Artificial intelligence in ophthalmology

MLgroup

MLgroup (Machine Learning Group)

https://uim.fei.stuba.sk/MLgroup/

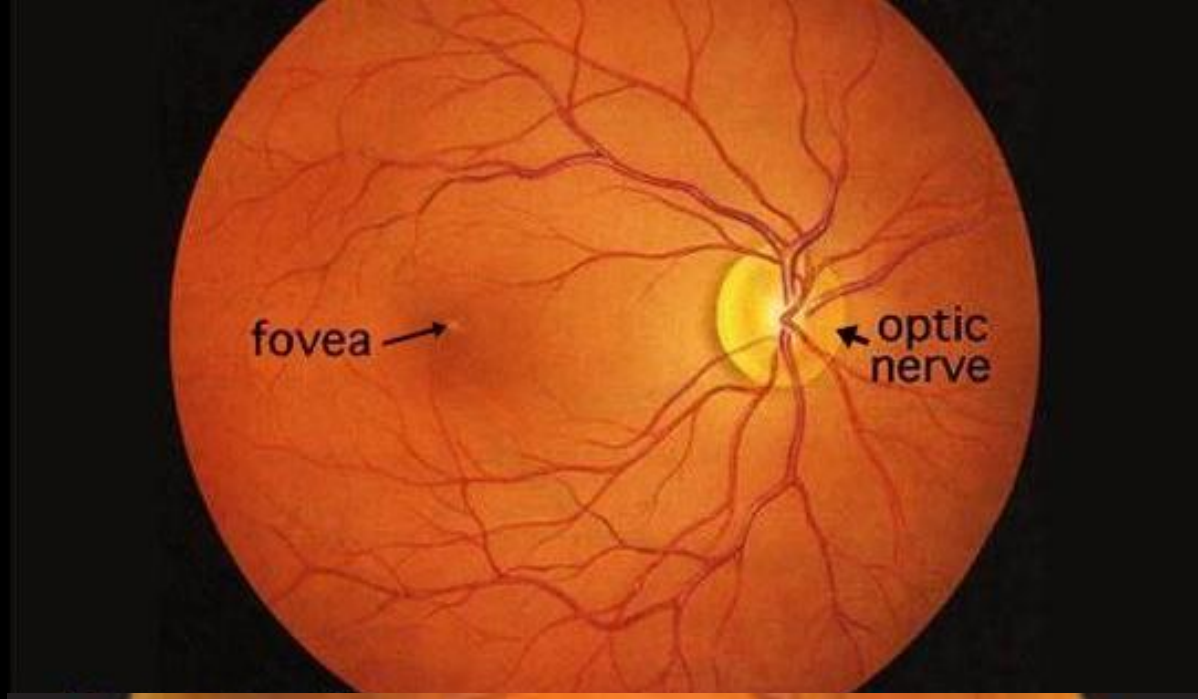
FEI STU in Bratislava, Slovakia

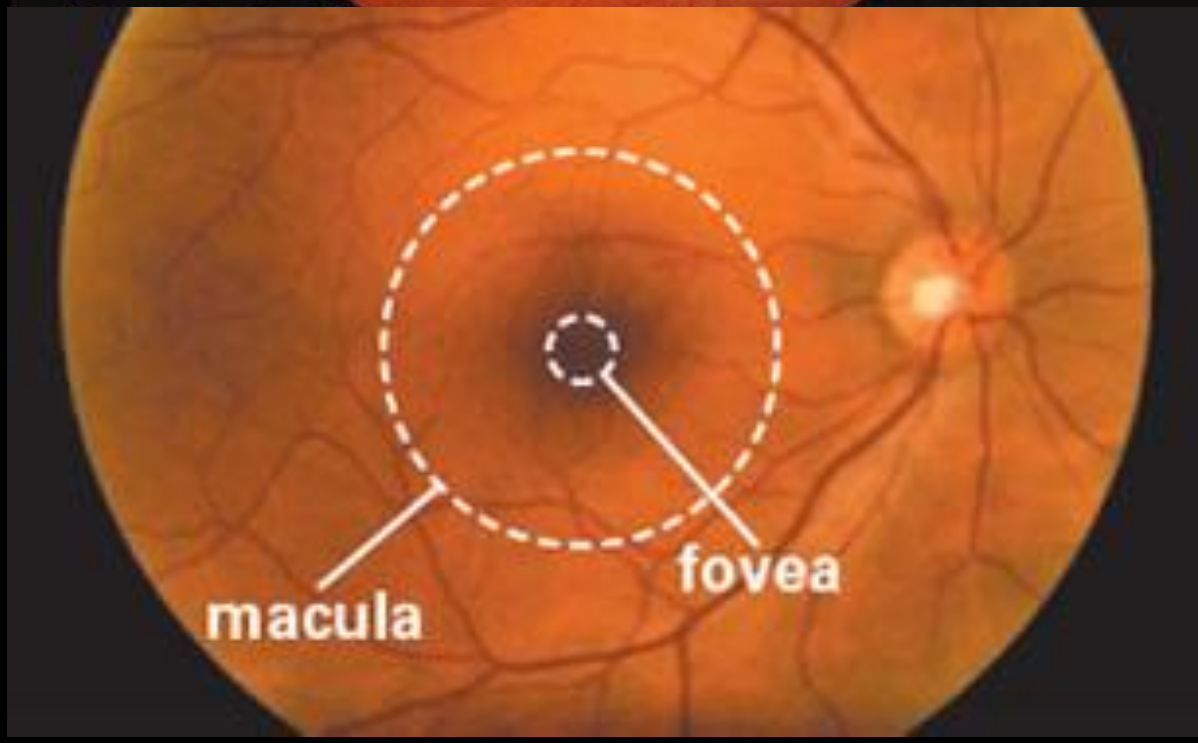
Areas of our interests

- automated diagnosis of fundus images with diabetic retinopathy altogether with anatomical findings detection and segmentation on healthy retinal images (i.e. retinal blood vessels)
- Classification and segmentation of OCT images
- Generating artificial fundus images using AI
- we work with image processing and machine learning methods, including deep neural networks
- we use publicly available retinal datasets: e-Ophtha-EX and e-OPhtha-MA, DiaretDB1, Messidor1, DRIVE, and STARE
- discovering new possibilities with smartphone screening in ophthalmology

Healthy fundus on funduscamera image

- optic nerve head (optic disc)
- macula
  - fovea - the center
- retinal blood vessels
- retina





Diabetic retinopathy

- is an ocular complication of diabetes type 1 and 2
- the most common practical cause of blindness in the working-age population in industrialized countries
- correlates with the duration of diabetes and its control
- it affects the retinal vessels at their micro level
- we divide it into non-proliferative and proliferative
- it is often complicated by edema of the central retina

Diabetic retinopathy

Images from Messidor database:
on the left, a healthy patient, in the middle and on the right, patients with diabetic retinopathy

Diabetic retinopathy

non-proliferative

Diabetic retinopathy

proliferative

Fundus images analysis

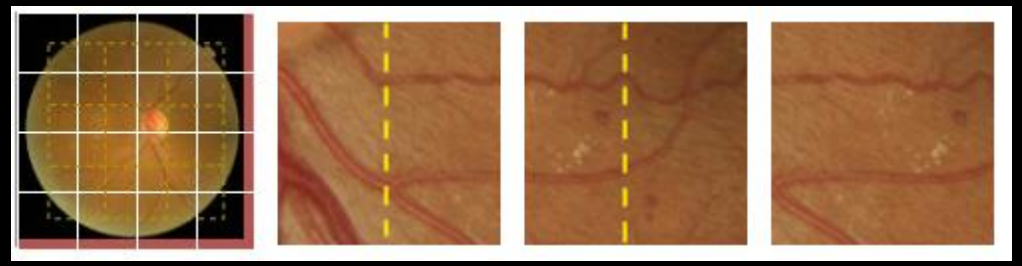
- Anatomical findings:
  - "mapping" the image
  - in order to recognize the sick, we must know the healthy
  - finding one structure to navigate to find another
  - removing the structure as part of preprocessing

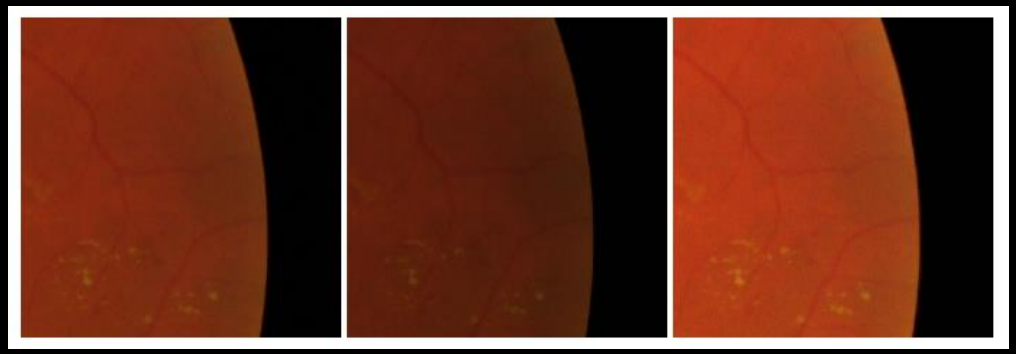
- Pathological findings:
  - screening and identification of diseases
  - determining the stage of the disease
  - follow-up the course of the disease and treatment outcomes

Data preparation and creation of training datasets I.

- whole images or their parts (image patches)

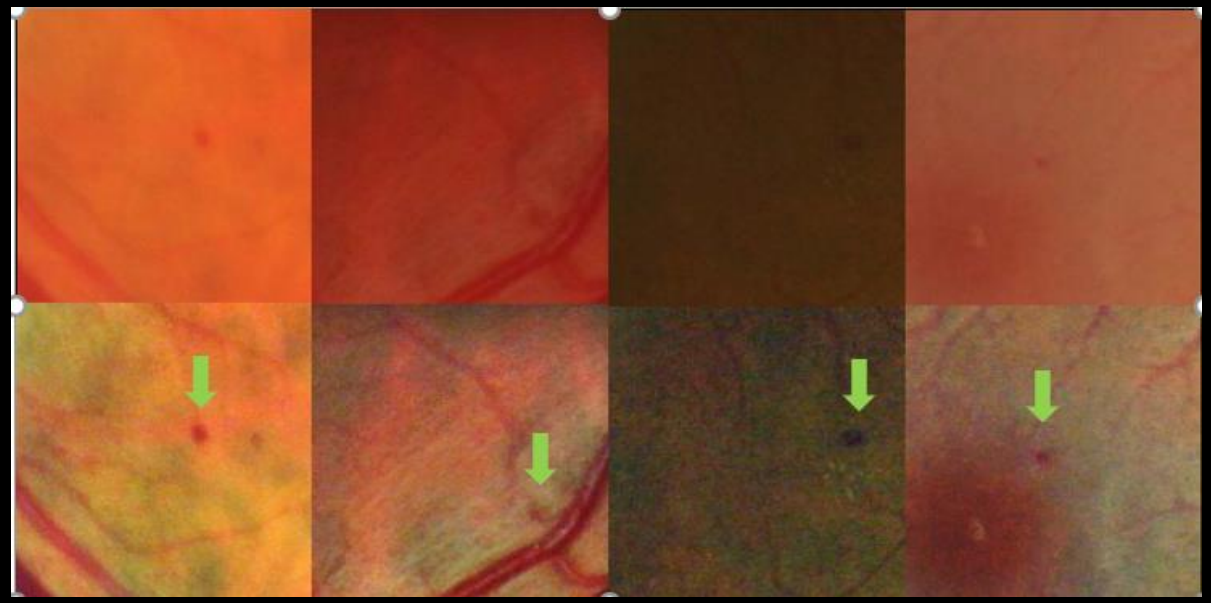
- data augmentation
  - rotation, mirroring, shifts, contrast and brightness modifications





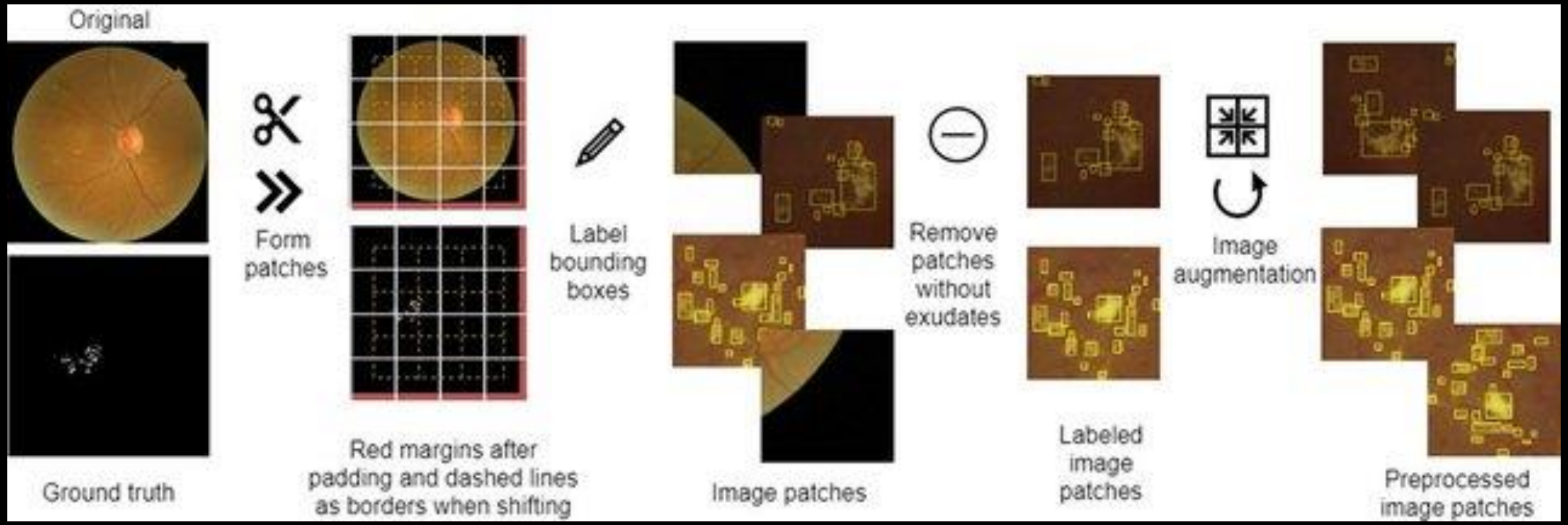
Data preparation and creation of training datasets II.

- image preprocessing, e.g. CLAHE in microaneurysms and macula detection



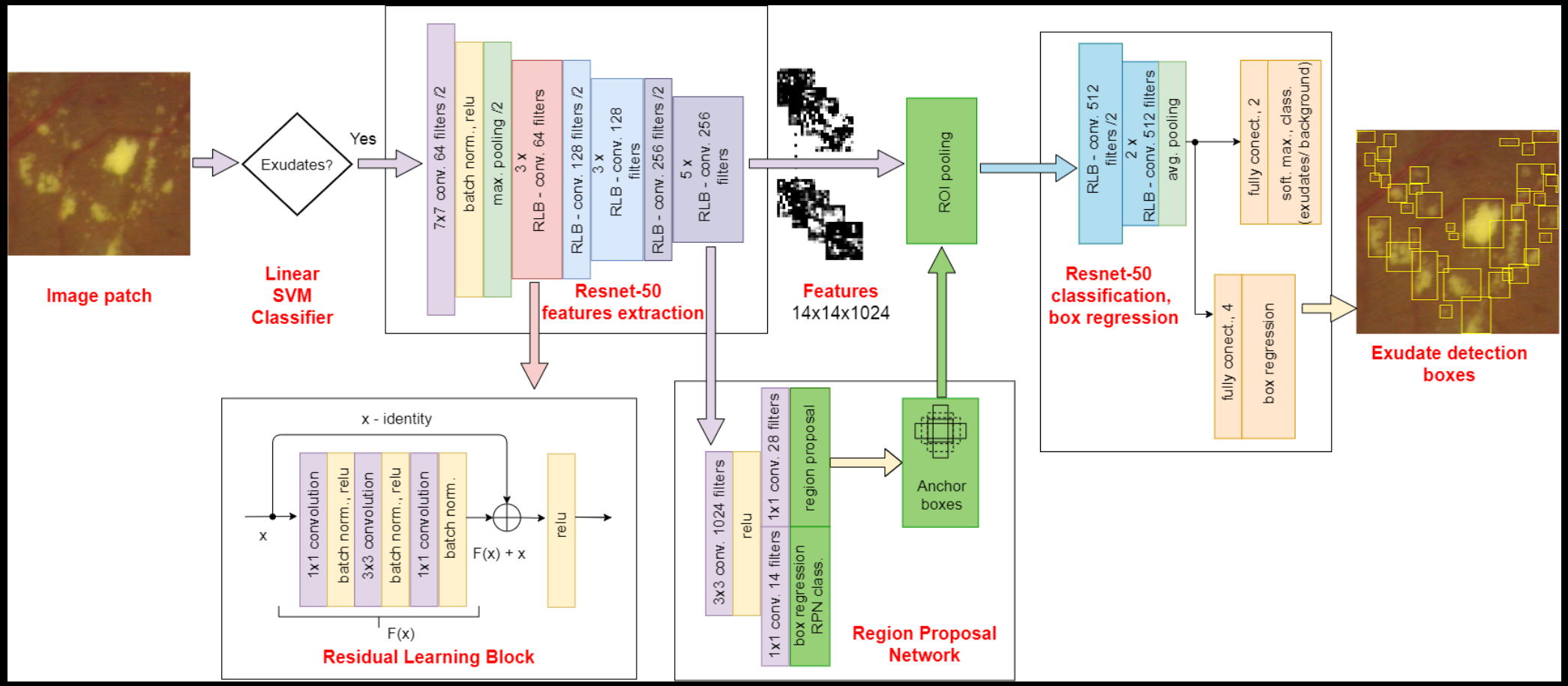
Hard exudates detection using faster R-CNN* object detector

- hard exudates, frequently found in diabetic retinopathy, are in connection with retinal oedema

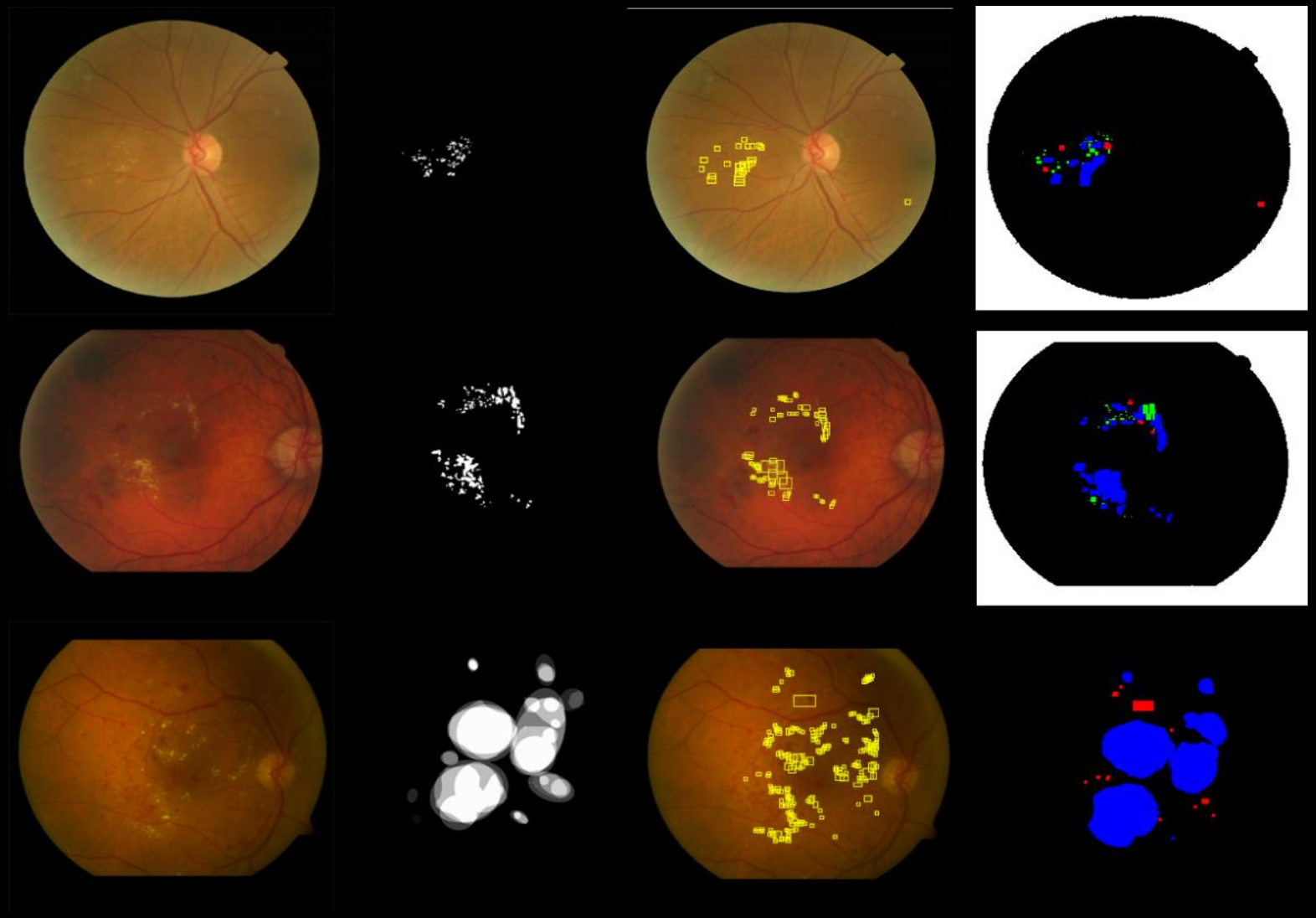


**Recurrent- Convolution Neural Network (R-CNN)*

- patches are firstly pre-scanned whether containing hard exudates using SVM classifier, followed by faster R-CNN exudates detection
- faster R-CNN was trained using features from pre-trained ResNet-50 to detect exudates on exudates-containing patches only



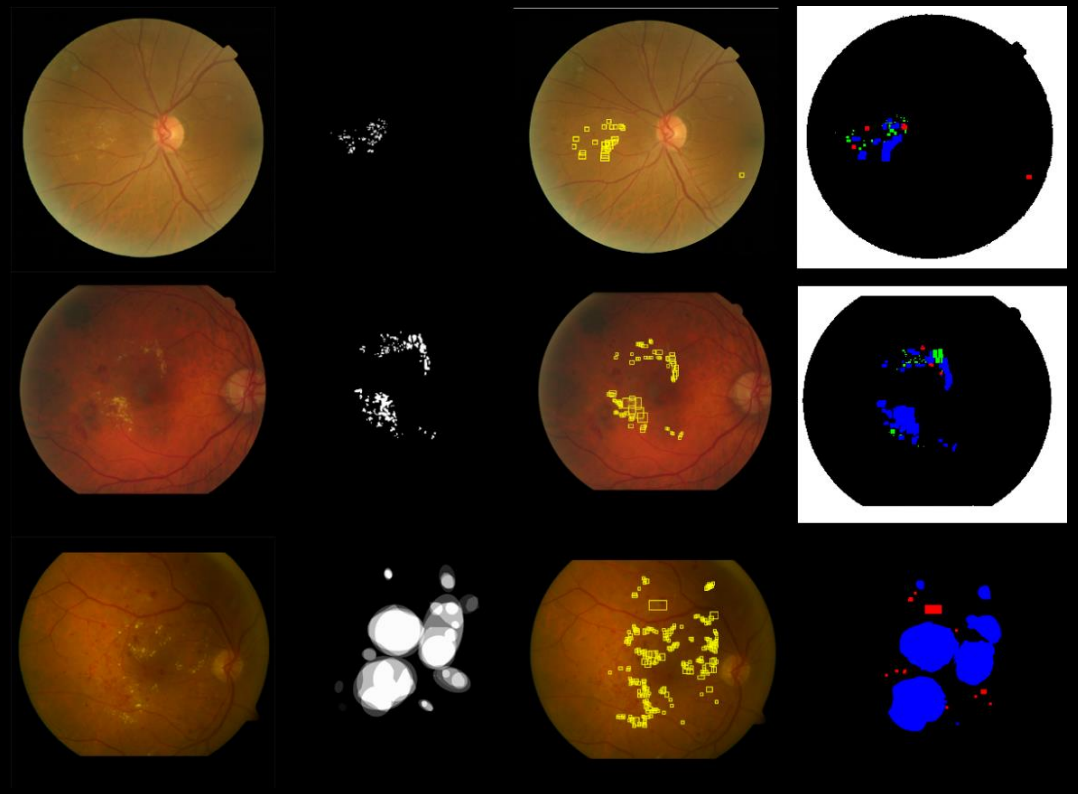
Results of proposed method



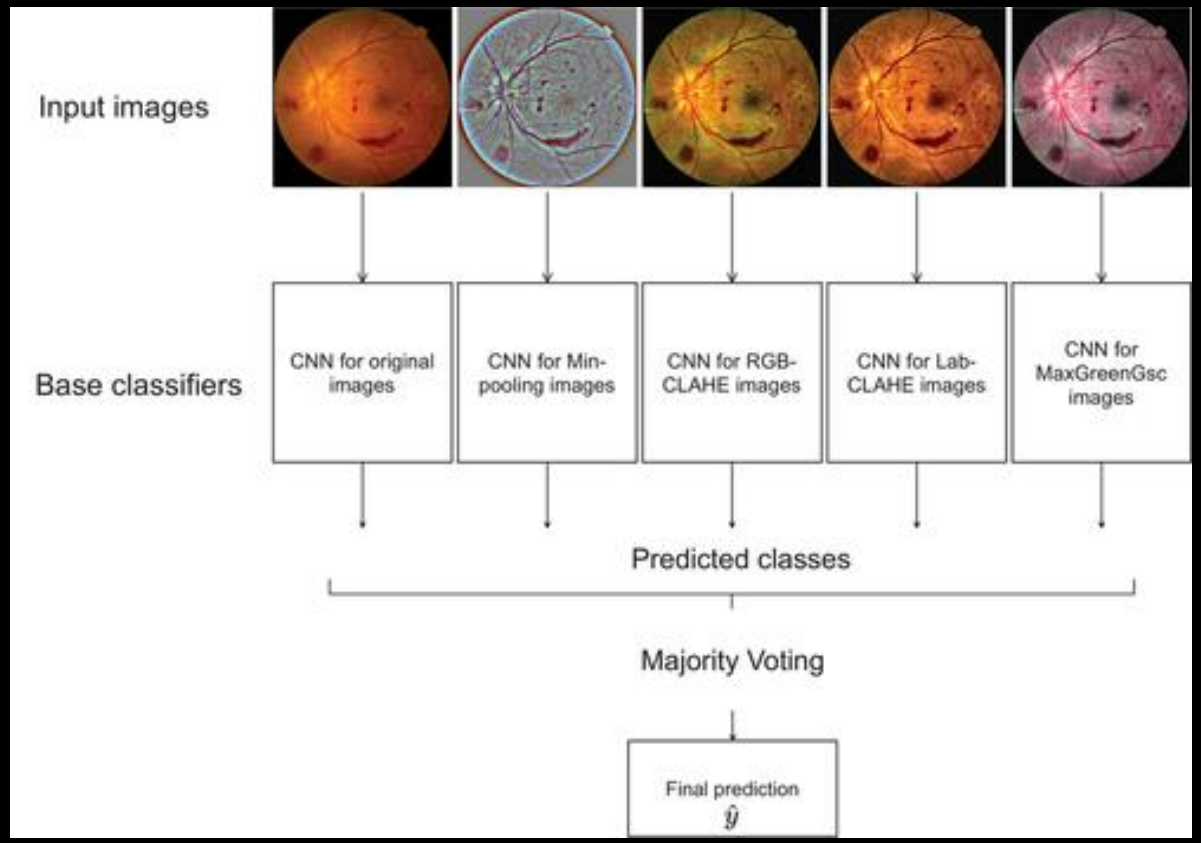
- first two rows are examples from the e-ophtha-EX dataset; last row is from the DiaretDB1 dataset.
- the first, second, third, and fourth columns show the original images, ground-truth data, object detection results, and evaluation map, respectively.
  - BLUE - true positives, GREEN - false negatives, RED - false positives.

- The results were published in **Nature Scientific Reports** journal

*KURILOVÁ, V., GOGA, J., ORAVEC, M., PAVLOVIČOVÁ, J., KAJAN, S. Support vector machine and deep-learning object detection for localisation of hard exudates. Sci Rep **11,** 16045 (2021).* [*https://doi.org/10.1038/s41598-021-95519-0*](https://doi.org/10.1038/s41598-021-95519-0)



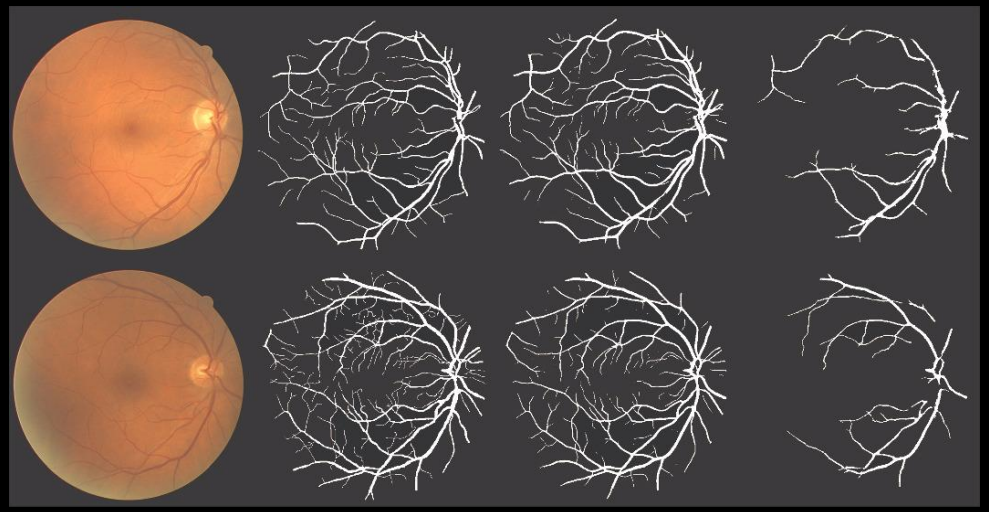
Diagnosing DR using ensemble learning methods



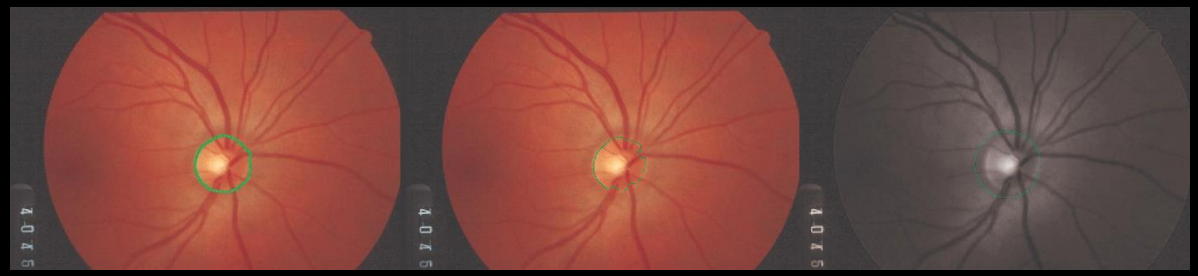
Macsik, P., Pavlovicova, J., Kajan, S., Goga, J., & Kurilova, V. (2024). Image preprocessing-based ensemble deep learning classification of diabetic retinopathy. IET Image Processing, 18(3), 807-828.

Other research, e.g.:

Retinal blood vessels segmentation

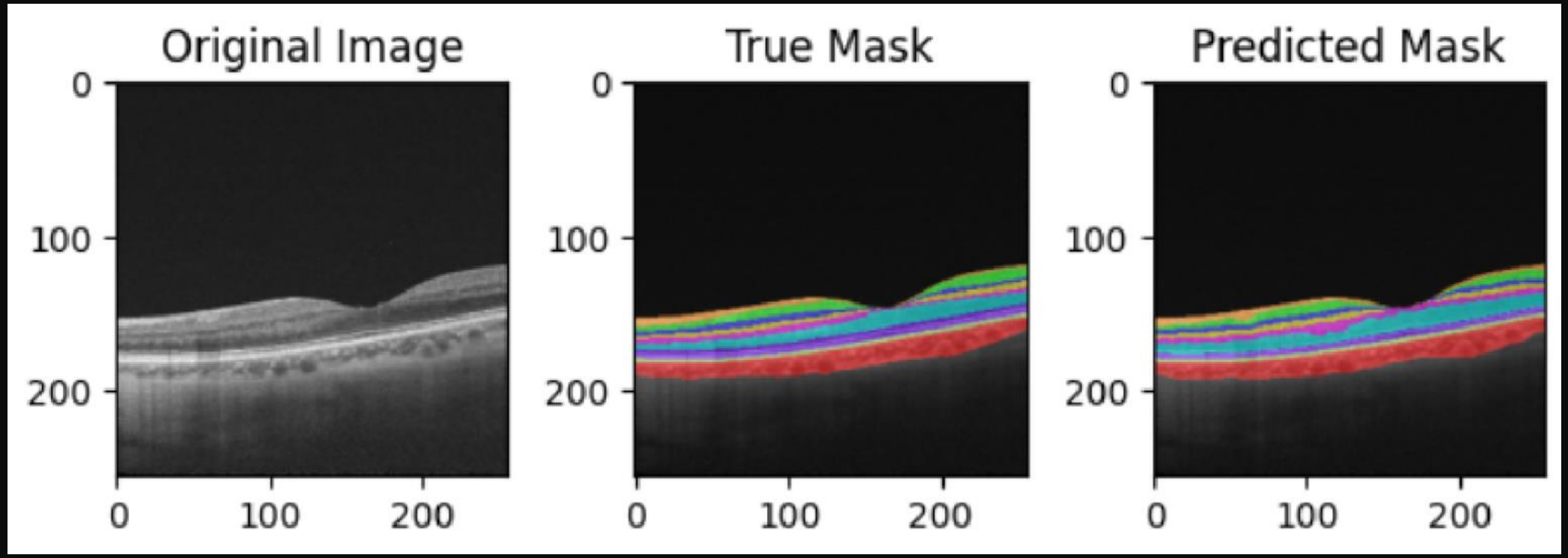


Optic nerve head localization

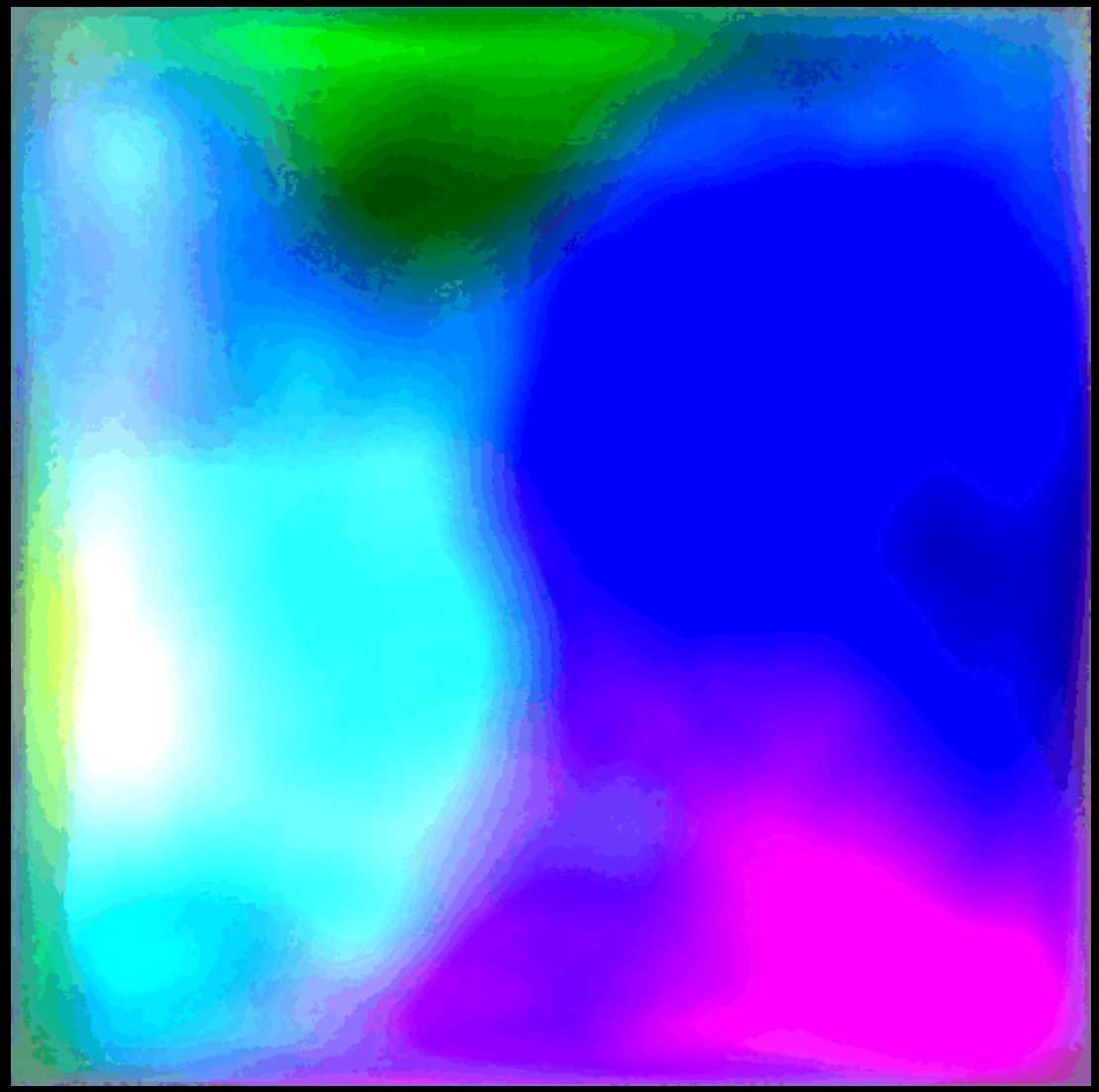


Pirhala M., Goga J., Kurilova V., Pavlovicova J., Kajan S. (2022) Segmentation of Significant Regions in Retinal Images: Perspective of U-Net Network Through a Comparative Approach. In: Rozinaj G., Vargic R. (eds) Systems, Signals and Image Processing. IWSSIP 2021. Communications in Computer and Information Science, vol 1527. **Springer**, https://doi.org/10.1007/978-3-030-96878-6_3

DL Segmentation of retinal layers on OCT macular images



Generating of synthetic retinal images



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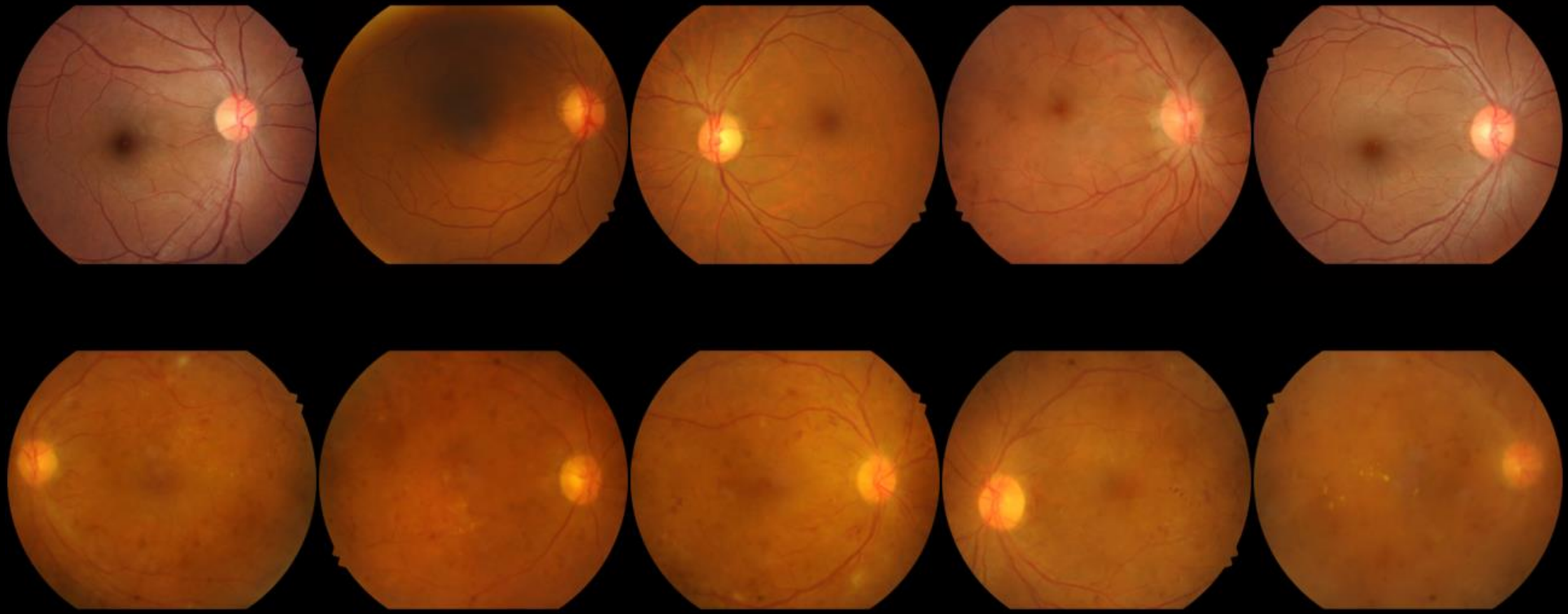
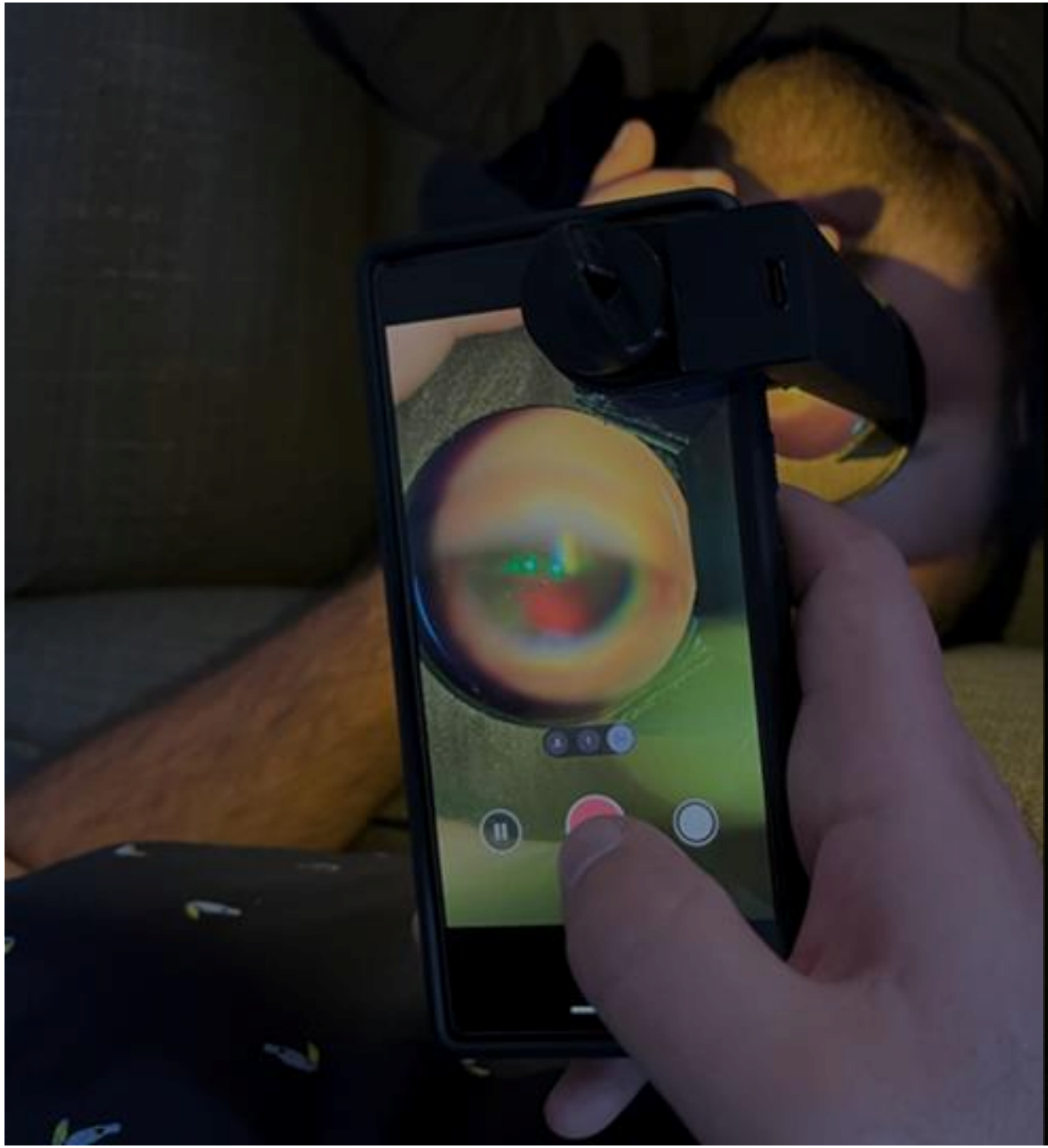


Current work- focusing also on smartphones

- portable, cheap, and available
- ideal for screening
- quality of camera is improving
- direct images, videos or images via attachments (fundus)
- creation of new potential datasets



Application,teams and cooperation

- **medical screening, follow-up analysis, education, telemedicine**
- **MLgroup @ FEI STU**
  - Machine Learning group, https://uim.fei.stuba.sk/MLgroup/
- **Department of Ophthalmology, University Hospital**
  - retinal images dataset creation
  - personalized medicine

Ophthalmologic research @ MLgroup (Machine Learning Group) is lead by:

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- Veronika Kurilová, veronika.kurilova@stuba.sk

Publications (from 2021)

- Danko, T., Oravec, M., Kurilová V., Pavlovičová, J. (2024) Small Object Detection in Fundus Images, In Proceedings ELMAR-2024: 66th Int. symposium. Zadar, Croatia. 16-18 September, 2024. Zagreb : University of Zagreb, 2024, pp.105-108

- Mácsik,P., Pavlovičová,J., Goga,J., Kajan,S., Kurilová,V.: Image Preprocessing Based Ensemble Deep Learning Classification of Diabetic Retinopathy. In IET Image Processing. 00, 1-22 (2023). ISSN 1751-9659. https://doi.org/10.1049/ipr2.12987 (November 15, 2023). https://doi.org/10.1049/ipr2.12987. WOS, SCOPUS, IF: 2,3; JCR:Q3, SJR Q2

- Kurilová,V., Bemberáková,D., Kocián,M., Šterbák,D., Knapčok,T., Palkovič,M, Hančák,S., Pavlovičová,J., Oravec,M., Thurzo,A., Kolář,P., Majtánová,N.: Unexpected corneal reflection phenomenon alters smartphone 3D image-based models of the eye. Journal of Electrical Engineering. Vol. 74, No. 6 (2023), pp. 513-520. ISSN 1335-3632 (2022: 0.800 – IF, Q4 – JCR Best Q, 0.218 – SJR, Q3 – SJR Best Q). DOI: 10.2478/jee-2023-0059 ; WOS: 001126592400010 ; SCOPUS: 2-s2.0-85180448090

- Kurilová,V., Rajcsányi,Sz., Rábeková,Z., Pavlovičová,J., Oravec,M., Majtánová,N.: Detecting glaucoma from fundus images using ensemble learning, Journal of Electrical Engineering, Vol. 74, No. 4, pp. 328-335, https://doi.org/10.2478/jee-2023-0040/ [abstract] [full-paper]

- MÁCSIK, Péter – PAVLOVIČOVÁ, Jarmila – GOGA, Jozef – KAJAN, Slavomír. Local binary CNN for diabetic retinopathy classification on fundus images. In *Acta Polytechnica Hungarica*. Vol. 19, no. 7 (2022), s. 27-45. ISSN 1785-8860 (2021: 1.711 – IF, Q3 – JCR Best Q, 0.380 – SJR, Q2 – SJR Best Q). V databáze: SCOPUS: 2-s2.0-85134760810.

- PIRHALA, M., GOGA, J., KURILOVÁ, V., PAVLOVIČOVÁ, J. (**2021**) Segmentation of significant areas in retinal images, IWSSIP 2021, Bratislava, Communications in Computer and Information Science, vol 1527. Springer, Cham. https://doi.org/10.1007/978-3-030-96878-6_3,

- Thurzo,A., Svobodová Kosnáčová,H., Kurilová,V. et al: Use of Advanced Artificial Intelligence in Forensic Medicine, Forensic Anthropology and Clinical Anatomy, **Healthcare** 2021, 9(11), 1545; https://doi.org/10.3390/healthcare9111545

- Kurilová, V., Goga, J., Oravec, M.,Pavlovičová, J., Kajan, S. (2021): Support vector machine and deep-learning object detection for localisation of hard exudates, **Nature Scientific Reports** 11, 16045 (2021), Q1, IF 4.379