
POLSKO-JAPOŃSKA
AKADEMIA TECHNIK
KOMPUTEROWYCH

**Julia Akahori**

s20936

# Alzheimer's disease detection and dementia progression prediction using Convolutional Neural Networks

MKR 2023

# 1. INTRODUCTION

Alzheimer's disease is a chronic neurodegenerative disease that affects millions of people worldwide. It is a progressive condition causing significant impairment of cognitive and behavioral functions, which is very difficult to detect at an early stage. It is the most common form of dementia, accounting for 60% to 80% of cases. Women are more frequently affected than men, and the risk increases with age, particularly between 65 and 85 years. Demographic forecasts predicting an aging population suggest a significant increase in Alzheimer-type dementia cases in the near future.

The effects of this disease impact both the patient and their surroundings, taking on both social and economic dimensions. The onset of the disease is difficult to capture, and most diagnoses are made only at an advanced stage of the disease with extensive neurodegenerative changes. Early treatment can slow the progression of dementia, likely by increasing the so-called cognitive reserve. In the early stages of the disease, intellectual stimulation, variety of stimuli, and high social and physical activity can inhibit cognitive and functional impairment. Therefore, it is extremely important to diagnose Alzheimer's disease as soon as possible and initiate appropriate therapy.

The aim of this project is to develop and implement a classification model based on a neural network capable of recognizing the degree of dementia based on the analysis of MRI brain scans.

# 2. ALZHEIMER’S DISEASE

## 2.1. Characteristics

The clinical course of the disease can be divided into three main phases: mild, moderate, and severe dementia. The disease most likely develops over many years before the onset of clinical symptoms. Even before the first cognitive impairments appear, many people with Alzheimer's disease experience mood swings, and often symptoms of depression.

In the first phase, there are minor disturbances mainly related to difficulties in recalling names or forgetting where objects were placed. These disturbances are often accompanied by abnormalities in emotional functions (apathy, irritability) and motivation disorders. Unfortunately, these symptoms are often attributed to old age.

In the second phase, memory problems deepen, problems with concentration and performing daily activities arise. Behavioral disorders gradually increase, such as aimless wandering, repetitive movements, verbal and sometimes physical aggression, mainly towards the caregiver. The ability to travel and manage one's own finances deteriorates. More than half of the patients at this stage experience delusions about being robbed or feeling physically threatened.

In the advanced phase, the patient is unable to live independently. There are permanent changes in behavior, mood, and the patient may experience hallucinations. They do not recognize their closest relatives, or even their own reflection in the mirror. These symptoms are accompanied by motor disorders, such as motor slowing, incontinence of urine and stool. The patient loses the ability to communicate with the environment and control their own body. The lifestyle gradually changes from sedentary to bedridden in the final stage of the disease.

Unfortunately, there is no cure for Alzheimer's disease. Therapy focuses on symptomatic and palliative treatment, aimed at improving the patient's quality of life and alleviating the suffering caused by the disease. In addition to pharmacological treatment, various forms of psychological interventions are used, such as cognitive therapy (memory training), reminiscence therapy (recalling memories), occupational therapy (practicing skills). For the patient's well-being, it is also crucial to create a safe, friendly, and unchanging environment. Treatment should be continued uninterrupted until the end of the patient's life.

## 2.2. Histological Basis of Neurodegeneration

Due to the complexity of neurodegenerative processes, a definitive pathomechanism responsible for the development of the disease has not yet been presented. Currently, the most probable hypothesis for the formation of pathological proteins is the amyloid cascade theory. In Alzheimer's disease, proteins with a pathological structure, mainly beta-amyloid and tau protein, accumulate in the brain. This is accompanied by pathological changes - neurofibrillary tangles and the formation of amyloid plaques. With the neurodegeneration of neurons, aggregates of proteins resistant to proteolytic enzymes accumulate, further damaging the signaling pathways. Amyloid deposits also form near blood vessels, adversely affecting the blood-brain barrier.

The disease gradually destroys the centers of the limbic system. Degeneration begins in the allocortex (olfactory cortex and hippocampal cortex), then encompasses the entire hippocampus, amygdala, thalamus, basal forebrain nuclei, and numerous brainstem nuclei.

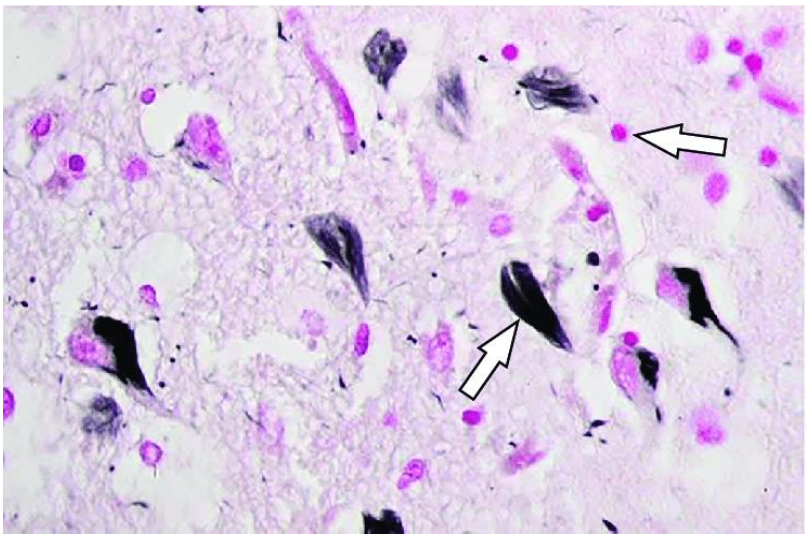

Fig.1. Amyloid plaques (pink) and neurofibrillary tangles (black) in Alzheimer's disease brain tissue

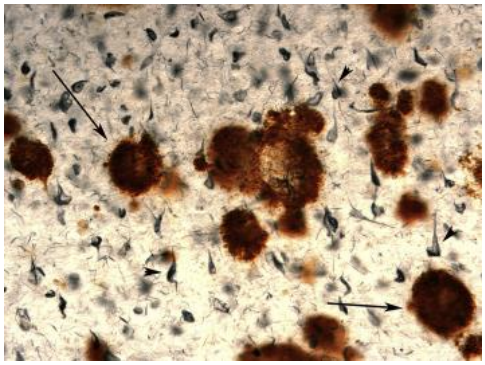

Fig. 2. Amyloid plaques (brown), hippocampus of a 61-year-old patient

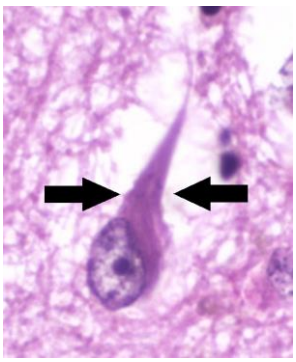

Fig. 3. Neurofibrillary tangles

## 2.3. Methods of diagnosis

Diagnosing Alzheimer's disease is a complex process consisting of many assessment elements. The doctor should conduct a detailed medical history, inquiring about symptoms, the patient's treatment history, and family history. Imaging tests such as MRI (magnetic resonance imaging) and PET (positron emission tomography) are particularly useful for assessing brain structure. Brain imaging allows for the early detection of structural atrophy and brain changes, such as those affecting the hippocampus. This makes it possible to detect degenerative processes even before the clinical symptoms typical of Alzheimer's disease appear. At a later stage, memory tests and intellectual function assessments characterize the patient's condition and the degree of disease progression.

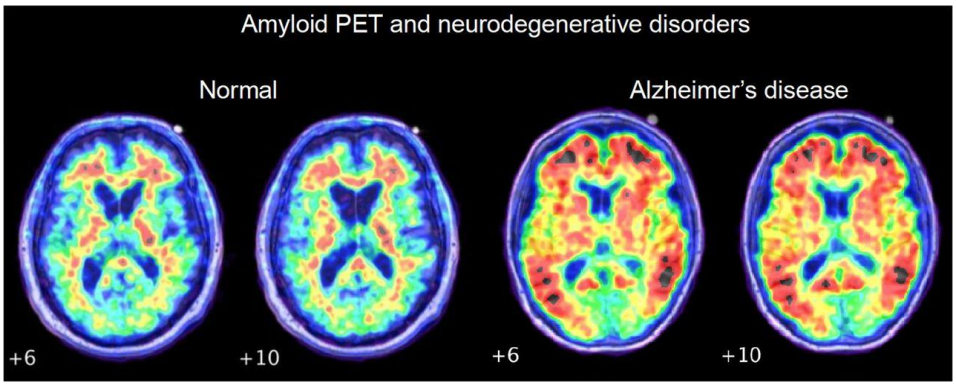


Fig. 4. PET image of the brain in a healthy person (left) and an Alzheimer's patient (right)

## 2.4. Motivation of the project

Unfortunately, despite medical advancements, the diagnosis of the disease often occurs too late, when symptoms are severe, and the limbic system of the brain is significantly damaged. It is estimated that in Poland, proper diagnosis of dementia in the course of Alzheimer's disease concerns about 15-20% of patients, with only 8-9% receiving adequate therapy. Early diagnosis would enable the implementation of effective pharmacological treatment and psychotherapy before the advanced stage. This would not only improve the quality and length of life for patients but also reduce the burden on the patient's family associated with care and its costs.

# 3. CONVOLUTIONAL NEURAL NETWORK

The project's goal is to create a neural network that determines whether an MRI scan shows a brain affected by dementia and the degree of its progression. The code was written in Python, and the convolutional network was built using TensorFlow and Keras libraries.

## 3.1. Input Data

The input data consists of MRI brain images of both healthy individuals and those suffering from dementia.

The images were obtained from https://www.kaggle.com/.

The input dataset consists of 6440 MRI images. The data belongs to 4 classes:

- Non_Demented - MRI of a healthy brain
- Very_Mild_Demented - MRI of a brain with very mild dementia
- Mild_Demented - MRI of a brain with mild dementia
- Moderate_Demented - MRI of a brain with moderate dementia

Their distribution is as follows:

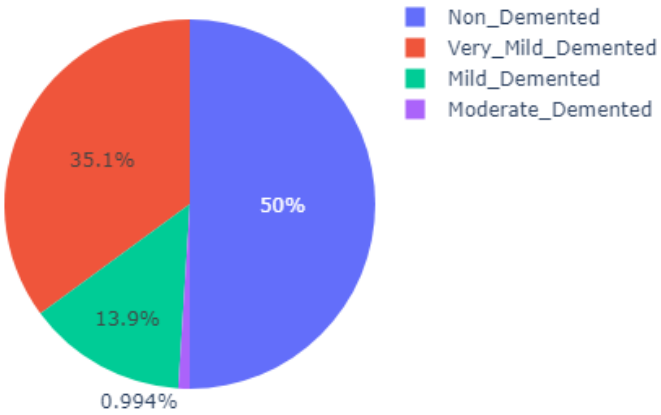


Chart 1. Pie chart of data distribution among classes

Sample data for each class:

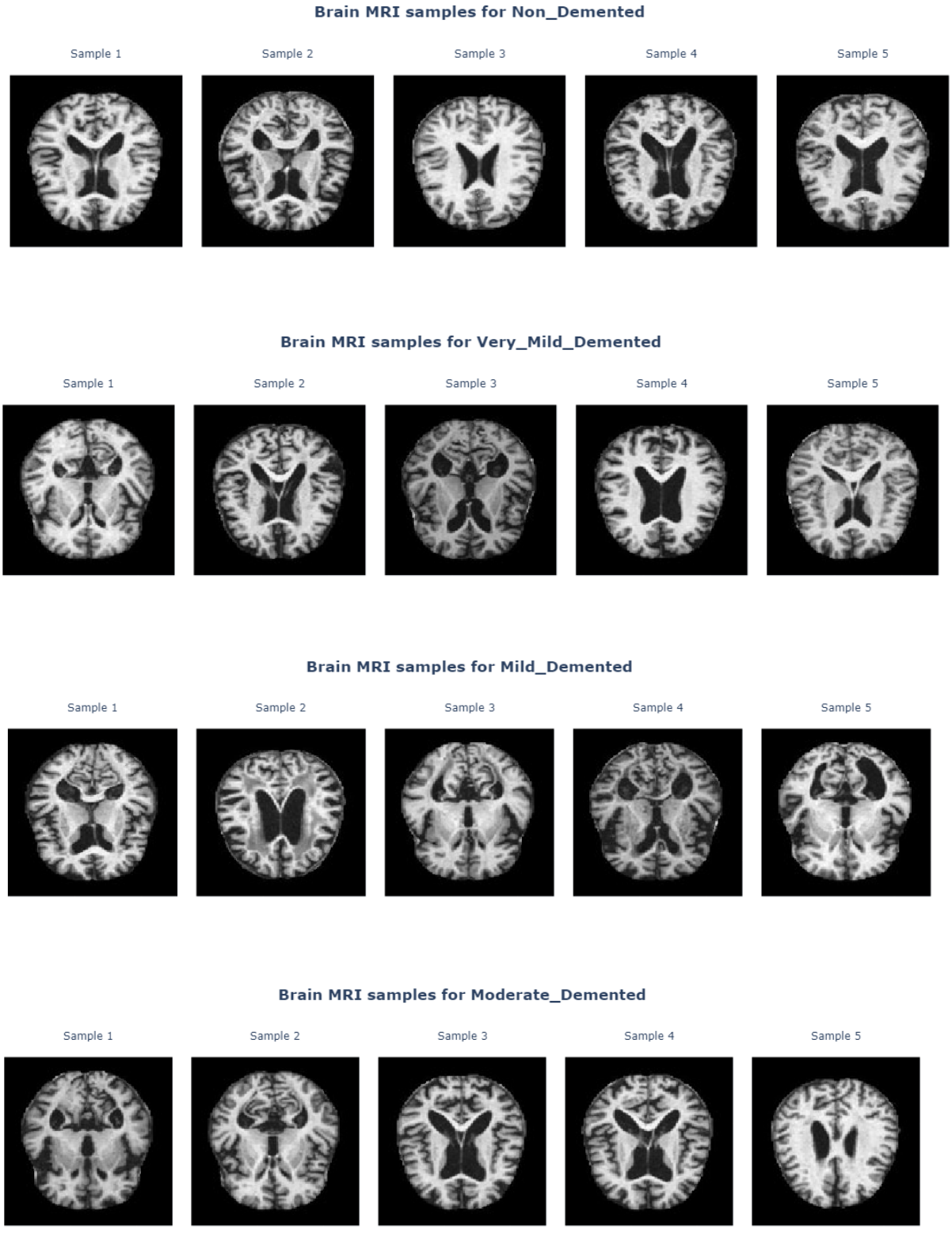


Fig. 5: Data samples for each of the 4 classes

## 3.2. CNN Model

The input data was divided into training and evaluation data in an 80% : 20% ratio.

```
IMG_HEIGHT = 128
IMG_WIDTH = 128

image_set = ImageDataGenerator(validation_split=0.2)
train = image_set.flow_from_directory(
    directory,
    color_mode='grayscale',
    batch_size=64,
    target_size=(IMG_HEIGHT, IMG_WIDTH),
    shuffle=True,
    seed=47,
    subset='training',
)

val = image_set.flow_from_directory(
    directory,
    color_mode='grayscale',
    batch_size=64,
    target_size=(IMG_HEIGHT, IMG_WIDTH),
    shuffle=True,
    seed=47,
    subset='validation',
)
```

```
Found 5153 images belonging to 4 classes.
Found 1287 images belonging to 4 classes.
```

Listing 1. Loading images - input data

Then, a convolutional network model was built.

```
def build_model():
    model = models.Sequential()
    model.add(keras.layers.experimental.preprocessing
      .Rescaling(1. / 255,input_shape=(IMG_HEIGHT, IMG_WIDTH, 1)))
    model.add(layers.Conv2D(16, (3, 3),
                            activation='relu',
                            padding='same',
                            input_shape=(128, 128, 3),
                            kernel_initializer='he_normal',
                            ))
    model.add(layers.MaxPooling2D((2, 2)))
    model.add(layers.Conv2D(32, (3, 3),
                            activation='relu',
                            padding='same',
                            input_shape=(128, 128, 3),
                            kernel_initializer='he_normal',
                            ))
    model.add(layers.MaxPooling2D((2, 2)))
    model.add(layers.Dropout(0.20))
    model.add(layers.Conv2D(64, (3, 3),
                            activation='relu',
                            padding='same',
                            kernel_initializer='he_normal',
                            ))
    model.add(layers.MaxPooling2D((2, 2)))

    model.add(keras.layers.Dropout(0.25))
    model.add(layers.Flatten())
    model.add(layers.Dense(128, activation='relu',
                           kernel_initializer='he_normal'))
    model.add(layers.Dense(64, activation='relu'))
    model.add(layers.Dense(4, activation='softmax'))
    model.compile(optimizer='Adam',
                  loss='categorical_crossentropy',
                  metrics=['accuracy'])
    print(model.summary())
    return model
```

Listing 2. Convolutional network model

### 3.3. Model Evaluation

The model was trained over 100 epochs. The final accuracy achieved was over 99%. The following charts show the model evaluation.

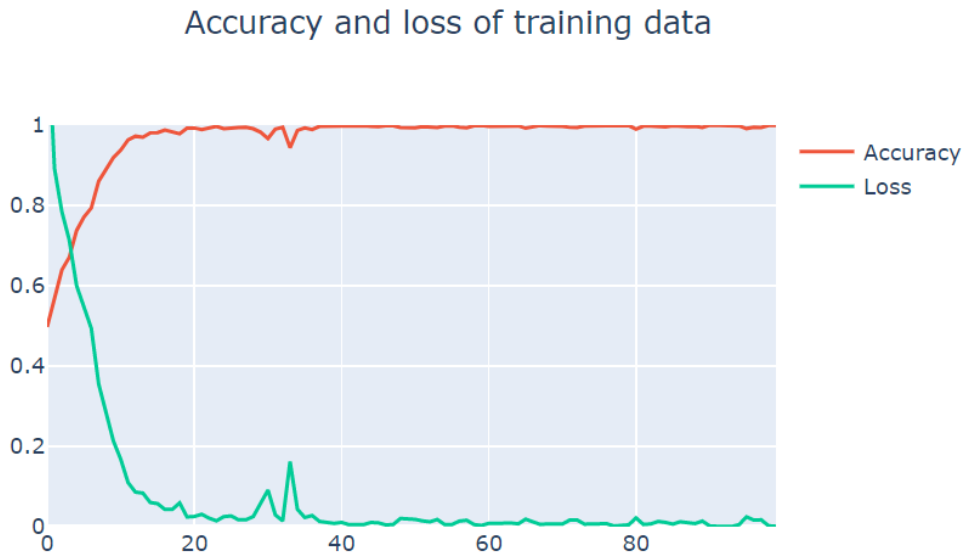


Chart 2. Accuracy and data loss on training data.

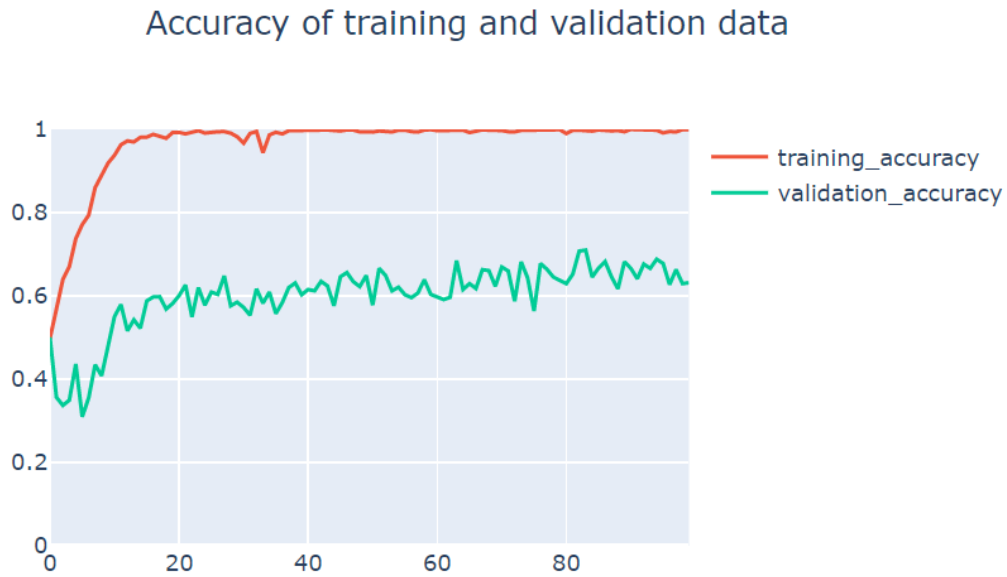


Chart 3. Accuracy of training data and accuracy of evaluation data

## 3.4. Results

The model evaluation was positive - as predicted, the accuracy increased with successive epochs up to ~99%, and data loss decreased almost to 0. For evaluation data, an accuracy between 60% and 70% was achieved. The completed model can be tested and used for analyzing MRI scans.

```
from PIL import Image

def preprocess_img(path):
  img = Image.open(path).convert('L')
  img = img.resize((IMG_WIDTH, IMG_HEIGHT), Image.ANTIALIAS)
  return img

test_path = '/content/dementia.png'
test_img = preprocess_img(test_path)
```

Listing 3. Photo preprocessing.

```
def show_prediction(image, prob_dict):
 fig = make_subplots(rows=1, cols=2, specs=[[{"type": "image"},
                                             {"type": "pie"}]])
  img = io.imread(test_path)
  fig.add_trace(go.Image(z=img), 1, 1)
  fig.add_trace(go.Pie(labels=list(prob_dict.keys()),
                       values=list(prob_dict.values()),
                       domain=dict(x=[0.5, 1.0]),
                       ), 1, 2)
  fig.update_layout(height=350, width=700,
            title_text="<b>Brain MRI Scan\tPrediction of Alzheimer<b>")
  fig.update_layout(title_x=0.5)
  fig.update_layout(
    margin=dict(l=30, r=30, t=50, b=50),
  )

  fig.update_xaxes(showticklabels=False)
  fig.update_yaxes(showticklabels=False)
  fig.show()

def get_prediction(image):
  pred = model.predict(tf.expand_dims(image, 0))[0]
  prob = list(tf.nn.softmax(pred).numpy())
  print(f'\nMost probable is:
                  {class_names[np.argmax(tf.nn.softmax(pred))]}\n')
  prob_dict = dict(zip(class_names, prob))
  show_prediction(image, prob_dict)
```

Listing 4. Model prediction and display of the submitted MRI image along with the probability of class membership.

Below are pictures of the model in action.

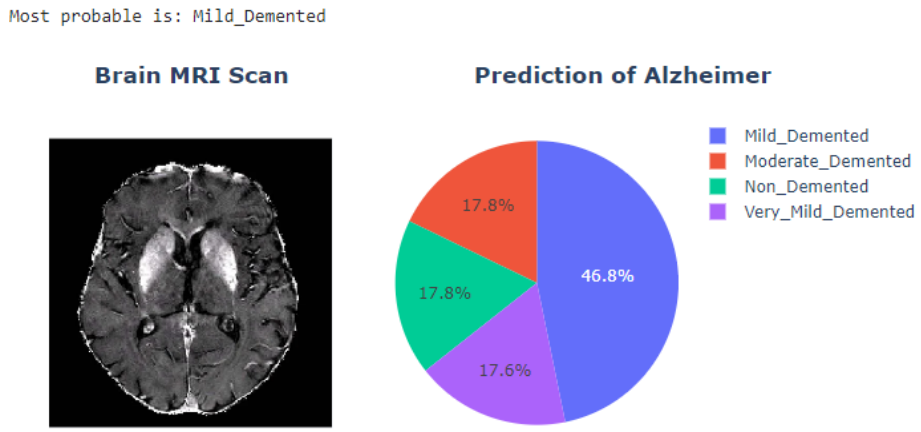


Fig. 6. Prediction 1., left uploaded image, right graph showing the probability of belonging to each class (degree of dementia)

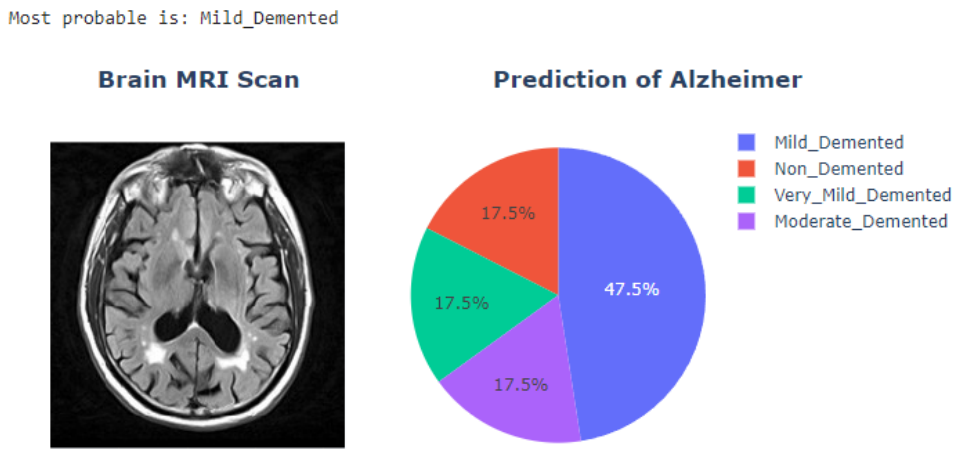


Fig. 7. Prediction 2.

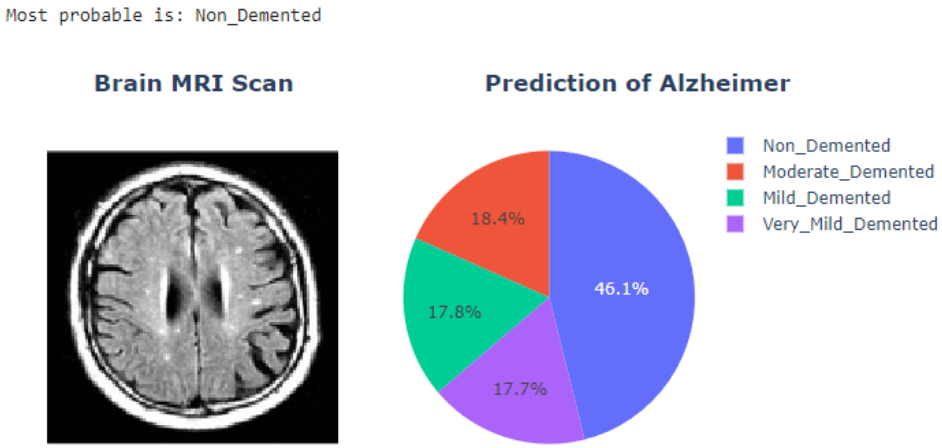


Fig. 8. Prediction 3.

# 4. SUMMARY

The paper describes Alzheimer's disease and its histopathological basis. A way to diagnose the disease using convolutional networks is proposed. The network can predict the presence of the disease and estimate the degree of severity of dementia based on the identified patterns of pathological patterns. It has been possible to build a model and achieve satisfactory results from its training. The model reached its accuracy limit for the data evaluation data of just over 60%. Therefore, despite the positive evaluation of the model, it is safe to conclude that radiologists are not so easily replaced.

# 5. BIBLIOGRAPHY

The following sources were used in this paper:


- LESZEK, Jerzy. Choroba Alzheimera: obecny stan wiedzy, perspektywy terapeutyczne. *Polski Przegląd Neurologiczny*, 2012, 8.3: 101-106.
- HAUSZ-PISKORZ, Beata; BUCZKOWSKI, Krzysztof. Diagnostyka i leczenie choroby Alzheimera w warunkach praktyki lekarza rodzinnego. In: *Forum Medycyny Rodzinnej*. 2013. p. 198-207.
- https://www.alzheimers.org.uk./
- https://careexperts.pl/alzheimer/choroba-alzheimera-etapy
- https://www.researchgate.net/figure/Amyloid-plaques-pink-and-neurofibrillary-tangles-black-in-Alzheimers-disease-brain_fig1_323312622
- https://www.sciencedirect.com/topics/medicine-and-dentistry/neurofibrillary-tangle
- https://commons.wikimedia.org/wiki/File:Histopathology_of_Alzheimer%27s_disease.jpg
- https://jnm.snmjournals.org/content/63/Supplement_1/13S.abstract