

Upper Digestive Endoscopic Scene Analyze

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Abstract: When the endoscopist is exploring the digestive cavity, the action of focusing on a particular organ area and of evoking diagnostic hypotheses underlies a complex march of the thought. This mind process has to be analyzed in terms of data fusion and of reasoning in order to lay foundations with a view to a computerized expert system in endoscopy. Provided with evolved functionalities (the similar case retrieval and the diagnostic hypothesis evaluation), a digestive endoscopy atlas can be used as a tool of training and even of diagnosis aid for “junior” endoscopists. The architecture of such a system is to have its grounds on a Case Based Reasoning (CBR), organized around two bases, one of endoscopic knowledge and one of case iconography.

The retrieval of similar cases can be assimilated to a fusion process with two steps, classification (global method) owing to the knowledge base and, afterwards, measurement (local method) by means of selected cases of the endoscopic case base. Lesion identification and Disease recognition – that is, the Scene analyze - are the driving forces not only in the Classification stage, but also in the Similarity measure stage. Besides, classification algorithms, tested on simulated endoscopic descriptions, afford results full of promise.

Keywords - Upper Digestive Endoscopy, Data Fusion, Case-Based Reasoning, Approximate Reasoning, Classification.

I. INTRODUCTION

The conceiving of a knowledge based inference system for help to decision in the upper digestive endoscopy implies a narrow collaboration between gastro-enterology physicians and information processing specialists, so as to adapt the medical reasoning in the computer world.

The project intends to be a computerized advanced adaptation of medical atlas-books. Next to a classic illustration of diagnoses by means of noteworthy iconography, such an atlas must, in addition, integrate the *similar case retrieval* and the *diagnostic hypothesis evaluation*. For the first point, the general idea is that, faced with a situation he can't interpret, any user is nevertheless able to describe its content and also that, with an image database system which includes content-based *indexing*, storage and *retrieval*, all the similar situations can be proposed with their interpretations in order to aid him. The second point corresponds to the case in which the user describes an endoscopic scene and puts forward a diagnostic; the system then supplies a hypothesis evaluation as well as similar scenes with similar or differential diagnoses.

The following section briefly describes the upper digestive endoscopy domain and the physician diagnostic approach. In section 3, the project is depicted through its aims and its general architecture. Next, section 4, the information in endoscopy, particularly the description as well of pathologies as of patient's exam iconography, is drawn up thanks to the scene/object modeling. In section 5, the scene analyze, the matter of the similar case retrieval, is sketched through a two-leveled fusion framework. Ensuing statistical tests, already, present promising results. In conclusion, further steps of research development will be suggested.

II. ENDOSCOPIC WORLD

Endoscopic examination of the upper gastrointestinal tract - esophagus, stomach and duodenum - is the most accurate and informative method that may evaluate a wide variety of digestive symptoms (see Figure 1). Since its introduction for widespread use in the late 1960's, the technique of endoscopy has expanded the understanding of numerous gastrointestinal diseases thanks to a careful inspection of the mucosal surface and thus has greatly improved ability to care affected patients. Since the end of the 80's, videoendoscopes, which incorporate miniature TV cameras at their tips, allow the image transmission for video display, storage and analysis.

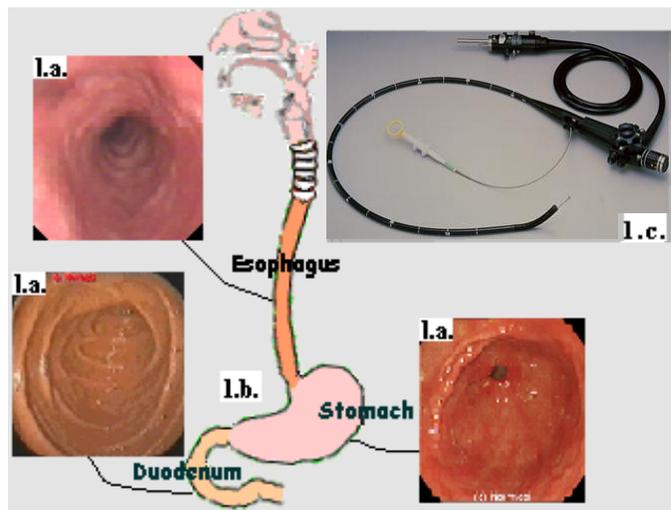


Figure 1: 1.a. Several endoscopic views
1.b. Visited organs
1.c. The endoscope

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Physician's reasoning [1] in endoscopy emphasizes, in the diagnostic process, two decision levels which refer to two information spaces: the endoscopic findings, i.e. the lesions, and the diseases. An interaction connects these two decision levels because the diagnosis of endoscopic findings meddles with the disease diagnostic decision. Inconsistencies in the final decision according to other information (medical context, other endoscopic findings) must lead to doubt about the validity of endoscopic finding diagnoses. At the disease level, the decision of assigning a diagnostic class also depends on the prevalence of this diagnosis in the current practice and on the endoscopist experience for rare cases.

The analysis of the medical context leads to distinguish two reasoning approaches. In one hand, the medical context is not specific. A systematic exploration of the organ permits to focus on lesions, according to abnormal variations of color, relief or anatomical repairs. Medical knowledge of lesion characteristics leads to the diagnosis of these elementary objects. The association of lesions compared with the knowledge of the endoscopic aspects of diseases induces to the generating of diagnostic hypothesis. In the other hand, a specific context earlier prompts to formulate diagnostic hypothesis and to consider endoscopic lesions whose association would confirm the diagnosis. Moreover, the endoscopist closely explores the regions where these lesions are usually found. During endoscopic examination, the two schematic approaches are not exclusive.

III. DIAGNOSIS AID IN ENDOSCOPY

First considering the system development and its capabilities, then the Case Based Reasoning (CBR) [2] is to be sketched as leaning on both a Case Base and a Knowledge Base (those to be detailed further).

A) General approach

For the present, with respect to the endoscopic imagery, there is no question of exploiting the numerical content of images or sequences because such a content would not be sufficient to "translate" the medical meaning of the situation. By this last term must be understood the patient context and the scene concept, i.e. the anatomical location, as well as any information, carried or not carried by the imagery, the whole guiding the doctor in his diagnostic interpretation. That is why the followed approach consists in elaborating a model of the situations encountered with the imagery, that is to say a knowledge base of endoscopic diagnoses exemplified by an iconographic base. This last one is constituted by a set of cases, i.e. images and/or sequences acquired from endoscopic examinations (stored on videotape) and illustrated by their diagnostic reports.

B) System capabilities

Classical retrieval

With this use mode, it is about functionalities given by a database management system; in other words, the retrieval according to a request or a logical combination of requests

Similar case retrieval

If a user describes a lesion, the images or sequences showing similar lesions and the related endoscopic reports are provided. Otherwise, if a user describes a patient's exam, i.e. the reasons of the endoscopy and the lesions, the system proposes the potential diagnosis(es) of disease(s) and images or sequences of similar cases.

Diagnostic hypothesis evaluation

The user describes a lesion and proposes a diagnostic about it; the system supplies a plausibility evaluation and shows similar lesions with similar or differential diagnoses. Otherwise, the user describes the patient's exam and proposes the diagnoses of the lesions and of the diseases; the system returns a likelihood of the situation and shows images and diagnoses which can confirm or contradict the user analyze.

C) Endoscopic CBR

As a physician exploits his medical knowledge (anatomy, physiology, epidemiology and pathology) and his experience (previously-encountered patient cases) in order to work out a diagnosis of the diseases, the system will be based on two bases, one of endoscopic semiology (disease descriptions) and one of endoscopic exams (patients' iconography).

A Case-Based Reasoning (CBR) [2] whose philosophy depends on the simple postulate that the experience gained in solving problems (cases) can, by analogy, permits to solve the similar ones (new cases), is well adapted to the diagnosis aid in endoscopy. The base of cases therefore represents the system "memory" when, thanks to the knowledge base, the indexing allows its "training".

The CBR cycle admits 4 steps: *–description, retrieval, correction and training* – (see Figure 2). The arrow from Retrieval to Description illustrates the intention to minimize the new case description; an adaptive algorithm will supply the user with a pertinent questioning.

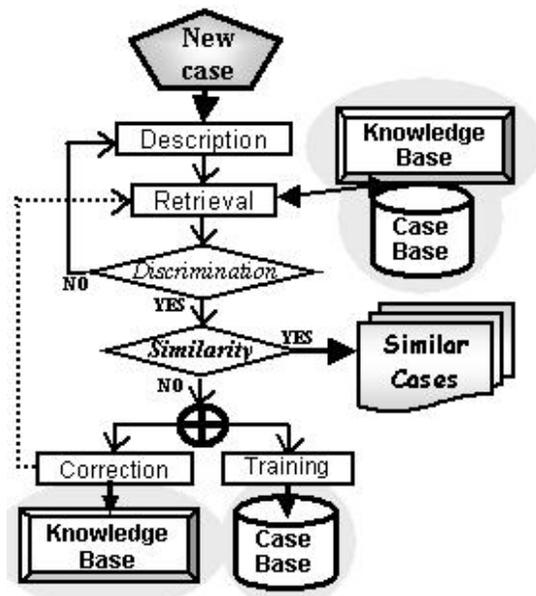


Figure 2: Endoscopic CBR scheme

IV. SCENE/OBJECT MODELING

Drawn from the Minimal Standard Terminology [3] of the ESGE (European Society of Gastro-Enterology), a two-leveled description mode of the endoscopic imaging and of the gastro-enterology pathologies is illustrated by the concept of Scenes with Objects.

A) Endoscopic Scenes

Owing to the federative concept of Scenes with Objects, the description of endoscopic information allows to distinguish three types of Scenes:

- Physical Scenes

The **file** of an image or of an image sequence is considered to be a *Physical Scene*. It visualizes an interesting part of the endoscopic exam, showing anomalies, that is the *Objects*.

- Logical Scenes

A *Logical Scene* represents a medical interpretation of endoscopic imagery, i.e. an endoscopic disease diagnosis, which associates a peculiar patient context, one or several endoscopical Finding(s) or *Object(s)* and their eventual spatial relations.

- Conceptual Scenes

As abstractions of Logical Scenes, *Conceptual Scenes* are the extended definitions of the upper digestive tract **pathologies**. Patient context, reasons for the endoscopy, one or several *Conceptual Objects* with their eventual spatial relations, and the complementary procedures to be advised, constitute the medical knowledge of these Scenes.

B) Object Information

Lesions or any element of interest, i.e. the "endoscopic findings", constitute the objects to be depicted thanks to an exhaustive description mode (see Figure 3). So, each object is described with 22 features (even 31 if a sub-object exists). To each feature is associated a set of choices, representative of all possibilities and judiciously defined by the expert.

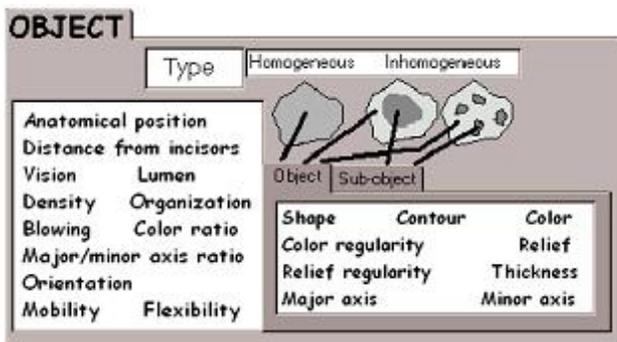


Figure 3: Object description features

C) Scene Information

At least one object, possible spatial relations and the patient profile represent the "how" and the "where" of a diagnosis, the complementary procedures to be envisaged denoting the "then". As shown on Figure 4, information on disease diagnosis well encompasses four relevant items:

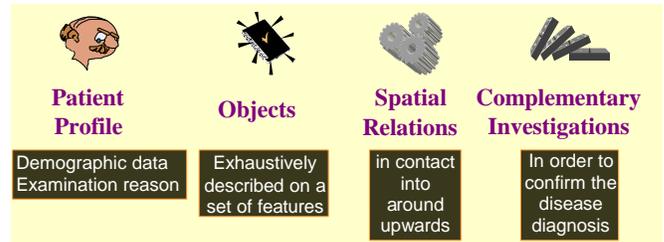


Figure 4: Disease associated Information

D) Endoscopic Knowledge Base

As an expert squeezes out his knowledge, using linguistic valuations and instilling even doubt, the chosen way (see Figure 5) is supposed to do the same, manipulating linguistic truth degrees as well as uncertainty or vagueness [4].

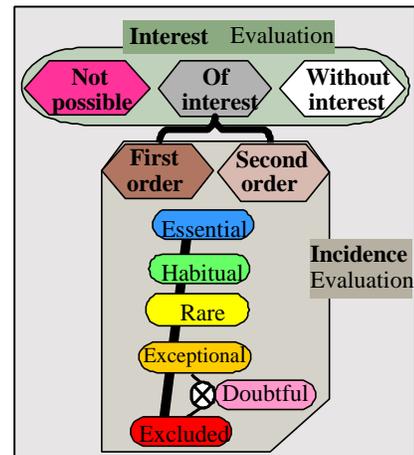


Figure 5: Knowledge Linguistic Valuation

An object is systematically illustrated upon 140 (or 205) modalities corresponding to the 22 (or 31) features with the Knowledge Linguistic Valuation and is marked by ESGE code and libel. A scene is depicted by a patient profile (the sex and age prevalence features as well as a predefined whole of clinical contexts), by the objects (one of them must be Essential), by eventual spatial relations between objects and by the complementary procedures, all these still with the Knowledge Linguistic Valuation. The diseases are called by an ESGE denomination and are classified as main or not.

To sum up, object and scene descriptions, i.e. the *Conceptual Scenes*, form a two-leveled knowledge base.

E) Endoscopic Case Base

For the imagery, it is a whole of endoscopic examinations, which must be indexed. Constituted of images or sequences and of a diagnostic report, each examination represents a set of *Physical Scenes* as well as a set of *Logical Scenes*. While a *Physical Scene* is a file where are visualized the objects, a *Logical Scene* represents an endoscopic diagnosis which consists of information concerning the patient (common to all the *Logical Scenes* of a same examination) and of all the objects attached to the diagnosis. Moreover, the indexing must hold into account that *Logical* and *Physical Scenes* do not tally.

V. SCENE ANALYZE

A) Towards solving new cases

Usually, the similar case retrieval is based either on a Similarity measure (computational approach) or on an Indexing structure (representational approach). But here, these two approaches (see Figure 6) are to be combined: a first step will classify owing to the Indexing structure (global method) and, after, a similarity measure (local method) will complete the retrieval of relevant cases.

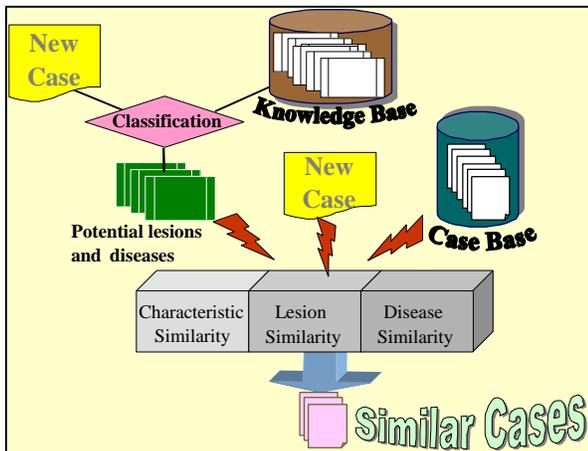


Figure 6: similar case retrieval scheme

Lesion and Disease Classification are the key points of the Scene analyze. With this intent, the questioning interface allows the user to depict an endoscopic exam, in other words the patient profile, the objects and possible spatial relations between objects. To avoid a boring description of objects, only 5 features (anatomical position, form, colour, relief and type) are wanted at first; the other ones, according to their discriminating power, will be selected to refine the object recognition. After the object classification, the whole description of the exam is analyzed to identify one or several Logical Scenes - i.e. the diagnoses of diseases -. This analysis of scene still allows perfecting the classification of the lesions - i.e. objects-. Indeed, as the level of the image (or of the sequence) generally represents the endoscopic lesion level, the classification should especially insist on the objects in order to select a subset of candidate cases (the similarity playing upon those), while, from a medical point of view, the level of interest should surely envisage the pathology diagnosis.

B) Classification results

Object Classification Algorithm

Thanks to the expert, 95 *Conceptual Objects* have been described on 31 features, i.e. on 205 modalities.

The Object Classification Algorithm eliminates owing to impossible or excluded valuation and ranks according to the Knowledge Linguistic Valuation. For each *Conceptual Object*, 300 *Logical Object* descriptions are generated and tested by means of the algorithm; Figure 7.a. shows a "perfect" classification of 95%.



7.a. with 22 features on average

7.b. with 8 features on average

Figure 7: Classification results on Object descriptions

Discrimination analyze

For each *Logical Object* description based on 22 features on average, a minimal description exists on fewer features. From where, anatomical position, form, color, relief and type usually belong to the minimal descriptions of the 95*300 precedent tests. Figure 7.b. shows the Classification test results with, at the beginning, a description on the 5 features, completed by 2 others as long as there are discriminating features. Results anyhow remain excellent.

Scene Classification Algorithm

The expert has described 150 *Conceptual Scenes* representative of 75 ESGE diagnoses.

The Scene Classification Algorithm selects by essential valuation, eliminates owing to impossible or excluded valuation and ranks according to the Knowledge Linguistic Valuation. For each *Conceptual Scene*, 50 *Logical Scene* descriptions are generated and tested with the algorithm; Figure 8 shows a "perfect" classification of 84%.

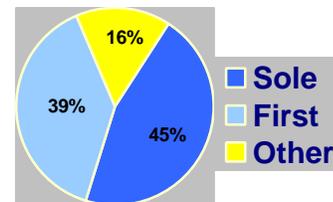


Figure 8: Classification results on Scene descriptions

VI. CONCLUDING

The present paper has, step by step, reported a laborious scrutiny for the knowledge representation and the case indexing in digestive endoscopy. The scene analyze shows cheering classification results -but those to be still improved-. The tackling of similarity measure will finish off the whole system. Further ambitions would look to evolving towards Telemedicine thanks to a user interface, developed with Internet tools...

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