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ARCHIVES OF HELLENIC MEDICINE: ISSN 11-05-3992

REVIEW
ΑΝΑΣΚΟΠΗΣΗ

ARCHIVES OF HELLENIC MEDICINE 2023, 40(6):748–753
ΑΡΧΕΙΑ ΕΛΛΗΝΙΚΗΣ ΙΑΤΡΙΚΗΣ 2023, 40(6):748–753

Dermoscopy image analysis
Where we are and perspectives for the future

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Dermoscopy is a non-invasive diagnostic method that allows the visualization of skin structures of melanocytic lesions, not visible with naked-eye examination. In the recent years, medical community has shown its interest in the emerging field of analysis of dermoscopic images, aiming to evaluate its potential application on melanoma diagnosis. This review aims to be an introduction to the field of dermoscopic image analysis and an overview of the recent research, examining the limitations that require further consideration, while it intends to give new perspectives for future researchers, as well.

Ανάλυση δερματοσκοπικής εικόνας: Πού είμαστε και προοπτικές για το μέλλον

Περίληψη στο τέλος του άρθρου

Key words

Artificial intelligence
Deep learning
Dermoscopy
Dermoscopy image analysis
Melanoma

Submitted 13.9.2022
Accepted 31.12.2022

1. INTRODUCTION

Melanoma is a potentially fatal malignancy, with an increasing incidence in the last decades, especially in fair-skinned populations.[1] Early detection of melanoma improves patient survival and decreases related mortality, so that medical community focuses on new strategies to earlier diagnosis.

In the past, diagnosis of melanoma was based on naked-eye examination, using ABCD acronym, devised by Friedman and colleagues,[2] according to the following features: *a*symmetry, *b*order irregularity, *c*olor variation and *d*iameter (more than 6 mm).[2] Although this diagnostic method is widely used, it lacks accuracy, especially in the diagnosis of *de novo* melanomas that are usually smaller than 6 mm.[2] In addition, it lacks specificity, as long as benign lesions exhibit "ABCD" characteristics.[3,4]

The introduction of dermoscopy or epiluminescent microscopy gave a new perspective on the diagnostic approach of patients with pigmented skin lesions, as it permits the visualization of skin structures, not visible to the naked eye.[5] Although this diagnostic tool has undoubtedly improved the diagnostic accuracy compared to naked-eye examination, there are still limitations. Its use depends on the clinical experience and training of the user.[6] Additionally, even with adequate clinical experience, there are aspects regarding the subjectivity of visual analysis.[7]

Recently, the Cochrane Skin Cancer Diagnostic Test Accuracy Group published a series of reviews on the diagnostic accuracy of newer imaging techniques, including reflectance confocal microscopy,[8] smartphone applications,[9] and computer-aided diagnostic methods.[10] The data that demonstrate the wide acceptance of these methods are limited though. Therefore, scientific community attempts to improve these technologies and to introduce an automated image analysis of melanocytic lesions, aiming to diagnostic accuracy, especially for equivocal lesions.

Our interest will be focused on Dermoscopy Image Analysis (DIA), due to the fact that dermoscopy is a widely favorable method among dermatologists.[11] Additionally, it is remarkable that the majority of literature regarding medical image analysis in dermatology concerns dermoscopic images.[12]

2. TERMINOLOGY: SEGMENTATION, FEATURE EXTRACTION, AND CLASSIFICATION

The term "Dermoscopy Image Analysis" was conceived in 2005 by Menzies et al,[13] when the accuracy of an automated DIA instrument for the diagnosis of melanoma was compared with that of various clinician groups, considering the histological results as the "gold standard" of the diagnosis.[13] Since then, the term was widely adopted by scientific community aiming to assess the accuracy of medical diagnostic algorithms of melanoma detection.[14,15]

Although DIA dates back to three decades ago, the lack of a large dataset of dermoscopic images hindered the rapid progress in this field. The publication of two dermoscopy atlases; the "Interactive atlas of dermoscopy" by Argenzianzo et al, and "An atlas of surface microscopy of pigmented skin lesion: Dermoscopy by Menzies et al" constituted the initial source of images for DIA. The problem of the limited dermoscopic image database was, however, virtually resolved after the publicly availability of 10,000 dermoscopic images from the International Skin Imaging Collaboration archive (ISIC), a database collected by internationally recognized clinical centers.[16]

In this section, we will present the basic steps in the pipeline of DIA through a computer-aided tool, which are the following: image pre-processing, segmentation, feature extraction, and classification.

Image-preprocessing is the first step in DIA and is absolutely necessary, especially for dermoscopic images that lack quality. This step includes the correction of artifacts in the images (e.g. hair), but also a color correction procedure, in cases of poor illuminations conditions.[17]

Segmentation constitutes the second step in this multistep process and refers to the boundary distinction of a skin lesion from the surrounding skin. Although it is an easy process for the clinician, it is a "challenging" task for computers, especially in cases where the transition from the lesion to the surrounding skin is rough.[18] Other aspects that make the computational segmentation of a skin lesion difficult include the heterogeneity of lesions in their size, shape, texture and color, including the diversity of imaging conditions, as well.[12,18]

The most used algorithmic approaches in the field of dermoscopy image segmentation include the active contour model, clustering, thresholding, and region growing algorithm. The latter achieves the best segmentation results, in comparison to the other three models.[19]

In feature extraction, which constitutes a crucial step in DIA, representative features of a skin lesion are obtained. These features may concern the general appearance of the lesion, such as shape, color, texture and symmetry, local features of the lesion, deep learning (DL) features detected by large Convolutional Neural Networks (CNNs) or specific dermoscopic structures, such as pigment networks, streaks, blue-white veil, which are correlated clinically with certain disease states.[17]

Lesion classification is the final step in DIA, in which the lesions are categorized into one of the two following subtypes, melanoma or non-melanoma. Nevertheless, there are recent classifiers, which offer a more refined classification of lesions, identifying more types of skin neoplasms. This classification is done through large CNNs, which constitute the classifiers of choice, offering high categorization accuracy.[20]

3. WHERE WE ARE

Artificial intelligence (AI) is a computer science that analyzes complex medical data and predicts outcome in various clinical scenarios, mimicking human cognition.[21,22]

In dermatology, AI focuses on melanoma detection. A large number of studies report accuracy to classify melanocytic lesions from medical images, on a level comparable to the clinician.[23,24]

Deep learning (DL) constitutes the most popular AI tool, in which large CNNs learn representations of data by transforming the input information (images) into output information (diagnoses), without requiring human engineering.[25] Recently, DL became popular in the field of DIA, where its capacity to perform complex tasks is used in the recognition and classification of melanocytic lesions.

The first attempt to train a CNN that could detect melanoma using 6,120 clinical images was performed in 2016.[26] The values of sensitivity and specificity for authors AI tool rated 0.81 and 0.80, respectively.[26] The limitation of this study was the lack of demographic data, so that the external adoption of this program cannot be well assessed.

To best of our knowledge, the first AI program, trained on dermoscopic images, was performed in 2016.[27] In this study, the potential of the program to discriminate between melanomas and melanocytic nevi from dermoscopic images was demonstrated. The value of specificity of the program exceeded the corresponding value, achieved by 8 dermatologists on the same set.[27]

Since then, several studies compared the accuracy of AI tools in categorizing dermoscopic images of melanocytic lesions against that of dermatologists. Indicatively, we report a study presented in 2017.[28] Therein, the authors tested their CNN classifier against 8 expert dermatologists in the critical distinction: melanomas versus melanocytic nevi. The results of their research showed a superior performance of the AI tool, compared to that achieved by dermatologists.[28] The outperformance of CNN classifier against 58 dermatologists was shown in a similar study.[29] The authors followed the same binary classification (melanomas versus nevi), using a large dataset of more than 100,000 dermoscopic images.[29]

In 2019, the research was focused on a more "challenging" situation; the distinction between melanomas and atypical nevi, with results of algorithm performance being similar to or exceeding clinicians' performance.[30] Additionally, the results from the melanoma classification benchmark of the study were used for future comparisons. The overall sensitivity and specificity of 157 German dermatologists to detect melanoma counted 89.4% and 64.4%, respectively.[31]

However, a binary classification of melanomas and nevi is not reflective of the daily clinical practice, in which the clinician must take into consideration multiple diagnoses in a skin cancer screening. In this context, scientific community is now focused on training multiclass CNN classifiers, with encouraging results.

Recently, a multiclass CNN classifier was trained through DL principles in distinguishing the five most common clinical entities in a skin cancer screening setting: actinic keratosis, basal cell carcinoma, lichen planus like-keratosis, melanocytic nevus and melanoma.[32] The findings of the study demonstrated the significant outperformance of the CNN classifier, compared to dermatologists.[32] This is also reflected in the results of a study of 2019,[33] in a multiclass classification task concerning seven disease classes.[33]

One step further, the translation of CNNs classifiers onto smartphone applications, and their use by individuals is a growing trend. Several studies have, however, shown that these applications lack accuracy in detecting melanoma, compared to clinical examination by dermatologists.[34,35] Additionally, it was found that 3 out of 4 applications missed 30% or more of melanomas, classifying incorrectly the lesions as non-atypical.[36] From the above, it seems that the current use of these applications is potentially dangerous, giving a false sense of security in the consumer.

4. THE FUTURE

The questions that emerge regard the limitations of DIA and AI programs and the way the scientific community can achieve a wide utilization of a computer-aided diagnosis.

Initially, the estimation of the required number of dermoscopic images to create an effective AI tool remains difficult. A small dataset can negatively influence the quality of the diagnostic algorithm, whereas a large dataset may reduce the applicability of the algorithm to the external clinical images.[22] The dataset should include, additionally, a wide spectrum of demographic parameters, so that the AI algorithm can be clinically valid.[37,38]

Other aspects that are totally ignored by computer-aided tools in DIA are clinical information of significant importance for the clinician, such as personal and familial history, number of nevi, gender and age. Another limitation is that these tools classify a lesion, without taking into consideration neither the rest of the lesions of a patient nor the temporal changes in a lesion.[38]

This fact causes inconsistency, as the repeated pattern in the nevi of a patient (signature nevus) and the lesion that differs from all the rest of a patient (ugly duckling sign) constitute very important principles for the clinician by managing a patient with multiple nevi.[4] Future computer-aided diagnosis should include such clinical metadata, so that the diagnostic accuracy of these tools is even higher and of wide acceptance by the medical community.

The lack of standardization in the conditions of obtaining a picture (zooming, lighting, etc.) and the variability in camera types constitute also severe limitations in AI programs. A restriction of the aforementioned factors could contribute to the reduction of the algorithm complexity and improvement of its efficacy.[37]

Except for technical issues that should be resolved, the research in the field of DIA needs to be expanded in more challenging clinical scenarios. The discrimination between a severe dysplastic nevus and a melanoma *in situ* is, in some cases, difficult, even with histological examination. This distinction is, however, of significant clinical importance, as the patients with an already diagnosed melanoma have a high risk of developing a second melanoma in the first five years; thus short-term follow-up is necessary.

Another perspective in medical image analysis is its application on histopathological images. Recent literature reveals a noticeable discordance (of about 26%) between pathologists in discriminating nevi from melanomas at histopathological level.[39] However, in a recently created CNN classifier based on 695 histopathological images, only a total discordance of 18% with a single histopathologist for diagnosing melanoma was shown.[39] The creation of CNN classifiers and their application on histopathological images could be in the current future an even more efficient AI tool for melanoma diagnosis.

At this point, it is important to refer the importance of a synergistic collaboration between clinicians and computer scientists, giving new scientific goals. It is a fact that the majority of papers with subject "AI" are published in computer science journals and not in medical ones.[37] This condition leads to inconsistency. On the one hand, computer scientists do not understand the clinical importance of the results, on the other hand clinicians are not informed on the progress of AI algorithms. Only with the active participation of dermatologists and by setting new clinical goals, the progress of a computer-aided diagnosis is possible.

Finally, using AI algorithms in medicine raises undoubtedly many ethical issues. These diagnostic tools can lead to an overdiagnosis, in cases of unnecessary screening.[38] Additionally, as the use of these methods is costly and healthcare funding is required, inequity in access may occur. Finally, the use of these technological advances by patients raises ethical issues and requires governance, especially in cases of easy availability of these tools via smartphone applications.[40]

5. CONCLUSIONS

In a society with "technological explosion", medicine could not remain uninfluenced. DIA and generally AI in dermatology are developing fields that give new perspectives in management of patients with atypical melanocytic lesions. An understanding of these tools and their use as adjuncts by the clinician is necessary, scoping to improve patient care.

ΠΕΡΙΛΗΨΗ

Ανάλυση δερματοσκοπικής εικόνας: Πού είμαστε και προοπτικές για το μέλλον

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Αρχεία Ελληνικής Ιατρικής 2023, 40(6):748–753

Η δερματοσκόπηση είναι μια μη επεμβατική διαγνωστική μέθοδος που επιτρέπει την οπτικοποίηση δομών των μελανοκυτταρικών βλαβών, οι οποίες δεν είναι ορατές με γυμνό οφθαλμό. Τα τελευταία έτη, το ενδιαφέρον της επιστημονικής κοινότητας έχει στραφεί στον εκκολαπτόμενο τομέα της ανάλυσης της δερματοσκοπικής εικόνας, με στόχο την πιθανή χρήση του στη διάγνωση του μελανώματος. Αυτή η ανασκόπηση στοχεύει να είναι μια βασική εισαγωγή στον τομέα της ανάλυσης της δερματοσκοπικής εικόνας, καθώς και μια σύνοψη της πρόσφατης έρευνας, εξετάζοντας τους περιορισμούς που απαιτούν περαιτέρω στοχασμό. Αποσκοπεί, επίσης, να δώσει νέες προοπτικές για μελλοντικούς ερευνητές.

Λέξεις ευρετηρίου: Ανάλυση δερματοσκοπικής εικόνας, Βαθιά μάθηση, Δερματοσκόπηση, Μελάνωμα, Τεχνητή νοημοσύνη

References

1. SUNG H, FERLAY J, SIEGEL RL, LAVERSANNE M, SOERJOMATARAM I, JEMAL A ET AL. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin* 2021, 71:209–249
2. FRIEDMAN RJ, RIGEL DS, KOPF AW. Early detection of malignant melanoma: The role of physician examination and self-examination of the skin. *CA Cancer J Clin* 1985, 35:130–151
3. BARZEGARI M, GHANINEZHAD H, MANSOORI P, TAHERI A, NARAGHI ZS, ASGARI M. Computer-aided dermoscopy for diagnosis of melanoma. *BMC Dermatol* 2005, 5:8
4. GOODSON AG, GROSSMAN D. Strategies for early melanoma detection: Approaches to the patient with nevi. *J Am Acad Dermatol* 2009, 60:719–735
5. ARGENZIANO G, SOYER HP, CHIMENTI S, TALAMINI R, CORONA R, SERA F ET AL. Dermoscopy of pigmented skin lesions: Results of a consensus meeting via the internet. *J Am Acad Dermatol* 2003, 48:679–693
6. CHEN SC, PENNIE MP, KOLM P, WARSHAW EM, WEISBERG EL, BROWN KM ET AL. Diagnosing and managing cutaneous pigmented lesions: Primary care physicians versus dermatologists. *J Gen Intern Med* 2006, 21:678–682
7. BAFOUNTA ML, BEAUCHET A, AEGERTER P, SAIAG P. Is dermoscopy (epiluminence microscopy) useful for the diagnosis of melanoma? Results of a meta-analysis using techniques adapted to the evaluation of diagnostic tests. *Arch Dermatol* 2001, 137:1343–1350
8. DINNES J, DEEKS JJ, SALEH D, CHUCHU N, BAYLISS SE, PATEL L ET AL. Reflectance confocal microscopy for diagnosing cutaneous melanoma in adults. *Cochrane Database Syst Rev* 2018, 12:CD013190
9. CHUCHU N, TAKWOINGI Y, DINNES J, MATIN RN, BASSET O, MOREAU JF ET AL. Smartphone applications for triaging adults with skin lesions that are suspicious for melanoma. *Cochrane Database Syst Rev* 2018, 12:CD013192
10. DI RUFFANO FL, TAKWOINGI Y, DINNES J, CHUCHU N, BAYLISS SE, DAVENPORT C ET AL. Computer-assisted diagnosis techniques (dermoscopy and spectroscopy-based) for diagnosing skin cancer in adults. *Cochrane Database Syst Rev* 2018,12:CD013186
11. PILIOURAS P, BUETTNER P, SOYER HP. Dermoscopy use in the next generation: A survey of Australian dermatology trainees. *Australas J Dermatol* 2014, 55:49–52
12. CELEBI ME, CODELLA N, HALPERN A. Dermoscopy image analysis: Overview and future directions. *IEEE J Biomed Health Inform* 2019, 23:474–478
13. MENZIES SW, BISCHOF L, TALBOT H, GUTENEV A, AVRAMIDIS M, WONG L ET AL. The performance of SolarScan: An automated dermoscopy image analysis instrument for the diagnosis of primary melanoma. *Arch Dermatol* 2005, 141:1388–1396
14. KOROTKOV K, GARCIA R. Computerized analysis of pigmented skin lesions: A review. *Artif Intell Med* 2012, 56:69–90
15. CELEBI ME, KINGRAVI HA, UDDIN B, IYATOMI H, ASLANDOGAN YA, STOECKER WV ET AL. A methodological approach to the classification of dermoscopy images. *Comput Med Imaging Graph* 2007, 31:362–373
16. OLVERES J, GONZÁLEZ G, TORRES F, MORENO-TAGLE JC, CARBAJAL-DEGANTE E, VALENCIA-RODRÍGUEZ A ET AL. What is new in computer vision and artificial intelligence in medical image applications. *Quant Imaging Med Surg* 2021, 11:3830–3853
17. BARATA C, CELEBI ME, MARQUES JS. A survey of feature extraction in dermoscopy image analysis of skin cancer. *IEEE J Biomed Health Inform* 2019, 23:1096–1109
18. TENENHAUS A, NKENGNE A, HORN JF, SERRUYS C, GIRON A, FERTIL B. Detection of melanoma from dermoscopic images of naevi acquired under uncontrolled conditions. *Skin Res Technol* 2010, 16:85–97
19. CUI X, WEI R, GONG L, QI R, ZHAO Z, CHEN H ET AL. Assessing the effectiveness of artificial intelligence methods for melanoma: A retrospective review. *J Am Acad Dermatol* 2019, 81:1176–1180
20. CODELLA N, CAI J, ABEDINI M, GARNAVI R, HALPERN A, SMITH JR. Deep learning, sparse coding, and SVM for melanoma recognition in dermoscopy images. Proceedings of 6th International Workshop on Machine Learning in Medical Imaging, Munich, 2015:118–126
21. RAMESH AN, KAMBHAMPATI C, MONSON JRT, DREW PJ. Artificial intelligence in medicine. *Ann R Coll Surg Engl* 2004, 86:334–338
22. HOGARTY DT, SU JC, PHAN K, ATTIA M, HOSSNY M, NAHAVANDI S ET AL. Artificial intelligence in dermatology – where we are and the way to the future: A review. *Am J Clin Dermatol* 2020, 21:41–47
23. YOUNG AT, XIONG M, PFAU J, KEISER MJ, WEI ML. Artificial intelligence in dermatology: A primer. *J Invest Dermatol* 2020, 140:1504–1512
24. PHILLIPS M, MARSDEN H, JAFFE W, MATIN RN, WALI GN, GREENHALGH J ET AL. Assessment of accuracy of an artificial intelligence algorithm to detect melanoma in images of skin lesions. *JAMA Netw Open* 2019, 2:e1913436
25. CHAN HP, SAMALA RK, HADJIISKI LM, ZHOU C. Deep learning in medical image analysis. *Adv Exp Med Biol* 2020, 1213:3–21
26. NASR-ESFAHANI E, SAMAVI S, KARIMI N, SOROUSHMEHR SMR, JAFARI MH, WARD K ET AL. Melanoma detection by analysis of clinical images using convolutional neural network. *Annu Int Conf IEEE Eng Med Biol Soc* 2016, 2016:1373–1376
27. CODELLA NCF, NGUYEN QB, PANKANTI S, GUTMAN DA, HELBA B, HALPERN AC ET AL. Deep learning ensembles for melanoma recognition in dermoscopy images. *IBM J Res Dev* 2017, 61:1–15
28. MARCHETTI MA, LIOPYRIS K, DUSZA SW, CODELLA NCF, GUTMAN DA, HELBA B ET AL. Computer algorithms show potential for improving dermatologists' accuracy to diagnose cutaneous melanoma: Results of the International Skin Imaging Collaboration 2017. *J Am Acad Dermatol* 2020, 82:622–627
29. HAENSSLE HA, FINK C, SCHNEIDERBAUER R, TOBERER F, BUHL T, BLUM A ET AL. Man against machine: Diagnostic performance of a deep learning convolutional neural network for dermoscopic melanoma recognition in comparison to 58 dermatologists. *Ann Oncol* 2018, 29:1836–1842
30. BRINKER TJ, HEKLER A, ENK AH, KLODE J, HAUSCHILD A, BERKING C ET AL. Deep learning outperformed 136 of 157 dermatologists in a head-to-head dermoscopic melanoma image clas-

sification task. *Eur J Cancer* 2019, 113:47–54

31. BRINKER TJ, HEKLER A, HAUSCHILD A, BERKING C, SCHILLING B, ENK AH ET AL. Comparing artificial intelligence algorithms to 157 German dermatologists: The melanoma classification brenchmark. *Eur J Cancer* 2019, 111:30–37
32. MARON RC, WEICHENTHAL M, UTIKAL JS, HEKLER A, BERKING C, HAUSCHILD A ET AL. Systematic outperformance of 112 dermatologists in multiclass skin cancer image classification by convolutional neural networks. *Eur J Cancer* 2019, 119:57–65
33. TCHANDL P, CODELLA N, AKAY BN, ARGENZIANO G, BRAUN RP, CABO H ET AL. Comparison of the accuracy of human readers versus machine-learning algorithms for pigmented skin lesion classification: An open, web-based, international, diagnostic study. *Lancet Oncol* 2019, 20:938–947
34. WOLF JA, MOREAU JF, PATTON TJ, WINGER DG, FERRIS LK. Prevalence and impact of health-related internet and smartphone use among dermatology patients. *Cutis* 2015, 95:323–328
35. MAIER T, KULICHOVA D, SCHOTTEN K, ASTRID R, RUZICKA T, BERKING C ET AL. Accuracy of a smartphone application using fractal image analysis of pigmented moles compared to clinical diagnosis and histological result. *J Eur Acad Dermatol Venereol* 2015, 29:663–667
36. WOLF JA, MOREAU JF, AKILOV O, PATTON T, ENGLISH JC 3rd, HO J ET AL. Diagnostic inaccuracy of smartphone applications for melanoma detection. *JAMA Dermatol* 2013, 149:422–426
37. HOGARTY DT, MACKEY DA, HEWITT AW. Current state and future prospects of artificial intelligence in ophthalmology: A review. *Clin Exp Ophthalmol* 2019, 47:128–139
38. NAVARRETE-DECHENT C, DUSZA SW, LIOPYRIS K, MARGHOOB AA, HALPERN AC, MARCHETTI MA. Automated dermatological diagnosis: Hype or reality? *J Invest Dermatol* 2018, 138:2277–2279
39. HEKLER A, UTIKAL JS, ENK AH, BERKING C, KLODE J, SCHADENDORF D ET AL. Pathologist-level classification of histopathological melanoma images with deep neural network. *Eur J Cancer* 2019, 115:79–83
40. ABBOTT LM, SMITH SD. Smartphone apps for skin cancer diagnosis: Implications for patients and practitioners. *Australas J Dermatol* 2018, 59:167–170

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