Deep Learning para diagnosticar Alzheimer usando imágenes de resonancia magnética

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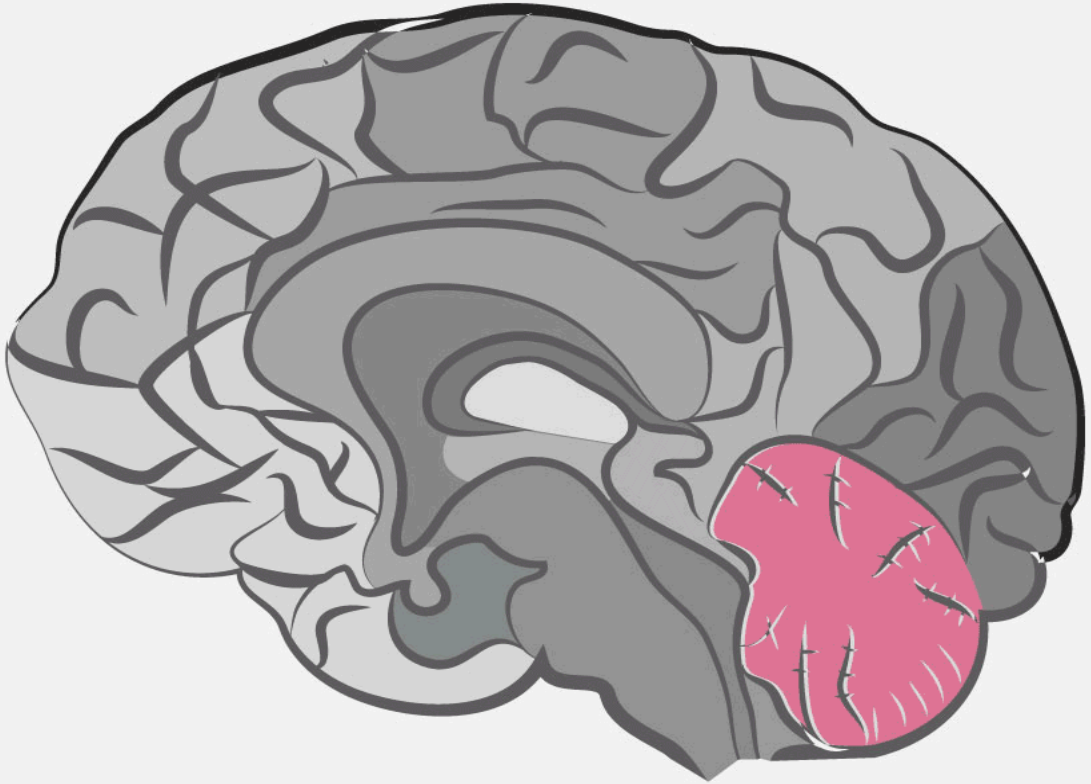
Introduction: Alzheimer

- **47 million people** suffer from demencia in the world, and 9.9 million new cases are registered each year.
- Alzheimer disease is the primary cause of dementia, gathering between **60% and 70%** of all the cases.
- Early diagnosis can cause major improvements in patients daily lives and life expectancy.

How Alzheimer's Affects the Cerebellum

As Alzheimer's disease attacks the cerebellum, a variety of symptoms may present themselves including:



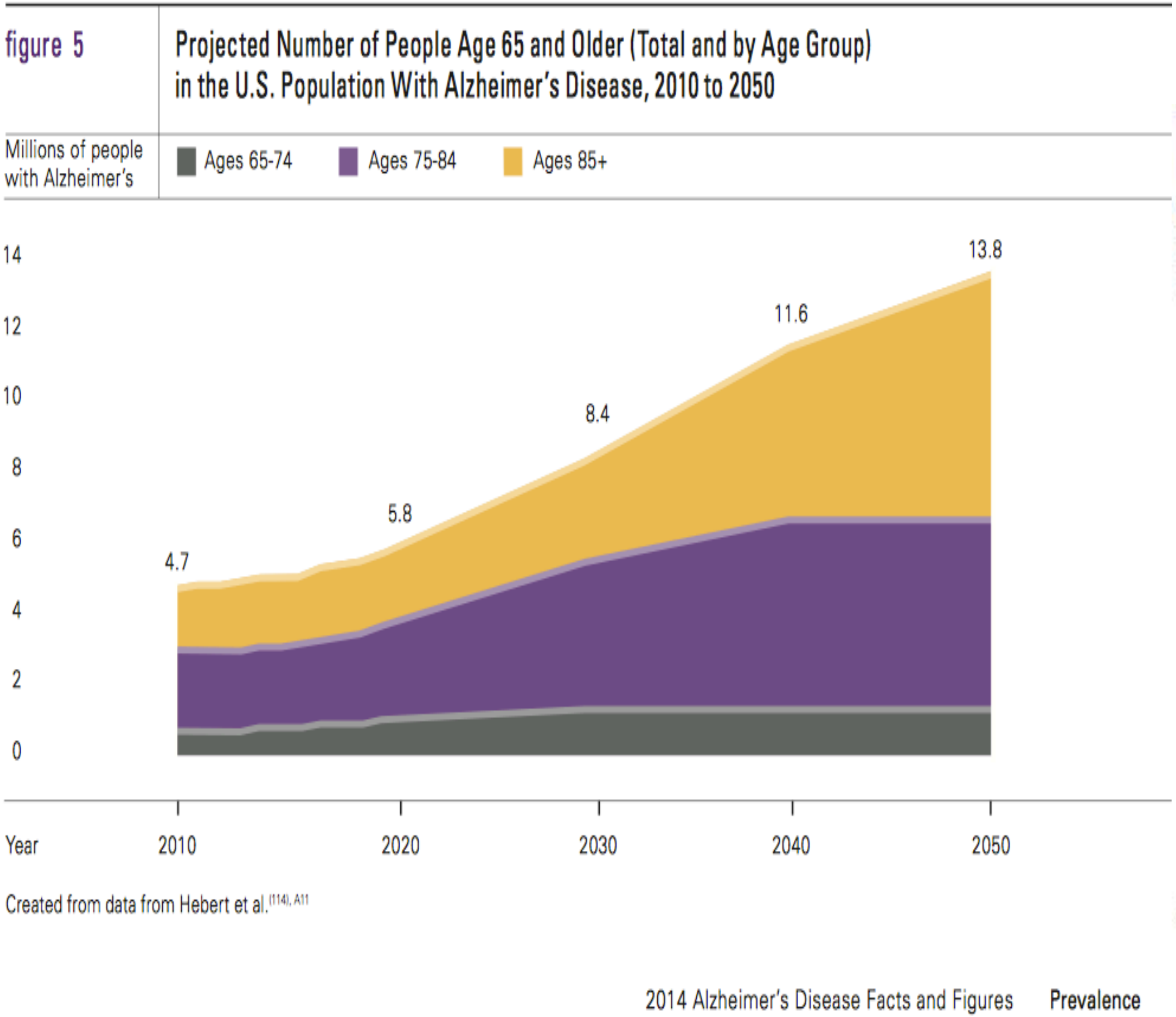


figure 5
Projected Number of People Age 65 and Older (Total and by Age Group) in the U.S. Population With Alzheimer's Disease, 2010 to 2050
Millions of people with Alzheimer's
Ages 65-74
Ages 75-84
Ages 85+
14
12
10
8
6
4
2
0
4.7
5.8
8.4
11.6
13.8
Year
2010
2020
2030
2040
2050
Created from data from Hebert et al.(114), A11
2014 Alzheimer's Disease Facts and Figures
Prevalence

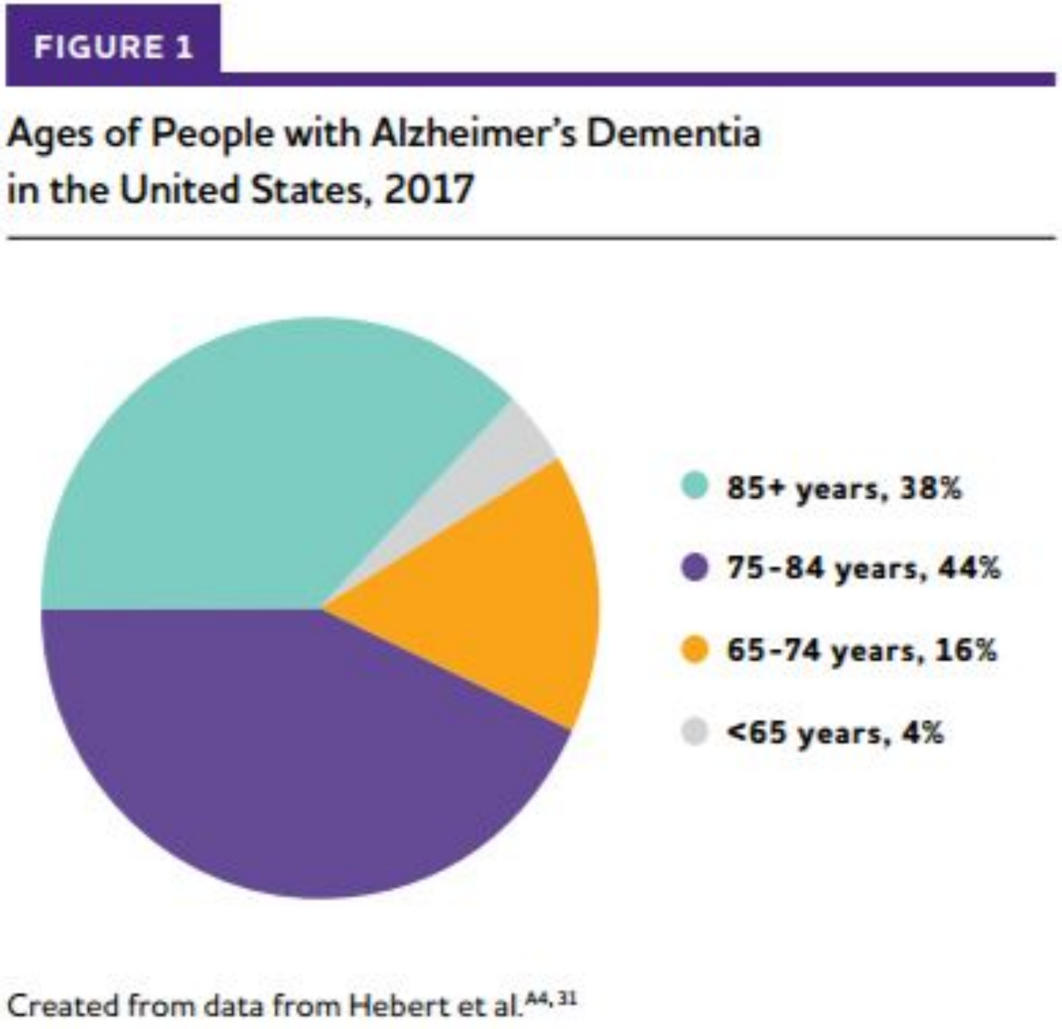


FIGURE 1
Ages of People with Alzheimer's Dementia in the United States, 2017
85+ years, 38%
75-84 years, 44%
65-74 years, 16%
<65 years, 4%
Created from data from Hebert et al.A4, 31

Previous works

- **Manually detecting of brain mass deterioration:** Neuronal loss and consequent brain atrophy causes widening of the sulci, thinning of the gyri and dilatation of the ventricles with a significant reduction in brain weight. Many studies have focused on quantifying focal atrophy in the temporal lobe (Scheltens, et al., 2003) and even exist visual scales to quantify the degree of atrophy, which are quick and easy to use.
- **Automatic methods:** volumetric and shape features together with PCA and SVM were used to classify MRI images as having the disease or not (Lee, et al., 2009).
- **Deep Learning:** using 3D Convolutional Neural Networks for classification. (Korelev 2017).

Goals

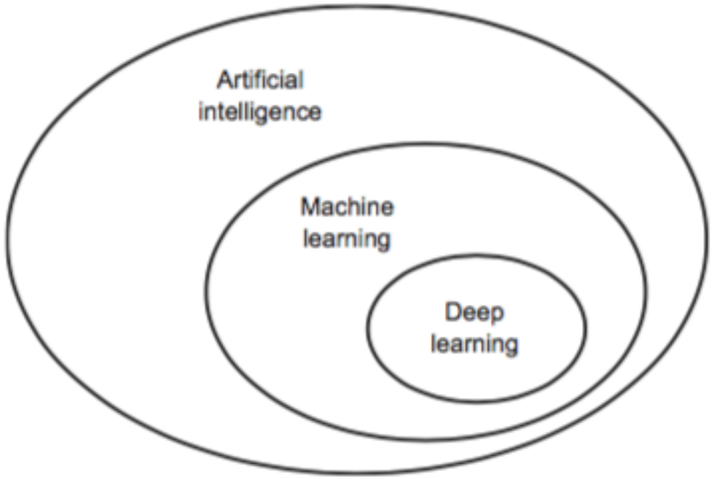
- **Analysis and processing of images.**
- **Analysis and selection of a Convolutional Neural Network Architecture.**
- **Neural Network optimization and methods for model selection.**
- **Analysis of results.**

Methods

Machine Learning: is a field of statistics and computer science that gives computer systems the ability to "learn" (i.e. progressively improve performance on a specific task) with data, without being explicitly programmed.

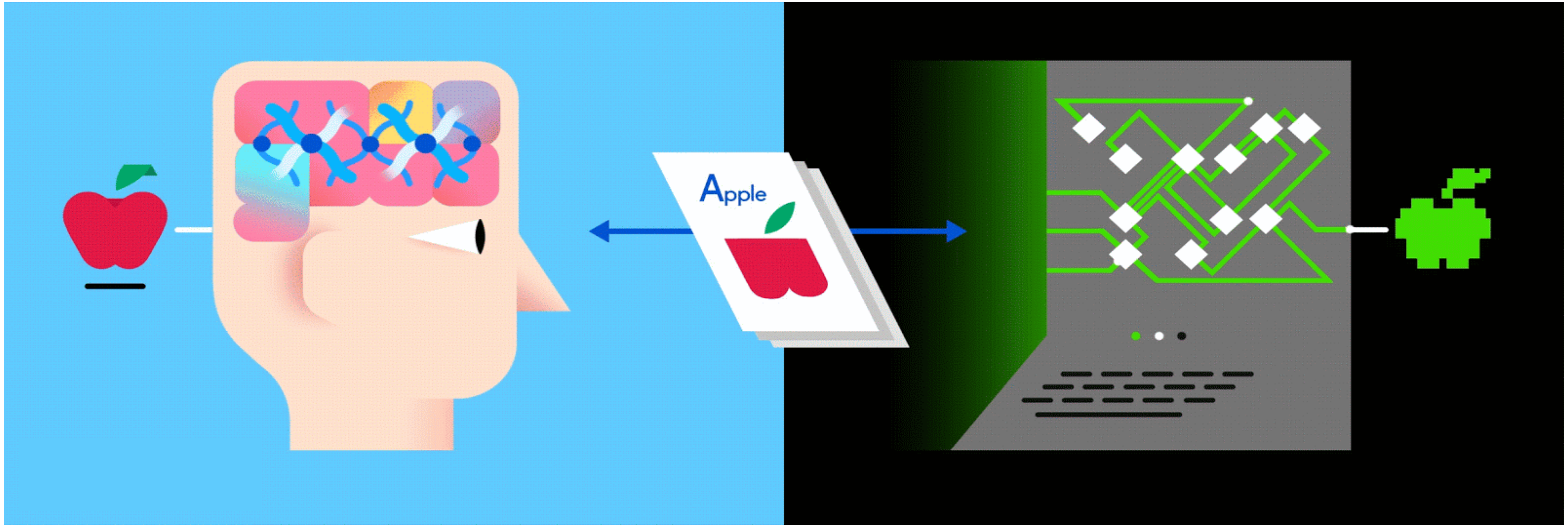
Supervised Learning: The computer is presented with example inputs and their desired outputs.

Deep Learning: subfield inside machine learning in which algorithms, mainly neural networks, have a considerable amount of hidden layers and highly computing cost.



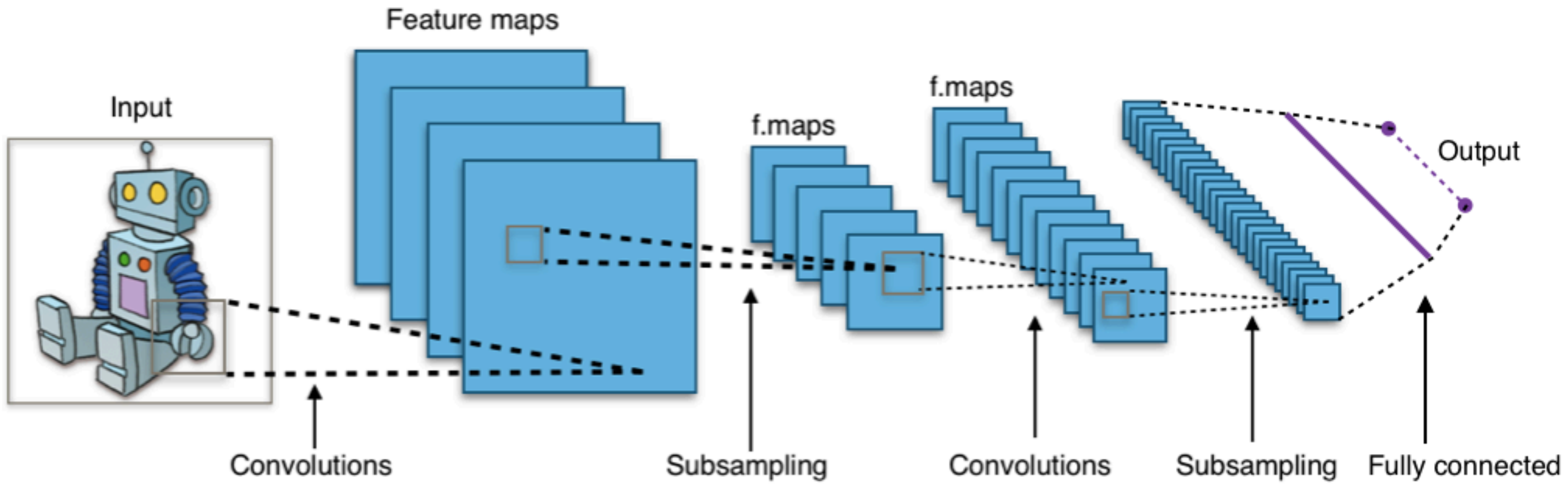
Methods

Artificial Neural Networks (ANN): Artificial neural networks are computing systems trying to imitate the behaviour of biological neural networks in our brain when they are learning about an specific phenomenon.



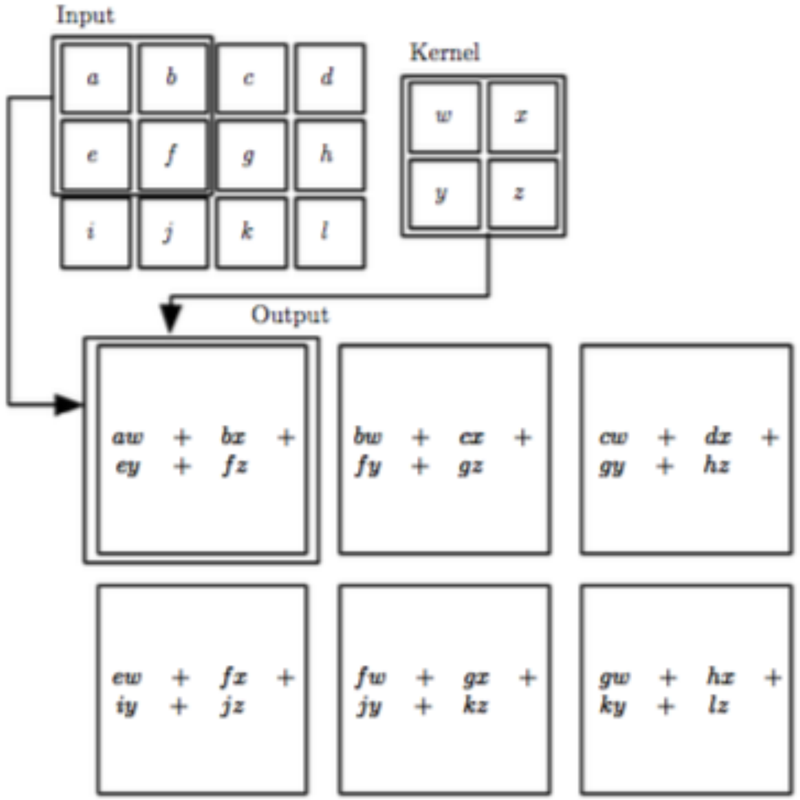
Methods

Convolutional Neural Networks (CNN): type of deep neural networks, which means they have a considerable number of hidden layers, using as a main operator the **convolution operator**. They has successfully been applied to analyzing visual imagery.



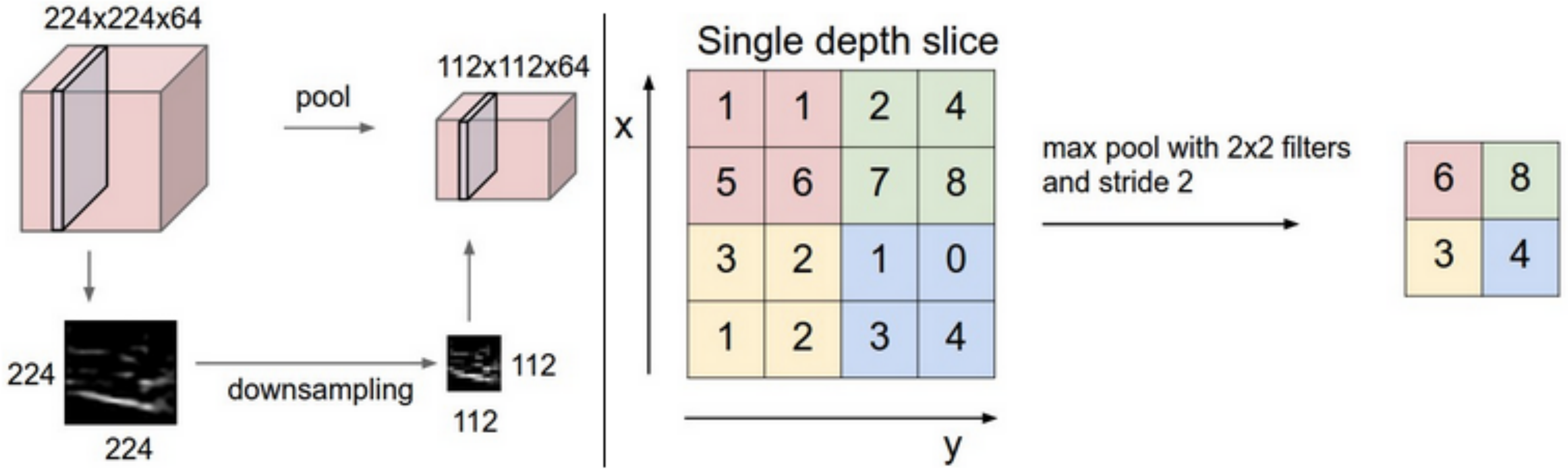
Methods

Convolution Operator: In its most general form, convolution is an operation on two functions of a real- valued argument. Convolution leverages three important ideas that can help improve a machine learning system: *sparse interactions*, *parameter sharing* and *equivariant representations*.



Methods

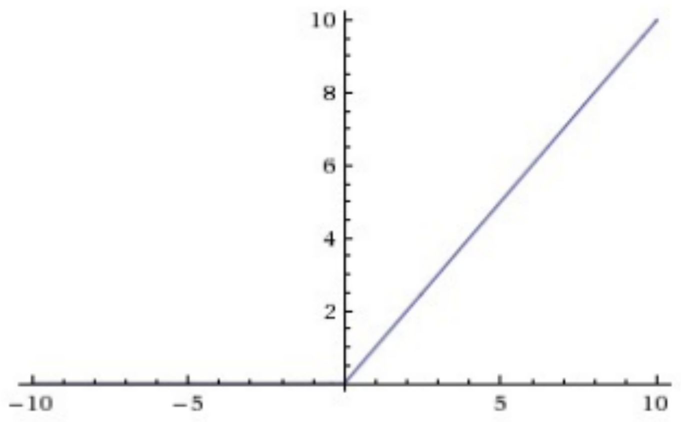
Pooling Operator: A pooling function replaces the output of the net at a certain location with a summary statistic of the nearby outputs. There are several operators but one broadly used is the max pooling operator.



Methods

Activation functions: the **activation function** of a node defines the output of that node given an input or set of inputs.

ReLU



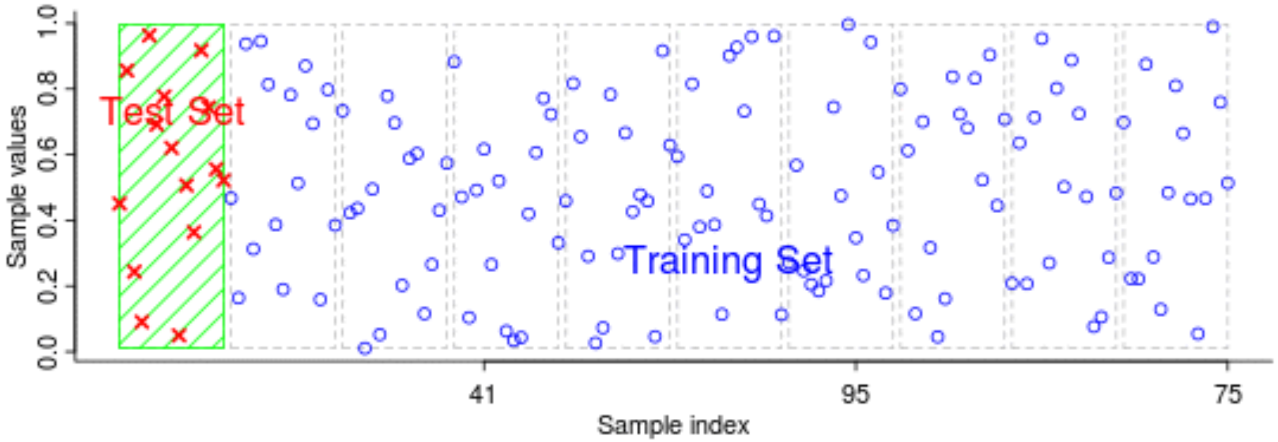
Softmax

$$S(y_i) = \frac{e^{y_i}}{\sum_j e^{y_j}}$$

Methods

Model evaluation methods

- **K-Fold Cross Validation:**



- **Leave-One-Out Cross Validation**: Particular case of k-Fold Cross Validation in which K is equal to the number of samples in the dataset.

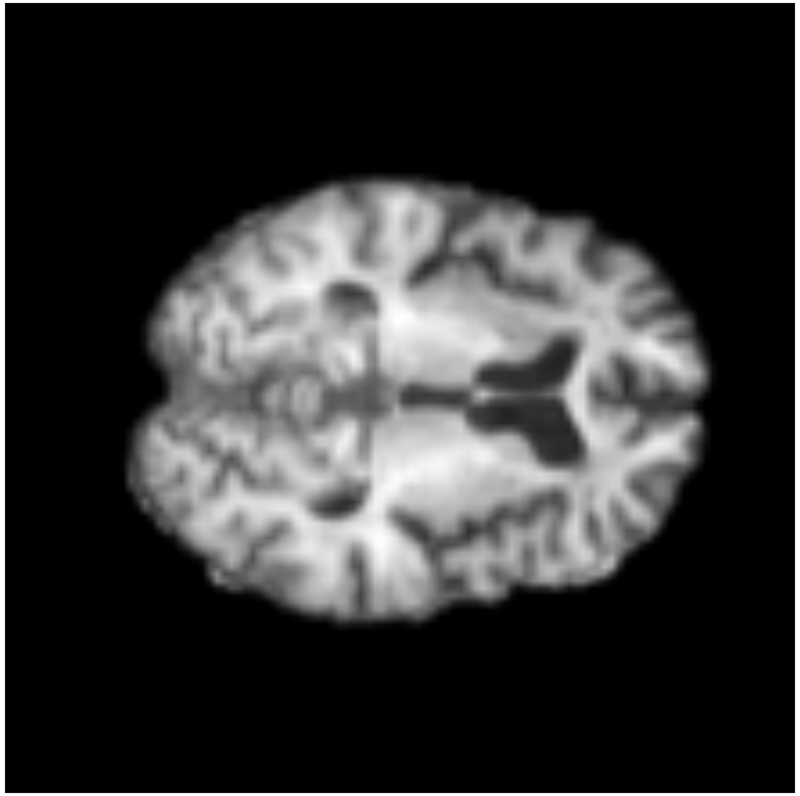
In this work, not including different images of the same patient both in training and test sets has been guaranteed.

ADNI Database

Alzheimer’s Disease Neuroimaging Initiative (ADNI): widely-used database for Alzheimer disease studying. This database presents clinical data of patients such as MRI and PET images, genetic reports, cognitive tests and blood biomarkers. There are four types of patientes: Healthy,Alzheimer and two middle-states (LMCI and EMCI).

ADNI
ALZHEIMER'S DISEASE
NEUROIMAGING INITIATIVE

ADNI Database



Example of image used for learning

An ADNI subset of images has been used. The following preprocessing steps have been applied:

- **Spatial Normalization:** the same pixel correspond to the same physical position in both images.
- **Masked:** delete cranial surface and bones.
- **N3 correction**: image intensity correction.

Experiments

Devices used for experiments

- **MacBook Air 2016**: CPU*,* 1,6 GHz Intel Core i5. *RAM*,8 GB 1600 MHz DDR3. Used for MRI images preprocessing.
- **Server**: *CPUs*, 2 Intel(R) Xeon(R) CPU E5645 @ 2.40GHz. *GPU*, 2 Tesla C2050 / C2075. Used for network training and testing

Framework and library for Deep Learning algorithms and NIFTI images processing

- **Keras** *(Keras)***:** Framework for Deep Learning algorithms.
- **Nibabel** *(Nibabel)***:** Python library for NIFTI images processing.

Hyperparameters for the network

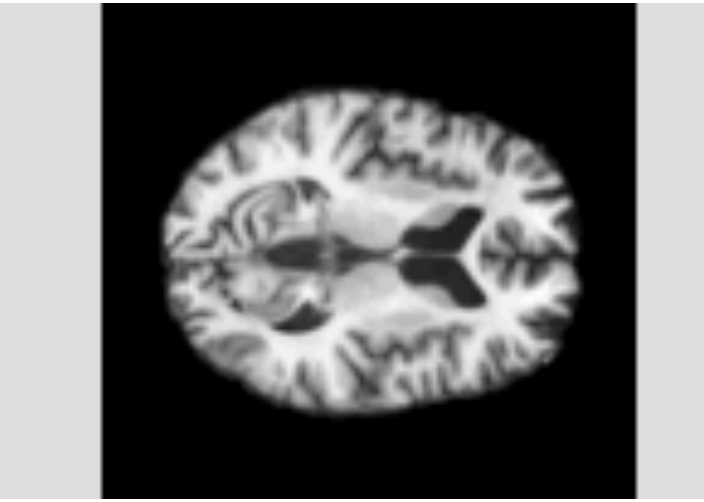
Loss function: Categorical cross-entropy, ***N of iterations:*** 70, ***Batch size:*** 10,

Learning-rate: 27*10^-6

Experiments

Analysis and images processing

Whe have used brain slices from 10 to 100 jumping 5 to 5, therefore having 19 different slices. With **Nibabel** and **Matplotlib** libraries we were able to obtain each slice as a 2D image and save it in PNG format.



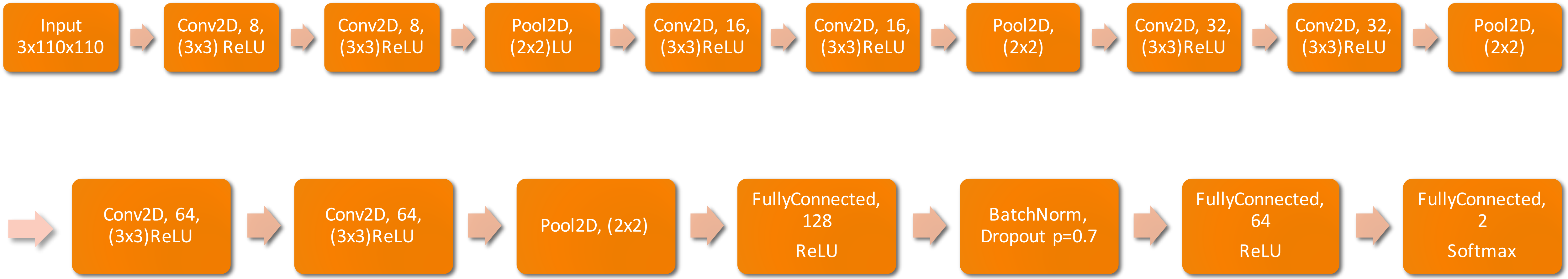
Images from slice 55

Images from slice 10 up to 100

Experimentos

CNN architecture

Final architecture was based on VGG architecture used in (*Korolev,2017).*



```python
model = Sequential()

model.add(Conv2D(8, (3, 3), input_shape=(110, 110,3)))
model.add(Activation("relu"))

model.add(Conv2D(8, (3, 3)))
model.add(Activation("relu"))

model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(16, (3, 3)))
model.add(Activation("relu"))

model.add(Conv2D(16, (3, 3)))
model.add(Activation("relu"))

model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(32, (3, 3)))
model.add(Activation("relu"))

model.add(Conv2D(32, (3, 3)))
model.add(Activation("relu"))

model.add(Conv2D(32, (3, 3)))
model.add(Activation("relu"))

model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(64, (3, 3)))
model.add(Activation("relu"))
```

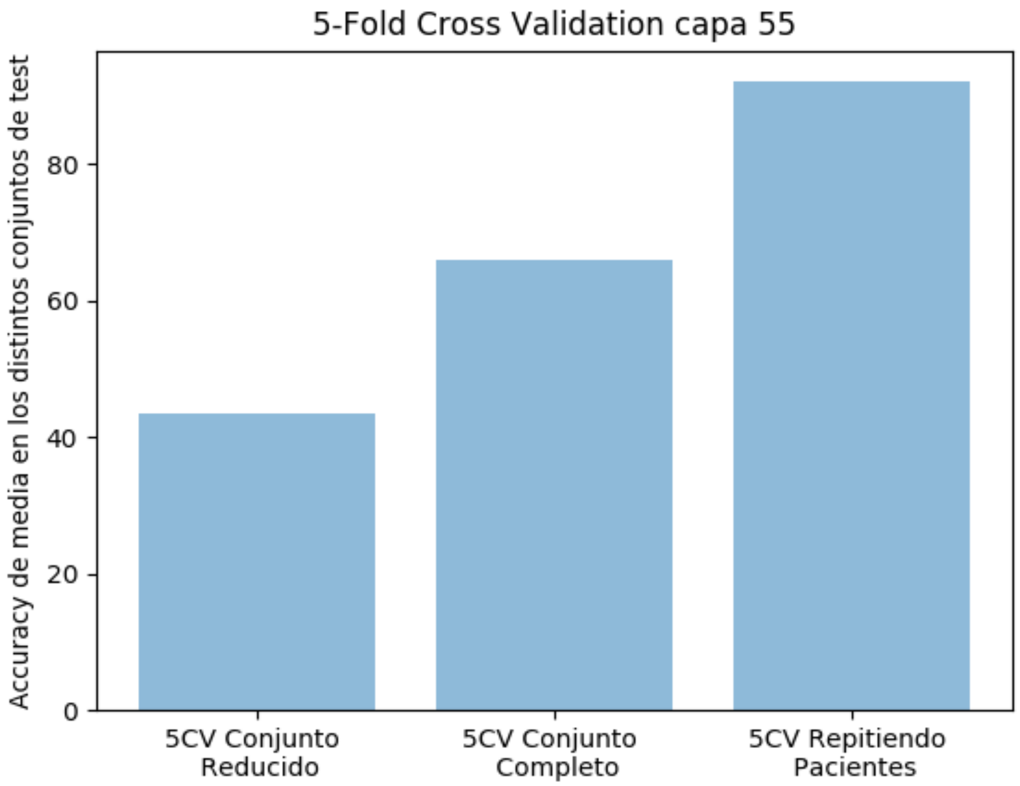
```python
model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Conv2D(64, (3, 3)))
model.add(Activation("relu"))

model.add(Conv2D(64, (3, 3)))
model.add(Activation("relu"))

model.add(Conv2D(64, (3, 3)))
model.add(Activation("relu"))

model.add(MaxPooling2D(pool_size=(2, 2)))

model.add(Flatten())
model.add(Dense(128))
model.add(Activation("relu"))
model.add(BatchNormalization(axis=1))

model.add(Dropout(0.7))

model.add(Dense(64))
model.add(Activation("relu"))


model.add(Dense(2))

model.add(Activation('softmax'))
model.compile(loss='categorical_crossentropy',
    optimizer=keras.optimizers.Adam(lr=27*1e-04,clipnorm=1., clipvalue=0.5),
    metrics=['accuracy'])
```

Experiments performed

- **First experiments:** 5-fold Cross Validation with slice 55 in small database(**only one image per pacient)** and complete database **(all pacients images).**
- **Selection of best 2D slices:** 5-fold Cross Validation to validate which slice is the best for classification.
- **Validation of previous results using LOO:** Leave-one-out Cross Validation per patient using best slices.

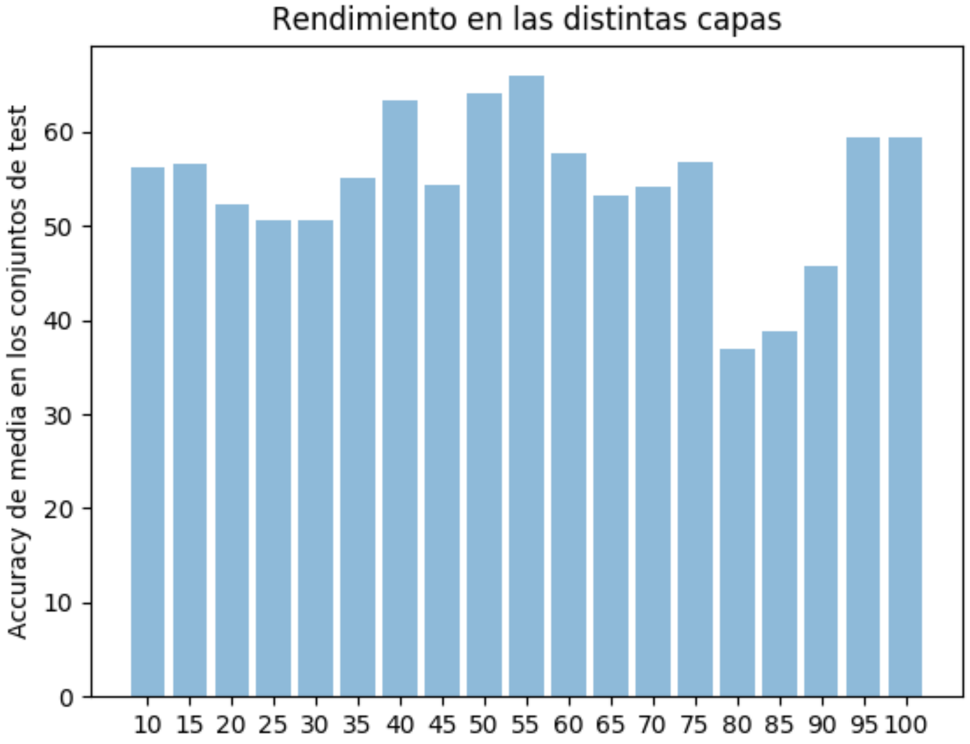
Results: 5-fold Cross Validation with slice 55 in the reduced and complete dataset

Previous experiments	Results
5-fold Cross Validation using the reduced dataset **(just one image per patient)** with slice 55	43’5%
5-fold Cross Validation using the complete dataset **(all the patient images)** with slice 55	65’9%
5-fold Cross Validation using the complete dataset with slice 55 without preventing repetition	92%



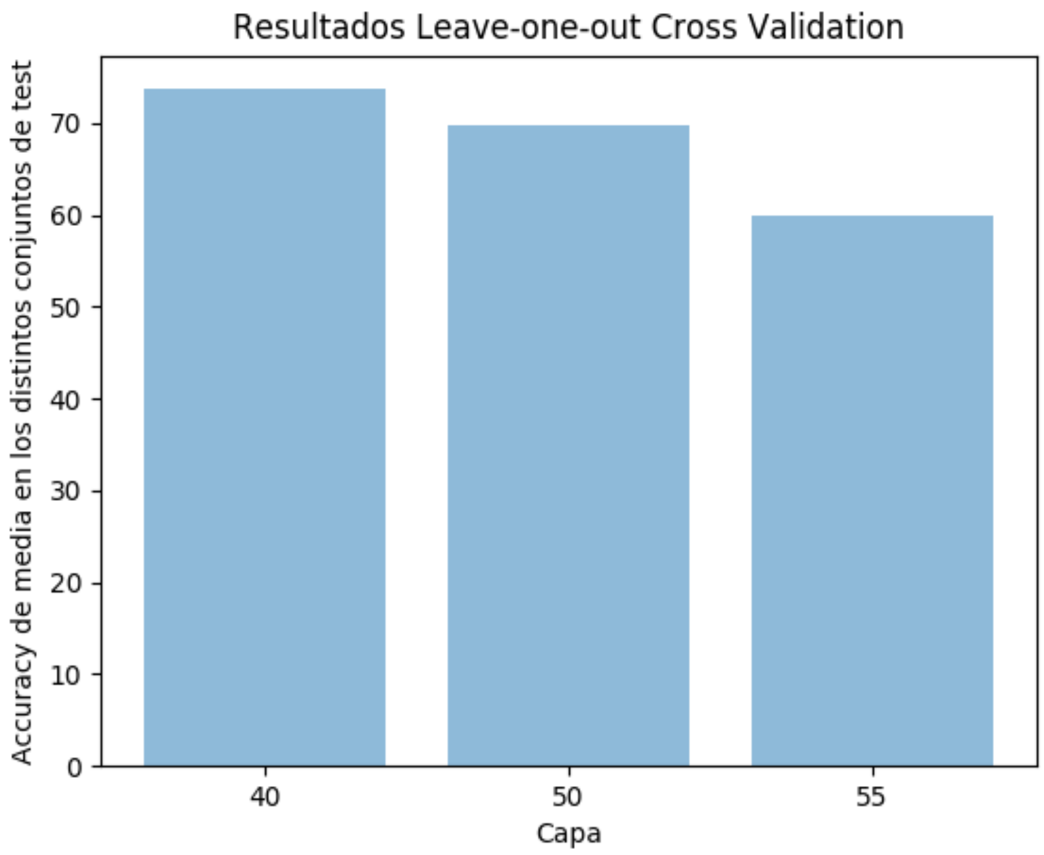
Results: 5-fold Cross Validation to test which is the best slice

Slice	Result	Slice	Result
10	56'3%	60	57’7%
15	56’6%	65	53’3%
20	52’3%	70	54'1%
25	50’7%	75	56’7%
30	50’7%	80	36’9%
35	55’2%	85	38’8%
40	**63’3%**	90	45’8%
45	54’4%	95	59’4%
50	**64’1%**	100	59’4%
55	**65’9%**		



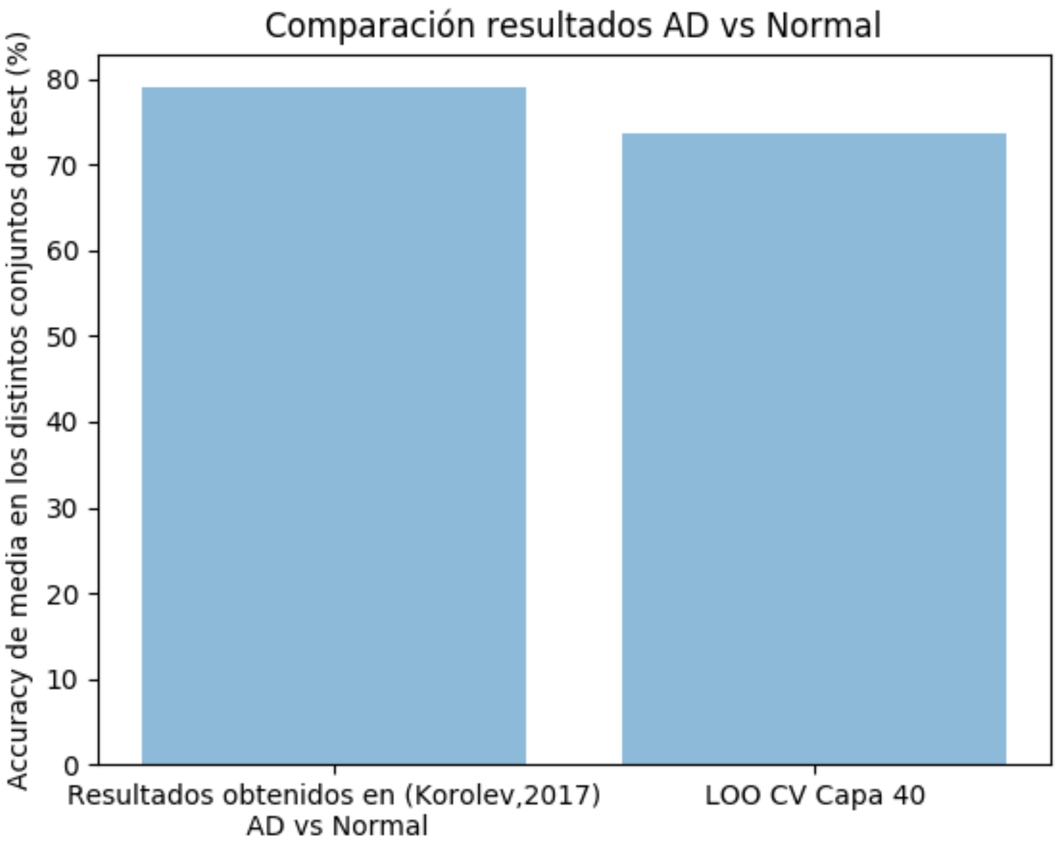
Results: Leave-one-out Cross Validation per patient with the best slices

Slice	Result
40	73’7%
50	69’7%
55	60%



Results

Result in *(Korolev,2017)* for AD vs Normal	LOO CV Slice 40
79% +- 0.8	73’7 %



Conclusions

- We have observed that proper results can be obtained using 2D images, which has not been performed before in literature.
- 2D images requiere less computational power, therefore using this approach in an hospital could be easier.
- Some slices work better tahn other, as observed in experiments.
- More images means better results.
- Nowadays there are a lot of information about Deep Learning and anyone can do amazing things.
- If I’ve done it you also can, because I’m not even smart.

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Don’t follow me down the street, you creepy audience

Thanks for your attention