MARK1 - A Decision Support System for the Early Detection of Malignant Melanoma

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Abstract—**Early stage detection of melanoma (one of the most common cancers today) is of major significance for increasing chances of long term survival of affected patients. Over the last decade there have been developments in skin diagnostics, facilitated by the use of technologies such as Total Body Photography (TBP), which provide a complete record of the skin, and by the development of applications on handheld devices seeking to characterize skin lesions as part of routine self-examination. Unfortunately, these processes are rather inefficient, inaccurate, and not fully automated, missing also critical components such as the automated ability to compare between two TBP image sets in order to locate essential new and altered skin lesions. Despite some progress and because of its many flaws, the common practice today for early detection is skin self-examination. However, it is important to note that skin self-examination is usually underestimated by individuals, resulting in poor prognosis. The main objective of the present paper is to present the conceptual architecture of a platform that can address the need for early and accurate detection of skin lesion through a screening solution that will be easily accessible to the general public with the guidance, supervision and inspection of the primary care physician.**

Keywords; Computer aided diagnosis, Decision Support, Melanoma, Total Body Photography, Skin cancer.

I. INTRODUCTION

Melanoma is a major cause of morbidity and mortality globally. According to the World Health Organization, approximately 2,500,000 skin cancers, among which 132,000 comprise melanoma skin cancers, are diagnosed each year worldwide. Skin cancers and melanoma represent 30% of total cancer incidences. The worldwide incidence and mortality rates are continuously increasing mainly due to the changes in life styles and the significant increase in ultraviolet radiation [1]. However, most of the skin cancers, including melanoma, are understudied. For several years, resources have been devoted mainly to the characterization, prevention, diagnosis, and therapy of common melanoma types. Nevertheless, recent scientific evidence has revealed that even common melanomas present different subtypes with distinct characteristics, compelling researchers to make progress in melanoma cancer detection in order to improve health care services to affected individuals [2].

The existing variety of different melanoma subtypes complicates the diagnostic inference of the visual observation of expert physicians, promoting false positive conclusions, which lead to unnecessary scarring operations and treatments that increase patient suffering and the overall cost of the disease management [3]. Diagnostic errors originate mainly from the lack of experience of experts; the biological complexity of melanomas hinders the establishment of concrete criteria able to predict the behaviour of tumours, and thus, to administrate proper treatments. The latter might explain the facts that although promising treatments have been proposed, death rates have not yet been reduced, while the cost of melanoma skin cancer management still remains one of the highest healthcare economic burdens worldwide [4]. If a good treatment is wrongly administrated to an incompatible patient due to wrong diagnostic assessment, then, the treatment is more likely to fail with significant increase of patient suffering and prohibitive management costs. There is a pressing need to develop methods for improving diagnostic accuracy in order to reduce diagnostic errors and, thus, guide successful choice of therapies. Accurate diagnosis linked to proper therapeutic strategies would eventually benefit patients with Melanoma skin cancers improving survival and quality of life, while at the same time, keeping healthcare costs at an acceptable level.

Therefore, early stage detection of melanoma is of major significance for increasing chances of long term survival of affected patients. The most effective method for early detection is skin self-examination. The individual investigates skin changes, especially in moles (existing or new) and reports to the doctor when suspicious regions require consultation from the medical experts. However, it has been shown that skin self-examination is usually underestimated by individuals, resulting

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in poor prognosis. Melanoma detected in later stages, is extremely aggressive and deadly, resulting in patient suffering and increased mortality/morbidity. This has driven researchers to seek solutions in automated, early diagnosis of skin lesions [5-10] and to render such procedures accessible to the general public. Recently, this need was addressed by applications on handheld devices [11-13], which however are in a preliminary stage of being employed to safely characterize skin lesions as part of routine self-examination.

Computer aided diagnosis has the potential to constitute an efficient second opinion tool that improves both sensitivity and specificity in the characterization of melanoma skin lesions [14]. Recent developments have introduced automated systems aiming at discriminating melanomas from other lesions including lesion boundary analysis [15], using features derived from the shape of the lesion boundary and using image surface features to model the surface in homogeneity of skin tumours [16], which is an important hint in early diagnosis of malignant melanomas. With the advent of hand held mobile devices a number of applications have recently been developed for image pre-processing, image feature extraction, and classification of melanomas [17-19]. However, the automation supported by the current applications imposes legal implications which prohibit their commercial utilization.

Towards this end, the main objective of the present paper is to present the conceptual architecture of MARK1, a framework designed to address the need for early and accurate detection of skin lesion through a screening solution that will be easily accessible to the general public with the guidance, supervision and inspection of the primary care physician.

II. METHODOLOGY

The vision of MARK1 is to address the need for early and accurate detection of malignant melanoma, through the intelligent and automatic scanning of the entire human body, facilitating the automatic focus on areas suspicious for skin cancer, while coupling the automation process with human experts supervision and guidance, as well as to enable the follow up and monitoring for further analysis or treatment whenever and wherever necessary, through a screening solution that will be easily accessible to the general public and location-independent. The proposed solution shall provide painless, effortless and efficient self-screening of skin lesions, for early, accurate detection of melanoma, independent of the patient's location, safeguard sensitive patient data and maintain patient-doctor confidentiality, as well as ensure accurate diagnosis delivered by the specialist (physician), independent of the physician's and patient's physical locations.

MARK1 goes beyond providing a pattern recognition system, and incorporates a self-screening application with a lightweight DSS which supports medical experts in reaching a diagnosis. MARK1 integrates clinical diagnosis rules based on Total Body Photography, a Decision Support and a content based image retrieval system to assist expert diagnosis, and the ubiquitous information access of the handheld modern devices. While today's technology provides an image alignment capability that enables the dermatologist to perform a manual comparison of changes, MARK1 utilize the physicians' feedback through a learning mechanism. Then, together with a prioritization algorithm, MARK1 presents the skin's changes in a way that saves the physicians' valuable time while also providing objective smart results such as priority based list of skin differences.

The MARK1 platform architecture follows a layered approach, which is graphically illustrated in Fig. 1.

A. *Secure Skin Cancer Image Database Connectors*

The bottom layer of the architecture implements secure connectors to existing databases of melanoma (skin cancer) images of patients, respecting their anonymity, which are either hosted in clinical premises, or are available online, free of charge for research purposes (e.g. http://www.dermnet.org.nz/sitemap.html).

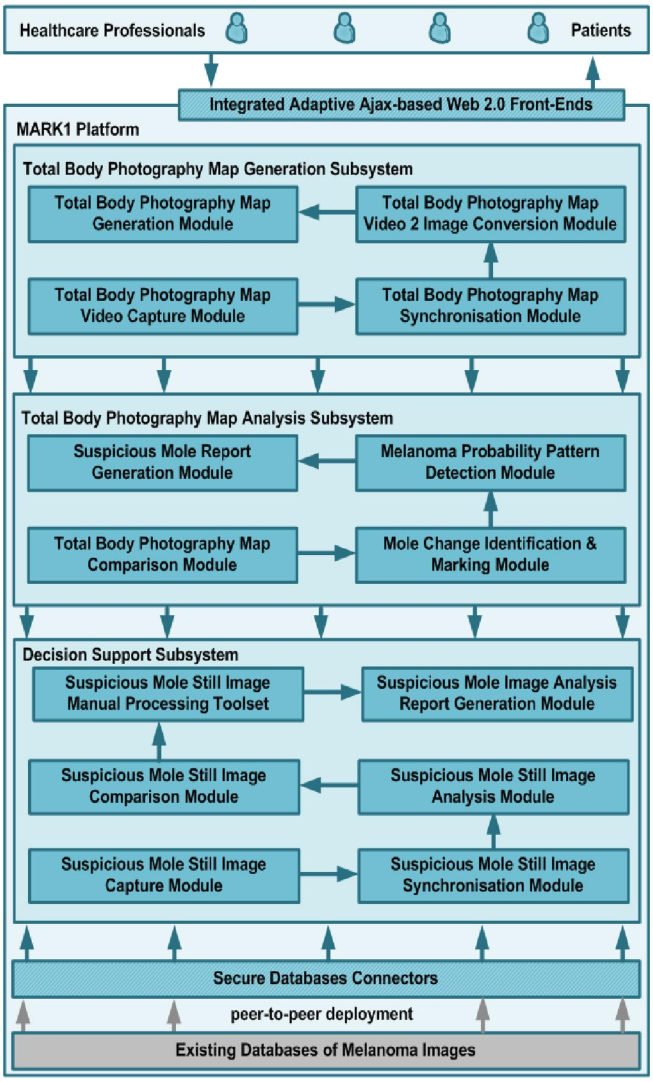

Figure 1. MARK1 conceptual architecture

B. *Total Body Photography Map (TBPM) Generation Layer*

The Total Body Photography Map (TBPM) Generation Layer implements an image map of the full body of a patient, which is utilized for the identification of alteration of existing moles or for the identification of new moles that have been developed. This layer incorporates four main modules: 1) The Total Body Photography Map Video Capture Module, which is responsible for producing a high resolution full body imaging, utilising the integrated camera of the user's smart phone, 2) the Total Body Photography Map Synchronisation Module, which is responsible for the synchronisation of the produced video file with the DermaCompare (a skin cancer diagnosis cloud based software which is provided to medical professionals and their patients as a service) SaaS based secure servers and its linkage with the patient medical record file, 3) the Total Body Photography Map Video-to-Image Conversion Module, which is responsible for the decomposition of the acquired video file to high resolution Total Body still images, and 4) the Total Body Photography Map Generation Module, which is responsible for the composition of the total body photography 2\3D map from the high resolution still images, which will be provided as input to the Total Body Photography Map Analysis Layer. With regards to the Total Body Photography, this can be obtained i) either at the clinic, where the physician / nurse uses an SLR camera to acquire the TBP following specific instructions, or ii) at home, where a "(in)formal carer" uses a smartphone to take a video streaming of the "patient's" body, following the online guidelines that will appear on the screen. The video is then uploaded to the system and is automatically converted into the " Total Body Photography Map".

C. *Total Body Photography Map Analysis Layer*

The Total Body Photography Map Analysis Layer receives as input the raw lesions (and other peripheral) data based on the Total Body Photography Map generated from the composition of high resolution still images. In addition, existing data from previous TBP (both the specific user and from other users) will also serve as an input. This layer's overall scope is to register all lesions on the patient's body, to identify the creation of new moles as well as the alteration over time of existing moles, and to present the high value target list of the suspicious moles on the patient's body map. More specifically, the Total Body Photography Map Analysis Layer comprises four main modules: 1) The Total Body Photography Map Comparison Module, which is responsible for implementing the "Ugly Duckling Sign" and the "ABCDE rule" which are in turn utilised by, 2) the Mole Change Identification & Marking Module, which is responsible for scanning the total body map and registering all lesions on the patient's body, as well as for identifying the creation of new moles that were not present in the previously produced total body map of the patient, and/or for identifying existing moles that have altered over time, 3) the Melanoma Probability Pattern Detection Module which is responsible for presenting the high value target list of the suspicious moles on the produced Total Body Photography Map, and 4) the Suspicious Mole Report Generation Module that is responsible for producing a conclusive report to be distributed both to the healthcare professional and to the patient as a reference of the scanning outcome. The body scan will exploit augmented reality development concepts to allow for the development of a mobile application with 3D vision.

D. *Decision Support Subsystem*

The Decision Support Subsystem receives as input the outcome of the Total Body Photography Map Analysis Layer highlighting the high value target list of the suspicious moles on the produced Total Body Photography Map, and is responsible for further analysing still images of the suspicious moles, for retrieving similar images from existing databases of malignant melanoma images of patients, and for delivering a decision support system that assists dermatologists in the analysis of the acquired images, while also providing a set of tools for the manual processing of these images. More specifically, the Decision Support Subsystem comprises of six main modules: 1) The Suspicious Mole Still Image Capture Module, which utilises the camera of a smartphone in order to capture high definition still images of the highlighted suspicious moles. 2) The Suspicious Mole Still Image Synchronisation Module, which is responsible for uploading the acquired images to the platform server, and for synchronizing them with the patient's health record. 3) The Suspicious Mole Still Image Analysis Module, which is responsible for the analysis of the still images for: a) preprocessing (image conditioning for impurities removal, filtering, boundary detection), b) feature generation (‘ABCD’ clinical features, textural features, color features, shape features and recently developed features employing LBP descriptors, H-descriptors and fusion of LBP descriptors and H-descriptors), c) feature reduction and feature selection using the GPU parallel computing framework (CUDA) and d) classification (examining individual classifiers as well as combination of them in order to select the most accurate classification scheme). 4) The Suspicious Mole Still Image Comparison Module, which is responsible for identifying the pattern of the moles. This will be achieved by triggering the Secure Skin Cancer Image Database Connectors in order to retrieve similar malignant melanoma images using content-based image retrieval techniques. The latter will be based on features extracted from the mole and classification algorithms and will provide a measure of feature-proximity of the current image and stored images in existing databases, which are either hosted in clinical premises or are available online, free of charge for research purposes, in order to assist the dermatologist in the diagnosis process. 5) the Suspicious Mole Still Image Manual Processing Toolset, which is responsible for delivering to the healthcare professional a set of tools for the manual processing of the image, including standard operations such as zoom in – zoom out, brightness and contrast adjustment, manual delineation of moles boundary, measuring geometric characteristics of suspicious mole (area measurement, boundary length measurement, eccentricity etc.) and 6) the Suspicious Mole Still Image Analysis Report Generation Module which is responsible for producing a conclusive report to be distributed both to the healthcare professional and to the patient as a reference of the scanning and analysis outcome.

E. *Integrated Adaptive Ajax-based Web 2.0 Front-Ends*

The upper layer of the MARK1 architecture is responsible for delivering the front ends through which the healthcare professionals will be able to interact with the MARK1 platform, through standard handheld devices. Different front ends will be developed and delivered to healthcare professionals / dermatologists and patients, based on the discrete needs on information access of each target group.

III. Discussion

In order to facilitate access to medical advice and enable individuals to play a more active role in managing their own health status, mobile teledermatology seems to be especially suited for either direct, live interaction between the patient and the dermatologist, or triage, namely referral based on the severity and character of the skin condition. However, not all cases are suitable for tele-dermatology. The type of cases suited for tele-dermatology is a topic, which requires more studies. In western studies, pigmented lesions suspicious of melanomas are one of the most referred cases for teledermatology. Some studies have observed that eczema and follicular lesions were diagnosed with relatively more certainty, while in some other studies it was seen that diagnoses were made with more certainty in cases like viral warts, herpes zoster, acne vulgaris, and superficial bacterial and fungal infections. Nevertheless, the inherently visual nature of dermatology makes it easily applicable to virtual medicine and holds great potential for revolutionizing the delivery of dermatologic services.

MARK1 aspires to provide a service that will be of value both to the physician who will be assisted in the diagnosis, as well as to the patient who can efficiently and timely contribute to improved self-management of health, disease prevention, management of diseases and/or health expenditure. MARK1 aspires to provide a computer based diagnostic tool, which will deal with the particular differential diagnosis problem of discriminating between patients with malignant melanoma and benign skin lesions, especially when presented with new, “unseen data”, namely information that have not yet been made available to the Decision Support System to be integrated.

MARK1 aspires to exploit GPU technology and parallel processing programming techniques, designing an optimum and reliable decision support system that is capable of being redesigned on site when additional verified data are added to its depository. Diagnosis will rely on the evaluation of expert dermatologists who will be assisted by the risk assessment of the DSS, as well as by the rest of the information that will be supplied by the system, i.e. the image of the lesion of the patient, along with demographic data, and a number of images with similar textual features. MARK1 will allow for feature combinations with high discriminatory power to be discovered and optimum classifier schemes to be realized. The proposed solution will provide technological innovation in new algorithms’ development for dermatology (e.g. content-based image and patient information retrieval, identification and registration algorithms), and cloud infrastructure for information availability.

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