzy Logic in the KB (Jagganathan, 1982).

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