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Collaborative Atlas in Upper Digestive Endoscopy

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Abstract

With this project about endoscopic images of the upper digestive tract, the matter is to build a collaborative atlas and a learning tool for junior endoscopists, to participate in the standardization of terminology in digestive endoscopy and to explore new ways to investigate the medical reasoning process. Previous work on endoscopic image indexing and retrieval has led to the development of a reasoning model of endoscopic diagnosis along with a determination of features to be used in finding and case descriptions. We present a web platform, based on this previous research, which creates a collaborative environment for indexing of endoscopic images. This is currently implemented using the 1500 endoscopic images collected from the data warehouse of the Clinical Outcomes Research Initiative (CORI) as published online in the OHSU Digital Resource Library. In addition, we describe our early investigations on similarity and the art of diagnostic reasoning.

Keywords:

endoscopy, gastrointestinal - image interpretation,
computer assisted indexing,
collaboration problem-based learning, internet

Introduction

Since its widespread use began in the late 1960's, endoscopic examination of the upper gastrointestinal tract (esophagus, stomach and duodenum), with its careful inspection of the mucosal surface, has expanded the understanding of numerous gastrointestinal diseases and has thus greatly improved patient care. During this time, advances in digital imaging have simplified the sharing of still images or video sequences. Collections of these images into atlases and, more specifically, their integration into a learning environment, presents new issues such as optimal indexing, communication, interactivity and collaboration. The aim of the Project is the development of collaborative tools for creating and sharing atlases and for teaching endoscopy.

In previous works [1], inspired by medical practice, we have defined a bi-leveled – disease and lesion – description language of diagnostic information in endoscopy in order to unify the representation of pathologies and of cases. Upon this analysis of the diagnostic reasoning process, all the elements were joined to a system of decision aid which suggests consistent diagnostic hypothesis and relevant cases according to the problematic case description. This system leans on two bases, one defines the endoscopic knowledge and the second corresponds to a case iconography. To identify potential cases within the same class than the problematic case, the similar case retrieval consists in a classification process upon the endoscopic knowledge. Potential cases are then sorted according to their similarity with the problematic case.

Now, it is the matter of presenting a web platform, based on these previous researches, allowing a collaborative symbolic indexing of the 1500 endoscopic images collected from the data warehouse of the Clinical Outcomes Research Initiative (CORI) - published online in the OHSU Digital Resource Library [2] – by using 150 already indexed pictures, excerpt of the Normedia atlas [3] - and allowing some experimentations to investigate the similarity and the diagnosis reasoning. The goal is to develop a learning tool, based on a previously limited and defined set of training scenarios that could be used in real conditions for demonstration and for evaluation with endoscopists.

The following section will describe the structure and processing of endoscopic information, the construction of knowledge and case bases, and their use for similar case retrieval. Next, in the 3rd section, the collaboration framework is sketched with the web platform allowing collaborative indexing and experimentations. After a discussion about investigations on similarity and reasoning, the proposed future works will conclude the paper.

Materials and methods

In order to help the endoscopist faced with a complex case, previous work [1] has been done in developing an “intelligent” endoscopic atlas. Such an atlas proposes consistent diagnosis hypothesis and relevant cases according to the endoscopist description of the case. At the same time this development has imposed to analyze the cognitive processes that underlay the medical decision making.

Endoscopic information structuration

Physician's reasoning [1] in endoscopy emphasizes, in the diagnostic process, two decision levels which refer to two information spaces: the endoscopical findings, i.e. the lesions, and the diseases. An interaction connects these two decision levels because the diagnosis of endoscopical findings meddles with the disease diagnostic decision. Inconsistencies in the final decision according to other information (medical context, other endoscopical findings) must lead to doubt about the validity of endoscopical 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.

Information structuration

Drawn from the physician reasoning and from the Minimal Standard Terminology of the European Society of Gastro-Enterology (ESGE) [4], a bi-leveled description mode of the endoscopic imaging and of the gastro-enterology pathologies is illustrated by the concept of Scenes with Objects whence three types of Scenes with Objects.

Physical Scene: the file of an image or of an image sequence It visualizes an interesting part of the endoscopic exam, showing anomalies, that is the Objects.

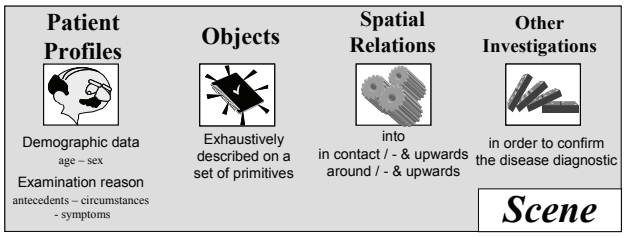

Figure 1- Logical and Conceptual Scene Information

Logical Scene: a medical interpretation of endoscopic imagery, i.e. an endoscopical diagnosis, which associates a peculiar patient context, one or several endoscopic Logical Findings or Objects and their eventual spatial relations (*Figure 1*).

Conceptual Scene: as abstraction of Logical Scene, 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 (*Figure 1*).

In these three kinds of scene, lesions or any element of interest, i.e. the "endoscopic findings", constitute the objects that can be depicted through an exhaustive description mode. To each descriptor or feature is associated a set of choices, representative of all possibilities and judiciously defined by the expert as shown *Figure 2*.

Knowledge and case bases

The Minimal Standard Terminology (MST) constitutes the framework for the identification and organization of endoscopic information and decisions while the basic concepts of the terminology imply the incompleteness of the description. However, the syntactic descriptors of endoscopic findings and the set of values for each descriptor can not be retrieved in MST while the terminology does not detail all the features of the endoscopic lesions. The finding descriptors refer to a lower implicit description level whose knowledge has to be acquired by endoscopic learning and training.

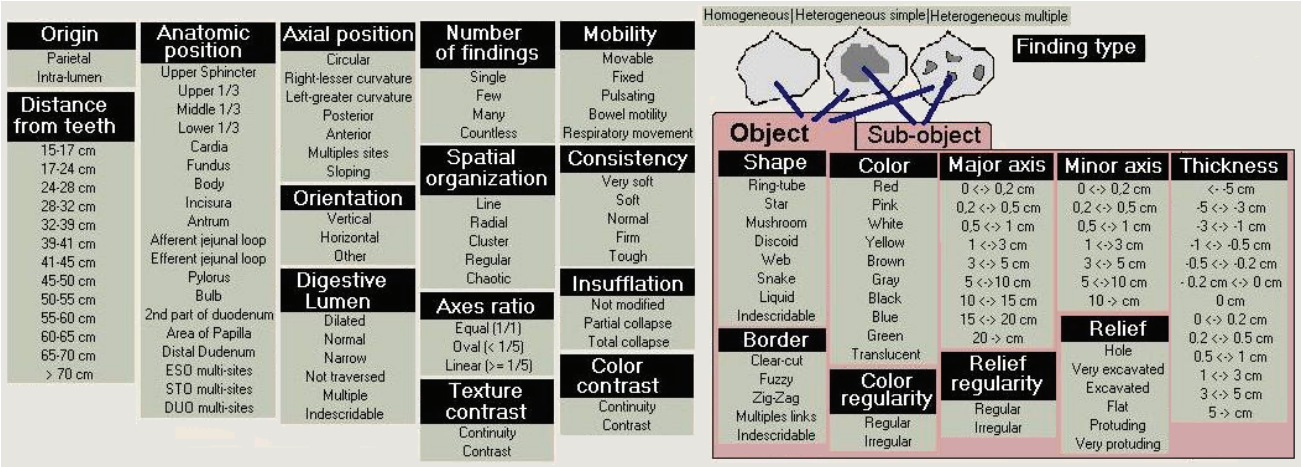

Figure 2 - Features and items of finding description

This approach leads to an a priori description of 150 Conceptual Scenes (diseases) and 100 Conceptual Objects (endoscopic findings).

The expert squeezes out his knowledge, using Linguistic Valuations (LV) instilling uncertainty or vagueness [5]. Each feature can be judged as without interest, impossible or of interest; in this last case, each feature item must be evaluated as *never, exceptional, rare, frequent* and *always*. A sixth level is also defined *doubtful* when the choice between never and exceptional cannot be stated: this level expresses the knowledge limits of the expert.

An object, identified with a code and a label is systematically described through 33 features as shown in *Figure 2*. To one feature corresponds several items which will be assigned a LV value. The actual number of considered items is 206. 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 "always") and by eventual spatial relations between objects.

The case base is constituted of indexed images; each of them represents an endoscopic diagnosis (Endoscopic Scene) with one or more findings, being described with one item by feature. The indexing is leisurely and fastidious task. Most of the images have been extracted from the Atlas of Digestive Endoscopy - Normed Verlag Editions (Homburg) [3] - with their authorization.

Reasoning with knowledge and cases

For a new situation, the similar case retrieval leans on the knowledge and case bases. Based on the knowledge base, the system looks for the potential finding and disease classes of the observed case. The retrieval is completed searching into these classes the more similar case according to similarity rules.

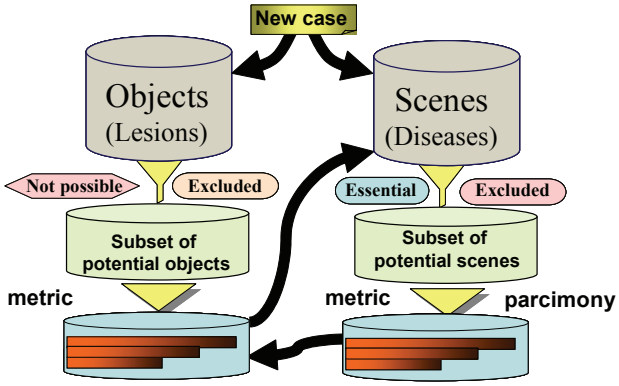

Figure 3 - New case classification

Lesion and Disease Classification, illustred by *Figure 3*, 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, color, 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.

The classification step having unveiled the objects and scenes potentially similar, it is a matter of illustrate them

by pertinent images. For this purpose, the new case is compared with selected cases according to three levels, characteristics, objects, and scenes. The Characteristic Similarity uses predefined tables for each feature with 5 values (incompatible - no similar - slightly similar - fairly similar - identical). Fusion of Object Similarities, of patient profile characteristic similarities and relation characteristic similarities complete the retrieval.

Such a system with evolved functionality is in keeping with the Pattern Recognition and Case Base Reasoning paradigms. A version of the endoscopic atlas is accessible via internet at http://i3se009d.univ-brest.fr/ -- Password medinfo2007. At the moment, then application contains around 150 endoscopic images (from Normedia) and 150 descriptions of 90 findings; it enables the user to describe an object or a scene in order to obtain the potential diagnoses and similar images. The reasoning model and the indexing criteria have been informally assessed by endoscopists with different levels of experience.

It is clear that the accuracy of the system to retrieve similar images depends strongly on the user's ability to analyze the endoscopic image. Faced with a diagnostically ambiguous image, it becomes difficult for the endoscopist to extract and describe the relevant features. This inherent weakness is common to other computer-assisted decision-making systems and limits their usefulness as real-time diagnostic aids. On the other hand, this work has demonstrated a method for precise description of the cases by experts, the flexibility of the research engine, the ability to store a large number of cases and to use web tools. With this background, we have continued to study the topics of similarity and reliability in the collaborative atlas Project.

Collaborative atlas project

The 1500 endoscopic images collected from the data warehouse of the Clinical Outcomes Research Initiative (CORI) as published online in the OHSU Digital Resource Library [2], constitutes a collection that may be sufficient for preliminary work, that is to say, to a reference atlas for further projects. This collection differs from the endoscopic case base described above, however, in that the images are not linked to patient information and are indexed with CORI terminology and not the MST-derived terminology described. Nevertheless, this collection allows us to explore issues in similarity such as the reliable assignment of indexing terms (including validation of images in the collection), comparisons of standardized vocabularities, metrics for similarities between images, and the technical and organizational requirements for collaboratively creating a shared, indexed case base for clinical care and education. Two projects have been initiated, the first in collaborative indexing, the second in development of educational scenarios for testing and education.

Collaborative indexing

In the setting of this collaboration, another web site http://i3se009d.univ-brest.fr/Collab - Email and Password: medinfo2007– is under construction and uses the 1500 endoscopic images from CORI as a base for collaborative image indexing and creation of a case base.

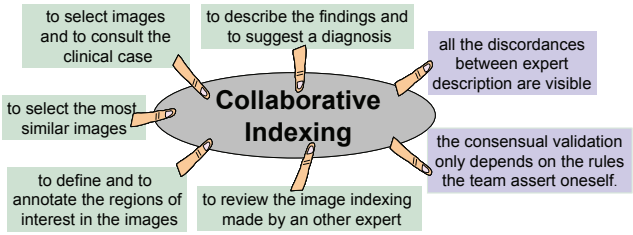

Figure 4 - Collaborative indexing

Already, the indexing module enables a domain expert to select images, to consult the clinical case, to describe the findings, to suggest a diagnosis, to select the most similar images from the atlas or to define the regions of interest in the images and to annotate them as seen *Figure 4*. The finding description is made easier by the ability to match the current image to a similar image already indexed - as shown *Figure 5* - and to adapt the description to its case; the validity is checked thanks to the Knowledge base; the expert can maintain a non valid description and, if necessary, the Knowledge base will be updated. Several experts can index the same picture and modify the descriptions. All of the discordances between experts are displayed; final validation of an image description depends on the rules which the team chooses.

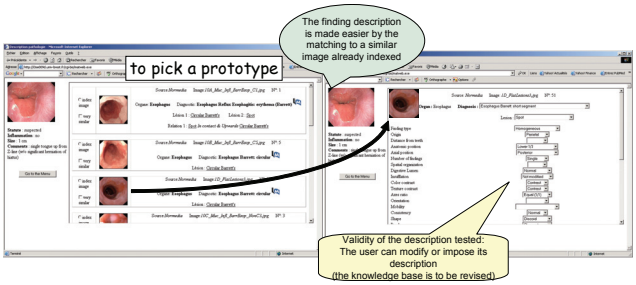

Figure 5 - Indexing thanks to previous cases

Educational scenarios

The educational/testing module is made up of HTML pages and combines images and test questions as presented *Figure 6*. For any learning scenario, the forms and their display order may be customized. Images within those forms can be displayed in a set order or randomly selected. The subject is given a scenario and one or more images

and answers questions about those images. In an educational mode, the subject may access the text description of the image and/or the case. In testing mode, following validation that all questions are answered, the responses are saved for subsequent analysis.

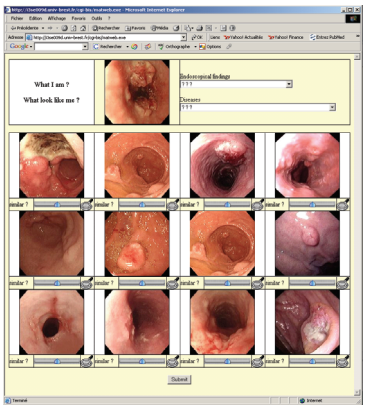

Figure 6 - Testing module

Preliminary work with this module suggests opportunities for development of some interactive tools and will enable to devise learning scenarios adapted to the reasoning methods of endoscopists and to the experience level of the apprentice.

Discussion

The difficulty by endoscopists in extracting relevant features from an ambiguous image and the interference of the diagnostic conviction in the description process leads to explore similarity in endoscopy.

Similarity exploration

A study of the similarity [6] in digestive endoscopy has been conducted first with endoscopists (both novice and experienced) and then with a group of college-level psychology students. The study used a library of 90 well-known endoscopic images and 3 study images. For each study image, the participants were asked to choose from the library the ten most similar images and, in addition, for the endoscopists, to list the most relevant diagnosis for each study image. A comparison of the subject responses according to diagnostic accuracy suggests there are correlations between the diagnostic accuracy, the perception of similar features, and the selection of images with the same expected diagnosis. One hypothesis could be that endoscopists choose images with similar diagnosis rather than in accordance with the aspect of the image. The choice of similar images would then depend predominantly on the diagnostic conviction of the endoscopist.

A comparison of the endoscopist and student responses suggests that similarity between endoscopic images can be perceived even by subjects who have no experience in the field of medicine. That is, similarity between images can be perceived based on intrinsic properties of image content but without requirements of knowledge and/or experience. A practical consequence of this finding might be that the search method for an endoscopic atlas could be based on a selection of similar images by the user, rather than on the verbal description of the case under investigation. Moreover, this study confirms the necessity of multi-expert in the image indexing task and validates the chosen collaborative approach.

Future works

As the verbal description or the query by similarity is influenced by the diagnostic conviction of the endoscopist, it will be indispensable to extract some features directly from the digital content of the images. A previous study with a global approach of the image numerical content did not have good results. But, with regions of interest in the picture defined by the experts at the time of annotation, some finding features will have to be obtained and interpreted by local numerical approaches. It will then be matter of developing new algorithms for the similar case retrieval, combining image analysis and text retrieval approaches.

In the future, the endoscopic e-learning could prepare resident to practice on real cases and thwart the inherent threefold weaknesses of the endoscopy teaching: “the unhappy patient, the unhappy student and the unhappy instructor”.

Acknowledgments

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