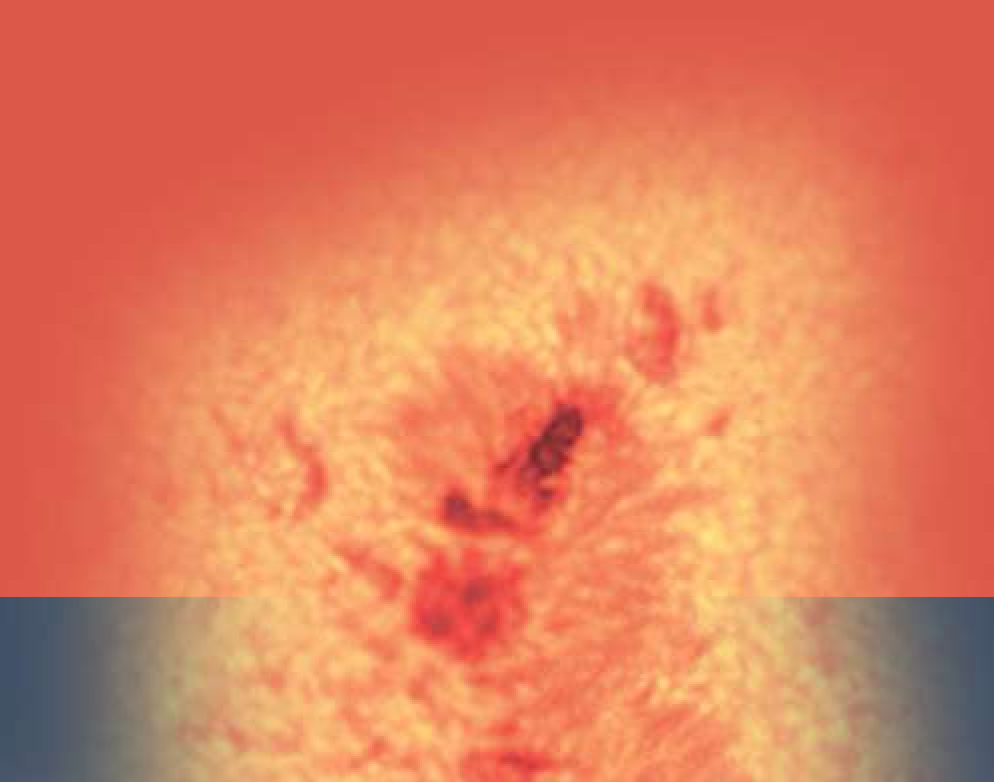
Sunspot class

sification using artific

Eduard Plic

Masaryk Grammar School

ial intelligence



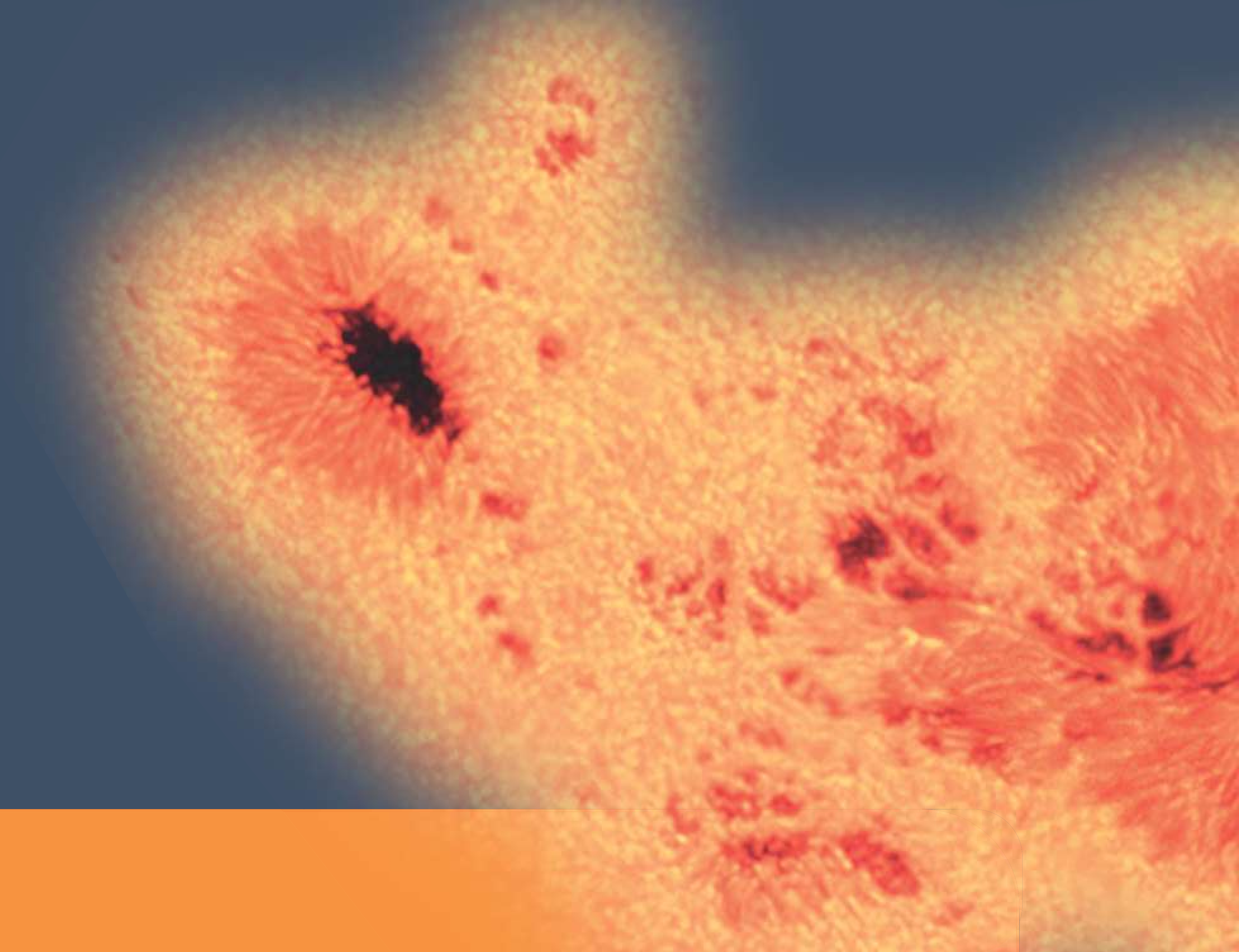
Abstract

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

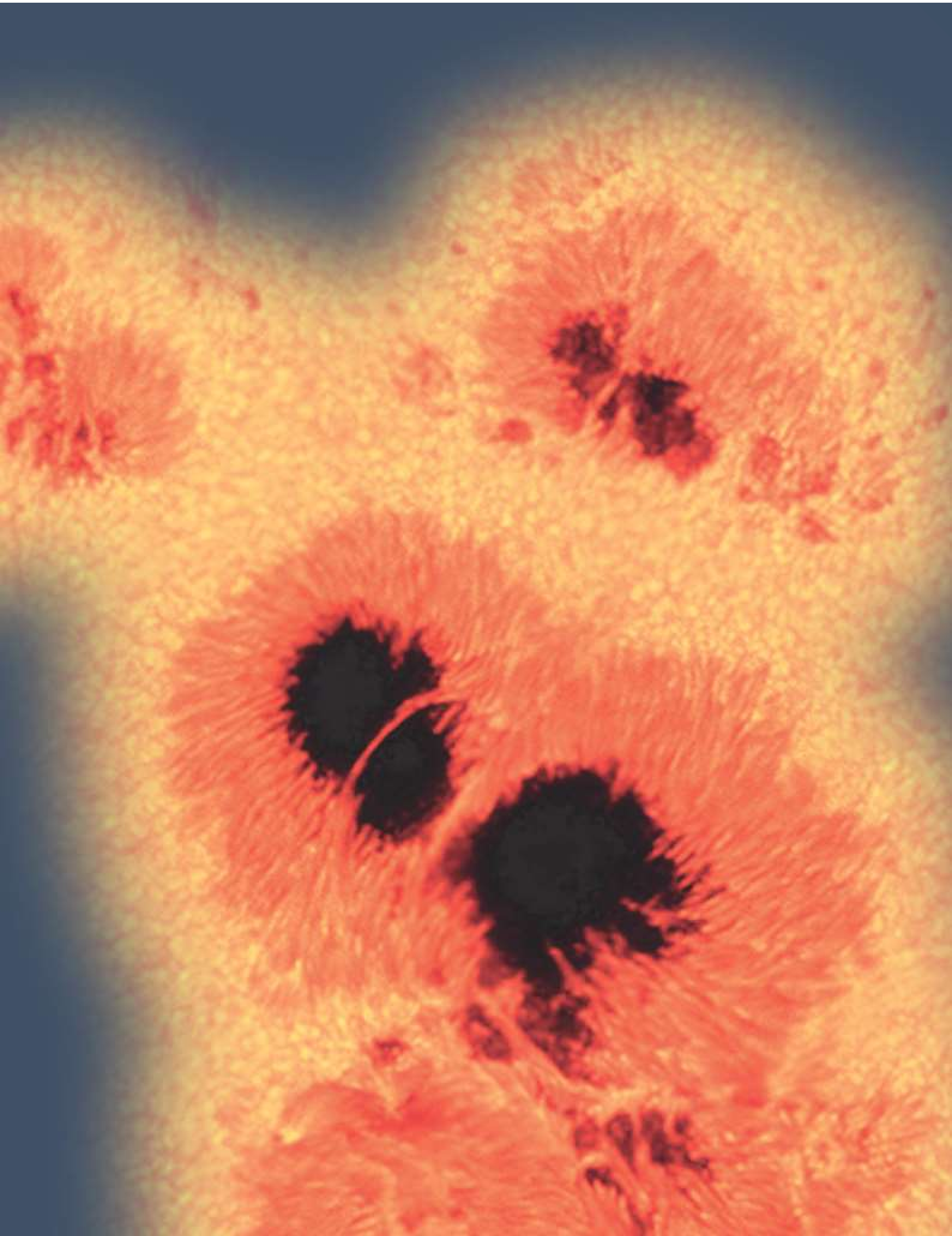
Metods

The preprocessing and classification of sunspot data w

eye at
g these
ty and
omating
s using
e of the
l neural
ification
my.

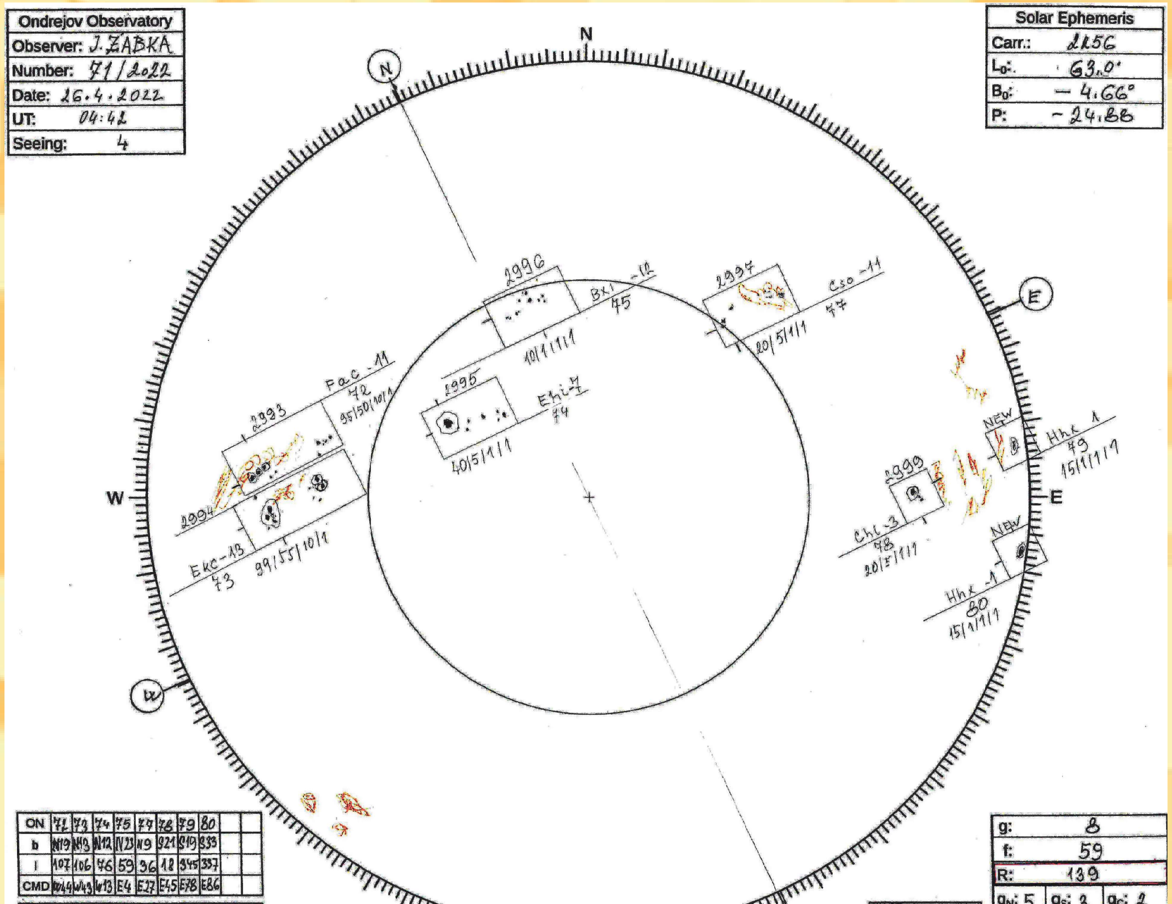


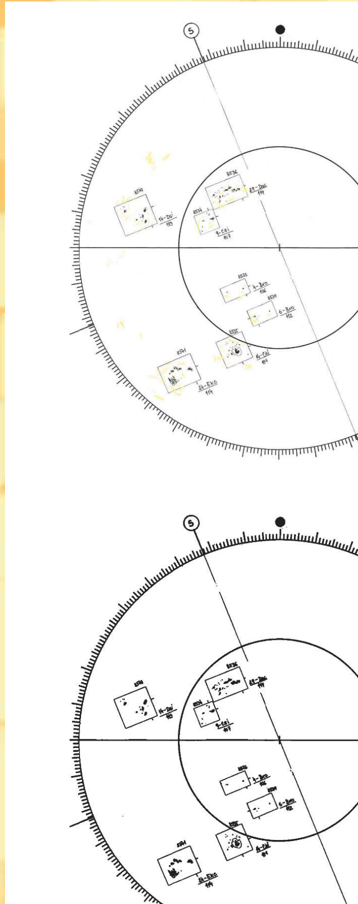
ere automated using Python. The initial



The preprocessing and classification of sunspot data we
dataset consisted of hand-drawn sunspot observations, w
through a series of adjustments. The processed images w
classification system, providing key information on sunspo

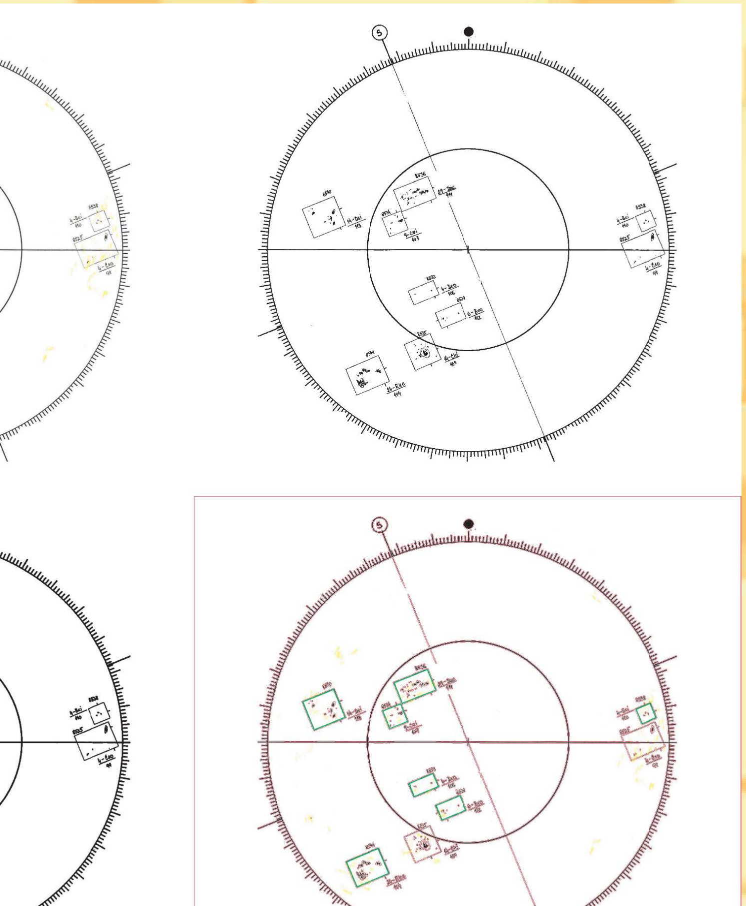
For model training, the dataset was divided into train
Convolutional Neural Network (CNN) to classify the sun
selection was based on the validation loss function, choos
were run on the test set, and the results were evaluated us

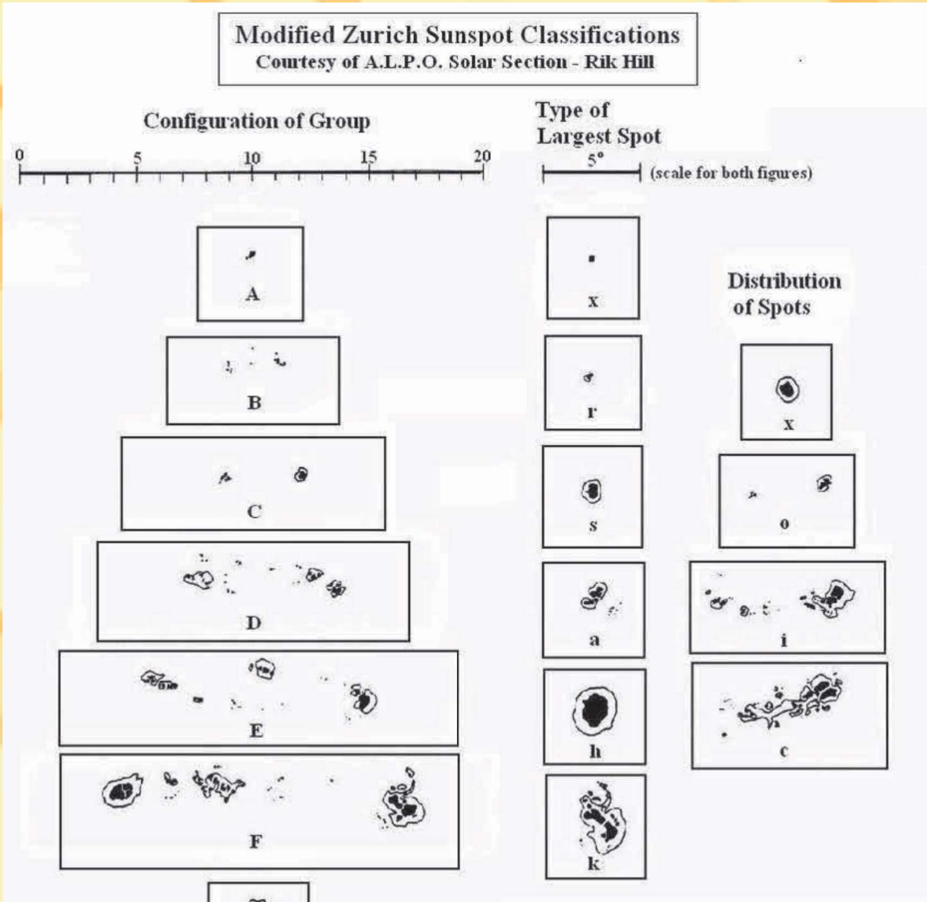




...ere automated using Python. The initial ...which were prepared for machine learning ...ere then labeled according to the McIntosh ...t size, structure, and distribution.

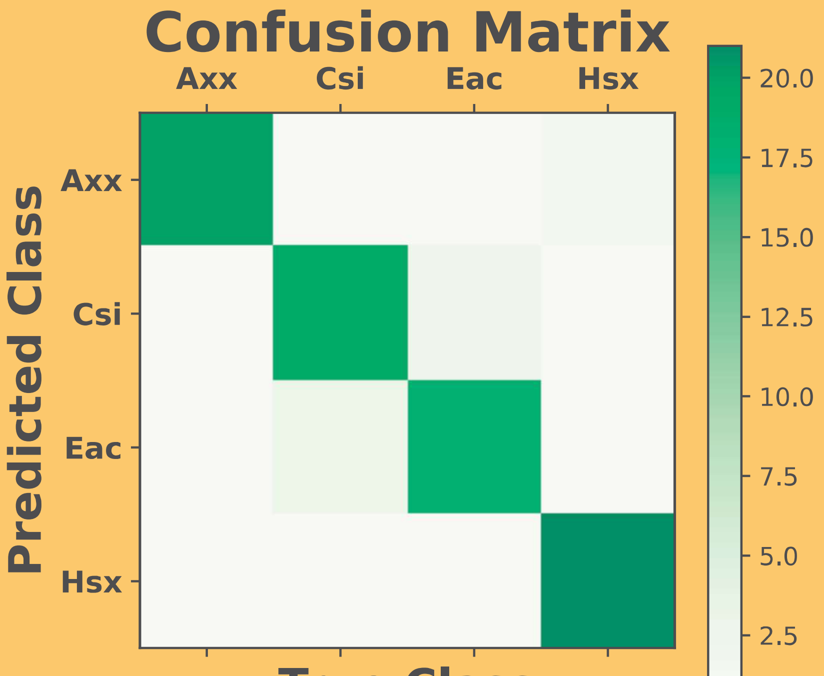
...ing, validation, and test sets in an 80-10-10 ratio. I used a ...spots, utilizing libraries such as Keras and TensorFlow. Model ...sing the model that minimized the loss. After training, predictions ...sing accuracy metrics and a confusion matrix.

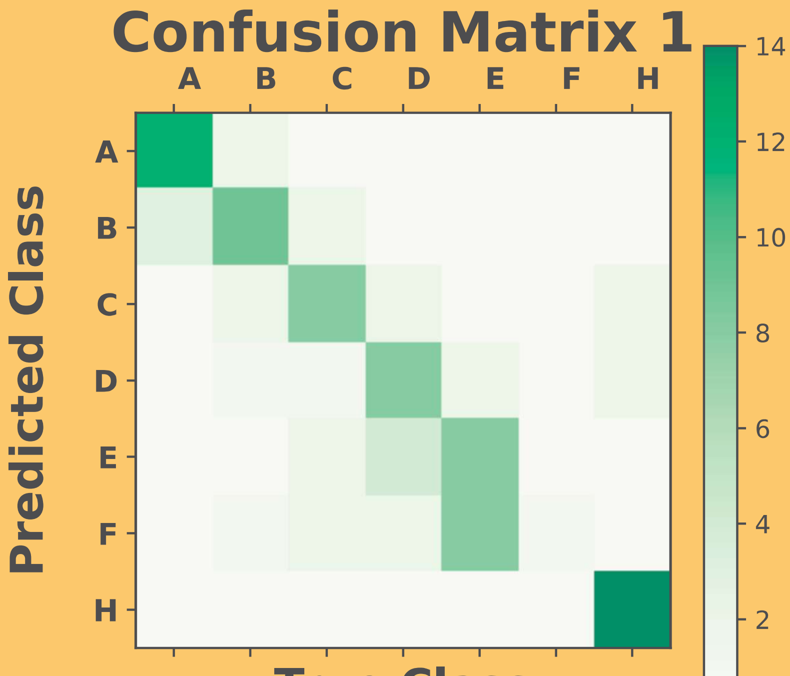




Results

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.





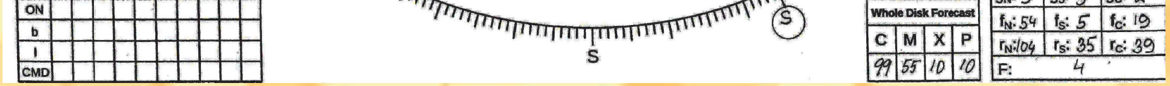


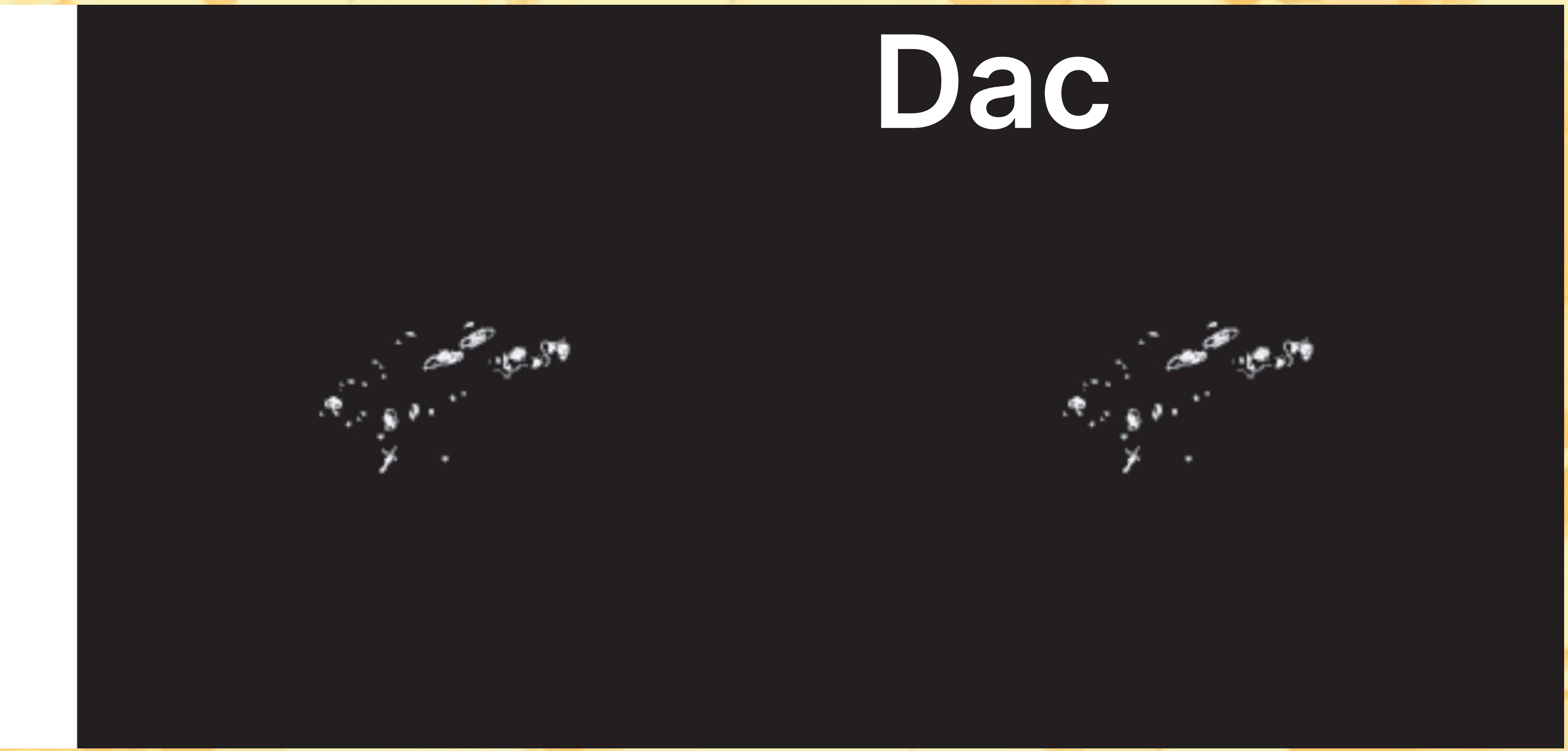
Figure 1: Original sunspot drawing from 26.04.2022 drawn on the Astronomical Institute of the Czech Academy of Sciences

Figure 2: Pr
of drawing
filaments
with blur a
[02d] Highli
green.

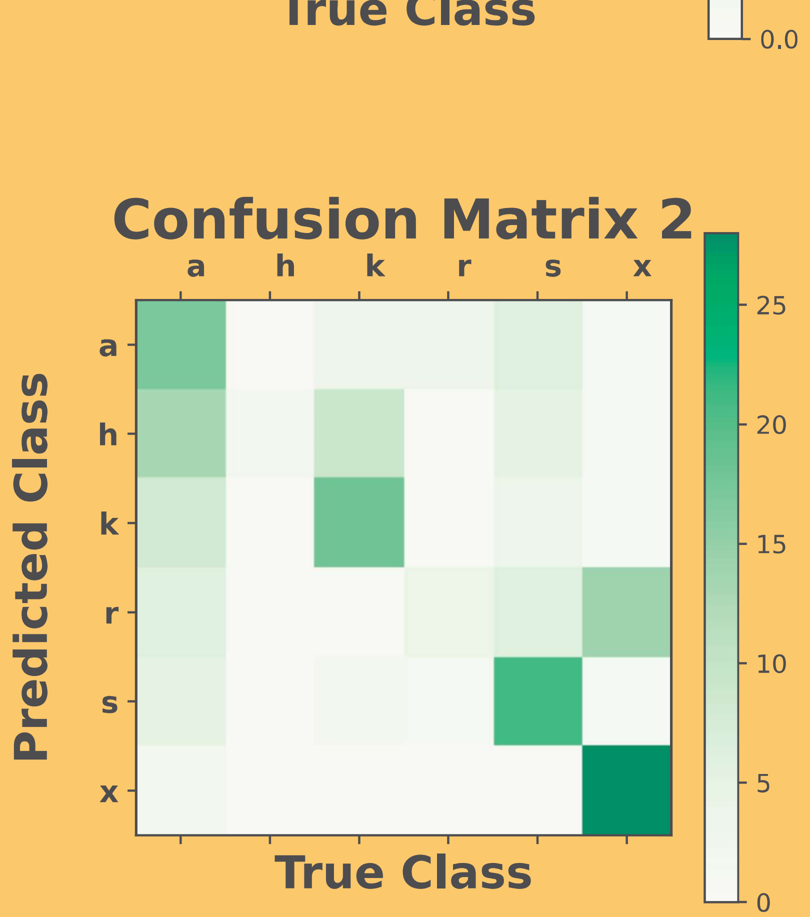
Figure 4: Preprocess of individual sunspot groups. [06a] Extracte
based on the detected rectangle. [06c] Inverted the colors to
supervised machine larning

eprocessing: [02a] Key area g [02b] Removed yellow [02c] Enhanced contours nd black-white conversion ighted detected contours in

Figure 3: Visualisation of each group of McIntosh classification system. McIntosh system classifies sunspots using three letters to indicate size, the largest sunspot's properties, and group distribution



d the square area containing the sunspot. [06b] Removed surrounding areas enhance machine learning performance. [06d] Visualisation of labeling for



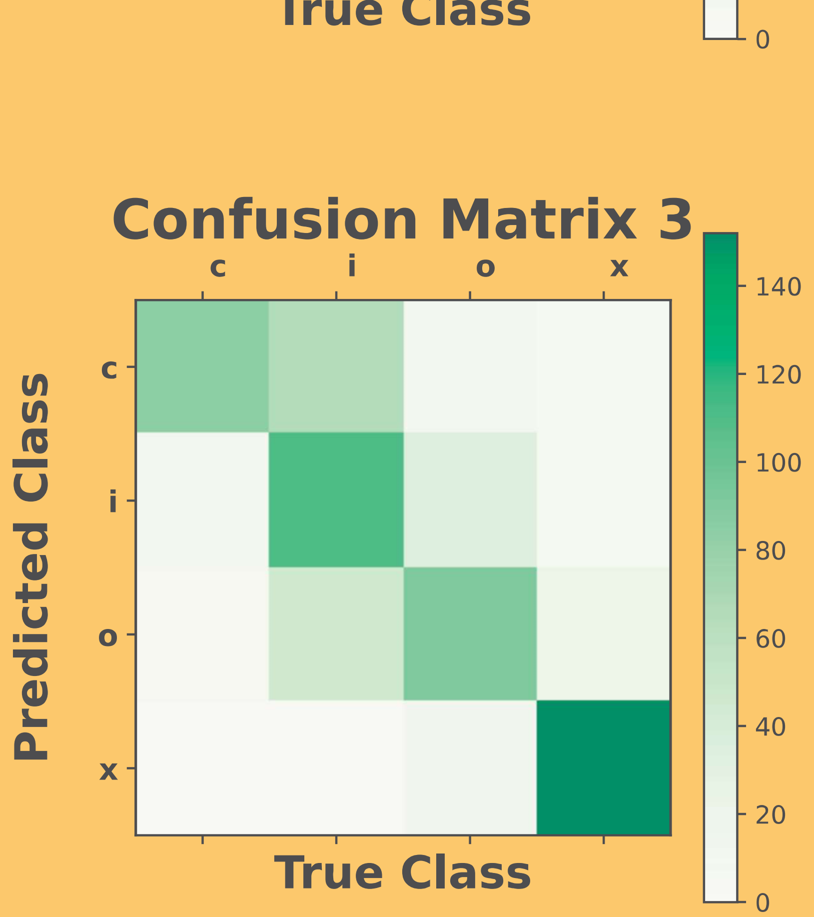


Figure 6: Confusion matrices of selected models. [09a] Model for classification between 4 groups, with 93% accuracy. [09b] Model for predicting the first letter of the McIntosh classification, with 61% accuracy. [09c] Model for predicting the second letter of the McIntosh classification, with 50% accuracy. [09d] Model for predicting the third letter of the McIntosh classification, with 68% accuracy.

supervised machine larning.

T

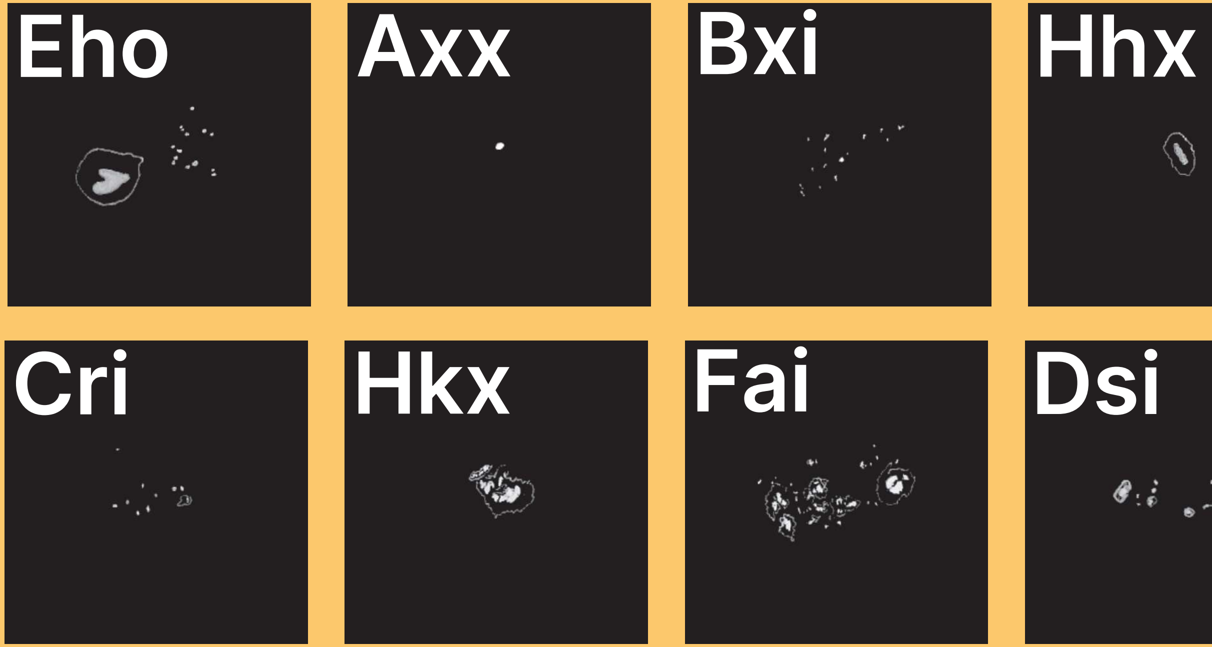


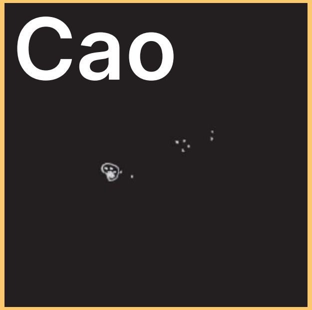
Figure 5: Visualization of dataset spl

Sour

[1] KIPPENHAHN, Rudolf. Odhalená tajemství Slunce. Praha
[2] PROJEKCE - ZÁKRES SLUNEČNÍ FOTOSFÉRY. Astron
https://www.asu.cas.cz/~sunwatch/cs/stranka/kresba

V

T



it into training, validation, and test groups.

rces

a: Mladá fronta, 1999. ISBN 80-204-0805-3.
nomický ústav AV ČR [online]. [cit. 2024-03-14]. Dostupné z:

Future possibilities

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.

[3] Sunspot SST 05Sep2016. Online. In: Wikipedia: the f
2001-. Dostupné z: https://upload.wikimedia.org/v
2024-10-06].
[4] Astronomický ústav Akademie věd České republi
www.asu.cas.cz/
[5] nějaký článek/bakalarska s AI?

free encyclopedia. San Francisco (CA): Wikimedia Foundation,
wikipedia/commons/e/eb/Sunspot_SST_05Sep2016.png. [cit.

iky [online]. c2024 [cit. 2024-10-06]. Dostupné z: https://

Figure 7: Sunspot group as drawn at Kanzelhöhe Observatory, Germany.