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Algorithms and tools for image labeling in dermatology through the use of Machine Learning

PHD THESIS SUMMARY

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Table of contents

I. THE CURRENT STATE OF KNOWLEDGE

1. Theoretical foundations

Dermatology, a field dedicated to the study and treatment of skin conditions, has made significant progress with the evolution of technology in medical imaging. The impact of using images in the diagnosis of dermatological conditions is vast, with the potential to optimize the diagnostic process and further improve patient care quality [1].

In addition to the benefits it offers, image-based diagnosis also presents some challenges. Image quality is an essential aspect, as unclear or low-quality images can lead to diagnostic errors [2]. Moreover, interpreting images requires expertise and experience, and variability in image interpretation among different dermatologists can lead to discrepancies in diagnosis.

Improving image-based diagnostic techniques and tools is particularly important for overcoming these challenges and optimizing dermatological diagnosis. The development of image processing and analysis algorithms can help improve image quality, while the use of artificial intelligence and deep learning can facilitate image interpretation and contribute to reducing variability in diagnosis [3]. Furthermore, the use of image-based diagnosis can facilitate the application of telemedicine in dermatology, allowing remote patient evaluation and providing dermatological expertise to individuals who do not have easy access to a dermatologist [4].

Artificial Intelligence (AI), Machine Learning (ML), and Deep Learning (DL) have become increasingly influential in many areas of medical research and practice. In dermatology, AI has the ability to analyze and learn from a variety of data, including dermatoscopic images, clinical images, histopathological and genetic data. Additionally, AI has the capacity to extract and learn from unstructured and unordered data, which can be extremely useful in the context of dermatological diagnosis, where information can often be scattered and disordered [5]. ML algorithms can be used to analyze dermatological images, facilitating the identification of skin conditions and reducing the likelihood of human errors. They can also be used to analyze clinical and genetic data, enabling healthcare professionals to better understand the links between certain genes and skin conditions and to personalize treatments based on this information [6]. DL has impressive applications in image analysis. An example is the research conducted by Esteva et al. (2017), who used convolutional neural networks (CNNs) to develop a skin tumor classification system that achieved performance comparable to that of dermatologists [3]. Moreover, CNNs have been used to develop algorithms that can identify and segment skin lesions from dermatoscopic images, playing a role in improving diagnostic accuracy and treatment efficiency [7].

2. Algorithms and models of Machine Learning for image labeling

ML algorithms play an important role in the process of image labeling in dermatology, being divided into several categories based on the training and usage method.

Supervised algorithms rely on labeled datasets to train models capable of making accurate predictions. Among these are logistic regression, SVMs, and decision trees. Logistic regression is frequently used for binary classification, such as distinguishing between benign and malignant lesions, having the advantage of simplicity and interpretability, but being limited in capturing complex relationships in data [8]. SVMs, effective in classifying dermatological images, are often used in combination with feature selection algorithms to improve diagnostic accuracy [9]. Decision trees and Random Forest provide an interpretable way to perform complex classifications, being frequently used in the diagnosis of skin conditions [10].

Unsupervised algorithms, on the other hand, learn from unlabeled data, identifying hidden patterns and structures. Common methods include clustering and principal component analysis (PCA). Clustering groups similar images, facilitating the discovery of new categories of lesions [11], while PCA is used for dimensionality reduction, identifying essential features of skin lesions [12]. Autoencoders, another unsupervised technique, are used for data compression without requiring external supervision [13].

Semi-supervised algorithms combine a small set of labeled data with a large set of unlabeled data to improve model accuracy. Additionally, transfer learning involves using a pre-trained model on a large dataset and applying it to a specific and smaller set. These methods are useful for reducing the need for manually labeled data and for efficiently adapting to specific tasks in dermatology.

Convolutional neural networks represent a specialized class of algorithms that are extremely efficient in the classification and segmentation of dermatological images. Architectures such as *ResNet*, *U-Net*, *DenseNet*, and *EfficientNet* are widely used in dermatology, each having specific advantages. *ResNet* addresses the issues related to vanishing gradients in very deep networks [14], *U-Net* is excellent for precise lesion segmentation [15], *DenseNet* facilitates efficient gradient propagation [16], and *EfficientNet* optimizes both accuracy and computational efficiency by uniformly scaling the network [17].

These various ML methods and architectures offer multiple opportunities for improving diagnoses and treatments in dermatology, with each approach contributing to the development of more accurate and efficient models for the analysis of skin imaging.

3. Performance evaluation and model validation

Evaluating the performance of ML models is important to determine their efficiency and accuracy, using metrics such as accuracy, precision, sensitivity, F1 score, and ROC curve. Accuracy, although popular, can be misleading in imbalanced datasets, where majority classes dominate the results. Precision and sensitivity help minimize false positives and false negatives, and the F1 score offers a balance between them, being useful in imbalanced datasets. The ROC curve and AUC summarize the overall performance of the model, with a higher value indicating superior performance.

Cross-validation, essential for robust evaluation, involves splitting the dataset into multiple subsets for training and testing. K-Fold Cross-Validation and its variants, such as LOOCV and Stratified Cross-Validation, ensure balanced and unbiased evaluation. Proper data splitting into training, validation, and testing sets prevents overfitting and ensures model generalization.

Bias and variance negatively affect model performance. Bias occurs when the model oversimplifies the data, while variance indicates excessive sensitivity to training data, leading to poor performance on new sets. To combat these issues, regularization (L1, L2), ensemble methods (Random Forests, Gradient Boosting), data augmentation, and cross-validation are applied, all contributing to reducing bias and variance, thus improving model robustness.

4. Applications of Artificial Intelligence in dermatology

AI has brought significant advances in the field of dermatology, contributing to the diagnosis and management of skin conditions through the development of innovative tools based on ML algorithms and deep neural networks. These technologies enable faster and more accurate diagnoses, supporting physicians in making clinical decisions. However, the integration of AI in dermatology is accompanied by multiple challenges, including ethical dilemmas, concerns about patient data confidentiality, and the complexity of algorithms, often perceived as a 'black box".

AI has already demonstrated its effectiveness in various dermatological applications, from early melanoma detection to differentiating between different classes of skin conditions [18,19]. This technology has the potential to democratize access to medical expertise, reducing inequalities in healthcare delivery and improving patient outcomes through faster and more accurate diagnoses. However, the opacity of AI algorithm decisions represents a significant obstacle in their understanding and acceptance by clinicians.

AI also brings important benefits in the triage of dermatological conditions and in teledermatology [20,21], contributing to more efficient patient monitoring, prioritization of severe cases, and optimization of resources within healthcare systems. By pre-analyzing images sent by patients, AI can provide dermatologists with preliminary assessments, facilitating the rapid management of cases requiring urgent intervention.

In the field of imaging diagnostics, AI has demonstrated that it can match or even surpass the abilities of experienced dermatologists in classifying and diagnosing skin conditions [22-24]. Research shows the success of convolutional neural networks and deep learning technologies in correctly identifying malignant and non-malignant lesions, as well as in diagnosing other dermatological conditions such as psoriasis and acne [25,26].

Moreover, AI offers advantages in monitoring chronic conditions by using severity scores and predicting treatment responses, enabling the personalization of therapeutic interventions and reducing subjectivity in clinical assessments [27,28]. Through these technologies, new possibilities arise for optimizing patient treatment and improving clinical outcomes.

In the field of genetics, AI contributes to accurate diagnosis and treatment personalization in dermatology, facilitating the identification of complex genetic correlations that may influence the predisposition and progression of skin conditions. AI-based analyses allow for a better understanding of the pathogenesis of inflammatory skin diseases, offering new perspectives for the development of more effective therapeutic strategies [29].

The technical and ethical challenges associated with the use of AI in dermatology are numerous. The performance of algorithms largely depends on the quality and diversity of training datasets, and ensuring patient data confidentiality remains a major concern. Additionally, the acceptance of AI by healthcare professionals and patients is essential for the successful implementation of these technologies.

In the future, AI promises to significantly transform dermatology, bringing an increase in transparency and interpretability of processes, which will enhance trust in these technologies. The development of explainable AI systems and the availability of extensive and diverse dermatological datasets will help ensure the reliability and accuracy of these tools across various populations and clinical settings. AI has the potential to revolutionize personalized and precision medicine, integrating into telemedicine and genomics platforms, thereby improving access to dermatological care, especially for underserved populations. However, new AI technologies will need to complement and amplify human expertise, keeping dermatologists at the center of the decision-making process. Continuous collaboration between professionals and stakeholders will accelerate innovations and their implementation in practice.

II. PERSONAL CONTRIBUTIONS

5. Hypothesis, scope and general objectives

In the context of rapid technological advancement, the integration of AI in dermatology opens up new perspectives for diagnosis, treatment, and patient management. However, the development, adoption, and efficient use of AI technologies depend on multiple factors, including the quality and availability of datasets, the perceptions and attitudes of physicians, integration with existing systems, continuous professional development, and ethical and confidentiality considerations.

The hypothesis of this thesis is that the integration of AI in dermatology can significantly improve the accuracy of diagnoses and the efficiency of treatments, while simultaneously reducing the inherent variability of human diagnosis. It is also assumed that the attitude and perception of dermatologists towards these technologies play an important role in their adoption in clinical practice.

The aim of this Doctoral Thesis is to address the challenges of dermatological image labeling and develop innovative solutions to improve diagnosis, monitoring, and personalization of treatments in dermatology, considering technological advances and the application of machine learning in medicine. To achieve this goal, the following objectives have been defined:

Investigating dermatologists' perceptions and attitudes towards AI

- Collecting and analyzing data regarding familiarity, experiences, and expectations of professionals in the field of dermatology regarding the use of AI.

Validation of remote image-based evaluations

- Comparing digital evaluations based on patient-submitted images with traditional clinical evaluations for a series of dermatological conditions to determine the level of agreement and consistency between methods.

Evaluating the performance of AI models in dermatology

- Investigating the effectiveness of advanced convolutional neural network architectures, such as EfficientNet, in diagnosing dermatological conditions through image analysis.

These objectives are achieved through the conduct of three distinct studies, each contributing to a deeper understanding of the potential and challenges associated with the use of AI in dermatology. The studies focus both on the technical aspects of AI algorithm performance and on the perceptions and attitudes of dermatologists, thus providing a comprehensive approach to the subject.

6. The general research methodology

To achieve the aim of the Doctoral Thesis, three studies were conducted, aiming to meet the general objectives mentioned in the subchapter of the thesis 'Hypothesis, scope and general objectives.'

The first doctoral study, titled *'Contributions regarding the implications of artificial intelligence in dermatology - Perceptions regarding integration into daily practice*,' aimed to initially assess, through a questionnaire, the level of dermatologists' familiarity with the concept of AI in dermatology and their perception of AI integration into clinical practice. The study analyzed perceived benefits, limitations, and challenges associated with this new technology, its influence on doctor-patient interaction, the future of dermatology, and ethical implications.

The second doctoral study focused on *'Reliability analysis and validation of remote assessment of the severity of skin conditions based on images'* and included three sub-studies that aimed to demonstrate that the severity analysis of certain dermatological conditions (atopic dermatitis, psoriasis, actinic keratoses) can also be performed by remotely labeling the skin characteristics of each condition based on images, with results comparable to in-clinic evaluations. Demonstrating that image-based assessments are similar to in-clinic assessments stems from the need to validate these image labels, which is essential for ensuring data accuracy and for training subsequent AI models.

The third doctoral study, titled *'Contributions regarding the use of Deep Learning for the examination and diagnosis of skin lesions*,' aimed to create a CNN architecture and subsequently evaluate the effectiveness and potential of this EfficientNet model in improving the diagnosis of dermatological conditions, with a special focus on differentiating between benign and malignant lesions.

7. Contributions regarding the implications of artificial intelligence in dermatology - Perceptions regarding integration into daily practice

In recent years, AI promises to revolutionize dermatological practice, offering new perspectives for diagnosis, treatment, and patient management. However, the integration of AI into clinical practice largely depends on how dermatologists perceive and accept these innovative technologies, as well as their level of preparedness to adopt them effectively. Thus, an essential chapter of the doctoral thesis was dedicated to investigating these aspects through a questionnaire addressed to dermatologists in Romania. The purpose of this questionnaire was to obtain detailed information about their attitudes, experiences, and expectations regarding AI.

This study aimed to achieve several key objectives: assessing the level of knowledge and understanding of the AI concept, identifying perceived benefits, analyzing anticipated challenges and limitations, investigating how AI might influence the doctor-patient relationship, exploring perceptions about the future of dermatology in the AI era, evaluating the training needs and resources for the effective adoption of AI, and examining ethical concerns related to this technology.

The questionnaire was distributed to dermatologists in Romania, and the responses collected from a sample of 62 respondents were analyzed to provide a clear picture of their perceptions. The results indicate moderate familiarity with AI technologies, with significant polarization between doctors who are very familiar and those not familiar at all. It is important to note that, contrary to expectations that young doctors, often perceived as more receptive to technological innovations, would have a high level of familiarity with AI, a significant percentage of them state that they are not familiar with these technologies at all. This finding highlights a clear need for ongoing training and education to improve knowledge and skills in the field of AI, especially among young professionals.

Perceived benefits of AI include improving diagnostic accuracy, increasing efficiency in patient management through AI's ability to triage and prioritize cases, the possibility of personalizing treatment plans, supporting research and development, and enhancing patient education and engagement. However, dermatologists also identified significant challenges, such as resistance to change among staff and technical difficulties related to integrating AI into existing systems. Nevertheless, there is a strong interest in continuous training, with many respondents mentioning the need for workshops, seminars, and other educational resources to learn how to use AI effectively.

The impact of AI on the doctor-patient relationship is viewed with both optimism and concern. Some doctors believe that AI can improve consultations and personalize treatments, while others fear a possible reduction in direct human interaction. Ethical concerns related to AI, such as algorithmic bias and data security, are acknowledged but not perceived as the main obstacles to adopting this technology.

In conclusion, to facilitate the effective adoption of AI in dermatology, the development of customized training programs, access to varied educational resources, and continuous technical support are necessary. The success of AI integration depends on the proper preparation of dermatologists, the adaptation of IT infrastructures, and the promotion of an organizational culture open to innovation. Ensuring the optimal use of AI technologies and maximizing their benefits for patients and dermatological practice depend on addressing all the aspects mentioned.

8. Contributions regarding the reliability and validation of remote assessment of the severity of skin conditions based on images

The importance of demonstrating that image-based assessments are similar to those made in-clinic stems from the need to validate the labeling of these images (e.g., diagnosis, identification of skin lesions, identification of their characteristics, and assessment of lesion severity based on severity scores). This validation is essential to ensure data accuracy and to subsequently train AI models. AI models trained on correctly labeled images can later take on tasks typically performed by doctors (e.g., diagnosis, evaluation, monitoring), offering much better results due to their ability to quickly and objectively analyze large amounts of data.

In the doctoral study, the reliability and validity of remote assessments of skin condition severity were evaluated using images captured by patients with mobile phones, involving a significant number of dermatologist evaluators (both in-clinic and 'remote'). The study was structured into three main sub-studies, each focusing on a specific condition: atopic dermatitis (AD), psoriasis, and actinic keratoses (AK).

Sub-study 1: The severity of mild and moderate forms of atopic dermatitis was investigated using images captured by patients with a mobile phone. The activities included in this sub-study aimed at comparing in-clinic evaluations with those conducted remotely based on images, as well as their validity and reliability, based on the EASI, SCORAD, and IGA severity scores [30].

Sub-study 2: Focused on evaluating the severity of mild and moderate forms of psoriasis using the same type of images. The goal was to compare clinical evaluations with those based on images and patients' self-reports regarding the extent of lesions, based on the PASI and PGA severity scores [31].

Sub-study 3: The level of agreement and reliability in analyzing actinic keratoses lesions based on images taken by the patient with a mobile phone was evaluated, using the Olsen scale and the AK-FAS score [32].

The study on AD severity demonstrated a good to excellent agreement between traditional clinical evaluations and photographic evaluations, suggesting that AD severity can be digitally assessed with high validity. Photographic evaluations showed very low inter-evaluator and intra-evaluator variability, indicating consistency and reliability in photographic assessments.

In the *study on psoriasis severity*, the high levels of concordance between clinical and photographic evaluations for PASI underline the reliability of using patient-taken images in monitoring this condition. The study also confirms that photographic evaluations are suitable for monitoring the severity of psoriasis lesion characteristics, such as erythema, induration, and scaling.

In the *study dedicated to AK*, the moderate to good concordance for the Olsen scale and the sub-components of AK-FAS suggests that photographic evaluations can be used to assess the severity of AK, although there may be tendencies to overestimate lesion severity in clinical evaluations. The doctoral study highlights the need for adjustments to existing scoring systems to better adapt to image-based evaluations.

The doctoral study presents several notable strengths that make it innovative and relevant in the field of dermatology. Firstly, it is among the first studies to investigate the reliability and validity of remote assessments for various skin conditions using images captured by patients with mobile phones. This approach opens up new perspectives for the monitoring and management of dermatological conditions, especially in contexts where access to dermatological services may be limited. The methodology used in this study is another strength. Comparing traditional clinical evaluations with photographic evaluations and involving multiple evaluators to ensure inter-evaluator reliability are important aspects that add value to the results obtained. Furthermore, the practical relevance of the study is evident, as it highlights the potential of photographic evaluations to offer a viable alternative for patients who may not easily access dermatological services.

In conclusion, by demonstrating the reliability and validity of image-based assessments, these studies support the possibility of providing more accessible and efficient dermatological care. The implementation of these methods can improve patients' access to quality dermatological care, reduce the need for frequent physical visits, and support clinical decision-making by providing precise and reliable information about the severity of conditions.

9. Contributions regarding the use of Deep Learning for the examination and diagnosis of skin lesions

The aim of the doctoral study was to develop and evaluate an AI model, based on the EfficientNetB3 architecture, to improve the diagnosis of dermatological conditions [33]. The model was trained and validated using an extensive set of clinical and dermatoscopic images, sourced from the personal image collection of the medical team at the Clinical Dermatology Section 2 of Colentina Clinical Hospital and the archive of the International Skin Imaging Collaboration (ISIC), a globally recognized database.

The total dataset included 8,222 images, grouped into six clinically relevant categories: three categories of malignant conditions (melanoma, basal cell carcinoma - BCC, squamous cell carcinoma - SCC) and three categories of non-malignant conditions (actinic keratosis - AK, benign keratosis-like lesions, and melanocytic nevi). Of the six condition categories, four were better represented in terms of the number of images per category; for this reason, the final results are presented by analyzing the model's performance using the four better-represented categories (melanoma, BCC, melanocytic nevi, benign keratosis-like lesions) and later using six condition categories (including AK and SCC). To ensure a fair evaluation of the model, the images were split into two subsets: 80% of the images were used for training (6,577 images), and 20% for testing (1,644 images).

Data pre-processing was an essential step to ensure the uniformity and quality of the dataset used. This included:

- Resizing the images to 300x300 pixels to standardize the size of the 'input' images.
- Normalization of pixel values, which involved scaling them within the range [0, 1], thus reducing differences and facilitating the training process.
- Mean subtraction and standardization of each pixel, a technique that contributed to accelerating the model's convergence.
- Data augmentation, an essential strategy that allowed the creation of new images through transformations of existing ones (flipping, translation, rotation, scaling, brightness adjustment, and noise addition). This process was used to balance the categories and to increase the diversity of the dataset, ensuring good generalization of the model in the testing phase.

The model architecture selected for this study was EfficientNetB3, due to its optimal balance between performance and computational efficiency. EfficientNet is known for its ability to extract relevant features from images using a compound scaling method that adjusts depth, width, and resolution in a balanced manner.

Combating overfitting was an important aspect of the model's development and was achieved through the application of the following techniques:

- Dropout was used to prevent excessive dependence on certain neurons, thus reducing the risk of the model memorizing the training data instead of learning general patterns.
- Batch Normalization accelerated training and stabilized the network, allowing the use of higher learning rates and improving the model's generalization ability.
- Data augmentation was applied to increase the diversity of the dataset, exposing the model to a greater variety of examples and thus reducing the risk of overfitting.

The model training was carried out using a series of advanced techniques to optimize performance:

- Transfer learning was employed by using pre-trained parameters on the ImageNet dataset, allowing the model to start with an existing understanding of general visual features.
- The Adamax optimizer was chosen to efficiently guide the model in adjusting parameters due to its stability and rapid convergence.
- Mixed precision training (using float16 and float32 data types) was implemented to accelerate processing and optimize the use of computational resources.

The study results demonstrated a progressive improvement in the model's performance during training, indicated by the continuous decrease in loss values and the increase in accuracy on the training and validation datasets.

Training on four categories (melanoma, BCC, benign keratosis-like lesions, melanocytic nevi) showed the following developments:

- In the first epoch, the model recorded a loss of 6.230 and an accuracy of 78.429% on the training set. On the validation set, the corresponding values were a loss of 4.40951 and an accuracy of 88.564%.
- By the fifth epoch, the training set loss had significantly decreased to 0.700, and accuracy had increased to 96.178%. On the validation set, the loss was 0.65040, and accuracy reached 92.336%. These results reflect the model's good capacity to learn from the training data but also indicate a potential risk of overfitting, observed through the slight decrease in performance on the validation set starting from the third epoch.

Training on six categories (including additionally SCC and AK) presented an additional challenge:

- At the beginning of training, the model had a loss of 7.5 and an accuracy of 58.1% on the training set, while the values on the validation set were a loss of 5.8 and an accuracy of 76.7%. As training progressed, a higher number of epochs was required for the model to reach a performance level comparable to that obtained in the four-category training. This was due to the increased complexity of the problem, considering the larger number of categories and the imbalance in the distribution of images between categories.

The results of testing the model on the two sets of categories showed variable performance depending on the representativeness of each category in the training set. Precision and recall were highest for melanoma (1.00 for both tests) and melanocytic nevi (0.96 in the first test and 0.94 in the second test). In contrast, categories with fewer images, such as AK and SCC, recorded slightly lower performance.

The overall accuracy of the model was 95.4% for the four disease categories and 88% for the six categories, highlighting robust performance when the model had access to a balanced and well-represented dataset.

The ROC curves and Confusion Matrix confirmed the model's excellent performance, with AUC values ranging from 0.98 to 1.00, and from 0.93 to 1.00, respectively. The Confusion Matrix showed that the majority of class examples were correctly classified, with minimal errors observed in the less-represented categories.

The EfficientNetB3 model developed in this study demonstrated a solid capacity to diagnose skin lesions, with slightly better results in the categories where the dataset was sufficiently extensive and balanced. The slightly lower performance in categories with fewer images underscores the need to develop and use extensive and diverse datasets to improve the model's ability to generalize results. Ensuring a wide, varied, and standardized dataset is essential to maintain the effectiveness and applicability of AI diagnostic algorithms across a wide range of skin conditions. The continuous growth of the dataset will support the model's ability to generalize effectively, thus improving diagnostic accuracy and reliability in various clinical scenarios.

III. CONCLUSION AND PERSONAL CONTRIBUTIONS

The aim of the Doctoral Thesis on analyzing algorithms and tools for image labeling using Machine Learning was demonstrated through the achievement of the three objectives corresponding to the activities carried out in the three doctoral studies, with the presentation of the corresponding results for each proposed objective.

The personal contributions consist of conducting a study aimed at evaluating the attitudes, experiences, and expectations of professionals in the field of dermatology regarding the use of AI technology and its integration into clinical practice. The results of this study identified moderate familiarity of doctors with AI technologies, recognizing potential benefits (improving diagnostic accuracy, increasing efficiency in patient management, and facilitating personalized treatment plans) but also noting some challenges (resistance to change among medical staff, algorithmic bias, data security and AI decision transparency, and technical issues with integration into existing systems). This outlines the need to develop customized training programs, access to various educational resources, and continuous technical support to facilitate the effective adoption of AI in dermatology.

Furthermore, the personal contributions include conducting the first studies evaluating the reliability of remote assessments of the severity of dermatological conditions based on images. Three sub-studies were conducted, involving three skin pathologies—atopic dermatitis, psoriasis, actinic keratoses—for which specific severity scores were evaluated both remotely, based on images captured by patients, and in the clinic. The studies demonstrated high levels of concordance between clinical and photographic evaluations, showing that photographic evaluations are suitable for monitoring the severity of skin conditions. The importance of demonstrating that image-based evaluations are similar to in-clinic evaluations stems from the need to validate these image labels, proving the accuracy of the data subsequently used to train AI models. AI models trained on correctly labeled images can eventually take on tasks traditionally performed by doctors, with the ability to deliver much better results due to their capacity to quickly and objectively analyze large amounts of data.

In the third Doctoral Study, the effectiveness and potential of the EfficientNet model in diagnosing dermatological conditions were evaluated, with a special focus on differentiating between benign and malignant lesions. The results of the doctoral study demonstrate that the model achieved a remarkable accuracy of 95.4% for four classes and 88.8% for six classes of conditions, demonstrating its ability to efficiently differentiate between various types of dermatological lesions. Additionally, the study's results showed that the model's performance remains robust when there is a sufficient number of images for each pathology.

Conclusions of doctoral thesis

Doctoral study 1

By analyzing the results of the questionnaire applied to dermatologists regarding perceptions related to AI integration, the following conclusions emerge:

Activity 1: Romanian dermatologists have a medium level of knowledge and understanding of the AI concept, with an important remark regarding the category of 'not at all familiar' doctors, mainly represented by young doctors with up to 5 years of experience (contrary to common expectations, which assume greater receptiveness and familiarity of young doctors with new technologies due to their increased exposure online).

Activity 2: The main benefits recognized by dermatologists are represented by the role of AI in improving diagnostic accuracy, increasing efficiency in patient management, supporting research and development, or enhancing patient education and engagement.

Activity 3: Dermatologists identified technical components and human resources as the main limitations and challenges of AI integration, paying less attention to concerns directly associated with new technologies, such as algorithmic bias, data confidentiality, or medico-legal responsibility in case of errors.

Activity 4: The positive effects of AI on the doctor-patient relationship, such as more efficient consultations and personalized treatments, are recognized, but there is also a fear of reducing direct human interaction.

Activity 5: Dermatologists mention that AI will decisively influence dermatological practice, reflecting a significant belief in the innovation brought by this technology.

Activity 6: There is a strong recognition of the need for training and education programs among medical staff, with support for organizing workshops, seminars, demos, or e-learning modules to gain a deeper understanding of emerging technologies and to facilitate the safe and efficient adoption of AI.

Activity 7: Ethical concerns related to algorithmic bias, data security, and AI decision transparency are acknowledged but are not perceived as the main barriers to AI adoption.

Doctoral Study 2

Consisting of three sub-studies, the following conclusions are outlined:

Sub-study 1: Evaluation of the severity of mild to moderate forms of atopic dermatitis using images captured by patients with a mobile phone

Activity 1.1: There is a good to excellent agreement between traditional clinical evaluations and photographic evaluations, suggesting that the severity of AD can be digitally assessed with high validity.

Activity 1.2: Photographic evaluations showed very low inter-evaluator and intra-evaluator variability, indicating consistency and reliability in photographic evaluations.

Sub-study 2: Evaluation of the severity of mild to moderate forms of psoriasis using images captured by patients with a mobile phone

Activity 2.1: There are high levels of concordance between clinical and photographic evaluations for PASI, which highlights the reliability of using images taken by patients in monitoring this condition.

Activity 2.2: The study confirms that photographic evaluations are adequate for monitoring the severity of individual psoriasis symptoms, such as erythema, induration, and scaling.

Sub-study 3: Evaluation of the level of agreement and reliability in the "remote" analysis, based on images, of actinic keratosis lesions

Activity 3.1: There is moderate to good concordance for the Olsen scale and the AK-FAS subcomponents, suggesting that photographic evaluations can be used to assess the severity of AK, although there may be tendencies to overestimate lesion severity in clinical evaluations.

Activity 3.2: The use of the front camera vs. the main camera does not significantly affect evaluations for the Olsen scale and partially the AK-FAS score (identification of solar deterioration and hyperkeratosis), but it does have an impact on the assessment of the affected skin area, potentially secondary to the lower resolution and a wider-angle lens, capturing more of the surrounding area to the detriment of the lesion characteristics.

Doctoral study 3

In the third Doctoral Study, the EfficientNet architectural network was used for the examination and diagnosis of dermatological conditions, with the following conclusions:

Activity 1: The EfficientNet-based model achieved a remarkable accuracy of 95.4% for four classes and 88.8% for six classes of conditions, demonstrating its ability to efficiently differentiate between various types of dermatological lesions.

Activity 2: The implementation of data augmentation techniques such as rotation, scaling, and brightness adjustment increased the diversity and quality of the training dataset, thus contributing to more effective model generalization and improved performance on new data.

Activity 3: To prevent overfitting, strategies such as dropout and batch normalization were implemented, and continuous monitoring of loss values during the training and validation stages allowed early detection and mitigation of overfitting effects, ensuring a robust and efficient model training.

Activity 4: Testing the model on an extensive set of clinical images demonstrated high accuracy, showing its potential to be integrated into clinical workflows.

Activity 5: EfficientNetB3 demonstrated superior results compared to other architectures, with additional advantages (shorter inference times, reduced costs, and smaller size compared to other models), supporting its potential integration into clinical practice.

In conclusion, the use of AI and ML technologies in dermatology offers numerous advantages, including increased diagnostic accuracy, improved patient management efficiency, and the possibility of personalized treatments. These technical advantages also translate into significant economic benefits, such as reducing costs associated with patient diagnosis and monitoring and optimizing the use of medical resources.

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