Detection of brain tumours with the use of AI

Capstone Project Proposal
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Assessment Cover Page

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Introduction (178 words)

This project addresses the use of artificial intelligence applied to medical imaging for the detection of brain tumours. The aim is to investigate and apply the best CNN model to detect and classify various brain tumours more accurately by achieving the highest probability of the model being correct. This document shows the complete process of data collection, model development and analysis of results. In addition, concepts about CNNs are explained for the understanding of the development of the system.

- Manual analysis of MRI scans for brain tumour detection is a complex and error-prone process, due to the variability of tumours and brain structures. In this study, the use of different CNN models to perform automatic brain tumour detection in medical images will be explored. Pre-trained models, such as VGG16, EfficientNetV2B3, and custom models creating a new CNN will be considered, and their performance on a problem-specific dataset will be evaluated. The use of pre-trained models allows taking advantage of prior knowledge acquired on large datasets, such as ImageNet, and adapting it to the brain tumour detection task.

Objectives (246 words)

The main objective of this project is to develop and evaluate a brain tumour detection system using Convolutional Neural Networks (CNN) and machine learning techniques. To achieve this goal, the following specific objectives are established:

- Collect and prepare a suitable dataset: a set of magnetic resonance imaging (MRI) medical images containing both positive cases of brain tumours and negative cases of normal brain tissue will be sought to be obtained. A pre-processing process of the images will be carried out to ensure their quality and homogeneity.

- Design and develop different CNN models: Several CNN models, including pre-trained models and customised sequential models, will be implemented in order to explore different architectures and approaches for brain tumour detection.

- Train and tune CNN models: A training process of the models will be carried out using the prepared dataset. The hyperparameters of the models will be adjusted to obtain the best possible performance.

- Evaluate and compare the models: A thorough evaluation of the trained models will be performed using appropriate performance metrics. The results obtained by the different models will be compared to determine which one is the most effective in brain tumour detection.

- Analyse the results and draw conclusions: A detailed analysis of the results obtained will be carried out and the effectiveness of the CNN models evaluated will be discussed. Conclusions will be drawn on the feasibility and applicability of machine learning techniques in the detection of brain tumours in medical images.

Problem definition (165 words)

A brain tumour is an accumulation or mass of abnormal cells in the brain. The skull, which encloses the brain, is very rigid. Any growth within such a restricted space can cause problems. Brain tumours can be cancerous (malignant) or non-cancerous (benign). When benign or malignant tumours grow, they can increase pressure inside the skull. This can cause brain damage and be life-threatening. The system used for the study is designed to classify medical images according to four categories:

- Non-tumour
- Glioma
- Meningioma
- Pituitary

The problem is to develop a brain tumour detection system using Convolutional Neural Networks that is able to correctly classify brain tumours. In addition, the aim is to determine which CNN model and which image pre-processing techniques are most effective for this particular problem.

By addressing this problem, it is hoped to improve the early and accurate detection of brain tumours, which can contribute to faster diagnosis, more effective treatment and a better quality of life for patients.

Scope (73 words)

The scope of the project focuses on the development and evaluation of CNN models for the detection of brain tumours in medical magnetic resonance images. Different CNN models, image pre-processing techniques and machine learning approaches will be considered.

The project is carried out using machine learning and image processing tools and libraries, such as TensorFlow and Keras. A publicly available dataset on the Kaggle platform is used. The programming language used is Python.

Methods (2033 words)

To carry out this project, various technologies and tools have been used to achieve the objectives of image classification.

The programming language selected is Python, as it is the standard in the world of artificial intelligence and has abundant libraries and frameworks for the development of deep learning tools.

- Libraries and Frameworks used

NumPy: Fundamental library for numerical computation in Python. It is widely used in manipulating matrices and tensors, which are essential data structures for training machine learning models. It is used when importing data to convert it into simpler matrices to work with when training models.

Matplotlib: 2D plotting library that allows visualisation of data and model results. Can be used to create graphs, scatter plots, histograms and more.

Scikit-learn: Widely used library for machine learning in Python.
It provides a variety of machine learning algorithms, evaluation metrics and data preprocessing tools that can be used in combination with Keras. Used to import the function to create the confusion matrix and accuracy report.

TensorFlow: Open-source machine learning library developed by Google.
Keras can run on top of TensorFlow as a backend, allowing you to take advantage of all the capabilities of TensorFlow along with the ease of use and flexibility of Keras.

Keras: High-level neural network library written in Python. It provides a simple and modular and modular interface for building and training deep learning models. Keras integrates seamlessly with TensorFlow as a backend, allowing you to leverage the power of TensorFlow while benefiting from the simplicity of Keras. Keras simplifies the process of designing and developing deep learning models by providing pre-defined layers, activation functions, optimisers and common metrics.

Seaborn: Data visualisation library based on Matplotlib. Seaborn provides a
high-level interface for creating attractive and informative statistical graphics. It is used in this case to display confusion matrices in colourful graphs to make it more visual.

- <u>Tools used</u>

Anaconda: Anaconda is a data science and software delivery platform that is widely used in the field of data science and machine learning. It provides a comprehensive development environment that includes the Anaconda package manager, with which popular scientific libraries and packages can be easily installed and managed.

Anaconda also includes the Jupyter Notebook integrated development environment (IDE), which allows users to create and run interactive notebooks. One of the advantages of Anaconda is that it facilitates the management of virtual environments and compatibility with different versions of libraries and packages, which helps to avoid dependency conflicts and allows for greater reproducibility in data science projects. This one in particular has been used for local testing.

- <u>Collection and preparation of the dataset</u>

This part explains the first process of developing the system by means of the models in order to obtain the data and then process them.

Here starts the code and experimentation part.

The following code is added which represents the generation of seeds for the system:

- `tf.random.set_seed(42)`.
- `np.random.seed(42)`.

These are used to set a seed in the TensorFlow (tf) and NumPy (np) random number generators, respectively.

The seed is used to initialise the random number generator so that the same random numbers are produced for each execution of the code. This is useful to ensure reproducibility of results in machine learning projects, especially when working with algorithms that make use of random numbers, such as weight initialisation in neural networks.
Setting a seed ensures that, although the overall behaviour of machine learning algorithms may be stochastic due to randomness, the results will be consistent and reproducible across different runs.

Once the libraries and resources needed to start operating with the system have been imported, the process of obtaining the images to deal with them begins.

The Dataset is divided into Train and Test, so the Python function 'splitfolder' will be used to split Train into Train and Validation. This is done to improve the training of the models. This function is specifically designed for these cases of data processing as it splits the data balancing the images so that it does not take for example and split and in Validation only the images of Glioma, but it does it balanced and therefore there is a good sample to validate during the training.

In order to make the division between train and validation, we have chosen to do it with 80% of the data for the train and 20% for the validation, as this is what usually done in these cases and what has been studied to obtain the best accuracy.

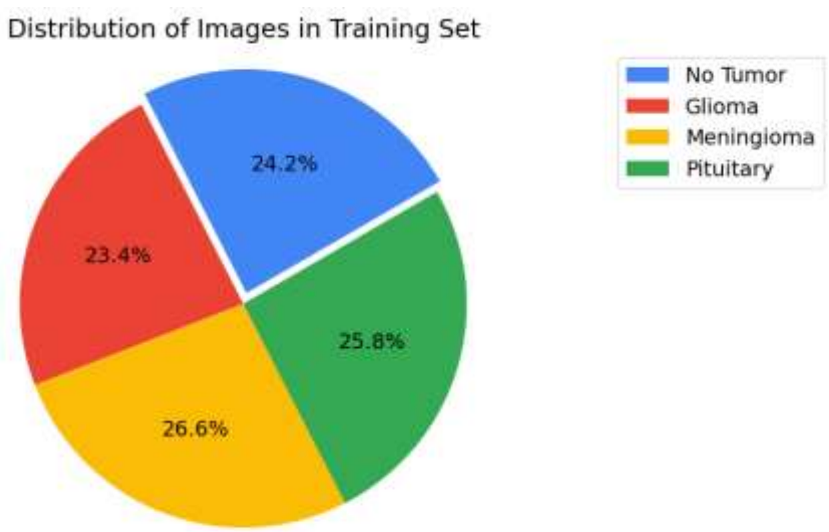

Image 1.Training set

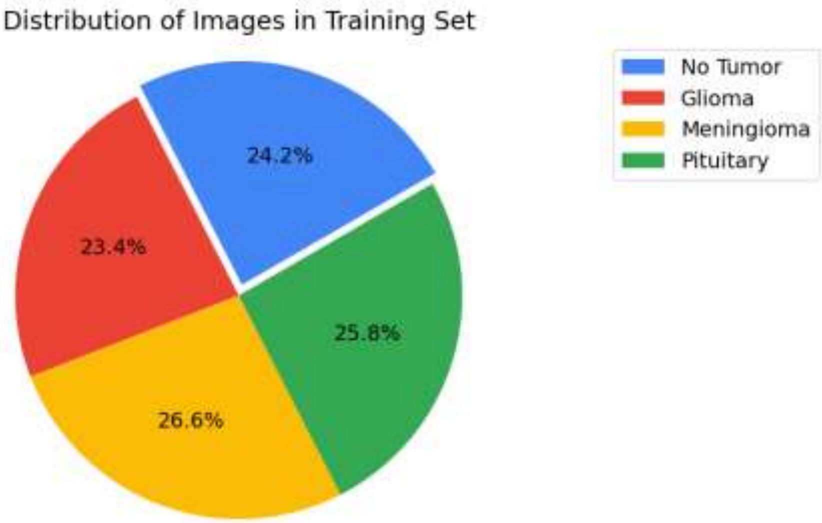

Image 2.Validation set

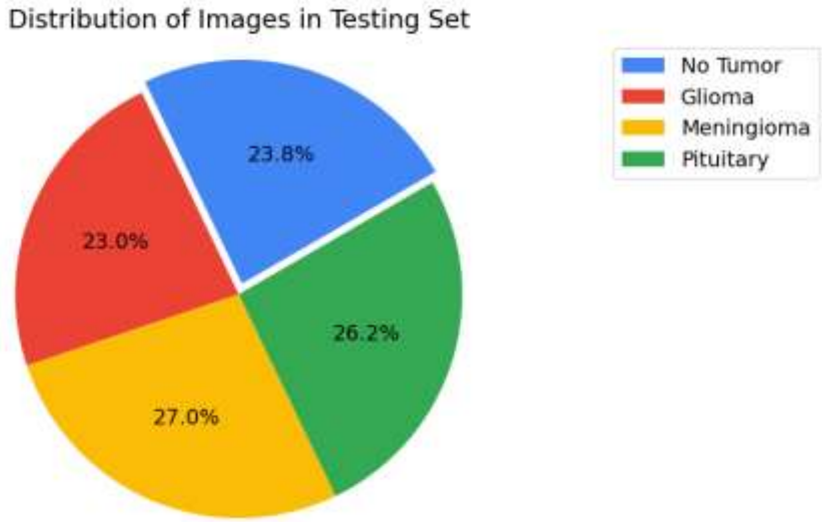

Image 3.Testing set

As can be seen in images 1, 2, and 3 the distribution of the various classes of images is well images is well balanced so that there is not too much difference and does not lead to model bias or overfitting.

Once we have the Dataset divided and balanced it is time to take the step of dealing with the images, for now nothing has been done with the images of the Dataset except to divide them into folders for further transformation and use for training.

The next step is to read the images from the folders we have and group them into variables in Python so that we can then deal with this data.

Two arrays are created for each folder, i.e. an array is created to store the Train images and another array is created to store the Train labels, i.e. the identification of each image and to know what it represents if it is a Glioma, for example.

- <u>This process is done with Train, Validation and Test.</u>

When this process is done, the size of the images is modified so that it is standard for all images and also so that the size is smaller, and the training is faster.
In this case the images are changed to 224 pixels x 224 pixels.

Once this data is loaded, the data is converted to Numpy type.

The conversion to NumPy arrays is common in machine learning projects because many machine learning libraries and algorithms are designed to work with data structures in the form of arrays or tensors. Converting data to NumPy matrices makes it easier to manipulate and process the data using the functions and methods provided by NumPy and other related libraries, such as TensorFlow or Scikit-Learn.

Furthermore, by converting the data into NumPy arrays, the efficiency and performance advantages offered by NumPy are exploited to perform mathematical operations and numerical calculations quickly and efficiently.

Once this process is done, the image tag arrays are converted into One-Hot Encoding.

- The One-hot encoding technique is used to represent categorical variables in the form of binary vectors. It consists of converting a variable that can take different categories into a numerical representation that indicates the presence or absence of each category.

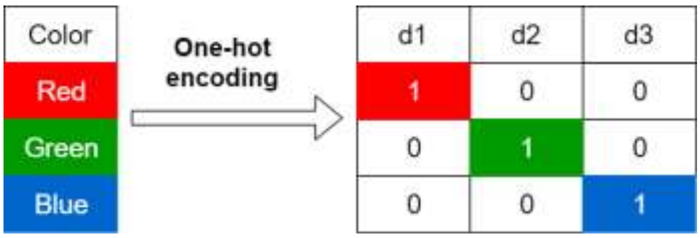

Image 4. Representation of image labels in One-Hot Encoding

As a last step in the preparation of the images, they are normalised. This serves to change the ranges of the pixel values of the images that are between 0 and 255 to a range between 0 and 1.

To perform this process, you must first have all the images in float32 format, so that you can then convert them to values between 0 and 1 by dividing by 255.

This technique is very common in Deep Learning problems, as it is more efficient to work with these values than with integers.

Once these processes have been carried out, the values of the arrays that store the images would look like this:

o Form of X_train: (4568, 224, 224, 3)
o Form of X_val: (1144, 224, 224, 3)
o Form of X_test: (1311, 224, 224, 224, 3)

The first number is the number of images it contains, the second and third are the pixels of the height and length of the image and the last one is because there are three RGB channels, which are the ones that give colour to the images.

- Model fitting and training.

In this part of the project is where several models are tested to check their performance and analyse the results to find out which one is the best suited to the problem that is being addressed with certain images.

In the end, it is a very empirical process in which many variants have to be tested and the one that best suits the problem to be solved has to be found.

The following models have been used for testing and searching for the best model to fit the problem at hand:

- VGG16
- ENV2B0
- RESNET50
- PERSONALISED SEQUENCE MODEL

These models are explained below for the understanding of these models.

- VGG16

VGG16 is a convolutional neural network (CNN) model that stands out for its deep architecture and its ability to extract complex visual features. It was developed by the Visual Geometry Group (VGG) at Oxford University. The VGG16 model consists of 16 convolutional and fully connected layers, making it a very deep model. It has been widely used in image recognition and classification tasks and has demonstrated impressive performance in visual recognition competitions.

- ENV2B0

ENV2B0 is a convolutional neural network model developed by EfficientNet, which is characterised by its efficiency and accuracy in image processing. The EfficientNet architecture is based on the idea of compound scaling, which means that it adjusts the width, depth and resolution of the network to obtain an optimal balance between efficiency and performance. ENV2B0 is the base model of EfficientNet and is commonly used as a starting point for classification and object detection tasks in images.The EfficientNet architecture is based on the idea of composite scaling, which means that it adjusts the width, depth and resolution of the network to obtain an optimal balance between efficiency and performance.

- <u>ResNet50</u>

ResNet50 is a deep neural network model that is based on the residual network architecture (ResNet). This architecture is characterised by the introduction of skip connections that allow information to flow directly through the layers, avoiding the performance degradation that can occur in deeper networks. ResNet50 has proven to be very effective in image classification and object detection tasks and is widely used in the machine learning community.

- <u>Custom Sequential Model</u>

A custom sequential model refers to a neural network model that has been designed and customised specifically for a particular task or dataset. Unlike predefined models such as VGG16 or ResNet, a custom sequential model involves a custom-designed architecture, where convolutional layers, clustering layers, fully connected layers and output layers can be added as required. This customisation allows the model to be tailored to the specific requirements of the problem and to obtain optimised performance for the task at hand.

These models have been used for testing. In addition, two variants with different TOP Models have been used to test all of the above-mentioned models except the Custom Sequential Model in order to achieve the best result.

For models other than the Customised Sequential Model, the Transfer Learning technique was used.

- <u>Evaluation and comparison of models</u>

To check their performance, Test values are predicted and then compared with the actual Test labels to check the accuracy of the models.

Split: 80% training, 20% test.

Accuracy values obtained by training with 80% of Train data.					
Model	**Accuracy**	**Glioma**	**Meningoma**	**No tumor**	**Pituitary**
RestNet50	0.35	0.82	0.94	0.66	0.88
VGG16100	**0.82**	**0.94**	**0.85**	**0.75**	**0.72**
ENV2B0	0.29	0.00	0.75	0.00	0.25
Personalized	0.47	0.49	0.46	0.41	0.55

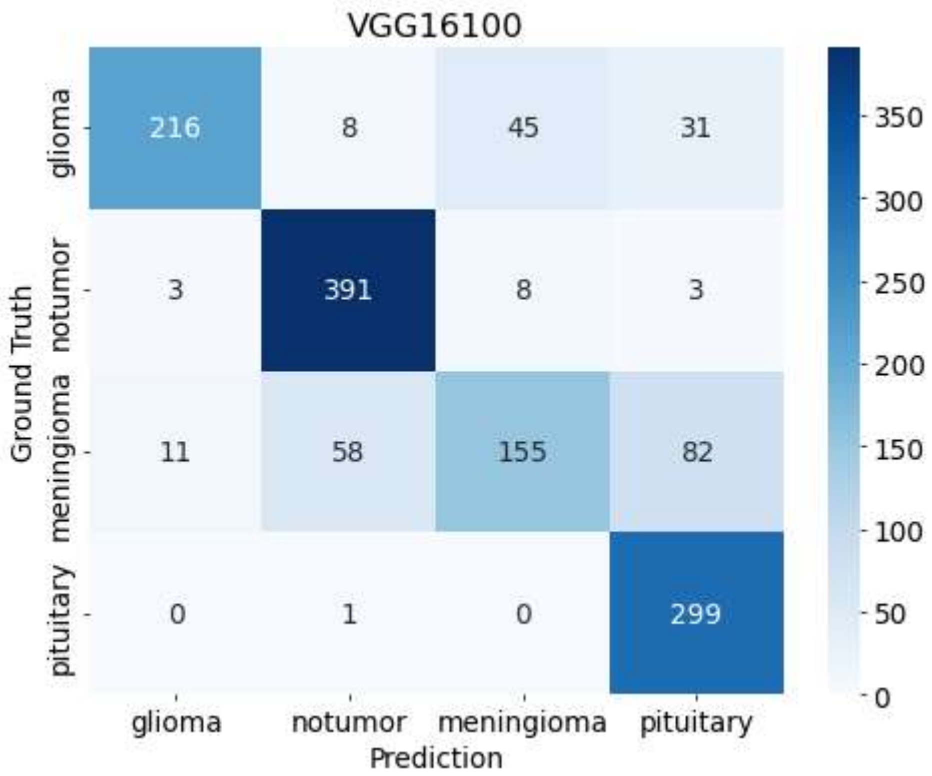

Image 5. Confusion Matrix of the best Model.

VGG16100 - Classification Report of the best result				
ENVB0	Precision	Recall	F1-score	Support
0	0.94	0.72	0.82	300
1	0.85	0.97	0.91	405
2	0.75	0.51	0.60	306
3	0.72	1.00	0.84	300
Accuracy			0.81	1311
Macro avg	0.81	0.80	0.79	1311
Weighted avg	0.82	0.81	0.80	1311

Data Source (110 words)

For the development of this tumour prediction and classification system, a Dataset from the Kaggle platform is used.

- This Dataset is a set of several Datasets in order to obtain a larger number of tests and therefore achieve a more efficient solution with a better hit rate.
- This Dataset focuses on differentiating and classifying between 'Glioma', 'Meningioma', 'Non-tumour' and 'Pituitary'. These are the four classes, and the aim is to get a high value of correct predictions by classifying these types.
- The images in this Dataset have different sizes so techniques have been applied to normalise values so that all images are treated in the same way.

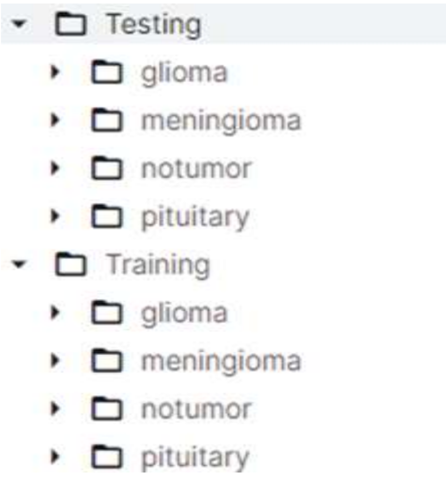

Image 6. Sample image dataset data used in this project.

Ethical Considerations (269 words)

AI development is an area that consumes a lot of resources and therefore generates a considerable carbon footprint. The image below shows how much the training of an AI model of a Transformer consumes compared to the carbon footprint of other things such as a person or a car.

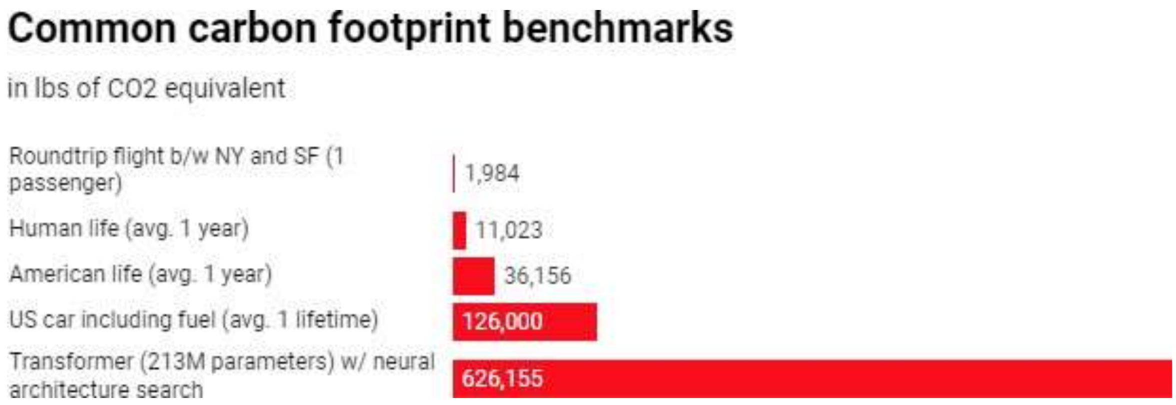

Image 7. Comparison of data on the carbon footprint impact of AIs.

As can be seen in Image 7, the training of the neural network consumes almost six times what a car consumes in its lifetime. This is something that is not appreciated when training models because it is not seen from a computer screen, or at least it does not feel like it is consuming that much.

The datasets used to train AI are getting bigger and bigger and require an enormous amount of energy to run. The MIT Technology Review reported that training just one AI model can emit as much carbon dioxide as five times the lifetime emissions of an average American car [8]. When we talk about these numbers we mean huge models, not like this particular project which is much smaller and consumes much less.

This is where AI would have to improve in order to consume fewer resources and generate less waste.

Despite the disadvantages of AI, it also has its advantages that are very important, such as the application of AI to help the field of medicine or in other aspects to improve the quality of life of people.
In this particular case, this project through AI aims to help the quality and well-being of people's lives and therefore identifies with SDG 3.

Image 8. Goal 3: Ensure healthy lives and promote wellbeing for all at all ages

Acronyms (28 words)

- CNN: Convolutional Neural Network / Convolutional Neural Network
- ENV2B0: EfficientNetV2B0
- ENV2B3: EfficientNetV2B3
- AI: Artificial Intelligence
- ML: Machine Learning
- SDGs: Sustainable Development Goals

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