A web-based melanoma image diagnosis support system using topic map and AJAX technologies

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Abstract
The design and implementation of a web-based diagnostic support tool for melanoma dermatological images and related diagnostic data is presented. The proposed system is semantic web-based and is driven by exploiting the combination of AJAX framework and topic map technology. A novel client/server architecture was developed that enables several clients to interact online with the topic map-based system. Users have the ability to access the system anywhere and anytime via a simple Internet browser. Additionally, an ABCD application has been developed for automated calculation of ABCD parameters and consequently embedded in the proposed TM-based system.

Keywords: Topic maps, AJAX, semantic web, melanoma, dermoscopy, ABCD rule

1. Introduction
Melanoma is one of the most aggressive types of skin cancer [1–3]. Early diagnosis is the most reliable solution for an effective treatment of melanoma [4–6]. There is a continuous research worldwide to support dermatologists with effective diagnostic tools and methods. Dermoscopy (dermatoscopy, epiluminescence microscopy) has been established as a non-invasive method for improving diagnosis of melanoma [7–11]. The dermoscopic diagnosis of melanoma is based on various analytic approaches and algorithms that have been set forth in the last few years [12–14]. The ABCD rule (A (asymmetry), B (border), C (color), D (diameter or differential structures)) is a standard used in dermatoscopy analysis for classification of dermatological images to benign, suspicious or melanoma [13,15].

There has been a great deal of scientific research that aims at providing reliable diagnostic support to dermatologists through computerized means, towards early diagnosis of...
melanoma. Computerized methods increase diagnostic accuracy for dermatologists and enable storing of images with diagnostic information for further investigation or creation of new diagnosis methods [16–23]. Furthermore, the increasing amount of digital dermoscopic images produced in medical institutions helps to develop new advanced image retrieval systems for more efficient information storage and management, and also for diagnostic and teaching support [24,25].

One of the major requirements of such a system is the ability to assure interoperability and reusability of images and related diagnostic data. Research is turning towards producing not stand-alone, but web-based applications that make information more accessible and interoperable by all the users involved. The recent network technology of mobile and satellite communications has significantly improved the accessibility of information resources. Additionally, such a system should be capable of demonstrating some form of knowledge-based reasoning and decision support [26–29]. Semantic web technologies, such as ontologies and topic maps, seem to have a great deal of potential to provide explicit representation of the semantics of data in order to achieve interoperability and reusability of data as well as advanced reasoning support in such a system [30–32].

Taking into consideration the above, the main target of this work is to provide an integrated semantic web-based system that manages and retrieves information from digital melanoma images and associative data. The objective of this paper is to present in detail the design and implementation of the proposed system, which is structured by exploiting the combination of AJAX framework and topic map technology. The ultimate goal of our work is to investigate the potential benefits of encoding medical information using topic map technology, in order to create an effective diagnostic support tool for melanoma cases.

2. Using topic map technology

As mentioned before, there has been a steady increase in malignant melanoma incidents worldwide. In order to support early diagnosis, new tools and methods are needed that manipulate the increasing amount of visual information produced in that field. The scope of this work is to exploit the potential advantages and difficulties of using the topic map standard for managing melanoma case images and their related data, in order to create a web-based medical application that provides diagnosis support utilities to dermatologists.

Topic map (TM) is an ontology technology, designed for information and knowledge organization [33–35]. By providing a standard interchange syntax specification [36], TM intends to support exchange, reusability and interoperability of knowledge among different applications. TMs are constructed around topics that represent subjects. Associations are used to describe n-ary relationships between topics and they are generally categorized according to association types. Topics that participate in an association, play roles referred to as ‘association roles’. A topic occurrence specifies information, which is related to a given subject. If the subject is a resource that can be addressed, the resource address can be used as a subject locator [33–39].

TMs have been designed to be able to manage and present any kind of subjects and any relationship between the subjects in any kind of ontological context [40,41]. A TM can build a domain knowledge model above related resources data, thus achieving the clear separation between knowledge and information layers. In this way, the TM enables advanced navigation and information retrieval in complex datasets [37–39]. Although a relational database is a reliable solution, it has to be rewritten in order to support a new class of entity and queries. By using TMs, the user needs only to alter properties and relationships, without having to rewrite program code or queries [37].
Finally, a functional knowledge repository should allow effective search and retrieval of information. Ontopia has developed Tolog 1.0 for querying TMs [42]. Tolog is a Prolog-like language based on first-order predicate logic. Complex queries can be expressed by applying Boolean variables and built-in predicates supporting in this way querying on both data and ontology [43]. Furthermore, the users can define inference rules in a separate file that gets included on the execution of a query. Then, inference rules can be used to simplify queries and to provide a way to capture implicit relationships through the declaration of simple rules [42–44].

3. Incorporating AJAX framework

A TM-based information management and retrieval system suitable for possible melanoma images has been developed during our research [45]. The programming language used is Java and in particular the Netbeans IDE platform [46]. The initial evaluation of the system shows promising results. Nevertheless, some problems have been identified during the evaluation and they are reported below.

The communication between client and server is quite slow. The uploading of images is rather time-consuming. In order to interact with the system and grant access to the server, the users have to install Ontomel application into their PCs. This procedure seems to be rather fuzzy for users, especially if they are not familiar with computers. A viable solution could be access to the system by using a common Internet browser like Internet Explorer. Netbeans environment provides many tools to programmers for creating Windows-based applications. Nevertheless, in practice the application produced was rather complicated. Thus, an attempt was made to simplify the programming process in order to create easy-to-use client interfaces.

The above problems can be solved and further improvement may be achieved by employing AJAX technology. The proposed system is web-based and is structured by exploiting the combination of AJAX framework and TM technology. A novel client/server architecture was developed that enables several clients (e.g. dermatologists) to interact online with the TM-based system. This framework allows the end users to view and modify huge amounts of medical information as well as to share the data. Web applications have many benefits over desktop applications; a larger audience can be reached, they have easier installation and support and also easier development. However, Internet applications are not always as appealing and user-friendly as traditional desktop applications. With AJAX, Internet applications can be made more attractive and user-friendly. AJAX stands for Asynchronous JavaScript and XML and is a web development technique for creating interactive web applications. AJAX is a promising solution for closing the gap between web applications and desktop applications regarding usability and responsiveness [47–50]. The AJAX web application model enhances the interaction of the user with the user interface by introducing an intermediary (AJAX engine) between the user and the server. In brief, instead of loading a web page at the start of each session, the browser loads an AJAX engine that is responsible for both rendering the user interface and communicating asynchronously with the backend servers [49].

4. Architecture of the proposed web-based topic map system

This section presents the framework developed for the generation of the web-based diagnostic support tool. The core of the proposed system is the Enterprise Topic Map Server (ETMS), which has been implemented using several Java servlets (user maintenance, ontology, information storage and retrieval, etc.). ETMS administrates the Ontomel TM and
coordinates communication issues with client application and MySQL database [45,51]. Communication issues and exchange of TM are established using the proposed AJAX framework via simple HTTP protocol requests, as illustrated in Figure 1.

Administration of TMs is made by ETMS using TM4J library. TM4J provides an Application Programming Interface (API) to allow programmers to create and modify TM structures [52]. The TM4J engine provides interfaces for querying TM structures using the Tolog query language and parsing TMs from XTM syntax files or writing TMs to XTM syntax files [42,52]. Finally, TM4J library manages TMs that are persistently stored in the relational database MySQL using the Hibernate O-R mapping [52].

4.1. Description of the overall system

The Ontomel framework is provided to the end-users who just want to access the system using a simple web interface but they do not have an implicit knowledge of TM technology. Specifically, simple form-based graphical user interfaces (GUIs) have been implemented.
using the Google web toolkit (based on AJAX framework) (Figure 2) [53]. Additionally, a software tool, called Yellow-TM Editor, is addressed to administrators of the system by the server. Yellow-TM tool was implemented during this research, aiming to provide an advanced tool for TM authoring [54]. The system administrator manages information using Yellow-TM and thus communicates with the TM-based server. Yellow-TM Editor enables authoring and visualization of TM, as well as definition of TM Schema and expression of rules and queries in Tolog [42,54].

4.2. Creating TM-based ontology

The present subsection describes in detail the creation of a functional TM-based knowledge base that contains digital dermoscopic images of possible melanoma cases, as well as data related to images, doctor reports, diagnostic findings and patient information (Figures 1 and 2).

The first step is to identify the basic components that have to be included in order to create a knowledge infrastructure of digital images and clinical data. Figure 3 depicts the basic structure of the proposed database. Each doctor will be associated to a patient. Then the patient is associated to a ‘concept’ melanoma and each melanoma is associated to a digital image. This is the main backbone of the database. Appropriate attributes must be defined for all components, so that the components can be annotated efficiently and describe the knowledge that they inherit. The properties of images are described by a set of variables required for the calculation of the TDS (Total Dermatoscopy Score) index [15], which is an efficient tool widely used in melanoma diagnosis. The calculation of TDS is based on four features, which are the ‘Asymmetry’, the ‘Border’, the ‘Colors’ and the ‘Diameter’. The value of each feature is multiplied by a given weight factor to yield the value of TDS according to the following formula:

$$ TDS = 1.3 \cdot A + 0.1 \cdot B + 0.5 \cdot C + 0.5 \cdot D $$

(1)

TDS contributes to the differentiation between benign and malignant lesions. Values of TDS less than 4.75 correspond to a benign skin lesion, values of TDS between 4.75 and 5.45

![Figure 2. Representation of TM-based system using a web user interface and AJAX framework to communicate with the TM-based server.](image-url)
correspond to a suspicious skin lesion, and finally values greater than 5.45 indicate that the skin lesion is a melanoma with a high degree of certainty. The attributes attached to every image are the date, the actual resource path of the photo, the ABCD values, the value of TDS, a possible diagnosis, and the results from the laboratory exams. Accordingly, for every patient, properties like name, age and gender can be defined.

A great advantage of TMs is the clear separation between the description of the information structure (ontology and knowledge layer) and the physical information resources (information layer) (Figure 4). In a TM, the ontology layer contains topic types, association types, role types and occurrence types while the knowledge base layer contains instances of the types defined in the ontology layer [18]. In Figure 4, the ontology layer outlines the types that must be established in order to encode the basic structure of the database presented in Figure 3 using the TM standard.

The Yellow-TM editor has been used to construct the knowledge repository based on the TM model that contains melanoma images and related data. The Yellow-TM editor is a form-based editing environment for the administration of the system [54,55]. The Yellow-TM tool displays visually the TM concepts providing a dynamic graphic representation (knowledge layer in Figure 4). Topics and associations of the TM are represented as nodes,
while roles are represented as arcs that connect topics and associations. By right clicking on the desired topic an editable ‘Properties’ panel appears showing all the corresponding properties. In detail, for a topic of topic type ‘image’ the actual resource address can be used as a subject while the date, the ABCD values and the TDS value are defined as occurrences. It must be noticed, that this is a preliminary database and only a basic design is attempted. However, the database can be easily expanded and enhanced with many more components and properties. TMs enable scalability and expandability of the implemented database, while

<table>
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<th>TOPIC TYPES</th>
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<td>patient</td>
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<td>melanoma</td>
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there is no need to alter the basic schema of the database. Thus, the program enables the user to add a new type of information, while a ‘topic type’ that corresponds to this information is created and employed in the TM. In this way, the system can be suitably modified depending on the user needs. Additionally, the Yellow-TM tool supports the input of queries and rules based on Tolog language [54]. Suitable rules and queries have been established using Tolog language [42] in order to enable the user to retrieve knowledge contained within the implemented TM and the associated dermoscopic images.

5. ABCD application

The main demand that seems to be indispensable for a diagnostic support tool of melanoma is the automatic detection of ABCD values. Therefore, an ‘ABCD’ program for automated calculation of ABCD values has been designed and incorporated into the TM-based system. The ABCD application is executed by the ETMS (Figure 5). When a user uploads an image to the system, the ABCD parameters are automatically estimated and attached to the specific dermatological image.

According to similar programs [23,25], the ABCD program (Figure 5) must perform the following steps:

- segmentation of image in order to separate the tumor area from the surrounding healthy skin,
- feature extraction for calculation of ABCD values and TDS,
- return of the estimated diagnostic values to the user.

The following subsections outline the image segmentation and feature extraction issues.

![Ontomel Web Application](image)

**Figure 5.** Schematic description of ABCD application in the TM-based system.
5.1. Image segmentation issues

According to the design analysis, the first step towards the implementation of an ABCD program is the definition of tumor area covered by melanoma and its extraction from the healthy skin. A new and fast algorithm has been developed in our laboratory (submitted for publication). This algorithm defines the lesion boundary in order to distinguish accurately the area of the melanoma from the rest of the skin in reasonable computing time.

5.2. Feature calculation

Assuming that the area of possible melanoma is estimated, several meaningful features can be extracted [21]. The ABCD calculation program is based on the ABCD dermoscopic classification rule. The features to be extracted from the images are the A, B, C and D values that correspond to the ABCD mnemonic rule [15].

In the proposed approach we chose four descriptors to represent the clinical features included in the ABCD rule, as follows: (1) derivation factor for Asymmetry; (2) perimeter factor for Border; (3) color presence for Color; and (4) the greatest diameter (in mm) of the lesion for Diameter.

5.2.1. A: Derivation factor. The derivation factor is estimated by the expression:

\[
s^2 = \frac{\left( \sum_{i=0}^{n} \sqrt{(x_i - m_x)^2 + (y_i - m_y)^2} - r \right)^2}{(n - 1)r}
\]

where \( n \) is the number of points of the lesion border, \( r \) is the radius of the circle that has the same area as that of the lesion, \((m_x, m_y)\) is the center of gravity of the border and the circle and \((x_i, y_i)\) is the \( i \)th point of the border. If the derivation factor is close to zero, the melanoma is almost perfectly circular.

5.2.2. B: Perimeter factor. Regarding border irregularities, the perimeter factor is calculated by:

\[
P_f = \frac{n}{2\pi r}
\]

where \( n \) is the number of points of the perimeter. When the \( P_f \) is close to 1, the perimeter is ‘smooth’.

5.2.3. C: Color presence. The presence of six main colors (white, red, light brown, dark brown, blue-gray, black), is considered. The presence of these six basic colors inside the lesion gives one point to each color for the calculation of the C score (0 – 6 points) [13,15]. A 6 x 6 item table is defined. Each row of the table contains the RGB lower and upper limit values that correspond to each one of the six colors. The C score is increased by one point if there is at least one pixel inside the test region whose RGB values are between the RGB limit values of any of the six colors.

5.2.4. D: Greatest diameter. The greatest diameter of the region is simply estimated in pixel coordinates by calculating the largest distance between the contour points of the region.
The ABCD application is implemented in C language and has been incorporated in the TM-based system. The program calculates the TDS according to the ABCD estimated values. Consequently, ETMS encodes these values and input data related to the image as TM structures and saves them in the system database.

6. Describing the Ontomel application

Registered users log into the system using an Internet browser anywhere and anytime, and subsequently interact with it (Figure 2). The user may upload a dermatological image, related data, patient data and clinical data in a simple way (Figure 6). By using the AJAX engine, several calls (asynchronous) can be established with the ETMS that resides in a Tomcat server. The ETMS encodes all input data according to the corresponding TM structure and saves them in the TM-based database.

When a user uploads a new dermoscopic image from his computer to the ETMS, the ABDC application automatically estimates the ABCD values. After the segmentation process and the ABCD calculation, the ABCD values are presented on the right of the image in a simple numerical output. In the background, ETMS encodes the estimated ABCD values, the uploaded image and all related input data as TM structures, which are saved in the MySQL database.

Moreover, enhanced navigational and retrieval functionalities are provided by easy-to-use GUIs. The user can locate a patient from a predefined list and see associated melanoma

![Figure 6. The user uploads a new image and the system returns ABCD values.](image-url)
images and clinical information (Figure 6). Additionally, the end-user can use the predefined rules and queries established in the system, for a more sophisticated access and retrieval of information, e.g. to find melanoma images with similar ABCD features. However, from the end-user perspective, the client application has to minimize the required user input. Also, the user probably will not have knowledge of TM or Tolog syntax. This problem is solved by providing an effective and easy-to-use GUI that runs the predefined rules and queries (Figure 7).

The URL of the implemented system is http://195.251.241.43:8080/WebOntomel/webontomel.Main/index.html. Researchers that are interested are encouraged to visit it and explore all its available features. Potential user opinions and evaluations will provide valuable feedback on how the overall system should be refined and integrated.

7. Conclusions

The design and implementation of a web-based diagnostic support tool for melanoma dermatological images and related diagnostic data was presented. The user can access the system via a simple Internet browser, thus exploiting the benefits provided by the modern network technology of mobile and satellite communications. The proposed system incorporates AJAX framework and TM technology. TM technology seems to offer the necessary framework for knowledge management to support share ability and reusability of information as well as advanced reasoning support. Also, AJAX technology offers the possibility of creating web applications that resemble desktop applications in terms of usability and responsiveness. Additionally, a calculation program for automatic estimation of the ABCD parameters of uploaded images has been implemented and incorporated into the proposed web-based system.
The main scope of this work is to explore the potential benefits of encoding information using TM technology and consequently to provide an efficient and integrated tool as diagnostic aid to dermatologists treating melanoma cases. Currently, the feasibility and efficiency of the proposed system is under evaluation and guidelines for future work are outlined.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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