

OncoVision

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1 PROJECT CONTEXT

Addressing health-related issues represents the next frontier of artificial intelligence. Regarding the healthcare context, several attempts have already been conducted to develop machine learning solutions, genetic algorithms and others. For instance, in the Aravind Eye Care System in India, ophthalmologists and computer scientists are working together to test and deploy an automated image classification system to screen millions of retinal photographs of diabetic patients. Since the mid-twentieth century, researchers have proposed and developed many clinical decision-support systems to help physicians. Rule-based approaches were proposed in the 1970s that allow us to:

- (1) diagnose diseases;
- (2) choose appropriate treatments;
- (3) provide interpretations of clinical reasoning;
- (4) assist physicians in generating diagnostic hypotheses in complex patient cases.

It seems a good approach but it presents several problems, such as:

- (1) it is costly to build;
- (2) it requires explicit expressions of decision rules and require human-authored updates;
- (3) it is difficult to encode higher-order interactions among different pieces of knowledge authored by different experts;
- (4) the performance of the systems is comprehensible only by a medical knowledge;
- (5) it was difficult to implement a system that integrates deterministic and probabilistic reasoning to narrow down relevant clinical context, prioritize diagnostic hypotheses, and recommend therapy.

Instead, recent AI research has leveraged machine learning methods, which can account for complex interactions, to identify patterns from the data. Moreover, machine-learning methods enable the development of AI applications that facilitate the discovery of previously unrecognized patterns in the data without the need to specify decision rules for each specific task [5]. Therefore, the main goal of an AI system in Medicine is to help the physicians in the clinical process, namely detect something, cluster the patient on some criteria, etc. On the other hand, AI systems pose new risks

for medicine. Failures in medical AI could erode public trust in Healthcare. For example, bias in AI can deliver erroneous medical evaluations. Moreover, AI models magnify existing cyber-security risks, potentially threatening patient privacy and confidentiality. In general, in a software project, we need three types of expert groups:

- the group developing the algorithm;
- a group of validators;
- the operational staff.

These groups are also needed in the healthcare sector to overcome the following 3 key challenges in AI:

- Conceptual challenges in formulating a problem that AI can solve;
- Technical challenges in implementing an AI solution;
- Humanistic challenges regarding AI's social and ethical implications.

Furthermore, the incapability to address these challenges could erode public trust in medical AI, which could in turn undermine trust in Healthcare institutions themselves. In the end, unlike physicians, AI cannot draw upon "common sense" or "clinical intuition" but using good data and the correct AI model configuration, we can obtain a good performance [3]. In this project we will focus on skin cancer, that is melanoma. Melanoma is a malignancy of melanocytes, which are pigment-producing cells of neuroectodermal origin that can be found throughout the body (including in the skin, iris and rectum). The cutaneous form of the disease is common in the Western world causing the majority (75%) of deaths related to skin cancer, in fact, its global incidence is 15–25 per 100,000 individuals. Survival rates in patients with melanoma (cumulative for all forms) have shown huge differences between countries in Europe, ranging between <50% in Eastern Europe to >90% in northern and central Europe for 5-year survival after primary diagnosis [4]. Figure 1 shows the incidence and mortality of cutaneous melanoma in the world. In accordance with Istituto Superiore di Sanità, the general melanoma diagnosis process is the following: the patient will conduct a dermoscopic examination and if the doctor has some suspects, he takes a skin sample in order to conduct histological analysis and then formulate the diagnosis. The biggest problem with this cancer type is a lack of early detection that does not allow therapy to treat the disease on time. That is why we decided to develop a melanoma detection AI system to help physicians with this disease. We have compared the performance obtained by our model with the proposed one by Di Biasi et al [2].

1.1 Related project

Di Biasi et al. proposed a system that combines Genetic Algorithms (GAs) with Convolutional Neural Networks (CNNs) to detect melanoma. They used GA for improving the architecture of CNN. Indeed, they defined a population of neural networks (NN) that are codified in vectors where each vector element represents a type of layer or pre-processing routine. Whereas for the hyperparameters of each individual, they fixed them to these values: 'sgdm', 'MaxEpochs', 16, 'MiniBatchSize', 12, 'Shuffle', 'every-epoch',

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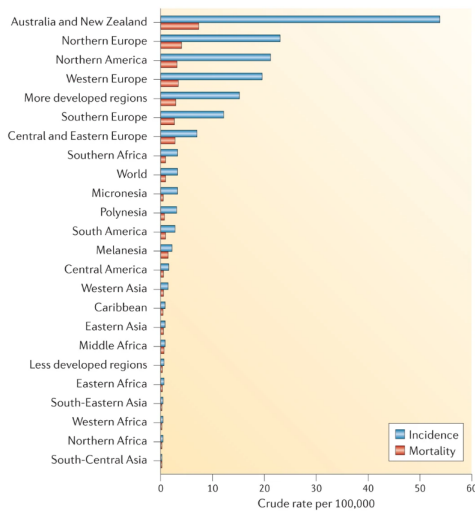


Figure 1: Incidence and mortality of cutaneous melanoma[4]

'InitialLe-arnRate', 0.0001, 'ExecutionEnvironment', 'auto'.

The authors defined the following constraints to the Genetic Algorithm in order to obtain a correct population of NN at each evolution step:

- The first gene of each entity must be an image input (II) or one of the pre-processing routines;
- If the gene q is a pre-processing routine, then the gene $q + 1$ must be a II layer or another pre-processing layer;
- The latest gene of an entity must be a classification layer.

Furthermore, they forced the possible values that the genes of an individual can assume in this range: *Convolution, ReLu, Cross Channel Normalization, Max Pooling Grouped Convolution, Fully Connected Layer, Dropout and Softmax.*

The authors stopped the GA when no accuracy improvement was detected for ten consecutive evolution steps or after 100 evolutionary steps. In conclusion, their dataset is composed of skin images and it is divided into two classes: melanoma (positive class) and moles (negative class). The number of instances for the positive class is 70 and 100 for the negative class.

2 PROJECT GOALS

In this work we will reply to the following research questions:

RQ₁: *What are the limitations of the selected approach?*

We have decided to investigate this aspect to understand problems that afflict the selected approach to develop a better model. The results of this **RQ** influence the input of **RQ₃** because we are going to try to define a model that is less affected by these problems.

RQ₂: *What are the most useful data types and what are the data problems in the melanoma domain?*

We have decided to investigate this aspect to understand which are the relevant data types to train the model for melanoma detection and which are the problems with the data. The results of this **RQ** influence **RQ₄** because based on data problems, we can identify the techniques to improve their quality. Moreover, this **RQ** influences **RQ₁** because we can understand if the detected problems are also in the existing approach.

RQ₃: *How to improve melanoma detection model performance?*

We have decided to investigate this aspect because, based on the results of the other **RQs**, we can understand which are the changes to apply to the model to improve performance.

RQ₄: *How to raise the data quality?*

We have decided to investigate this aspect to understand which are the useful techniques for improving data quality to highlight relevant features that the model will learn for making more precise predictions.

Based on the previous research questions, we have defined the following project goals:

- (1) Conduct a detailed investigation of the baseline approach selected from the literature to understand the performance of the approach and its limitation;
- (2) Understand the problems related to the datasets, namely lack of relevant features, few samples, etc;
- (3) Definition of an AI pipeline that might be used for cancer detection and is not affected by the problems which the baseline approach selected from the literature suffers.

Our project is available on GitHub at this link: <https://github.com/Rocco000/OncoVision>

3 DETAILS OF THE CHOSEN MODEL

In this study we decided to use Convolutional Neural Network (CNN) because it represents various benefits. Before all, we must first explain how it formed and how it works. CNN is a classic artificial neural network (ANN) with input, hidden and output layers. The input layer has the role to propagate the input in the network, instead, the output layer has the role to provide the prediction of the model. Each layer can contain one or more neurons that are linked with some neurons of the previous layer and each link has an associated weight. Every neuron calculates its activation like a weighted sum of its input and then added a bias value. After which, it applies an activation function to the obtained value. CNN has an important feature which is the convolutional layer. As stated in the paper by Kun-Hsing Yu et al.[5], this type of layer is useful for extracting spatial or temporal relations in an image and allows us to summarize and transform clusters of image pixels to extract high-level features. Moreover, according with Albawi et al [1], CNN has these benefits:

- (1) The assumption about problems that are solved by CNN is that the problems have no spatially dependent features, therefore, it provides an opportunity to detect and recognize

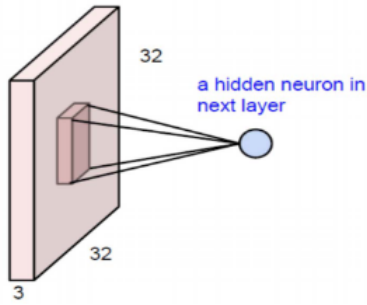


Figure 2: Example of how CNN hidden layer's neuron is responsible for a local region in the picture

features regardless of their positions in the image. For example, in face detection, we do not need to pay attention to where the faces are located in the images;

- (2) Each layer can detect a particular feature when input propagates toward the network. For example, the first layer detects the edges, the second detect shapes, etc;
- (3) It can reduce the number of parameters to improve the computational complexity of the training process.

To understand the third point we can use an image detection problem as an example. Consider an image $32 \times 32 \times 3$ as input. If we use classic ANN, for connecting the input layer with a hidden layer's neuron we need $32 \times 32 \times 3$ weight connections and this number must be multiplied by the number of neurons in the hidden layer. This amount of parameters is required only to connect the input layer with the hidden layer's neurons! Instead, in the convolutional neural network, each neuron in the hidden layer is responsible for an image local region as shown in Figure 2. It means that a neuron of the next layer can only get input from the corresponding part of the previous layer (i.e. the neuron is connected only with specific neurons of the previous layer). For example, it can only be connected to 5×5 neurons. Therefore, if we want 32×32 neurons in the next layer, we will have $5 \times 5 \times 3$ by 32×32 connections, which is 76,800 connections compared with 3,145,728 in ANN. Another assumption for simplification; is to keep the local connection weights fixed for the entire neurons of the next layer. This will connect the neighbour neurons in the next layer with exactly the same weight to the local region of the previous layer. With this assumption, the layers are similar to a window of $5 \times 5 \times 3$ sliding on input neurons and mapping the generated output to the corresponding place. For this reason, this type of layer is named convolutional and it looks like a filter in image processing. Therefore, each layer can be associated with different filters. The network architecture and the configuration of the training algorithm hyperparameters have been defined by the genetic algorithm output described in Section ??.

3.1 PEAS Specification

The problem that we have treated has the PEAS specification that is shown in Table 1.

Performance	For evaluating our model, we used these metrics: accuracy, recall, precision and F1-score. In particular, we will focus on recall because we need to minimize the number of false negatives.
Environment	Our model operates in an environment that has these features: <ol style="list-style-type: none"> (1) Fully observable: because the sensors provide our model full environment state; (2) Static: because the environment doesn't change after an action that our model did or during the time; (3) Discrete: because the environment limits the perceptions and actions of our model; (4) Episodic: because an action that our model did, is independent of the previous actions; (5) Single-agent
Actuators	The model interacts with the environment through the standard output of the machine
Sensors	The model can receive the environment input through the standard input of the machine

Table 1: PEAS Specification

4 METHODOICAL STEPS

Based on the goals set defined in Section 2, the methodical steps that we have conducted to address it are:

- Define a survey for physicians who are experts on cancer disease to understand data problems, [data types that are useful for defining a good model and how to measure data quality](#). We conducted this step by using Google Forms;
- Re-implement the existing approach because its source code is not available. We need to do this in order to compare our model performance with the performance of the existing approach;
- Investigate some image processing techniques that are useful to improve data quality, [like contrast and brightness improvement techniques](#). We chose other techniques based on survey results and all of these are implemented directly in the model;
- Search one or more new datasets in order to train and test our model and test the existing approach. We conducted these researches by using Kaggle;
- Develop three genetic algorithms (GAs) that produce a population of convolutional neural networks (CNNs) that are optimized from three points of view:
 - The goal of the first one is to improve the hyperparameters of the network;
 - The goal of the second one is to improve the architecture of the network. After that, we selected the best individual and applied the Grid Search algorithm on it in order to improve hyperparameters;

- The goal of the last one is to improve both hyperparameters and the architecture of the network.

At the end of each Genetic Algorithm, we will select the best individual in the last population obtained based on the evaluation metrics. For developing these alternatives we used Python and its libraries.

Finally, we compared the results obtained by our models with the results of the baseline approach selected. Figure 3 summarizes the methodical steps that we conducted.

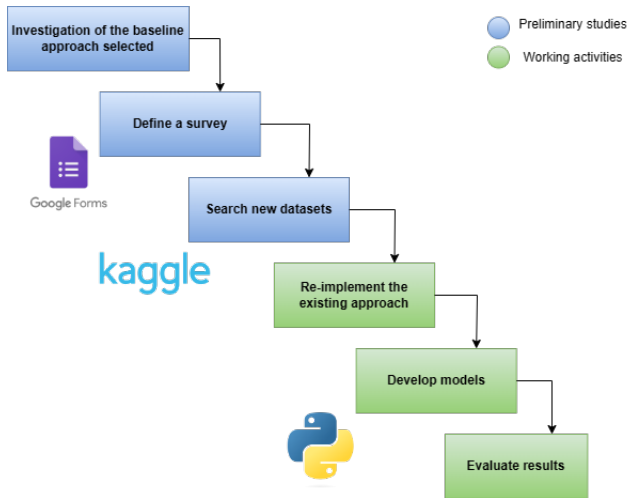


Figure 3: Methodology

4.1 Data Collection

After a preliminary analysis of the existing project, we observed that this project uses a very small dataset, composed only of 170 images. Generally, a deep learning (DL) model needs a lot of training data for good performance. That is why we have researched new data. On **Kaggle** we have found several datasets related to the skin cancer problem. We chose two datasets with which we tested the selected approach and trained our models:

- The first one, available at this link, has 10000 images divided into test and train. Each folder contains two sub-folders named *benign* and *malignant* that contains the negative and positive instances respectively.
- The second one is available at this link. Also in this case there are 10000 images, but they are classified into more category groups. Moreover, there are two folders that contain all the images and csv file named *HAM10000_metadata* that report the matching between the image ID and the related category of problem. The categories are:
 - **akiec**, Actinic keratoses and intraepithelial carcinoma / Bowen's disease;
 - **bcc**, basal cell carcinoma;
 - **bkl**, benign keratosis-like lesions such as solar lentigines / seborrheic keratoses and lichen-planus like keratoses;
 - **df**, dermatofibroma;
 - **mel**, melanoma;

- **nv**, melanocytic nevi;
- **vasc**, vascular lesions such as angiomas, angiokeratomas, pyogenic granulomas and haemorrhage

Therefore, in this case, we need to collapse these different categories into two classes. We did this after we conducted some research to verify if each class is benign or malignant.

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