Quality of Life through Quality of Information
J. Mantas et al. (Eds.)
IOS Press, 2012

doi:10.3233/978-1-61499-101-4-159

IRMA Code II: Unique Annotation of Medical Images for Access and Retrieval

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Abstract. Content-based image retrieval (CBIR) provides novel options to access large repositories of medical images, in particular for storing, querying and reporting. This requires a revisit of nomenclatures for image classification such as DICOM, SNOMED, and RadLex. For instance, DICOM defines only about 20 concept terms for body regions, which partly overlap. This is insufficient to access the visual image characteristics. In 2002, the Image Retrieval in Medical Applications (IRMA) project proposed a mono-hierarchic, multi-axial coding scheme called IRMA Code. It was used in the Cross Language Evaluation Forum (ImageCLEF) annotation tasks. Ten years of experience have discovered several weak points. In this paper, we propose eight axes of three levels in hierarchy for (A) anatomy, (B) biological system, (C) configuration, (D) direction, (E) equipment, (F) finding, (G) generation, and (H) human maneuver as well as additional flags for age class, body side, contrast agent, ethnicity, finding certainty, gender, quality, and scanned film, which are captured in form of another axis (I). Using a tag-based notation IRMA Code II supports multiple selection coding within one axis, which is required for the new main categories.

Keywords. Medical Imaging, Content-based Image Retrieval, Terminologies, Image Categorization, Radiology

Introduction

The IRMA project aims at providing a flexible framework for content-based image retrieval (CBIR) applications in medicine (http://irma-project.org). The first version of the IRMA Code was based on a strict mono-hierarchic multi-axial coding scheme, which included four axes with three to four positions (0-9 and a-z) on technique (imaging modality), direction (body orientation), anatomy (body region) and biosystem (biological system examined) [1]. IRMA Code I intended unique labeling of images and was used in the Cross Language Evaluation Forum (CLEF) image annotation tasks – a project providing the evaluation of different visual information retrieval systems

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	DICOM	IRMA	RadLex	SNOMED
Radiological reporting	x		x	x
Image classification	x	x		x
Image storage	x	x	x	
Semantic-based image retrieval	x	x	x	x
Content-based image retrieval		x	x	

Table 1. Medical terminologies [5,6,7,8]

[2,3]. The practical use of the terminology discovered several weak points: e.g., pathologies are not included, individual parameters such as gender or age are absent, inconsistent differentiation between right and left side of the body, the defined depth of the hierarchy is not sufficient in parts and ambiguities due to inconsistencies between is-part-of relations within deeper levels of the hierarchy.

In previous work [4], we particularly described the problem. In this paper, we focus on the resulting new approach: IRMA Code II.

1. Methods

A classification scheme supporting image retrieval should be unique, clearly arranged and extensible. The code should reflect the optical appearance of the image. In the past years, new terminologies for medical imaging have been developed and partly linked to existing schemes that suffered from insufficient coverage of radiological terms and concepts [5]. Table 1 briefly summarizes our evaluation:

- The Digital Imaging and Communication in Medicine (DICOM) standard defines roughly twenty concept terms for body regions, which partly overlap.
- The Systematized Nomenclature of Medicine (SNOMED) is designed to match meaning from unstructured text and, consequently, provides ambiguities for classification. For instance, the anatomical field provides identical terms on equal level (e.g., “abdominal structure” is a subclass of “abdomen and pelvis” and “chest and abdomen”). Furthermore, SNOMED lacks specific radiological terms [1,5].
- The Lexicon for Uniform Indexing and Retrieval of Radiology Information Resources (RadLex) was proposed by the Radiological Society of North America (RSNA). It provides the radiologist with a unified language to organize and retrieve images, imaging reports and medical records. Recently RadLex has been extended by terms and synonyms for imaging signs [6,7]. However, the hierarchical relations are partly ambiguous, e.g., within the class “anatomical entity” all the terms “hand” and “finger”, “arm” and “forearm” can be found at one level, which contradicts the part-of relation.
- With respect to IRMA Code I, we collected problems and monitored difficulties that appeared in the course of manually labeling medical images. These images were obtained from the Picture Archiving and Communication System (PACS) of RWTH University Hospital Aachen as well as the medical image search engine of the American Roentgen Ray Society (ARRS) GoldMiner® [8]. Mostly radiographic and in small numbers computed tomographic, sonographic and magnetic resonance images were classified (e.g., 12,000 images of 116 classes in ImageCLEF 2007) [2].

Based on ten years of experience as well as collected cases with shortcomings and ambiguities, we revisited the existing IRMA Code axes in order to normalize and

Code	Terms
000	unspecified
100	non medical foreign body
…	…
200	medical equipment
210	medical equipment; wire
211	medical equipment; wire; electrocardiogram lead
212	medical equipment; wire; infusion lead
…	…

Table 2. Example section of IRMA Code II "Equipment axis" and three levels of hierarchy

simplify the hierarchy tree. Main criterions were capturing visual differences in image content such as color, shape, and texture.

2. Results

With respect to uniqueness and ambiguities, it was necessary to add further axes and additional flags, simultaneously revising the remaining parts of IRMA Code I.

2.1. Axes

The resulting structure of IRMA Code II consists of eight axes, each of it with three positions for refinement and an eights code position holding the flags:

- A (anatomy) = body region, adopted from IRMA Code I [1]
- B (biological system) = general system of the body [1]
- C (configuration) = general positioning of the body (e.g., extremities) [new]
- D (direction) = body position with respect to the device [1]
- E (equipment) = specific objects or equipment (e.g., ECG electrodes) [new]
- F (finding) = type of visual observation (e.g., pathological process) [new]
- G (generation) = imaging technique and parameters of modality [1]
- H (human maneuver) = patient activity (e.g., inspiration, micturition) [new].

Patient positioning impacts the entire appearance of the image bitmap. For instance, the fingers of a hand may be closed or spread, and the patient may sit, stand, or lay down. In IRMA Code I, this is partly covered in the direction axis resulting in ambiguous codes. Therefore, we implemented a new axis for *configuration*.

Visual image appearance is often determined by artificial objects, such as plates from the accident surgery or body decoration like a ring not taken off from the finger. By means of the *equipment axis,* those artifacts can be differed from quality reduction caused by imaging technique. Table 2 gives some examples of the code hierarchy.

So far, pathologies and findings are barely modeled in IRMA Code II. Regarding computer-aided diagnosis (CAD) [10], it is necessary to have a particular axis for visual observations like calcification or infection signs (*findings axis*).

Developing the configuration axis pointed out that it would cause many circumstantial ramifications to combine position descriptions with specific patient maneuvers, such as specific breathing (e.g., inspiration, Valsalva test) or examination of the swallowing. Hence, we added one more axis for *human maneuver*s.

Figure 1: Example images labeled with IRMA Code II

A:463 B:700 C:100 D:120 E:2gb F:110 G111 H:xxx – s1332231
A: upper extremity, upper arm, unspecified
B: musculo-skeletal system, unspecified, unspecified
C: elevation, angle < 45-degree, unspecified
D: coronal, anteroposterior, unspecified
E: medical equipment, fixateur externe, unspecified
F: fracture, humerus shaft, unspecified
G: x-ray, plain radiography, overview
H: unspecified, unspecified, unspecified
I: Age class: 30 – 40years (s); Body side: right (1); Contrast agent: none (3); Ethnicity: Caucasian (3); Finding certainty: secure (3); Gender: male (2); Quality: good (3); Scanned film: true (1)

A:500 B:900 C:370 D:220 E:278 F:945 G:111 H:112 – v3332122
A: chest, unspecified, unspecified
B: respiratory system, unspecified, unspecified
C: trunk position, standing, unspecified
D: coronal, posterioanterior, unspecified
E: medical equipment, catheter, port catheter
F: opacity, infiltration, pneumonia
G: x-ray, plain radiography, high beam energy
H: active maneuver, breathing, inspiration
I: Age class: 60 – 70years (v); Body side: unspecified (0); Contrast agent: none (3); Ethnicity: Asian (3); Finding certainty: probably (2); Gender: female (1); Quality: good (2); Scanned film: false (2)

2.2. Flags

According to the RadLex class "patient identifiers" [6], we integrated flags for age, gender, and ethnical group, which is relevant for comparative studies. For instance, coding of age classes – not to be confused with the chronological age, determined by date of birth and date of examination – is important with respect to computer-assisted bone age assessment from plain radiography. As further extending flags of IRMA Code II, we implemented coding options for contrast agent and finding certainty. Therefore, the result of a biopsy of a mass can be distinguished from the pure suspicion arising from an observation. In summary, we suggest the following flags that may be notated as an additional axis of eight positions named with the letter "I" for each attribute:

– Age class (0: unspecified; 1: [0 − 0.5[years; 2: [0.5 − 1[years; etc.);
– Body side (0: unspecified; 1: right; 2: left; 3: various);
– Contrast agent (0: unspecified; 1: x-ray positive; 2: x-ray negative; 3: none);
– Ethnicity (0: unspecified; 1: African-American; 2: Asian; 3: Caucasian; etc.);
– Finding certainty (0: unspecified; 1: insecure; 2: probably; 3: secure);
– Gender (0: unspecified; 1: female; 2: male; 3: intersexual);
– Quality (0: unspecified; 1: poor; 2: acceptable; 3: good; 4: best) and
– Scanned film (0: unspecified; 1: true; 2: false).

In order to illustrate the new coding options there are presented two example images (Fig. 1). IRMA Code II allows the following annotations in form of A:xxx B:xxx C:xxx D:xxx E:xxx F:xxx G:xxx H:xxx – IIIIIIII. Depending on the task, not all of the axes may be necessary. If, for example, an image does not show any equipment, it could be coded "E:xxx" in the equipment string. If the radiologist recognizes a pathology without an idea what kind of, he could use the code "F:000" standing for "Finding - not further specified". Integration of the new axes caused the problem of variety (e.g., medical images often show more than one pathology). Hence, we decided to use a tag-based notation allowing multiple coding's in one axis. An computed tomographical image showing a circumscribed mass and a resulting stenosis of an

adjacent organ, for instance, would consequently be labeled "…F:351 F:361 G:211…". This way, IRMA Code II can be used as a modular framework.

3. Discussion

IRMA Code II provides more consistence with more coding options especially for abnormal image contents. In comparison to IRMA Code I the new basic structure enables the user to differ between poor image quality due to technical problems and artifacts caused by pathologies or non-physiological material. By means of the extended flag area many of the confusing ramifications (e.g., side information of an anatomical structure) could be removed. Thereby, this modification offers the possibility to label any image with particular attributes. In IRMA Code I, for instance, only the images labeled with the biosystem category "musculoskeletal system" could be annotated with an age class information. Besides, the possibility of further extensions is simplified. While in IRMA Code I particular characteristics had to be modeled in partly unsuitable axes, such as ethnic origin information placed in the direction axis, the new scheme provides easy additions.

Compared to other radiological relevant medical terminologies IRMA Code II offers advantages due to its clearly arranged basic structure and its uniqueness even at deeper hierarchical levels. Especially the strict conformity of the three level framework within the subdivisions contributes to this.

4. Future plans

Evaluation of IRMA Code II will result from its application in future ImageCLEF projects and other retrieval tasks. Besides, we plan mappings to other terminologies.

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