

Digital Pen in Mammography Patient Forms

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ABSTRACT

This paper presents a digital pen based interface for clinical radiology reports in the field of mammography. It is of utmost importance in future radiology practices that the radiology reports be uniform, comprehensive, and easily managed. This means that reports must be “readable” to humans and machines alike. In order to improve reporting practices in mammography, we allow the radiologist to write structured reports with a special pen on normal paper. A handwriting recognition and interpretation software takes care of the interpretation of the written report which is transferred into an ontological representation. In addition, a gesture recogniser allows radiologists to encircle predefined annotation suggestions which turns out to be the most beneficial feature. The resulting, automatically generated PDF report is then stored in a semantic backend system for further use and contains all transcribed annotations as well as all recognised sketches. We will focus on the new pen-based interface and new interaction possibilities with gestures in this multimodal scenario with unprecedented accuracy.

Categories and Subject Descriptors

H.5.2 [User Interfaces]: Input Devices and Strategies, Natural Language, Graphical HCl, Prototyping

Keywords

Design, Pen/Ink Interface, Medical Healthcare

General Terms

Reliability

1. INTRODUCTION

The current practice in hospitals is that a radiologist’s dictated or written patient report is transcribed by hospital staff and sent back to the radiologist for approval. The turnaround time is 2-30 hours and the process inefficient. In order to improve the general medical scenario, we implemented an prototype for radiology findings[8]. In our improved scenario presented in this paper, we use a pen-based interface and a new “interactive” paper writing modality. We extend the interactive paper for the patient reporting approach

with an even more specific approach for mammography (the examination of the human breast). The goal of mammography is the early detection of breast cancer and involves computer tomography (CT), magnetic resonance imaging (MRI), as well as a physical examination. Our goal is to provide one computer-based user interface that can be used for all three scenarios: the CT images are examined at a desktop station, the physical examination is done in a separate room, and the MRI is only assessed for ambiguous cases a few days later at the imaging centre. In all three examinations, a written report with specific manually written annotation is compulsory. In this situation, we are developing intelligent user interfaces that eliminate the proofing of transcriptions and generate more accurate and complete findings reports without interrupting the compulsory annotation process on a physical finding form. A digital pen based interface should enable radiologists to create high-quality mammography reports more efficiently. In addition, in the current mammography practice the results are often inaccurate because pre-specified standardised terminologies for anatomy, disease, or special image characteristics are seldom used. That’s why we base our development on a special mammography form where radiologists can encircle special characteristics and add free text commands which can only be filled in with medical terms of a prespecified medical vocabulary, as well as free form sketches.

In this demo, we present a new interaction method that shows how a radiologist can use our special mammography paper writing system to conduct a full mammography patient finding process. Thereby, he or she uses a digital pen-based interface. A special feature is the possibility to mark regions (circles, checkmarks, or arrows) of interest on the predefined sketches and refer to them in the pre-specified and free-form annotations. The results of the writing process on normal paper can then be inspected on the computer screen in this multimodal setting. The radiologist’s signature triggers the PDF generation process.

2. DIGITAL PEN TECHNOLOGY

We developed a digital pen interface which recognises and interprets the semantics of handwritten annotations on printed paper sheets. A variety of approaches have been investigated to enable these kinds of paper-driven digital services: cameras, graphics tablets (www.wacom.com), ultrasonic positioning, RFID antennas, bar code readers, or Anoto’s technology (www.anoto.com). The Anoto technology, which we use, is particularly interesting because it is based on regular paper and the recording is precise and reliable. In order to become interactive, documents are Anoto-enabled at print time by augmenting the paper with a special Anoto dot pattern. We use *iGesture* to recognise any pen-based gestures and to translate them into the corresponding digital operations. These gestures turn out

to be of utmost importance, because in the current practice, pre-specified finding terms on the physical paper are encircled by the radiologists. For the recognition of the contents of the form's text fields, either the MyScript Builder from Vision Objects [7] or the Microsoft handwriting recognition engine [6] can be used. Our framework interprets the paper-based user actions and activates the corresponding digital actions.

Many digital writing solutions that specialise in healthcare with Anoto technology (<http://anoto.com/healthcare-cases-3.aspx>) are available, but these systems are “one-way”, do not use a special terminology for the terms to be recognised, and/or do not allow any gestures. In our scenario, we developed a prototype with these extensions. The user (radiologist) is in the patient finding process, namely the extended mammography part. (The complete interactive system is based on a generic framework for implementing multimodal dialogue systems, see [10, 9]). More modalities, such as the new digital pen modality, allow for more natural communication, which normally employs multiple channels of expression. In particular, while using the interactive paper, we address the knowledge acquisition bottleneck problem for image contents in the context of medical findings/structured reporting. A *structured report* [2] is a report generation technique that permits the use of pre-determined data elements or formats for semantic-based indexing of image report elements (figure 1). (The Radiological Society of North America (RSNA) provides textual templates for us.) With the RSNA templates (and similar ones), we are able to pre-specify annotation vocabulary fields. This means “more natural communication” applies not only for a potential casual user of the digital pen technology, but to radiology experts who fill in physical document forms with pre-specified fields as part of a complex, educated patient management and medication process. The written documents with signatures are an important part of the patient management process which cannot be replaced by purely digital forms according to treatment responsibility laws (in the German public health sector.) These requirements are quite unique in the research literature. In other related work, [1] for example, the input modality of choice is a tablet PC. While a tablet PC supports handwritten strokes, writing on it does not feel the same as writing on normal paper; and the physical paper serves as a certificate.

The form filling process of CT image reporting elements (as shown in figure 1, bottom) has been extended by the mammography form which, essentially, differs from the CT image forms in the input fields by providing freeform sketch areas and the predefined annotation vocabulary fields (see figure 2). The “operational” interactive paper form for structured mammography reports spans over two full pages and is a bit more complicated as illustrated in this demo paper. However, the important new development concerns the interplay between the free-form sketches and the annotation vocabulary fields. This will be presented in detail in the next section.

3. SCENARIO IMPLEMENTATION

Figure 3 shows the mammography scenario. The digital pen annotation framework is available at the patient finding workstation and the examination room. The radiologists finish their mammography reports at the patient finding station where they can inspect the results of the digital pen process. With the radiologist's signature, a formal report is generated according to the mammography annotations. The sketches the expert has drawn are also included in the final digital report. Anoto's digital pen was originally designed to digitise handwritten text on normal paper and uses a patented dot pattern on a very fine grid that is printed with carbon ink on con-

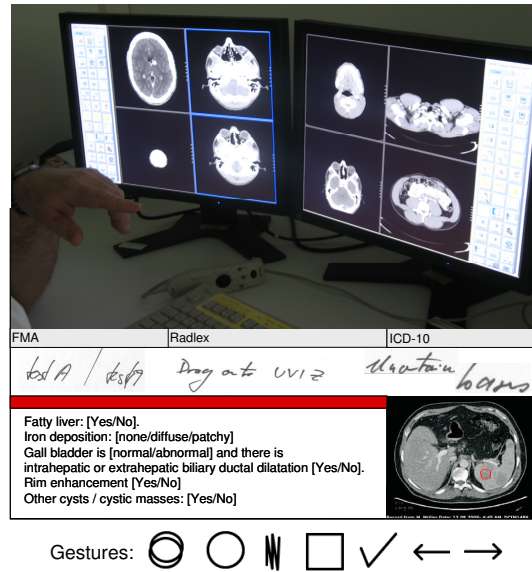


Figure 1: Radiology environment, interactive paper for structured CT image reports and active gesture set

ventional paper forms. We use the highest resolution dot pattern (to be printed with at least 600 dpi) to guarantee that the sketches in the freeform sketches can be digitised with the correct boundaries. To use the high resolution dot pattern, the Bluetooth receiver is installed at the finding station; this ensures an almost perfect wireless connection. Please note that we use the digital pen in the streaming mode to ensure that the radiologist can inspect the results on screen at any time; our special Anoto pen version accommodates a Bluetooth sender to transmit pen positions and stroke information in real-time to the nearby host computer at the finding station.

Freeform text area. In the medical finding process, presentations and standards play a major role. In complex medical database systems, a common ground of terms and structures is absolutely necessary. For annotations, we reuse existing reference ontologies and terminologies. For anatomical annotations, we use the Foundational Model of Anatomy (FMA) ontology [4]. To express features of the visual manifestation of a particular anatomical entity or disease of the current image, we use fragments of RadLex [3]. Diseases are formalised using the International Classification of Diseases (ICD-10). In any case, the system maps the handwriting recognition (HWR) output to one ontological instance (similar to [5]). Images can be segmented into *regions of interest* (ROI). Each of these regions can be annotated independently with anatomical concepts (e.g., “lymph node”), with information about the visual manifestation of the anatomical concept (e.g., “enlarged”), and with a disease category using ICD-10 classes (e.g., “Nodular lymphoma” or “Lymphoblastic”). However, any combination of anatomical, visual, and disease annotations is allowed and multiple annotations of the same region are possible.

Multiple Sketch Annotations. The structured form eases the task of finding appropriate annotations (from FMA, ICD-10, or

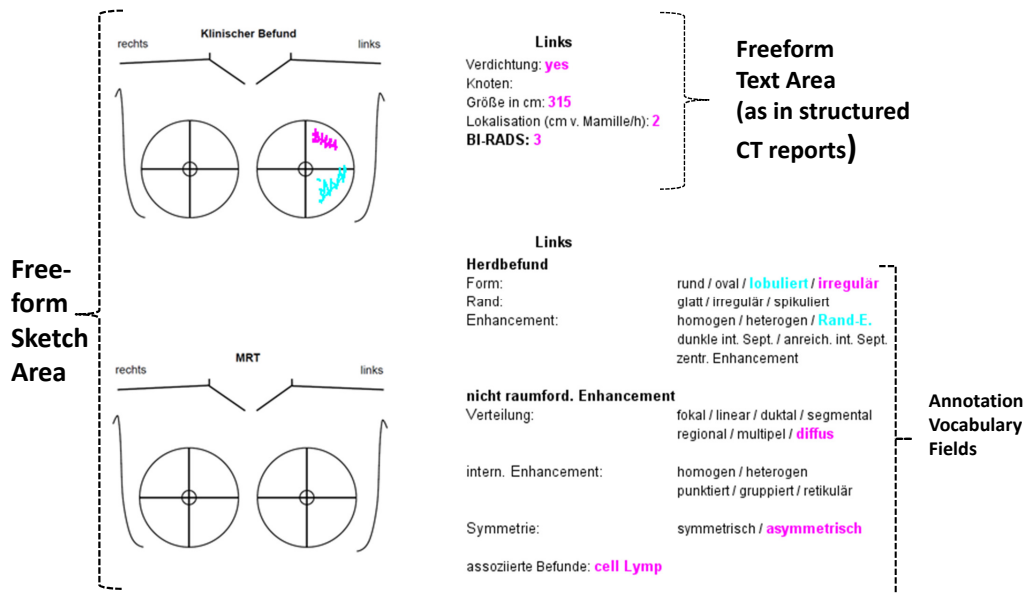


Figure 2: Interactive paper for structured mammography reports

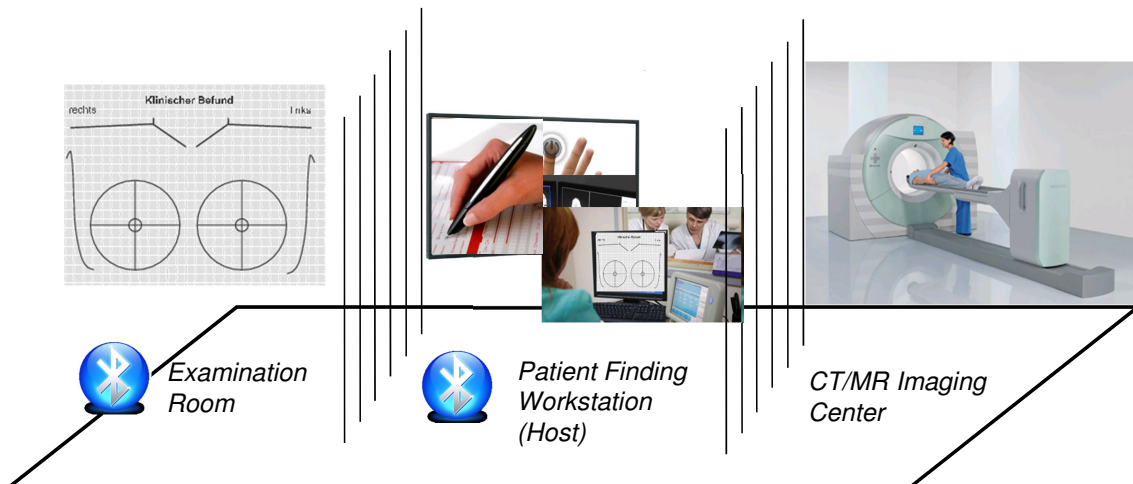


Figure 3: Complete mammography scenario

Anmeldungszeit:	<input type="checkbox"/> LKK	<input type="checkbox"/> BKK	<input type="checkbox"/> IKK	<input type="checkbox"/> VdAK	<input type="checkbox"/> Selbst-zahler
privat					

Datum: _____

Mammographie

Rechts links

Dichtetyp:
 I. lipomatös
 II. fibroglandulär
 III. inhomogen dicht
 IV. extrem dicht

Herdbefund
 Form: rund / oval / lobulär / irregu
 Begrenzung: glatt / mikrolobuliert / überl
 Strahlendichte: hyper- / iso- / hypodens- / f
 Größe in cm: 7,8

Verkalkung
 gutartig: Haut- / Gefäß- / Popcornka
astartig / rund / Eierschal-
 dystrophisch
 mittelgrad. suspekt: amorph / **granulär**
 hochsuspekt: fein pleomorph / fein
 Verteilungsmuster: diffus / **segmental** /
 Architekturstörung:
 Spezialfälle:
 Lokalisation (cm v. Mamille / h): 2, 14
 BiRad:

1:
 2: **Second annotation**
 3: **Third annotation**
 4: **t-o who -**

Figure 4: Multiple annotations with automatic numbering

RadLex); some yes/no or multiple choice questions complete the finding process. As can be seen in figure 2, multiple colours can be selected for multiple tissue manifestations. A specific feature is the automatic numbering mode. A new manifestation (i.e., a new sketch) is recognised automatically after a delay time of 500ms without any stroke and numbered automatically. As preliminary user tests show, this feature can be learned easily, and the automatic numbering defers the user to a dedicate freetext entry field. When this process is properly applied, the resulting annotations (figure 4) are much less ambiguous and less prone to error as the annotations gained from a pure physical form filling process.

Annotation selection and correction. The user is able to use multiple gestures, e.g., underline or scratch-out a concept in the grey boxes. Then he has the possibility to select a more specific term (displayed on the computer screen) or refine/correct a potential recognition error. This makes the paper interaction really interactive and multimodal. We also use the iGesture framework to select the colours on a (virtual) colour palette printed on the physical forms (in colour); the user can circle a new paint-pot to get this colour's ink (figure 4, bottom).

4. CONCLUSION AND DISCUSSION

We presented a digital pen based interface mammography forms. The radiologist can (1) provide the image and image region annotations mapped to a FMA, RadLex, or ICD10 code, (2) provide free text entries, and (3) correct/select annotations while using multiple gestures on the forms and sketch regions. Finally, after controlling the results on screen, a signature triggers a PDF report generation process. This improves the quality and consistency of mammography reports. Most importantly, complete reports are available in seconds; the demo shows that the time required to release a report is within seconds instead of several hours. The common annotation and querying framework for pen-based structured reporting

will now be tested at the University Hospital in Erlangen as a part of a clinical study. Educators may find these interactive papers for mammography can help trainees learn the important elements of reports and encourage the proper use of special radiology terms.

Our system does not target to recognise the meaning of the hand-written strokes in the sketch areas. [1] try to recognise sketches, but the system does not support unconstrained sketches and hand-written text. Although they're very fancy, interestingly, this and similar sketch recognition features, is not needed in the mammography scenario; rather, the uninterpreted sketch serves as supportive material.

Reviewer information: the supportive material consists of the fully operational mammography forms. In the demo, the two pages can be filled out; results are shown in real-time.

5. ACKNOWLEDGEMENTS

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