Sunspot class

sification using artific

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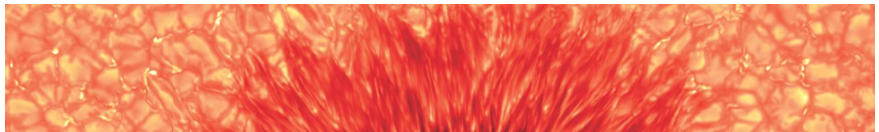
Abstract

Sunspots, visible through telescopes or with the naked eye at sunset, are caused by the Sun’s magnetic field. Studying these phenomena is crucial for predicting solar activity and understanding the Sun's cycle. My research focuses on automating the recognition, classification, and analysis of sunspots using hand-drawn observations from the Astronomical Institute of the Czech Academy of Sciences. I trained a convolutional neural network to label sunspots based on the McIntosh classification system, aiming to bridge deep learning with solar

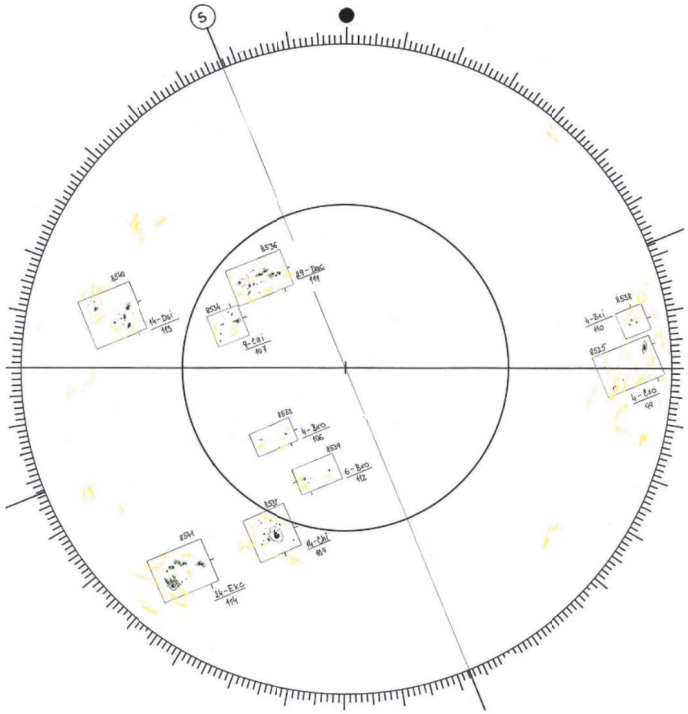
Sunspots

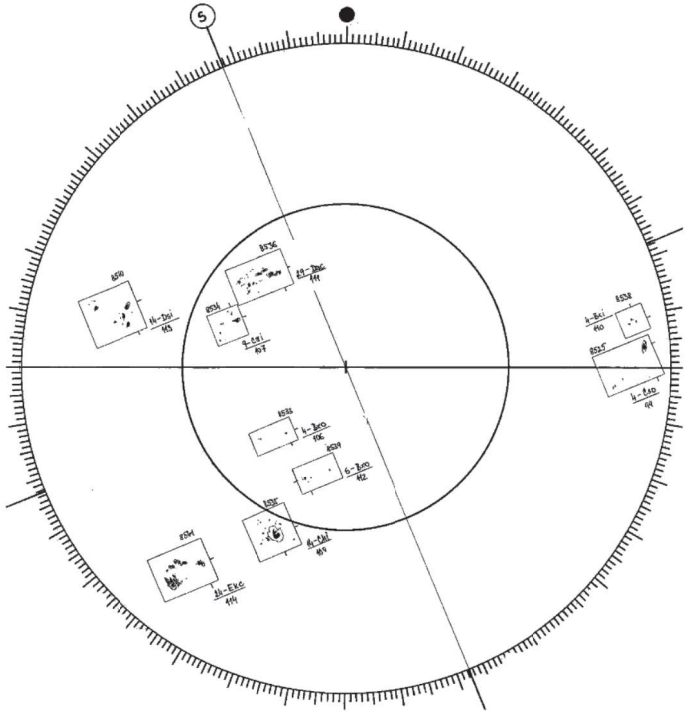
Sunspots are dark areas on the Sun caused by magnetic

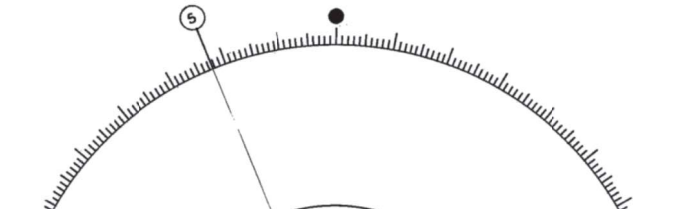


Metods - preprocesing

The processing was made via python. Having the sunspotdrawing, I adjust its size and contrast to imporove the results of findingrectangels.

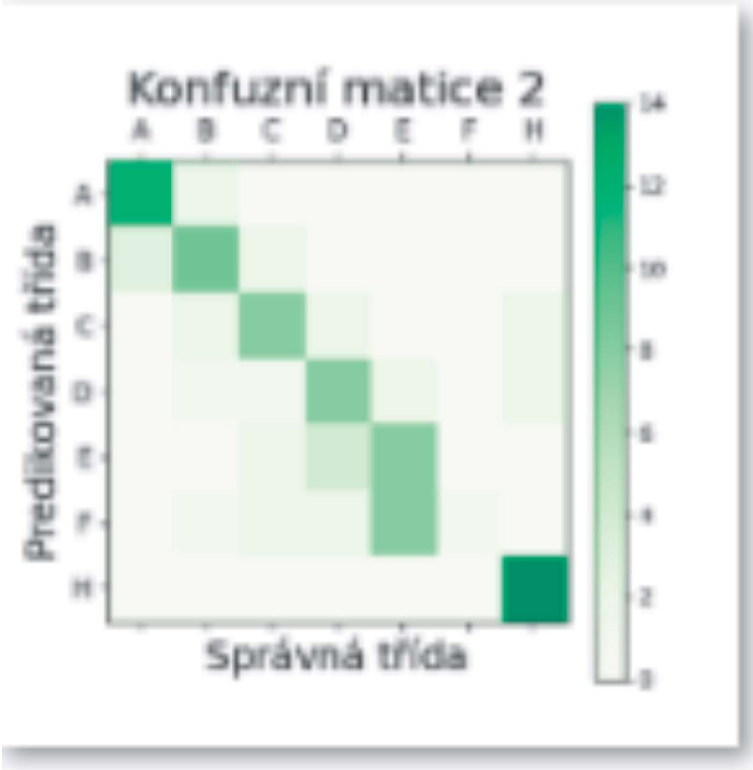


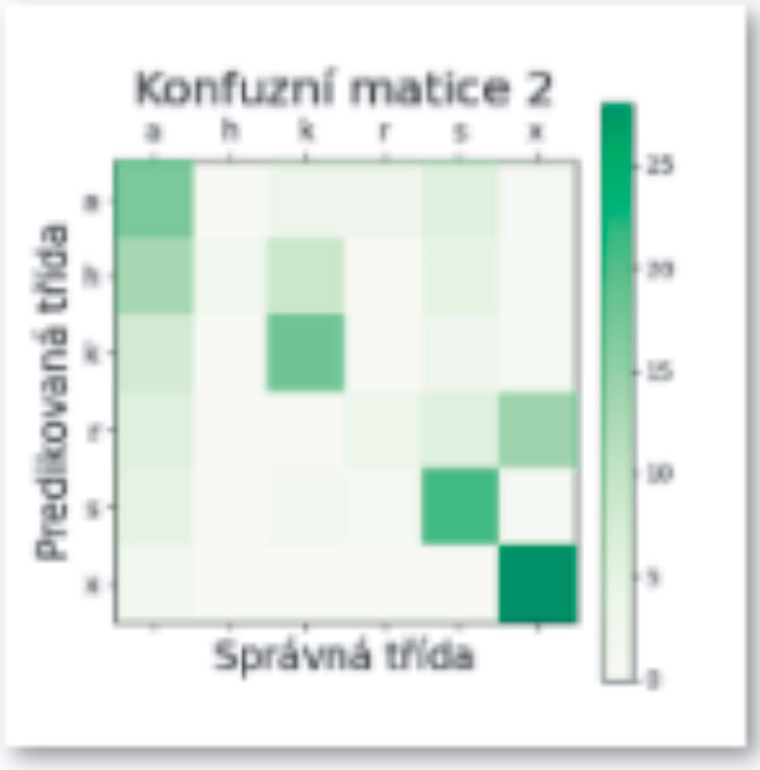




Ressults

I've trained several convolutional neural network (CNN) models capable of detecting sunspots at varying levels of complexity, showcasing the potential applications of AI in solar astronomy. Additionally, I have outlined several pathways for future research in this field.





disturbances, consisting of a dark umbra and lighter penumbra. They are linked to solar flares and eruptions, which can impact Earth, causing auroras, aviation disruptions, and power grid failurest

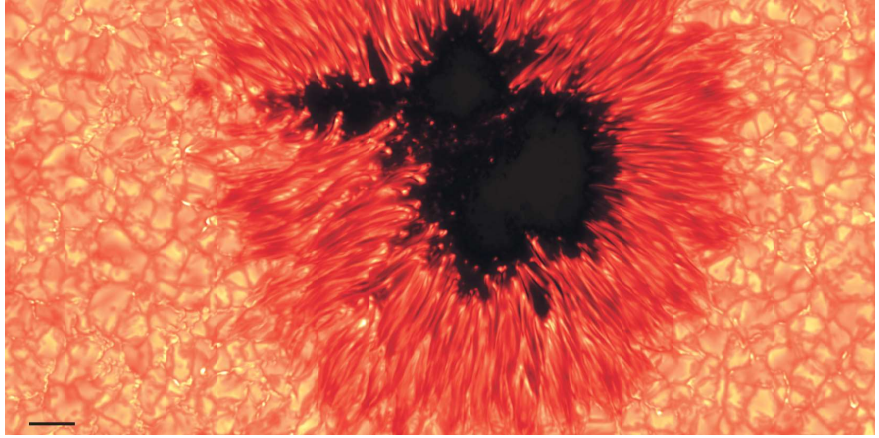
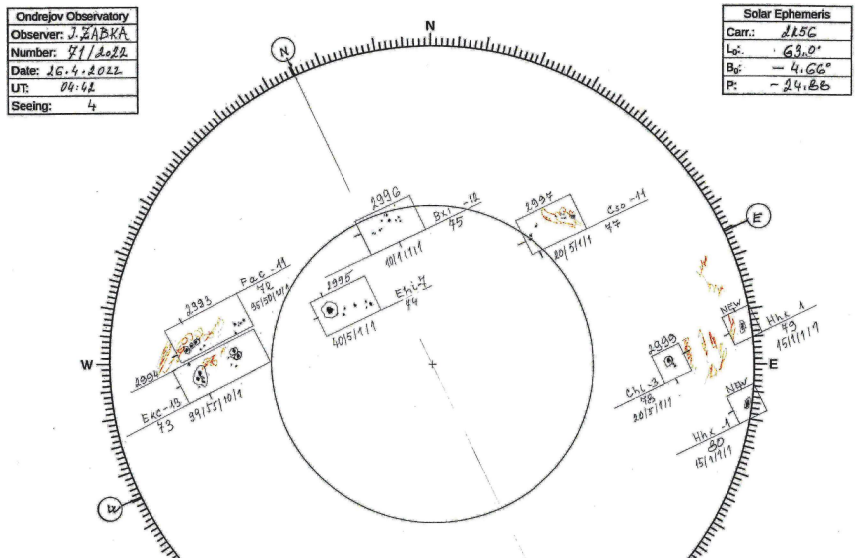
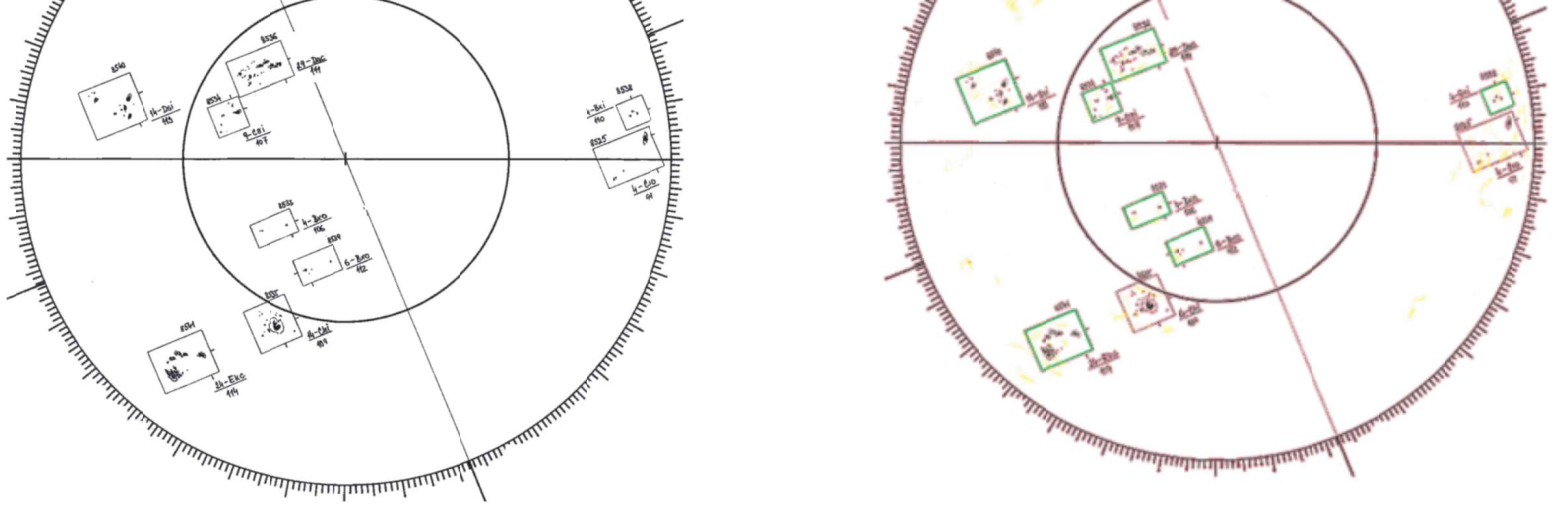


Fig. 01: Sunspot with observable umbra and penumbra

Sunspot drawing

One of the earliest methods for capturing sunspots involved projecting the Sun's image onto paper. This simple technique has been used for centuries and is still relevant for improving solar predictions when satellite





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After that, I extracted the individuals sunspot groops and converted them into friendly black and white picture.

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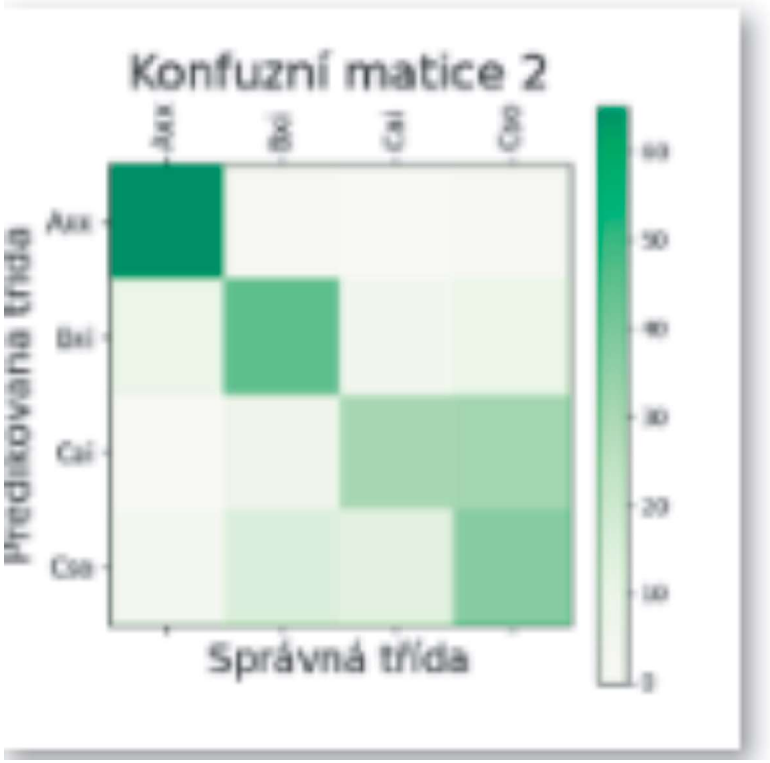

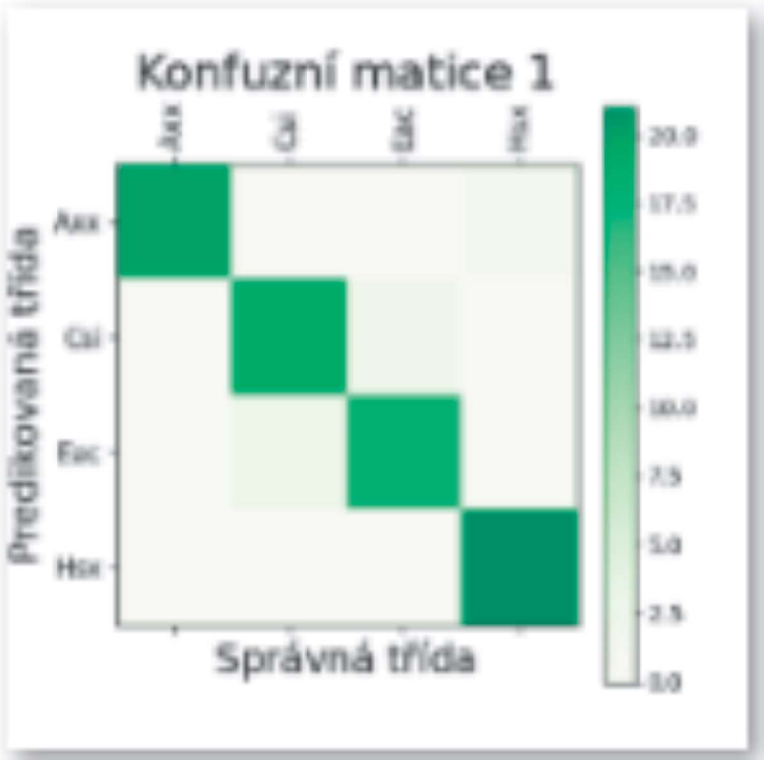

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Future

data is lacking. However, the number of sunspot observers has declined, and public awareness of these historical records is low.

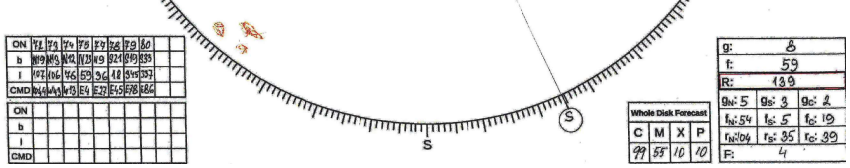
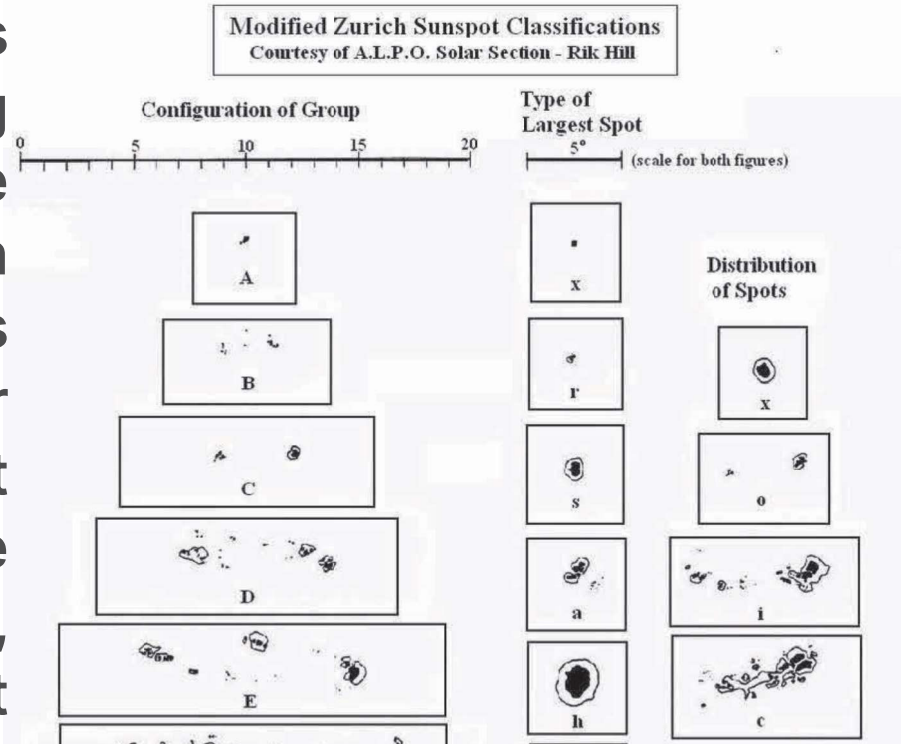


Fig. 02: Sunspot drawing from the Astronomical Institute of the Czech Academy of Sciences

McIntosh classification

Classifying sunspots is crucial for understanding solar activity. I used the Zurich classification, which relies on visible data and is accessible for amateur astronomers. Each sunspot group is labeled with three letters indicating size, properties of the largest



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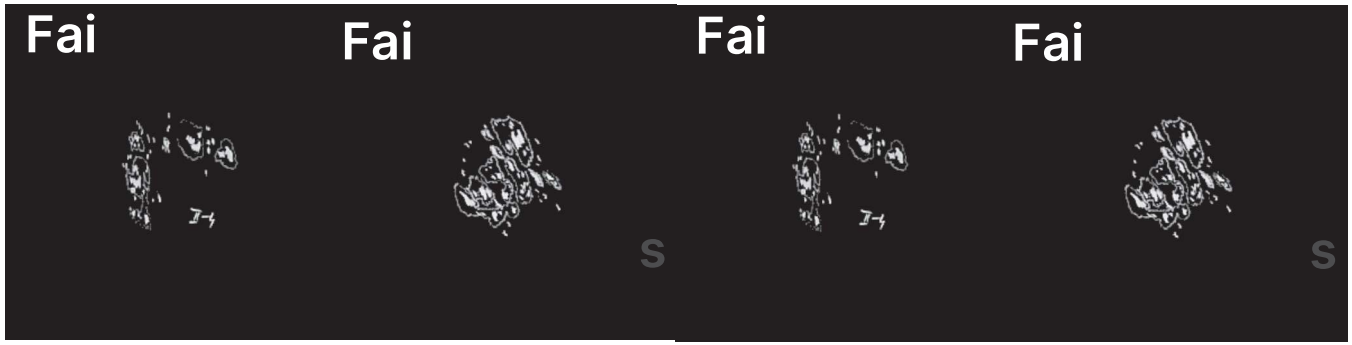
Metods - CNN Training

The dataset preparation involved labeling the black-and-white sunspot images with their classifications from the McIntosh system. I then divided the dataset into training, validation, and test sets in an 80-10-10 ratio.



Future work could focus on developing more accurate models, improving spot detection, or incorporating data from additional observatories. Expanding model complexity with deeper layers and more neurons could also enhance precision. Another direction is creating a tool for automatic sunspot classification, aiding observatories in verifying manual classifications.

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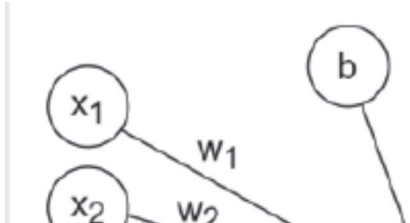
sunspot, and distribution within the group, with different associations to potential solar eruptions.

Fig. 03: Visualisation of each group of McIntosh classification system

Neural networks

Neural networks, used in applications like large language models (LLMs) and image recognition, consist of neurons that compute values based on previous outputs [Fig. 04]. They typically have input, output, and hidden layers for complex calculations. A convolutional neural network (CNN) is a type of neural network designed for processing images. CNNs use filters, or kernels, to analyze and extract features from images.



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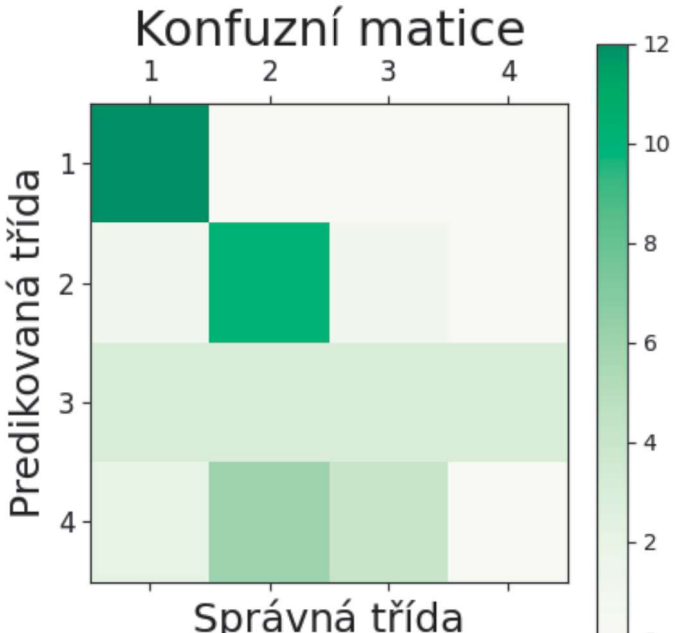
With this structure, I began training the CNN in Python using libraries like Keras and TensorFlow. I selected the final model based on the validation loss function, choosing the one where the loss was minimal.



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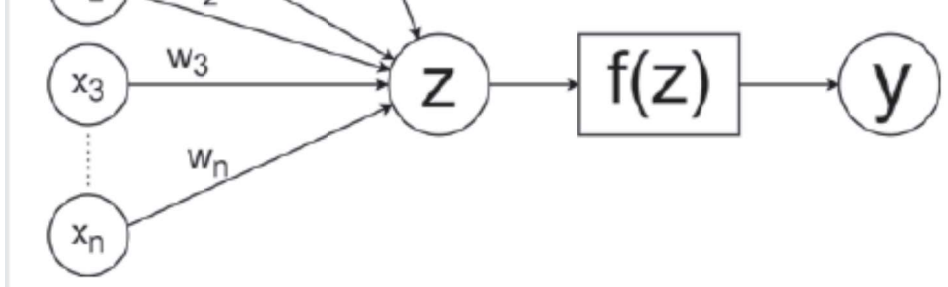
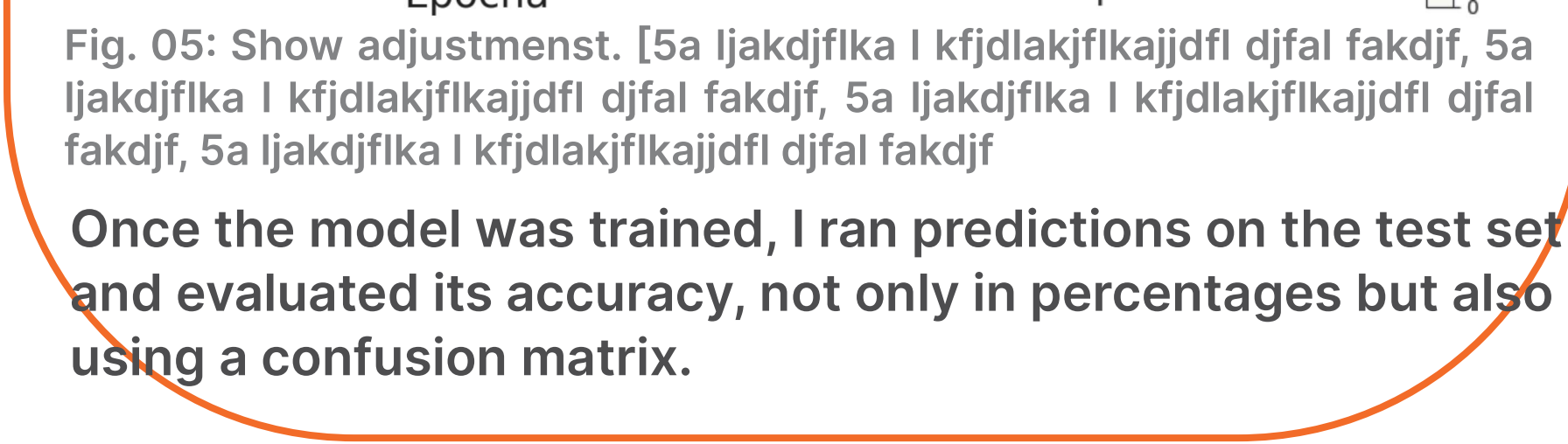


Fig. 04: Calculation of neuron value: A neuron's value y is determined by applying an activation function $f(z)$ to the sum z of the weighted inputs xi plus a bias b.



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Once the model was trained, I ran predictions on the test set and evaluated its accuracy, not only in percentages but also using a confusion matrix.

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