Survey of Computational Intelligence in the Management of Skin Disorders

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ABSTRACT: *Health care systems undergone rapid changes due to the infusion of computational intelligence and information technology as a whole. Dermatology developments are mainly possible due to the technology applications. It is the field that experiences vast changes and these are reflected in mobile health and other means. Besides, many more mobile applications are making influence in the medical care and diagnosis and found suitable to modern medical systems. We in this work carried out a survey using mobile applications which use computational intelligence for sensing skin disorders. The applications consider mainly on the level of sensitivity, specificity and overall accuracy of the given diagnoses in comparison to the accuracy of a dermatologist. In the survey we observed many applications of care and diagnosis of skin diseases. It is noticed that only a few list the techniques that use these applications for the classification of the disease. Many applications use a high levels of precision, and mainly those that utilize artificial neural networks and vector support machine algorithms. Even with the developments the techniques are available only for a number of limited diseases. These issues lead to conclude that the direction of the research towards the field of dermatology can contribute to the minimization of the gap between stakeholders.*

Keywords: Mobile Applications, Dermatology Apps, Skin Care, Dermatology, Smartphone, Articial Intelligence

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1. Introduction

A report by the World Health Organization mentions that although considerable progress has been made in the treatment of cutaneous diseases, they are still frequent in many rural communities of developing countries, with serious socio-economic and sanitary repercussions, and directly or indirectly, causing disability.

The implementation of new technologies in healthcare and the advancement of telecommunications have spurred a rapid growth of telemedicine in the different health systems. New information and communication technologies (ICT) have allowed for innumerable possibilities in the exchange of health information, as well as new forms of healthcare assistance such as assistance given remotely from the healthcare professional to the patient, with teledermatology being one of the fields of telemedicine application. Currently, many technologies are used in the field of telemedicine. Research in this area focuses on the development of smartphone applications for the detection of skin diseases, mainly of skin cancer.

On the other hand, Artificial Intelligence (AI) has resurfaced recently in scientific and public awareness. As technology companies and scientists announce recent advances and technologies at a dizzying pace, AI tries to understand and build intelligent agents, often instantiated as software programs[19]. As a result, the use of mobile phones with artificial intelligence apps for dermatology is spreading. It has been determined that at the end of 2018 there were an estimated 5,000 million subscriptions worldwide with a projection of 7,200 million smartphones subscriptions for the year 2024 [17].

It is important to mention that a smartphone camera's function is an innovative development to which artificial intelligence systems have been incorporated at a low price. This addition is made so that, through images, people from isolated communities and poor countries may receive assistance in scanning, analyzing and performing regular dermatological exams at any given time and place [20][18]. This helps prevent or detect any anomaly on the skin's surface and classifies the image as benign or malignant.

This study was created due to the interest in investigating the applicability of artificial intelligence to the field of dermatology through the development of mobile applications. Said applications demonstrate an acceptable overall level of precision of diagnosis as to the precision of dermatologists. The applications take into account the sensitivity and specificity of the tests, in order to be consist with in-person medical services. In this manner, people with limited access to medical assistance due to distance, physical disability, employment, costs or schedules may receive quality health services and thus contribute to bridge the doctor-patient gap.

For a better description of what was found in the studies, this document has been organized as follows: Section 2 presents a general description of the main techniques of artificial intelligence and its applicability in the development of mobile applications, section 3 describes the elements of the research protocol, section 4 shows the results of the investigation, section 5 discusses the results found and answers the posed research questions, and finally section 6 presents the conclusions of the work done.

2. Background

Even though the use of artificial intelligence in dermatology is not new, the high degree of precision that is now possible using convolutional neural networks (CNN) raises questions about the future role of dermatologists in the diagnosis and management of melanoma and other skin cancers. Recently, the convolutional neural networks captured in 129,450 clinical images reached the level of dermatologist precision in the diagnosis of skin malignancy [1,19].

Convolutional neural networks have proven crucial to the success of image analysis and are also responsible for the subsequent evolution in medical imaging. Along with CNNs other techniques are also used for diagnosis, such as Support Vector Machines (SVMs).

2.1. How a CNN Functions in Image Analysis

A CNN uses a special type of layer, called a convolutional layer, to summarize and transform groups of pixels into images and extract high-level features. They can operate on the raw image and learn useful features from the training sets. This simplifies the formation process and facilitates the identification of image patterns. Although the formation phase of the deep learning model can be expensive from a computational point of view, the finalized diagnostic model may be displayed on mobile devices, potentially improving levels of sensitivity and specificity [19].

Sensibility It is defined as the probability of correctly classifying an individual as sick, as in, the probability of a sick subject receiving a positive result on the test. In other words, sensitivity can be defined as the ability of a test to detect disease [14].

Therefore, it represents the fraction of true positives. When expressed as a percentage, it represents the percentage of positive results regarding the total number of patients, as in, the percentage of true positives that will be obtained when applying the diagnostic test to the patients [7].

Specificity It is defined as the probability of correctly classifying an individual as healthy, as in, the probability of a healthy subject receiving a negative result. In other words, you can say that specificity is the ability to detect healthiness [14].

Therefore, it represents the fraction of true negatives. When expressed as a percentage, it represents the percentage of negative results regarding the total of healthy people, in other words, the percentage of true negatives obtained by applying the test to healthy people [7].

2.2. How a Support Vector Machine Functions (SVM)

They are a set of supervised learning algorithms, one of the most widely used methods to classify data. The basic concept is that an SVM maps the input data to an dimensional space, where it tries to find the optimal hyperplane to separate data sets. Its popularity lies in its flexibility to be used in a wide range of areas and pattern recognition problems. Its main characteristics are: the use of the nuclei, the absence of local minimums, the solution and capacity control obtained through margin optimization [10].

3. Systematic Mapping Study Method

An SMS (Systematic Mapping Study), is a method that consists of a literary investigation about an area of interest to determine the nature, scope and quantity of published primary studies, as well as give an overview of the researched area through the classification and counting of literary contributions [13].

This study follows the guidelines established in Petersen's Guidelines for conducting systematic mapping studies in software engineering. The purpose of this SMS is to answer the following research questions RQ (Research Question).

– **RQ1** Which mobile applications for skin disease care and diagnosis use artificial intelligence?

– **RQ2** What type of dermatological diseases do the identified mobile applications target?

– **RQ3** What artificial intelligence technique is applied in the development of the mobile applications?

– **RQ4** What are the overall levels of sensitivity, specificity and accuracy of the implemented diagnostic tests?

Several systematic reviews have been found in the literature where topics related to artificial intelligence techniques used by mobile applications for the diagnosis of skin diseases are addressed. Most of them focus solely on skin cancer, however, we must consider that there are other types of dermatological diseases which can be problematic due to their side effects. The aforementioned diseases lead to very serious, risky and/or expensive therapies which considerably reduce the patient's quality of life. Therefore, for the purpose of this study, research questions are posed in the context of mobile applications for the care and diagnosis of dermatological diseases in general.

3.1 Search Strategy

In order to identify keywords and formulate the search chain, the PICO strategy, (Population, Intervention, Comparison and Results) suggested in Guidelines for performing Systematic Literature Reviews in Software Engineering by Kitchen- ham [11] was used. The aim was to extract studies that help answer the research questions.

– **Population** Within the context of this study, population corresponds to the set of mobile applications for the care and diagnosis of dermatological diseases for which the following keywords were selected: "apps" OR "mobile applications" OR "dermatology apps" AND "smartphone".

– **Intervention** Management or intervention of interest for this study to constitute the artificial intelligence technique used for the mobile applications, keyword: "artificial intelligence".

– **Comparison** No empirical comparison is made, there is no alternative intervention to compare, although the same is not always available, so this component is omitted and the PICO strategy becomes PIO.

– **Outcome** It is the relevant consequence of interest. The expected result is skin care, keywords: "skin care" OR "dermatology".

The sources used for the selection of the primary studies were the following digital bases: IEEE Xplore, Scopus, SpringerLink, Web of Science and MED- LINE, MEDLINE can be accessed via PubMed Central. The period of time considered for searching in the digital bases is from 2012 to 2019. 2012 was chosen because an article had been published in that specific year describing a mobile hardware / software system (DERMA / Care) which helps detect skin cancer [10]. For each base the following search string was defined:

– **IEEE Xplore** ((“apps” OR “mobile applications” OR “dermatology apps”) AND (“skin care” OR “dermatology”) AND (“smartphone”) AND (“artificial intelligence”))

– **Scopus** ALL((“apps” OR “mobile applications” OR “dermatology apps”) AND (“skin care” OR “dermatology”) AND (“smartphone”) AND (“artificial intelligence”))

– **SpringerLink** ALL((“apps” OR “mobile applications” OR “dermatology apps”) AND (“skin care” OR “dermatology”) AND (“smartphone”) AND (“artificial intelligence”))

– **Web of Science** TS=(“apps” OR “mobile applications” OR “dermatology apps”) AND TS=(“skin care” OR “dermatology”) AND TS=(“smartphone”) AND TS=(“artificial intelligence”)

– **MEDLINE via PUBMED Central** ((“apps” OR “mobile applications” OR “dermatology apps”) AND (“skin care” OR “dermatology”) AND (“smartphone”) AND (“artificial intelligence”))

In Table 1 you can see the studies found according to the Library Catalog.

Database	**Search results**
IEEE Xplore	11
Scopus	76
SpringerLink	33
Web of Science	4
PUBMED Central	16
Total	143

Table 1. Number of studies per database

3.2. Study Selection

The snowball method was used for the selection of the studies in the digital bases. Only studies corresponding to journal articles and conference articles were extracted, thus ensuring that they have been reviewed by peers. Inclusion criteria (IC) and exclusion criteria (EC) were defined to select relevant articles in the literature that are relevant to the research questions [8].

The following inclusion criteria were applied to titles and abstracts:

– **IC1** Studies whose content refers to mobile applications for the care and diagnosis of skin diseases.

– **IC2** Studies in which the application of artificial intelligence techniques in mobile applications has been identified.

– **IC3** Studies in which dermatological diseases that can be treated or diagnosed with the use of a mobile application are mentioned.

– **IC4** Studies in which reference is made to the levels of sensitivity and specificity of the diagnostic test, or the level of confidence and accuracy of the classifier.

The following criteria state when a study was excluded:

– **EC1** Studies in which the use of a mobile application is not identified.

– **EC2** Studies that do not provide information about the artificial intelligence technique used.

– **EC3** Studies that do not focus on dermatological diseases.

– **EC4** Studies that do not determine any level of sensitivity, specificity or accuracy of the diagnostic test.

The preliminary investigation resulted in 143 relevant results. To reach this result, the search focused on finding keywords the in the titles, abstracts and sections of the introduction respectively. Of the 143 studies found, 105 studies were downloaded, and 38 articles were discarded, of which 11 were duplicated, 1 was in another language and 26 corresponded to conference summaries. To carry out this activity, an open-source bibliographic manager was used, which permitted the collection, administration and citation of research. This software automatically detects bibliographic sources and imports data directly from web pages. The details of the studies found and downloaded are shown in Table 2.

Database	Found	Duplicates	Summaries	Other Language	Pre-selected
IEEE Xplore	11		2		9
Scopus	76	2			74
SpringerLink	33	1	20	1	11
Web of Science	4	3			1
PUBMED Central	19	5	4		10
Total	143	11	26	1	105

Table 2. Number of pre-selected and downloaded articles

3.3. Data Extraction

From the total amount of publications extracted from the digital bases (105 preselected), it was necessary to extract the relevant information to determine the number of studies that met the inclusion criteria and could answer the research questions. The bibliographic manager allowed the extraction of the relevant information from each publication and generated a report with the data shown in the Table 3:

Data Item	Value
Type	Type of article, conference article or journal article.
Author	Names of the authors of the document
Date	Date of document
DOI	Digital Object Identifier.
Lybrary Catalog	DataBase where the article is hosted.
Conference	Conference Name
Abstract	Article Summary
Short Title	Added
Date	Date where the article was hosted in database.
Modified	Date of last update
Tags	keywords

Table 3. Data extraction form

3.4. Analysis, Classification and Selection

After reading and analyzing the abstracts of the pre-selected articles from the previous phase, those whose content were relevant to the research questions were selected. The Table 4 shows the number of articles selected according to the digital base:

Database	Pre-selected	Selected
IEEE Xplore	9	2
Scopus	74	6
SpringerLink	11	1
Web of Science	1	0
PUBMED Central	10	0
Total	105	9

Table 4. Selected Articles

3.5. Study Quality Verification

The studies which could answer the research questions were selected and verified using the following quality verification criteria (VC):

– **VC1** Does the selected study contribute to answering the research questions?

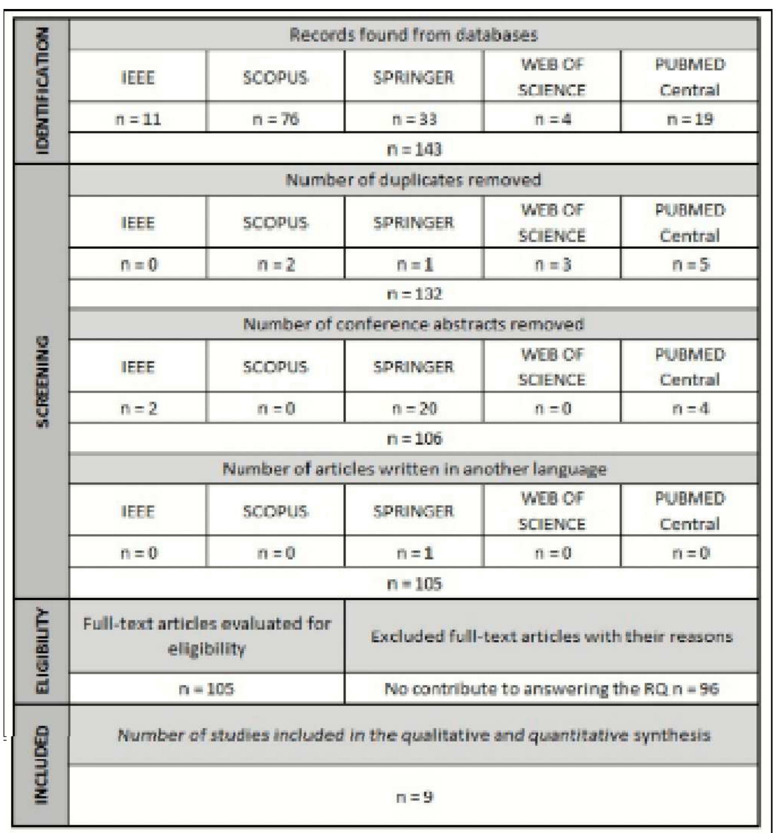

Figure 1. Adapted version of the PRISMA model

– **VC2** Does the selected study contain references to studies published in journals, conferences or congresses?

– **VC3** Is the study based on research?

– **VC4** Is there a clear statement of the research's objectives?

– **VC5** Is there a clear statement of the results?

– **VC6** Is the selected study written in the English language?

4. Results

Figure 1 describes the process that was followed to select the studies using the eligibility criteria previously specified. In the graph, a modification is made to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta- Analyzes) flow chart. Said flow chart establishes the proper practices for reporting the results of a search for systematic reviews [12], and has been applied to the selection of articles in this study.

No.	Title	Author	Year
1	DERMA/Care: An advanced image processing mobile application for monitoring skin cancer	Karargyris, A.; Karargyris, O.; Pantelopoulos, A.	2012
2	m-skin doctor: A mobile enabled system for early melanoma skin cancer detection using support vector machine	Taufiq, M.A.; Hameed, N.; Anjum, A.; Hameed, F.	2017
3	Facial skin image classification system using Convolutional Neural Networks deep learning algorithm	Chin, C.; Chin, M.; Tsai, T.; Chen, W.	2018
4	Smartphone applications for triaging adults with skin lesions that are suspicious for melanoma	Chuchu, N.; Takwoingi, Y.; Dinnes, J.; Matin, R.N.; et al.	2018
5	Accessible Melanoma Detection Using Smartphones and Mobile Image Analysis	3cmDo, T.-T.; Hoang, T.; Pomponiu, V.; Zhou, Y.; Chen, Z.; Cheung, N.-M.; Koh, D.; Tan, A.; Tan, S.-H.	2018
6	A Mobile Application for Early Detection of Melanoma by Image Processing Algorithms	Alizadeh, S.M.; Mahloojifar, A.	2019
7	Deep Neural Network Based Mobile Dermoscopy Application for Triaging Skin Cancer Detection	Ech-Cherif, A.; Misbhauddin, M.; Ech-Cherif, M.	2019
8	Artificial Intelligence in Skin Cancer	Reiter, Ofer; Rotemberg,Veronica; Kose, Kivanc; Halpern, Allan C.	2019
9	Skin cancer diagnostics with an all-inclusive smartphone application	Kalwa, U.; Legner, C.; Kong, T.; Pandey, S.	2019

Table 5. Publications per Author and Year

The year 2012 was used as the starting point for the search of articles in the bases. This year was chosen because it is the year in which the first publication is registered referring to a mobile application that used artificial intelligence techniques in its development. In Table 5 the selected studies along with their title, author and year of publication is presented.

In Table 6 the articles selected according to their type of study and the reference is presented.

From the total articles selected, 44% (n = 4) are conference articles, while 56% (n = 5) correspond to articles published in peer-reviewed and indexed journals. The details are shown in Figure 2.

Figure 3 demonstrates that 2019 and 2018 are the years when more publications were made about mobile applications which use artificial intelligence techniques.

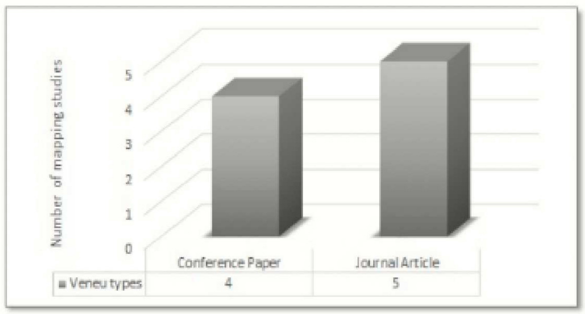

Figure 2. Number of mapping studies

Item Type	**Reference**
Conference Paper	[2,3,6,10]
Journal Article	[4,5,9,15,16]

Table 6. Venue types

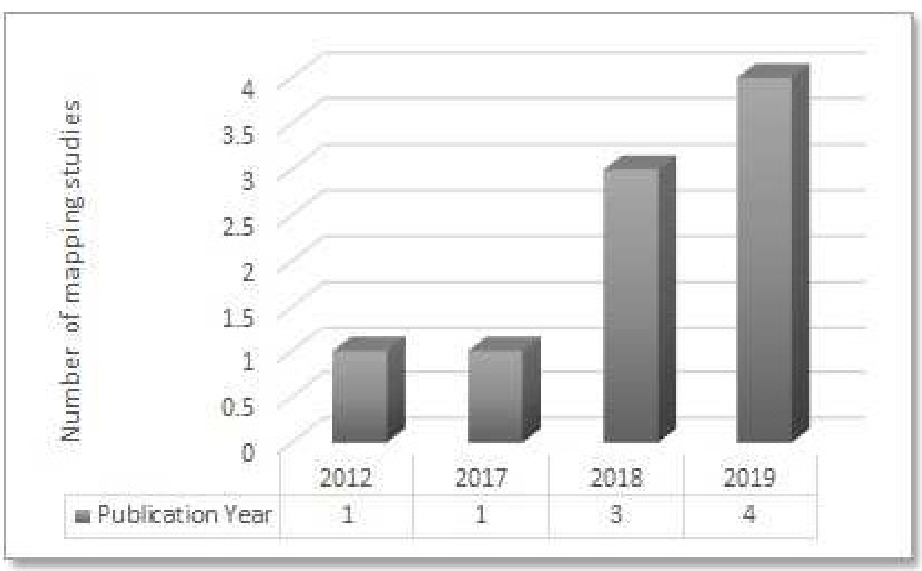

Figure 3. Publications per year

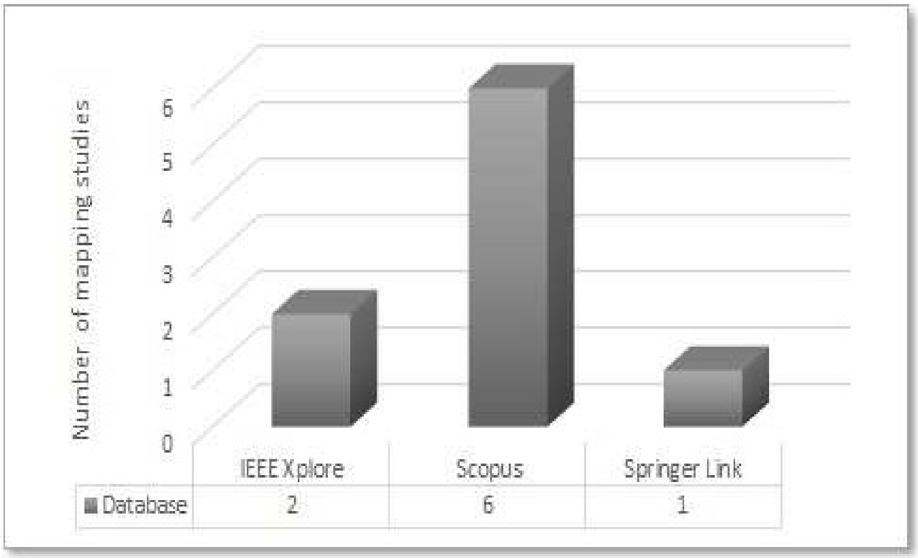

Figure 4. Publications per database

44% (n = 4) of these articles were published in 2019, 33% (n = 3) of these articles were published in 2018, 11% (n = 1) in 2017 and 11% (n = 1) in 2012 where the first mobile application with artificial intelligence has been registered. Figure 4 shows the distribution of publications according to the digital base.

The most used research protocol is design science, 78% (n = 7) of primary studies refer to the development of dermatological mobile applications; in cases of studies, 11% (n = 1) corresponds to the applicability of an existing application; and 11% (n = 1) is a systematic review of literature.

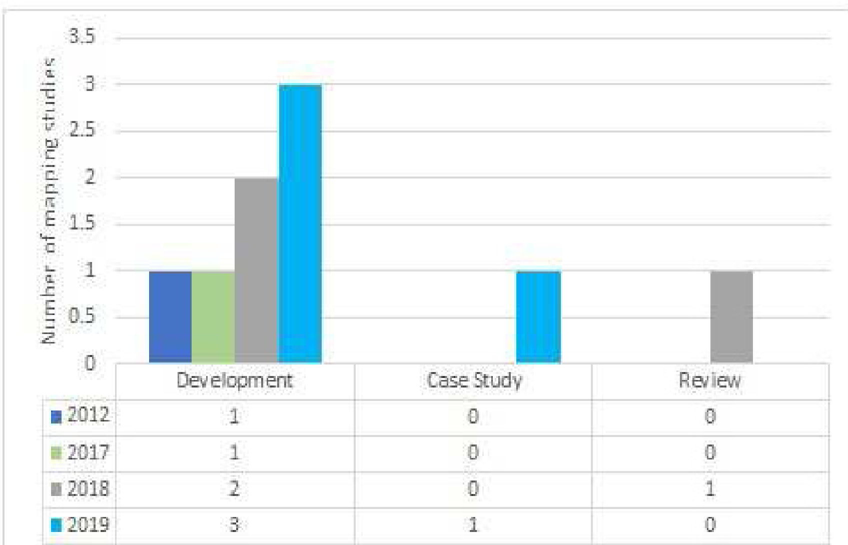

Figure 5. Distribution of primary studies per year and proposal

5. Discussion

This section analyzes the information of the articles extracted in the previous phase to answer the research questions, based on full text reading. The following applications have been found.

A mobile application called DERMA /care was developed in 2012 for melanoma detection. It uses image processing through a Support Vector Machine. No sensitivity levels or specificity are detailed, but it is mentioned in this study due to being the first study found which uses artificial intelligence techniques [10].

A recent systematic review found very little information based on the evidence of the effectiveness of mobile applications for dermatology. Two studies were identified, both at high risk of bias, which tested four diagnostic applications of melanoma. The sensitivity ranges from 7% to 73% and the specificity from 37% to 94%. The authors concluded that these applications for smart phones have not shown sufficient proof of their accuracy and the existing data [15,4].

Another study found that an all-inclusive mobile app was developed for the diagnosis of melanoma. This app uses a Support Vector Machine (SVM) with a public database of 200 images. Using the Synthetic Minorities Oversampling Technique of Ethnicity (SMOTE) obtained 80% sensitivity, 90% specificity, 88% accuracy and 85% area under curve (AUC) and without SMOTE it obtained 55% sensitivity, 95% specificity, 90% accuracy and 75% AUC. The performance metrics and calculation times evaluated are comparable to or better than the previous methods [9].

In another study, a mobile application is implemented for the early detection of melanoma employing real-time image processing algorithms along with a normal Bayesian classifier. The lesions may be classified by using a Support Vector Machine (SVM) as well, using a base of 150 images (90 for training and 60 for testing). This method obtains results for accuracy, sensitivity and specificity of 95%, 98%, and 92.19% on average, respectively. It should be taken into account that these results are more reliable when the lesions are geometrically different [2].

Another study implements an application with a set of image data provided by the National Skin Center - Singapore (117 benign and 67 malignant). In this study the effectiveness of the proposed system for detection of melanoma is confirmed with 89.09% sensitivity in comparison to 90% specificity of a SVM [5].

m- Skin Doctor is an application that uses VSM for classification with 84 images of melanoma and non-melanoma that were used in equal amounts to train the SVM and another 36 images in equal proportions of melanoma and non-melanoma images were used for the test. This resulted in a sensitivity and specificity of 80% and 75% respectively [16].

Another mobile application based on a deep learning algorithm of a convolutional neural network was found. It uses a data set of 300 images of which 80% of the images are for training and 20% of the images are for testing. 3 types of model were used in the development process, with 2, 3 and 5 layers convoluted respectively. These resulted in an overall pressure of 87% for model 1, 93% for model 2 and 86% for model 3 which is the most commonly used CNN [3].

Lastly, an application for the diagnosis of skin cancer was found. Said application uses a data set of 48,373 dermoscopic images which were collected from three different files and labeled and validated by dermatologist experts. A convolutional neural network model called MobileNetV2 is trained manually using learning transfer in order to classify skin lesions as benign or malignant. After singing the 32-lot size, the trained model obtained results with a global accuracy of 91.33%. No sensitivity and specificity levels are reported [6].

6. Conclusions

Smartphone applications in the field of dermatology are becoming increasingly important. They can be particularly effective for reaching a large number of people and improving their daily habits, but it is crucial to know if these applications represent a risk if they aren't able to make adequate diagnoses especially when it comes to serious diseases. On the other hand, it is necessary to mention that improvements have been made in the development of these applications thanks to techniques such as artificial intelligence, deep learning, and vector support machine. These tools have raised the level of confidence in classifi ers, provided faster calculation speeds and improved the results. In conclusion, it can be said that these artificial intelligence techniques in mobile applications help considerably in making diagnostic decisions with a high degree of precision. However, most of these applications are still under development and available only for a limited number of diseases. Likewise, it has been proven that advances in smartphone applications have improved health sciences, created awareness of the importance of a healthy lifestyle and greatly contributed to shorten the gap between doctor and patient.

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