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Artificial Intelligence for Detecting Indoor Visual Discomfort from Facial Analysis of Building Occupants

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Motivations

- Glare is a common local visual discomfort induced by exposure to blinding (sun) light
- Greatly impairs comfort, satisfaction and productivity of building occupants
- Glare discomfort often occurs in office workplaces
- It is one of the main drivers for occupants to activate solar shadings

Problematics

Indoor glare discomfort depends on:

- Location and orientation of occupants
- Location and orientation of windows
- Furniture layout
- Position of the sun in the sky
- Cloud cover
- Surfaces blocking or reflecting sunlight

Problematics

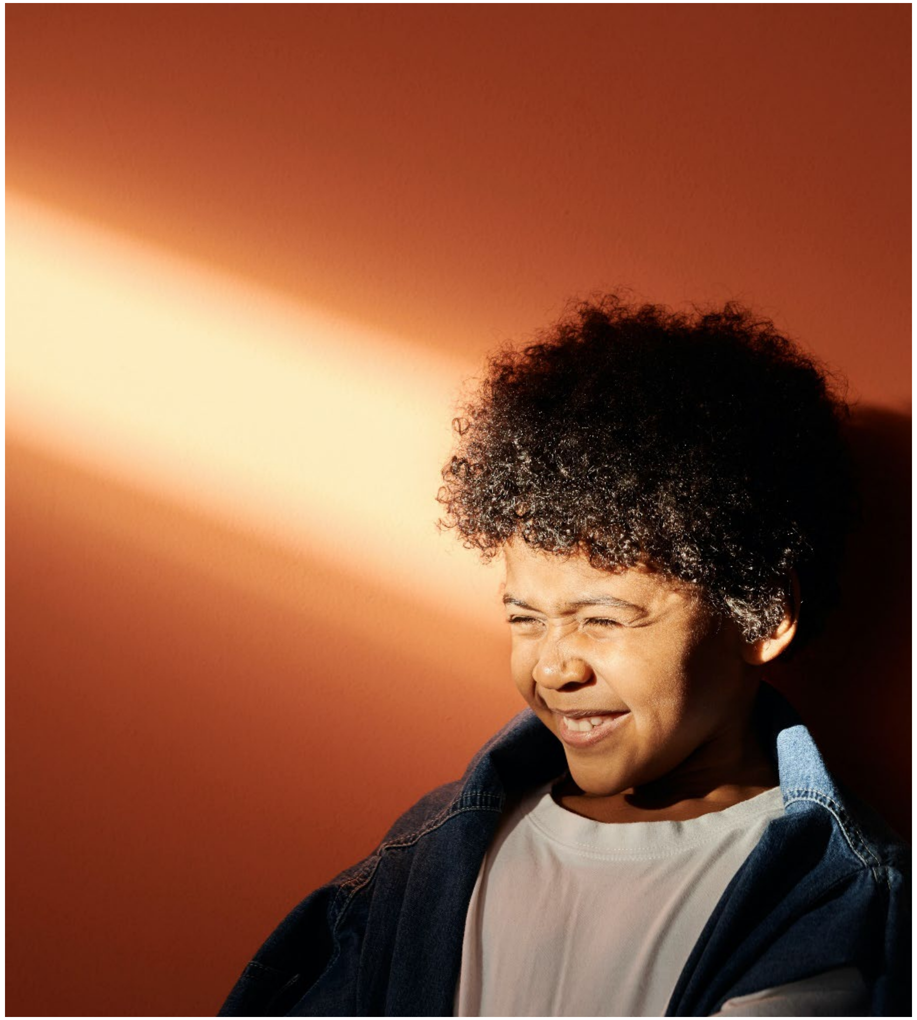
- Very complicated to assess local subjective visual comfort with fixed light sensors

- Visual comfort can drastically change within few seconds because of rapid cloud cover variations (like in Denmark)

- Thus difficult to provide valid feedback to automated shading devices to block glare

New opportunities with AI and computer vision

- Glare induces distinctive facial responses to humans
- Reshape orbital rims and eyes
- Very visible anatomic reflex on the face
- Beam of light striking the eyes leaves clear over-exposed light patches on the face



New opportunities with AI and computer vision

- These distinctive face features could be identified by AI-based image analysis

- Machine learning methods for AI and computer vision have made considerable progress

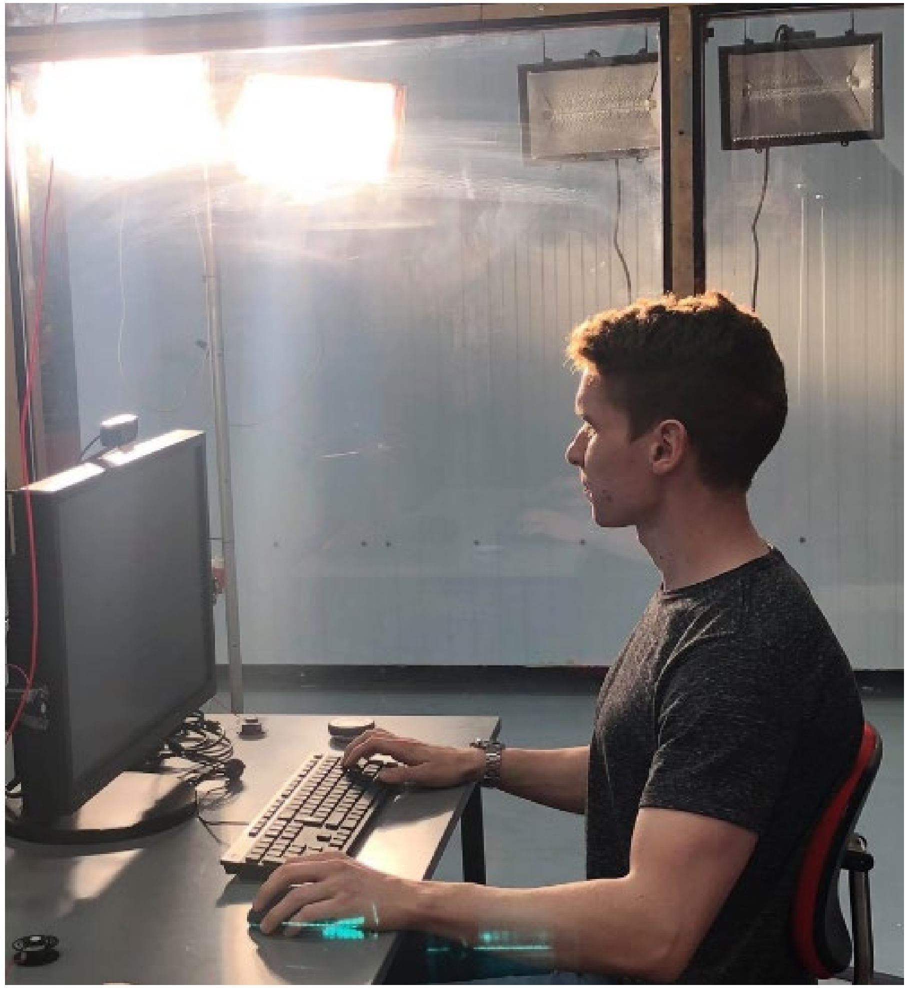
- This technology is mature enough to decipher human’s facial expressions

Aims of this study

- The face of the building occupant is directly used as a visual comfort sensor
- A computer vision AI algorithm is used to detect the subjective local glare discomfort from the images of the occupant's face
- A prototype that can be used to provide control feedback to a smart shading device

Study case description

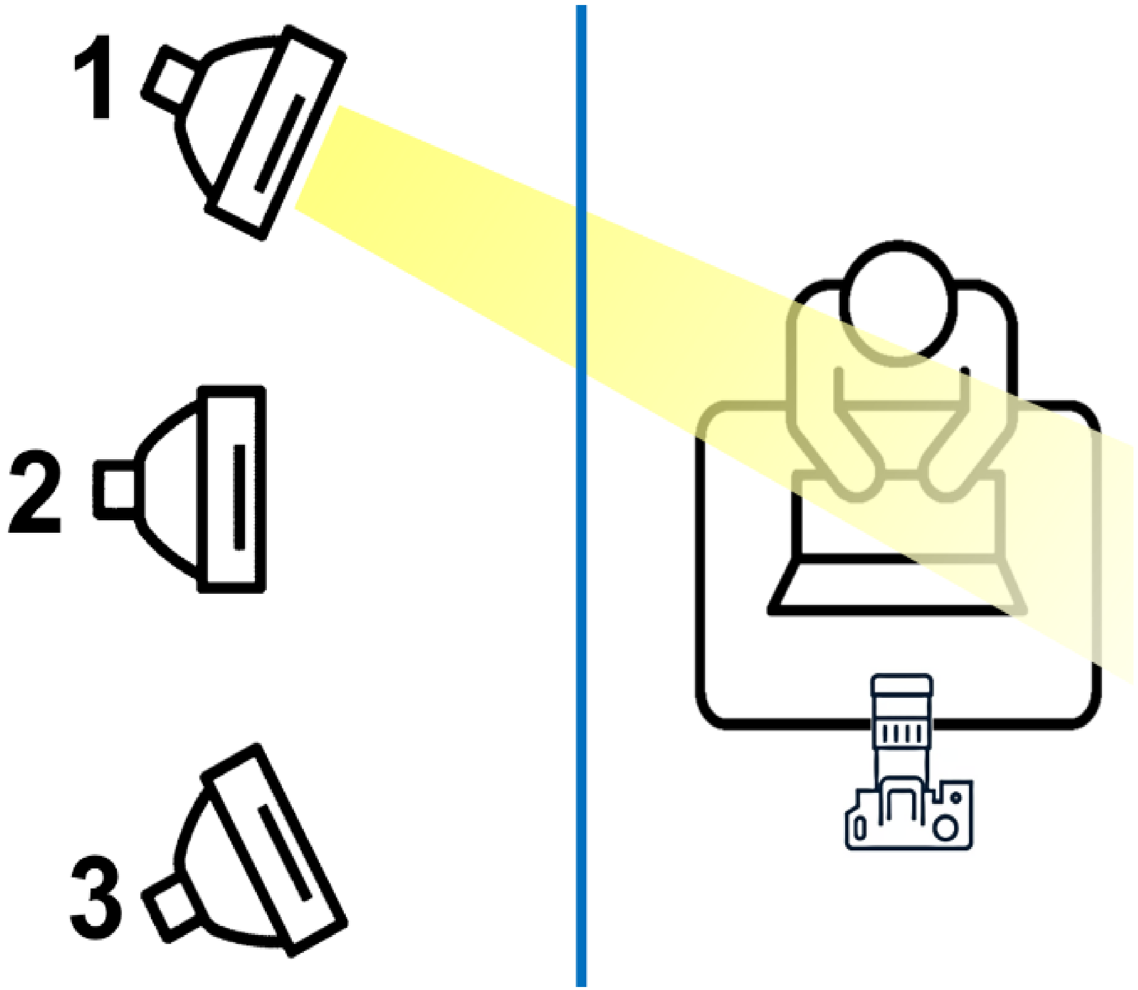
- Single-occupant office room
- Working at computer station
- Glare from sun through large window
- Glare source: spotlights emulating the sun when low on the horizon (sunrise or sunset)
- Face images acquired by webcam placed on top of computer screen



Training data for the AI algorithm

Generate a labelled set of training data:

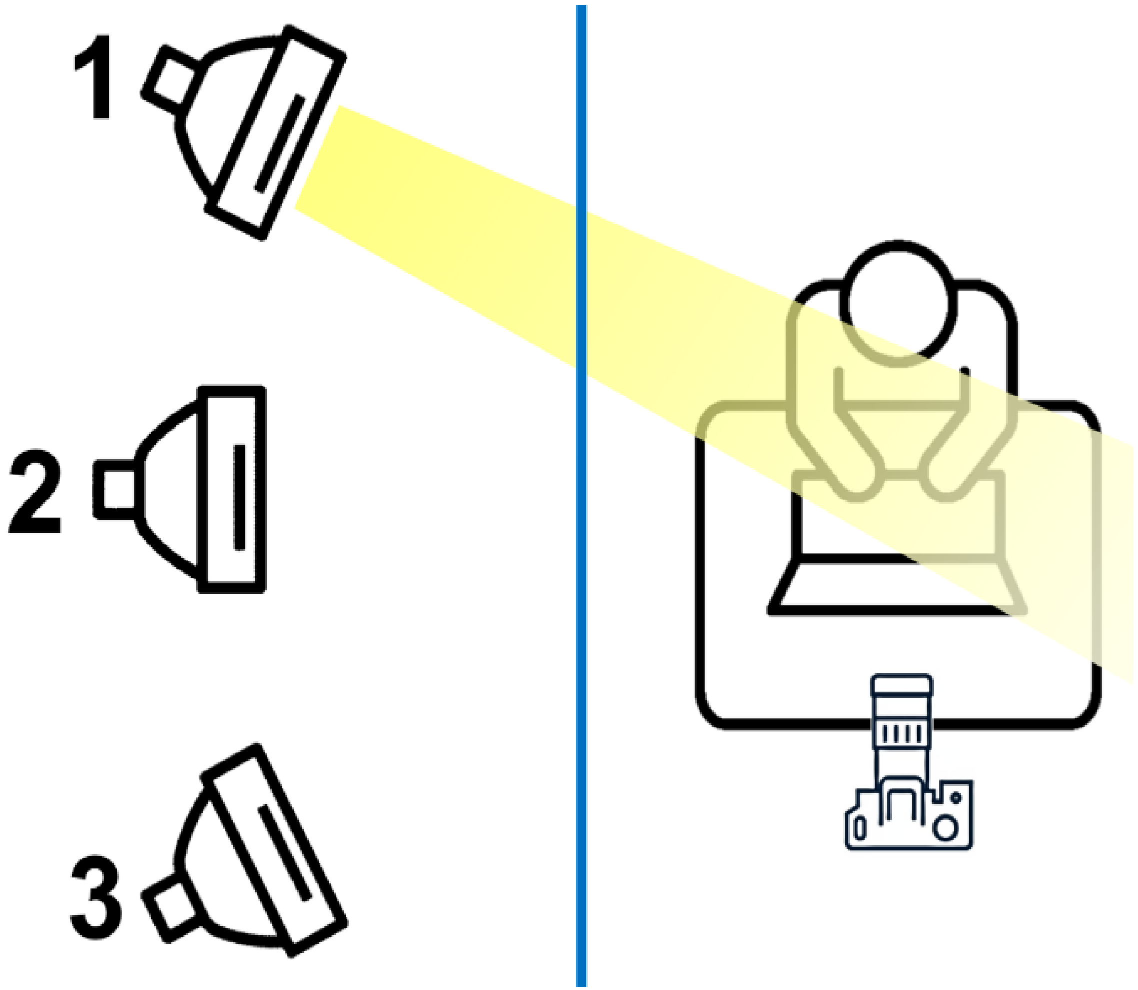
- Face video footage of humans
- Indications about visual discomfort
- Various lighting conditions
- Various participants



Training data for the AI algorithm

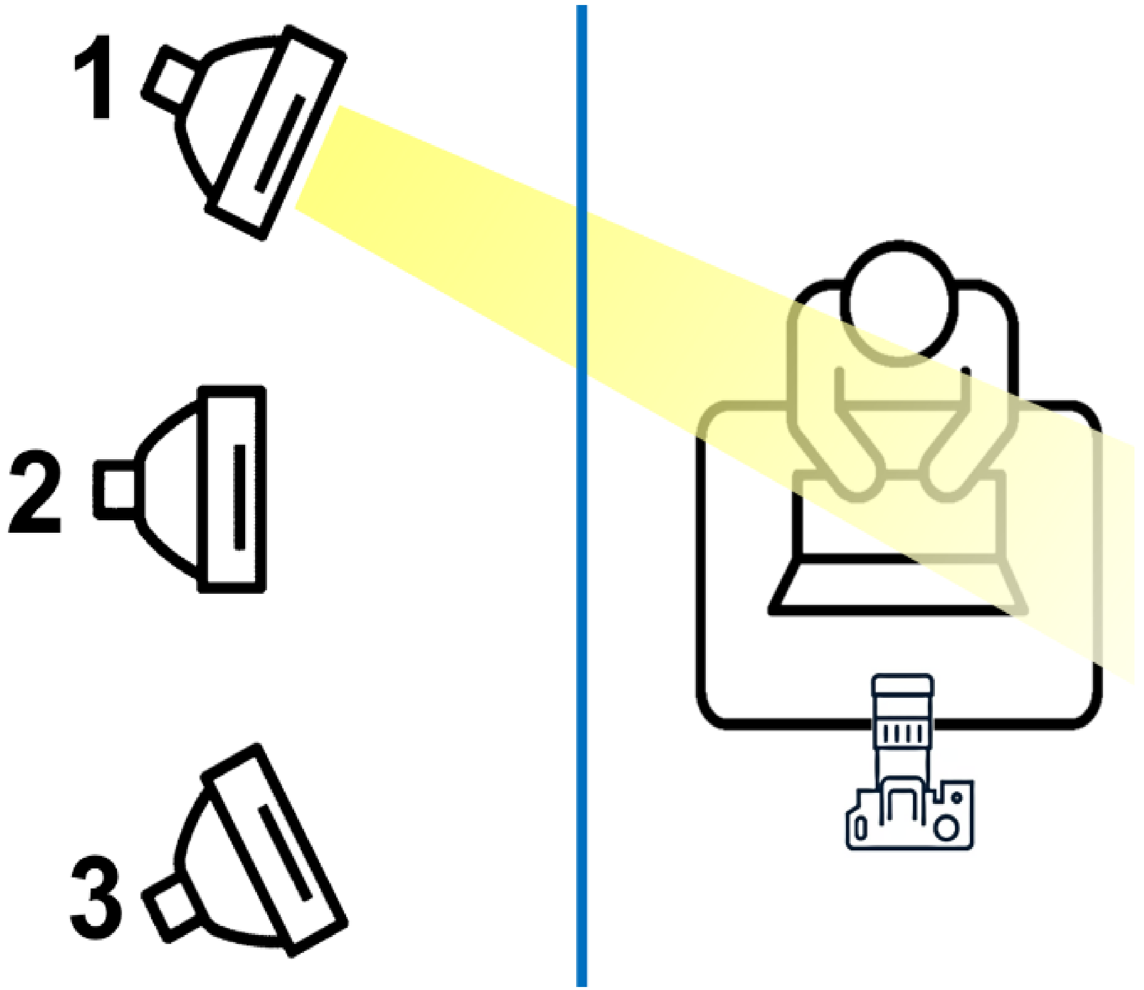
Use of laboratory test room:

- Controlled light conditions
- Spotlights to generate glare from different angles
- 17 experimental tests
- Variety of facial features, age, gender, glasses, etc



Training data for the AI algorithm

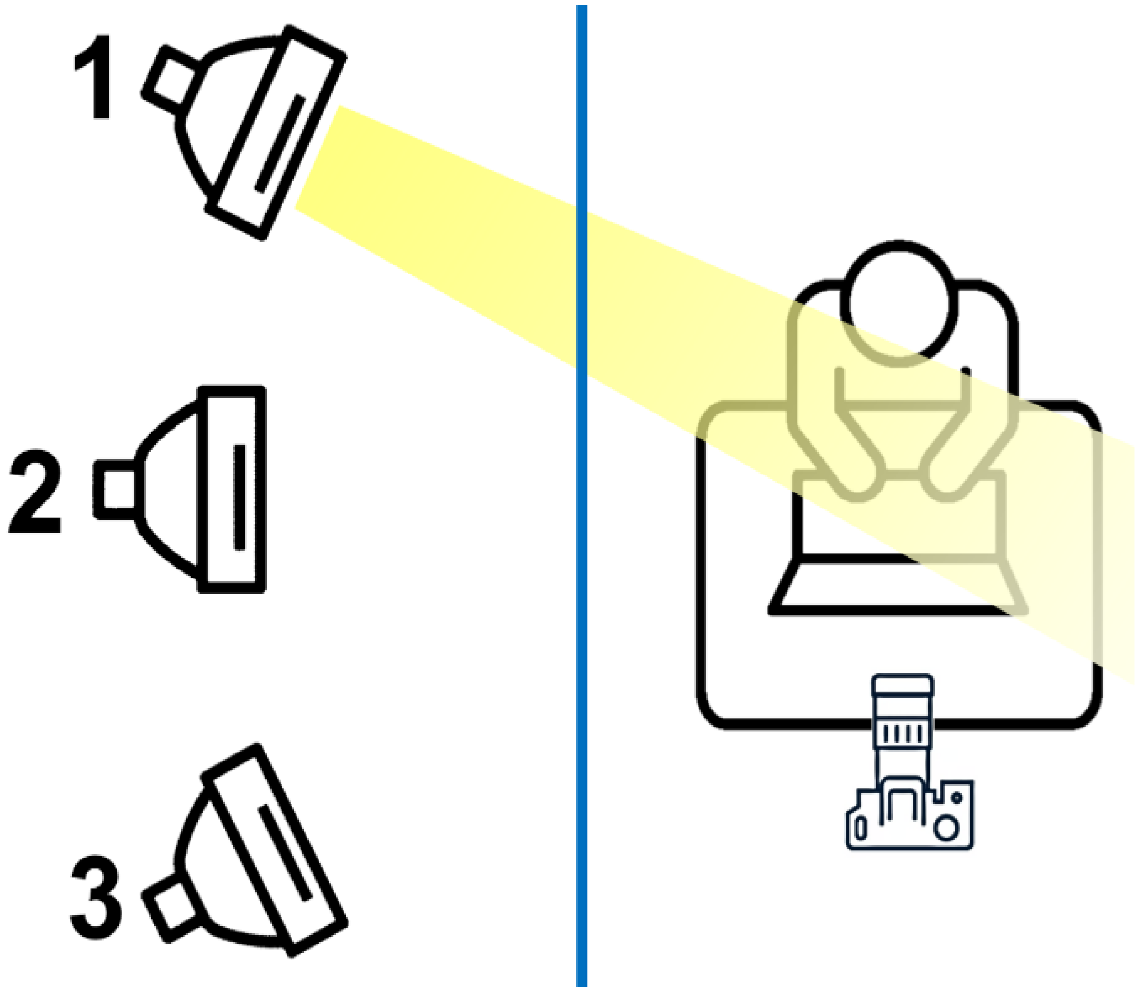
- Each test comprises several phases:
  - Neutral phases: 500 lux and no glare
  - Glare phases: 1 of the 3 spotlights is switched on to induce glare
- 12 phases: 6 neutral, 6 with glare from different angles



Training data for the AI algorithm

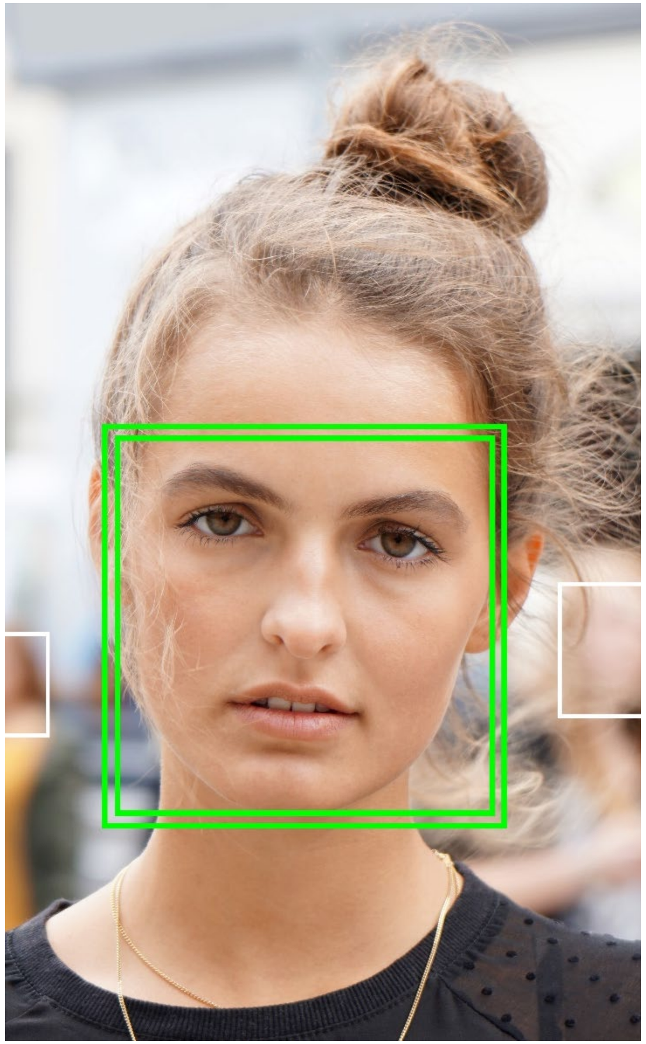
- Participants are asked to read a text and answer questions about it

- At end of each phase, participant indicates if currently experiencing:
  - Thermal discomfort
  - Acoustic discomfort
  - Visual discomfort



Developing the AI algorithm

- Facial analysis algorithm is a binary classifier: visual discomfort / visual comfort
- 1st step: locate and crop down a face from the whole image
- Performed by pre-trained face classifier based on the *Haar Feature-based Cascade Classifier*

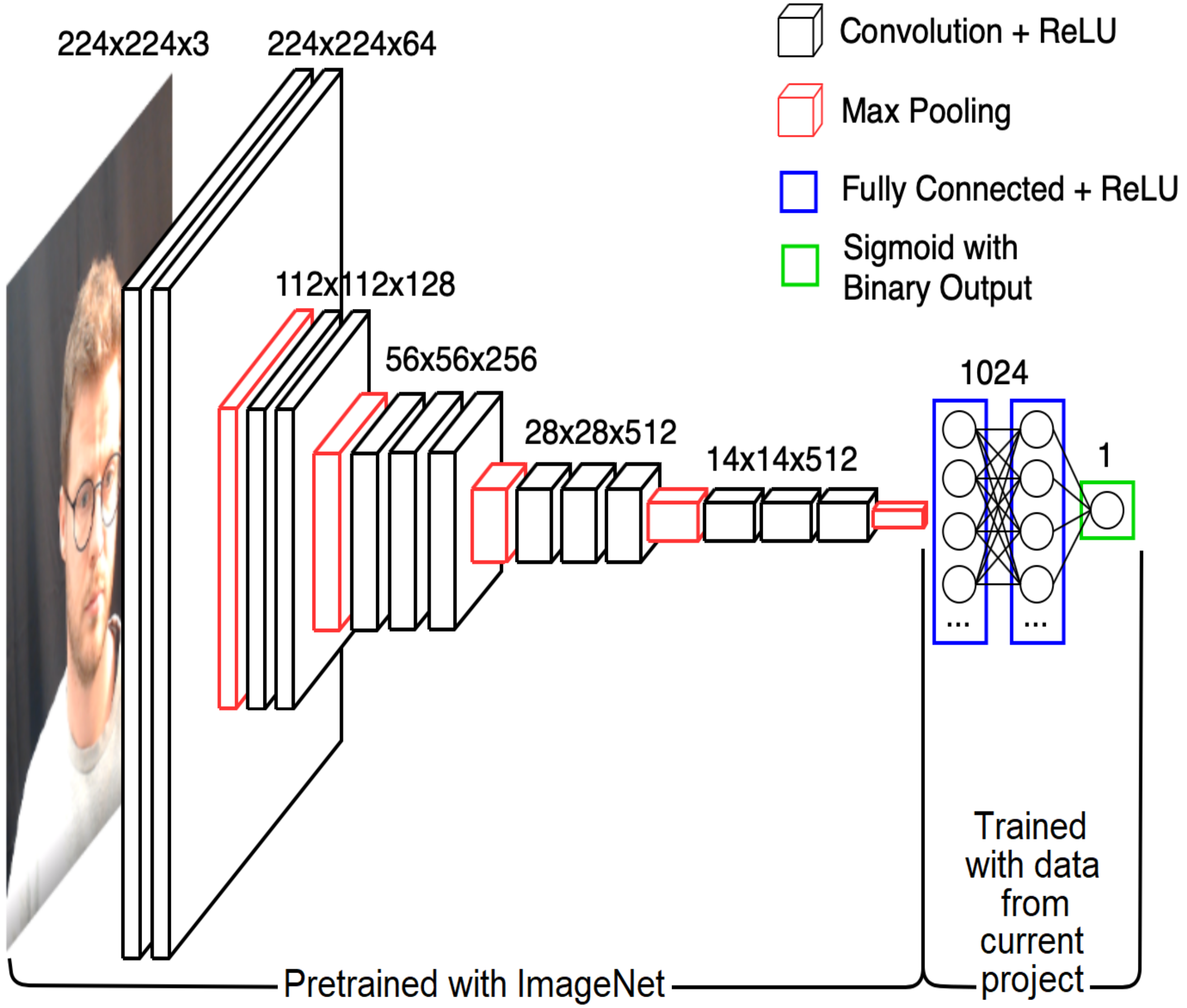


Developing the AI algorithm

- 2^{nd} step: the facial analysis is performed by a Convolutional Neural Network (CNN)

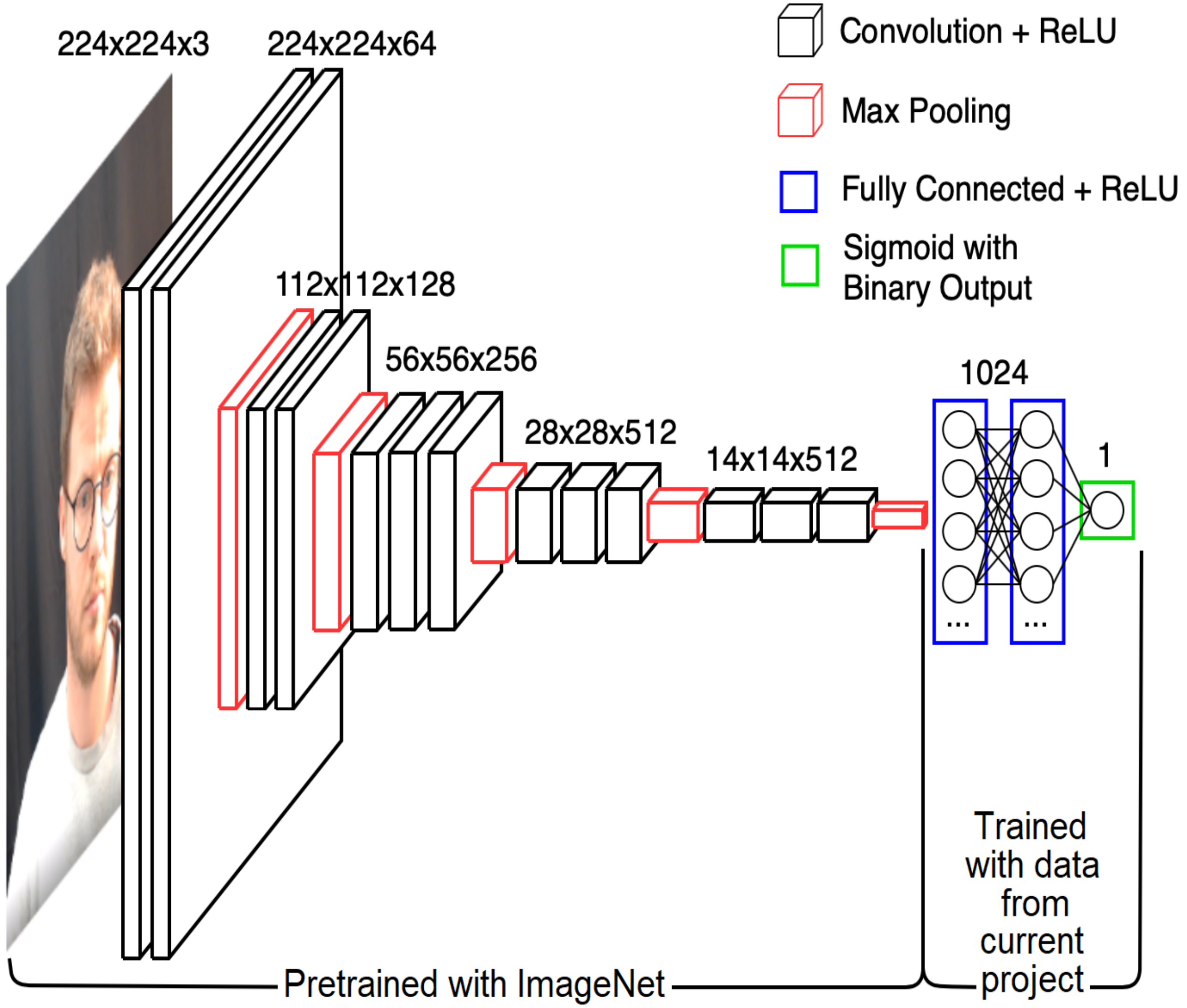
- VGG-16 CNN network with *TensorFlow Keras* implementation

- 16 layers



Developing the AI algorithm

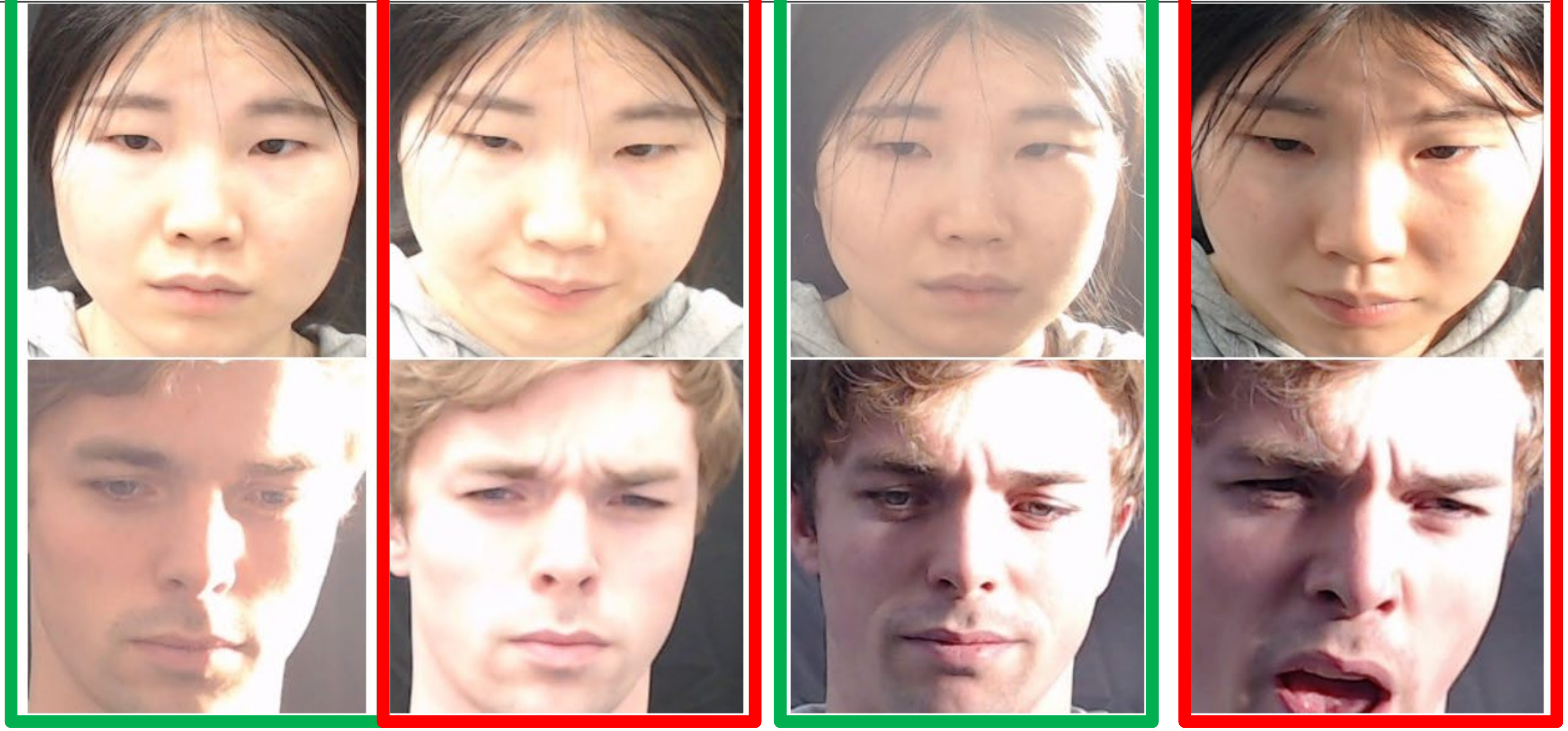
- Inputs: rescaled 224x224 pixels RGB images
- Pre-trained on the *ImageNet* dataset: 1.2 million images labelled with 1000 object classes
- The last layers for comfort/discomfort classification are trained with the labelled training data from the laboratory tests



Results

Out-of-sample validation tests: 90% accuracy (correct classification)

True label	Comfort	Comfort	Discomfort	Discomfort
Algorithm classification	Comfort	Discomfort	Discomfort	Comfort
Example 1				
Example 2				



Conclusions

- AI algorithm for glare detection has been developed from off-the-shelf pre-trained neural networks

- Only train last layers for specific applications with small training dataset and minimum computation time

Conclusions

- AI algorithm detects local glare discomfort from the facial analysis of the building's occupants.
- 90% classification accuracy: similar to other face analysis AI applications
- Can be used as feedback to control smart shading devices in a single-office room and rapidly eliminate local glare discomfort

Future work

- Improve algorithm accuracy and response time
- Increase size and quality of the training dataset
- Gain a deeper understanding of the artificial neural network operation (explainable AI)
- Use output of glare detection algorithm to regulate simple shading devices (on-going)
- Expand applications to offices with multiple occupants and complex situations

Demonstration video

Prototype demonstration video:

https://youtu.be/ip9fuWbtEsc

Thank you for your attention !
Any questions ?

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