A TOOL FOR ENDOSCOPIC CAPSULE DATASET PREPARATION FOR CLINICAL VIDEO EVENT DETECTOR ALGORITHMS

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Abstract: In all R&D projects there's at least one phase of model verification and accuracy, and when we are working with visual information (such as pictures and video) this phase should be emphasised. When working with medical information and clinical trials the truth of automatic results must be accurate. This work is based on the need of a huge and well annotated dataset of pictures retrieved from endoscopic capsule. This datasets should be used to learn the computer vision algorithms focused on endoscopic capsule video processing, and event detection.

1 INTRODUCTION

The endoscopic capsule (EC) (Ravens et al., 2002; Iddan et al, 2000) is a small device with a behavior similar to a photographic camera that flows through the human digestive system recording pictures after being swallowed by the patient. Considering that the exam lasts between 6 to 8 hours, and that the EC records/store frames with a 2 frames per second cadence, it results on approximately 57600 frames to be analysed, which could take up to 90 minutes (Qureshi et al., 2004).

With this amount of information, pattern recognition and machine learning algorithms are helpful to augment review time efficiency by automating or semi-automating this task. To achieve this level of automatic analysis we need many theoretical studies, which can benefit immensely from experimental software that has been specifically designed to support hypothesis testing and validation.

On the other hand these algorithms require a substantial number of test sets and correspondent training ones. Therefore to fulfil this gap the ECCA software was created (described bellow).

The principal motivation for its creation was the lack of annotated EC events at large scale in a way that could be used on computer vision algorithms. The several repositories (also called atlas) on the internet with endoscopic images and videos (GIA, ;AGE,) are for education purposes only. Its information is disease centric, containing patterns and symptoms for each one so it maintains all the clinicians all over the world up to date.

The ECCA repository has a different philosophy. Its paradigm is based on machine learning algorithms. Therefore it's not sufficient one or two photos from each disease neither it's important many of the clinical and symptomatic information.

In this paper we describe the "*Endoscopic Capsule Capview cAtaloguer*" (ECCA), a tool for creating subsets of annotated images for simplified collection and management of image datasets.

The tool here described is intended to be a complement of the *Capview* software platform (Cunha et al., 2006) that is already used by doctors to perform an agile diagnostic review of videos from the Endoscopic Capsule (EC). It integrates several functionalities, such as flexible report generation facilities or a MPEG-7 features extraction engine to support automatic detectors for bleeding events and topographic segmentation (Coimbra et al., 2006; Cunha et al., 2008; Coimbra et al., 2005). At the end of a review process with *Capview*, we will have a set of events marked by the clinician. These events

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(short videos around the image where a particular event was marked, such as a polyp) are the data units we use for the ECCA tool. We aim at using them for further annotation of independent clinicians to obtain a multi-reviewer consensus degree on the collected events.

The present tool is then intended to generate and manage the multi-expert annotation and dataset creation for further development of new detectors that will be integrated in the *Capview* platform.

2 ECCA TOOL

2.1 Objectives

With this software tool we'll retrieve several subsets of endoscopic images (gathered from real exams), divided by type of disease, size of polyps or tumours when applied, and their morphology. Those images will also have information about image quality, where high quality means low presence of food and/or fecal matter, and good light conditions.

Thus, its primary objective is to contain an on-line repository with enough information to test and verify each new algorithm that works with EC video and/or images.

On the course of the development process, another challenge came up: Use this software to teach fresh intern doctors analysing this kind of exams. We then need the ability to compare two different catalogues, and identify their differences so that performance of training doctors could be measured.

2.2 Architecture

ECCA has a database-centric architecture. This means that the main logic of it is to store information. In this particular case we want to store a catalogue of image annotations.

In this framework, a catalogue of EC images needs to store information on event category and Medical doctor (MD) responsible for that annotation (Figure 1).

The application needs a thin layer of security, where each medical doctor has its own username/password to distinct each catalogue from another. Thus one user cannot see or edit other user catalogue. Therefore the results of one doctor aren't biased by others.

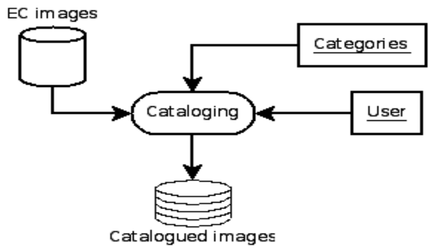

Figure 1: Simplified architecture.

2.2.1 Workflow

An MD enters its username and password, giving access to main window (Figure 2) where EC images will appear.

Figure 2: Main window.

He selects the desired image, by double-clicking on it, and then a popup window () appears with only the selected image and a panel with the categories available to that image. After the MD makes his choice of type of illness, its description, and quality, the save button must be clicked. When clicked, the information for that image is automatically stored in the database (xml file for simplicity), and the next image in line appears inside the popup window.

When all MD's finished their annotations, the database will have information about each image and correspondent illness and description.

With that database, we can create the subsets of annotated images about each disease based on the multi-expert classification obtained through ECCA tool and establish the "*gold standard*" set by choosing only the events where all experts agreed.

2.3 Applications

After describing how the software was designed it's necessary to show what can be done with it. The tool has 2 main applications "Dataset Manager" and "Pedagogical/Teaching".

Figure 3: ECCA popup window.

2.3.1 Dataset Manager

Like it was said before the purpose of this dataset manager is to create a considerable amount of annotated EC exams, containing images and small video clips, so following has validated and reliable data to work on.

The images contained in this database have mainly low resolution with 256x256 pixels, and the newer capsules with 512x512 pixels. Previous studies using computer aided tumor detection (Karkanis et al, 2003) use 1K*1K pixels which is 16 times better than the first and 4 times better than the last. Therefore the analysis and algorithms to detect events such as tumors or polyps using this kind of exams should be tested exhaustively against many samples.

The methodology in the creation of this database took advantage of the IEETA-CapDB (Campos, 2006) which contains considerable amount of endoscopic capsule exams and respective diagnosis retrieved from different clinicians that used the CapView software, and submitted those diagnosis to IEETA-CapDB repository on an anonymous and freely manner.

Focusing on diagnosis of polyps, tumors and normal cases 1900 randomly selected event images and corresponding videos were gathered on an uniform basis (evenly distributed by each test case).

The manager allows the creation of a gold standard set of events derived from the annotation of clinicians using the workflow described above. Then they are filtered by similarity, i.e only the annotations that are equal by all EC experts will be present on the gold standard. At the end a confident, distinct and valid dataset of annotated events is available.

2.3.2 Pedagogical

Using it as pedagogical/teaching tool has an important requirement. The gold standard (GS) database must already be present. This GS database or dataset is created using only the annotations from the clinicians belonging to the capsule experts group using for that matter the dataset manager, which contains all the exams and respective annotations.

With the gold standard reference dataset and the methodology bellow it’s possible to evaluate each person.

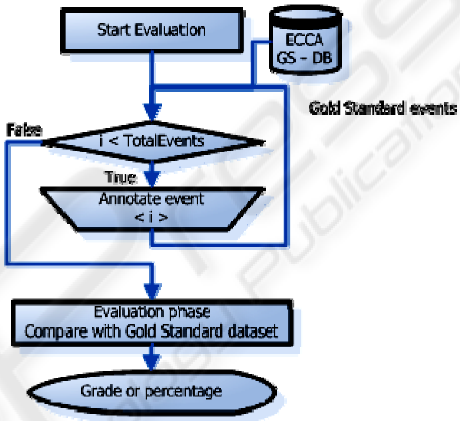

Figure 4: Evaluation workflow.

The schematic above illustrates the methodology to evaluate each one. It cycles through all exams inside GS dataset and the student/person to evaluate must annotate it. After all the exams were annotated the final step will evaluate his responses/annotations.

In the evaluation phase all the events are compared to the GS dataset and it will grade each response based on the following equation:

EVAL = 60% x Type + 40% x (# correct characteristics / # GS characteristics) (1)

The equation (1) gives more weight to the type of illness (either it's a polyp, tumor or normal case), and the remaining will be equally distributed by all the characteristics of that illness (*inside characteristics.xml file, see results section*).

The evaluation takes into account the following:

- type of illness: normal case, tumor or polyp
- characteristics of each illness:
  - *polyp*: size, morphology, color.
  - *tumor*: size, morphology, color
  - *normal*: not applied, it hasn't any characteristics.

There are also some extra categories that will not be considered because it's only for image quality screening such as food remains, image quality, and others. This "others" category means that image doesn't belong to any of the categories above. The "image quality" is evaluated using some qualitative expressions such "good", "bad" or "moderate".

At the end there is an overall rating resulting from the average of each grade of each event.

With the methodology illustrated in it's possible to quantify the capacity each group of clinicians has to diagnose using the endoscopic capsule method.

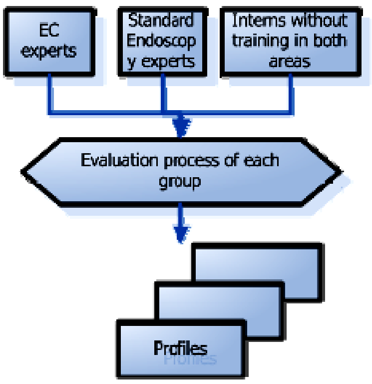

Figure 5: Group evaluation.

This methodology will show the capability of distinct group of clinicians to diagnose using EC method. Because those results are off scope of this article they would be presented in a future work. Then with more insight and reasonable amount of clinicians using this software, it would be possible to answer some of the questions above.

3 RESULTS

The present version of the event database has an overall of 1900 events. Our clinical partners at HGSA, Porto are using this software. Until the present date two experts in Endoscopic Capsule diagnosis and a couple of interns used it and had an overall of 3700 annotations. About 900 were annotated 3 times, and the remaining 1000 were annotated only once. Thus, the confidence on those first 900 events is very high. It is only a question of time to annotate all events.

The tool is able to produce a "results file" in the form of a ZIP file. That ZIP file will contain a directory with all the images, and one CSV file with the raw data. These CSV file has the following structure:

(imagepath), (type), (GoldStandard), (characteristic), (value), {(characteristic),(value)}

The first column contains the path of the image. Second the type of illness (tumour, polyp, or normal). Third the GoldStandard is a boolean field, telling if that image is part of the Gold standard dataset. The fields after has a list of characteristics and respective value for that image. This list can have many pairs (characteristic, value), ex: (Size, 5mm), (Colour, Red). All the possible characteristics and its values will be discriminated on the file `caracteristics.xml` also inside the ZIP file. Its structure follows:

<characteristics>
 ...
  <characteristic>
   <value1>
   <value2>
   ...
  </characteristic>
 ...
</characteristics>

4 DISCUSSION

The experts in EC diagnosis at HGSA are creating the gold standard dataset which will be used to test and train future computer vision algorithms. Their feedback tells us that it's easy to use and a handy tool, with the only setback being the time needed to annotate all the events which takes over 4 hours.

The ECCA software generates subsets of annotated events derived from those high confidence ones that will be used in the development of computer vision algorithms to be integrated in the Capview software, which is our main research goal. Therefore a well annotated and high confidence dataset of events is at the most importance. Thus it could be used as train/test sets for machine learning algorithms. The difference between Capview and ECCA tool is that the first is used for clinical and diagnosis annotation, while the ECCA aims a construction of a well defined dataset with necessary information for event detector algorithms.

Those algorithms need to minimize the classification error rate and improve its performance. One of the main aspects to take into attention is the training and test sets size and quality. It should be large enough and independent from one another (Jain et al., 2000). This can easily be generated using the ECCA tool.

The evidence of pedagogical relevance is not proved yet, because there were not subjects that tried this software, therefore there are not results to demonstrate this approach.

5 CONCLUSIONS

The ECCA software is not another endoscopic or endogastric atlas. The atlas is for humans as is this tool for computers. Those atlas are available on the internet or books which intends to instruct and provide up to date information about endogastric diseases, in a way that medical doctors can provide the best care possible, while the tool described in this paper aims a similar learning phase for computers and artificial intelligence algorithms.

The main objective is to create a large set of data capable of training and testing several machine learning and computer vision algorithms. In that way distinct algorithms could be tested with the same or similar test and training data. Therefore, the comparison between them could be performed more directly and with high accuracy.

Several on going studies taken place at SIAS-IEETA R&D department using computer vision applied to EC video benefit from the data gathered from this tool. The development and evaluation of these computer vision and detection algorithms, based on EC video processing, become a simpler process by using the data gathered by this tool.

Furthermore, it may be used as a teaching tool for EC specialist trainees. Due to lack of test subjects, students willing to expend some time trying this tool, there are not data that prove or not the pedagogical relevance of this software, in spite accreditation by the EC specialists.

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