2024 Video and Image Processing Cup

SS-OCT Image Analysis

Official Document of the Signal Processing Society's 2024 Video and Image Processing Cup

Final Version [1.1] *24 January 2024*

1. Introduction

Optical Coherence Tomography (OCT) is a retina non-invasive imaging technique widely used for diagnosis and treatment of many eye-related diseases. Different anomalies such as Age related Macular Degeneration (AMD), Diabetic Retinopathy (DR) or Diabetic Macular Edema (DME) can be diagnosed by OCT images. Due to the importance of early stage and accurate diagnosis of eye-related diseases, providing high resolution and clear OCT images is of high importance. Therefore, analyzing and processing of OCT images have been known as one of the important and applicable biomedical image processing research areas.

Different processings have been applied on OCT images, such as image super-resolution, image de-noising, image reconstruction, image classification and image segmentation. Despite many algorithms working on OCT image analysis, still there is a need for improving the quality of the resulting images and the accuracy of classification. Therefore, this challenge has been dedicated to the problem of OCT image enhancement and classification.

2. Competition Details

2.1 Task Description

The challenge contains the following three tasks:

1- De-noising of noisy OCT images.

Since many of captured OCT images are noisy and this can highly decrease the accuracy of diagnosis of eye related diseases, de-noising can be considered as one of the important steps in OCT image analysis. Hence, this task is dedicated to the problem of OCT image de-noising. The task is to de-noise the available noisy OCT B-scans and try to produce the best results. A sample for a noisy B-scan has been shown in Figure.1

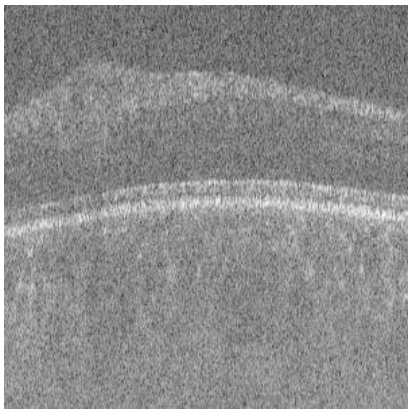

Figure 1: A sample noisy B-scan

2- Super-resolution

To prevent motion artifacts, capturing OCT images is usually done at rates lower than nominal sampling rate, which results in low resolution images. Using super-resolution methods, high resolution images can be reconstructed from the low resolution ones. Due to the importance of this issue, this task has been dedicated to the super-resolution problem. The aim is to obtain high-resolution OCT B-scans from low-resolution OCT B-scans.

3- Volume-based classification of OCT dataset into several sub-classes.

The aim of this task is to classify several observed cases (where there are several B-scans for each case) into healthy (0), diabetic patients with DME (1) and non-diabetic patients with other ocular diseases (2) classes.

Keywords: Optical Coherence Tomography (OCT), De-noising, Super-resolution, Classification

2.2 Dataset Description

The dataset has been captured in Didavaran clinic, Isfahan, Iran, using a custom-made Swept-Source OCT imaging system built in department. of Biomedical Engineering, University of Basel. The central wavelength and spectral bandwidth of the OCT system are 1064 nm and 100 nm, respectively. This dataset includes 124 volume OCT data from 124 subjects. These volume OCT data have been captured from different subjects and categorized into three groups: Healthy (0), diabetic with DME (1), and non-diabetic patients with other ocular diseases (2) where, each volume contains several B-scans of size 300×300.

Approval of all ethical and experimental procedures and protocols was granted by IR.NIMAD.REC.1397.314.

References:

1 - M. Tajmirriahi, Z. Amini, A. Hamidi, A. Zam and H. Rabbani, "Modeling of Retinal Optical Coherence Tomography Based on Stochastic Differential Equations: Application to Denoising," in IEEE Transactions on Medical Imaging, vol. 40, no. 8, pp. 2129-2141, Aug. 2021

2- M. Tajmirriahi, R. Rostamian, Z. Amini, A. Hamidi, A. Zam and H. Rabbani, "Stochastic Differential Equations for Automatic Quality Control of Retinal Optical Coherence Tomography images," *2022 44th Annual International Conference of the IEEE Engineering in Medicine & Biology Society (EMBC)*, Glasgow, Scotland, United Kingdom, 2022, pp. 3870-3873, doi: 10.1109/EMBC48229.2022.9870918.

3- Z. Amini and H. Rabbani, "Statistical Modeling of Retinal Optical Coherence Tomography," in *IEEE Transactions on Medical Imaging*, vol. 35, no. 6, pp. 1544-1554, June 2016, doi: 10.1109/TMI.2016.2519439.

4- Amini Z, Rabbani H. Optical coherence tomography image denoising using Gaussianization transform. Journal of Biomedical Optics. 2017 Aug 1;22(8):086011-.

5- Kafieh R, Rabbani H, Abramoff MD, Sonka M. Curvature correction of retinal OCTs using graph-based geometry detection. Physics in Medicine & Biology. 2013 Apr 11;58(9):2925.

2.3 License

3. Evaluation Protocol

1- For the volume classification task:

The aim is to find a classification method with high Accuracy, Precision, Sensitivity, Specificity and F-score.

2- For the de-noising task:

The aim is to obtain OCT de-noised B-scans with the best visual quality, Mean-to-standard-deviation ratio (MSR), Contrast-to-Noise Ratio (CNR), Texture Preservation (TP), and Edge Preservation (EP) measures. These measures do

not need the reference image and choosing several regions of interest (ROIs) from the images is required in their computation. These ROIs consist of interesting details and significant parameters for the metrics.

3- For the super-resolution task:

MSR and CNR of the output in addition to its visual quality will be used as evaluation metrics.

Evaluation Metrics

- Accuracy, Precision, Sensitivity, Specificity and F-score are defined as

$$\text{Accuracy} = \frac{T_P + T_N}{T_P + T_N + F_N + F_P}$$

$$\text{Precision} = \frac{T_P}{T_P + F_P}$$

$$\text{Sensitivity} = \frac{T_P}{T_P + F_N}$$

$$\text{Specificity} = \frac{T_N}{T_N + F_P}$$

$$\text{F\_score} = 2\frac{\text{Presision} \times \text{Sensitivity}}{\text{Presision} + \text{Sensitivity}}$$

Where,

T_P: is the number of actual positive events which have been predicted correctly.

T_N: is the number of actual negative events which have been predicted correctly.

F_P: is the number of actual negative events which have been predicted incorrectly.

F_N: is the number of actual positive events which have been predicted incorrectly.

- CNR is defined as

$$CNR = 10\log\frac{\left|\mu_f - \mu_b\right|}{\sqrt{0.5(\sigma_f^2 + \sigma_b^2)}}$$

where σ_b and μ_b denote the standard deviation and the mean of the background region, while μ_f and σ_f represent the corresponding parameters for the foreground regions. The ROIs for calculating CNR are chosen between different layers to show how the contrast is changed.

- MSR is defined as follows:

$$MSR = \frac{\mu_f}{\sigma_f}$$

where μ_f and σ_f are the mean and the standard deviation of the foreground regions (regions are encompassed the retinal layers).

- TP evaluates the conserving of the texture between two images and calculated as

$$TP_m = \frac{\sigma_m^2}{(\sigma_m^2)'}\sqrt{\frac{\mu_{den}}{\mu_{in}}}$$

where σ_m and σ_m' denote the standard deviation of the de-noised and noisy images in *m*-th ROI. μ_{in} and μ_{den} represent the mean value of noisy and de-noised images, respectively. The ROIs for calculating TP should encompass the intra-layer regions.

- EP evaluates the conserving of the edges between two images and calculated as

$$EP = \frac{\Gamma(\Delta I'_m - \overline{\Delta I'_m}, \Delta I_m - \overline{\Delta I_m})}{\sqrt{\Gamma(\Delta I'_m - \overline{\Delta I'_m}, \Delta I'_m - \overline{\Delta I'_m})\Gamma(\Delta I_m - \overline{\Delta I_m}, \Delta I_m - \overline{\Delta I_m})}}$$

where I_m and I'_m are matrices that contain the de-noised and the noisy image regions, respectively, in the *m*-th ROI. And Δ represents the Laplacian operator and Γ measures the correlation of images. For calculation of EP measure, the related ROIs should be included edges.

4. Participants submissions

The participants are requested to submit their results in all of three tasks. Each group *Must* submit a zip file named as "Participant name_ICIP2024_OCT_Challenge" which includes the following two items:

4.1 Results

- A zip file including the output images for the test dataset (two separate folders for the results of super-resolution and de-noising tasks). This is not needed for the classification task.

4.2 Technical Report

Each group should submit a technical report that includes:

- A comprehensive description of their methods including all of the details and results. The report should include the numerical results (based on the evaluation metrics) and sample visual outputs of their algorithms (for the super-resolution and de-noising tasks). For the classification task, the report should contain the evaluation results of the train dataset and classification results of the test dataset, i.e, it should be determined that each case belong to which group (0,1 or 2).

Note that team members who have previously accessed to the dataset are *not* eligible for the competition.

5. SPS SP Cup and VIP Cup Competition Terms & Conditions

***! IMPORTANT:* All** team members must fully read and agree to the terms in this SPS Student Competition Terms and Conditions document in order to be eligible in any SPS Student Competition. By checking the agreement checkbox during team registration, all team members agree to all of the Terms & Conditions mentioned in this document.

***! IMPORTANT:* [Judges and Team Supervisors]** The IEEE Conflict of Interest form must be completed before participating in the competition. Full information is included in Section 5.2 below. The Conflict of Interest form can be completed at the following link: https://www.ieee.org/about/compliance/conflict-of-interest/coiandpob.html

5.1 Team Formation and Eligibility

5.1.a. Team Composition

- Each team MUST be composed of: (i) One faculty member (the Supervisor) and (ii) At least 3 but no more than 10 undergraduates; *Optionally* (iii) At most one graduate student (the Tutor).
    - At least three of the undergraduate team members must be SPS student members at time of team registration.
- Further definitions of each team position are as follows:
    - Faculty (Supervisor): A faculty member or someone with a PhD degree employed by the university. *Postdocs and research associates are not considered as faculty members.*
    - Graduate Student (Tutor): A graduate student is a student having earned at least a 4-year University degree at the time of submission. *Please note: Tutors are not eligible to receive travel grants or prize money.*
    - Undergraduate: An undergraduate student is a student without a 4-year degree.
- Team members cannot be changed after the team registration deadline.
- At least one undergraduate team member must be in attendance (in-person) of the final round of the competition held at the respective conference (ICASSP or ICIP) to present the team's work.*****
- Students receiving the travel grant and prize payments MUST be active SPS members at time of team formation. Signal Processing Society membership can be added here.

***Important notice:** Upon registering a team for the competition, the team must commit to at least one undergraduate team member representing the team by attending the physical competition and participating in the final round of the competition at the physical conference. Should a team not be able to participate physically (in-person) in the final round of the competition held at the respective conference (ICASSP or ICIP) for any reason, at any point in the competition, then the team must notify SPS Staff and organizers immediately. This will likely result in the team being ineligible to continue in the competition, therefore forfeiting their position in the competition. Teams must make every effort to attend the final round at the conference; visa issues *may* be an exception. *If all team members are unable to obtain visas, please be prepared to present proof of visa process, communication to obtain visa, as well as a visa denial. All eligibility decisions are at the discretion of the SPS Student Services Committee and competition organizers*.

Should a team be disqualified or forfeit their finalist position for any reason, the next team selected by the organizers may be contacted to compete in the final round, following the same rules listed above.

5.1.b Team ineligibility (Further clarification)

Specific team **ineligibility,** in addition to the above. *Any of these criteria will result in the team being disqualified/ineligible to continue in the competition:*

- Teams that are composed with 50% or more of its members being students who have previously participated on a finalist team of another SPS competition within the last calendar year are not eligible.
- Teams with the exact same member composition of a previously placed team in the top 3 of another SPS competition within the last calendar year are not eligible.
- Any team members who have placed in the top three teams of any SPS competition held during the previous conference and/or calendar year, i.e. a member from one of the 3 finalist teams of the 2024 SP Cup or 5-MICC (at ICASSP) will not be eligible to participate in the 2024 VIP Cup or 5-MICC (at ICIP).
- Team members cannot simultaneously participate in more than one competition at the same time.
- Team members cannot participate on more than one team at the same time.

5.2 Final Round Judging Criteria for SPS Competitions

The judging for the final phase of the competition held live at the conference will be based on five equally weighted criteria, unless other specified by the competition organizers in the Official VIP Cup Document/Call for Participation. Each of the three finalist teams will be scored on the five criteria and the team with the highest score will place 1st, the team with the second highest score will place 2nd, and the team with the third highest score will place 3rd in the competition.

The five equally weighted criteria are:

1. Innovation of the proposed approach
2. Performance of the first stage competition (by choosing the best submission, score as indicated on the website)
3. Performance of the last submission (second phase held live at the conference) separately on the dataset(s)
4. Quality and clarity of the final report
5. Quality and clarity of the presentation

Each criterion is scored with a 1, 2, or 3; the best team in each criterion will receive 3 points, the second best team will receive 2 points, and the third best team will receive 1 point. The final winning rankings will be based on the highest points awarded from the five criteria during judge deliberations at the end of the competition. Final rankings are ultimately decided by the judges, at their discretion.

5.3 Judge & Team Supervisor Participation and Conflict of Interest

Any judge or team supervisor participating in the competition must sign a Conflict-of-Interest Form agreeing to the following key points. Full information is on the Conflict-of-Interest Form.

> Conflict of Interest concerns shall be disclosed and addressed in accordance with IEEE Policies 9.9 A, B. and C and IEEE Policy 4.4.H. - Eligibility and Process Limitations. Judges involved at any stage of the team rankings/scoring process for an SP competition shall be ineligible to judge/vote on the outcome of team rankings for the competition in which the conflict exists. Any real and perceived conflict of interest shall be avoided. Conflict of interest shall be defined as any relationships, professional or otherwise, that can affect impartiality and objectivity. Such relationships include, but are not limited to the below list. This list also applies
>
> a. faculty supervisor/student,
> b. faculty supervisor/post-doc,
> c. manager/employee,
> d. shared institutional affiliations,

e. recent (less than five years) research collaborations or joint authorship,
f. judge/team supervisor
g. In the case of a conflict of interest, the judge should neither listen to nor speak in the discussion and should not vote on the team scoring/ranking process.

In our SPS Policies and Procedures (https://signalprocessingsociety.org/volunteers/policy-and-procedures-manual)

(Also mentioned above) **The IEEE Conflict of Interest form must be completed before participating in the competition. The Conflict of Interest form can be completed at the following link: https://www.ieee.org/about/compliance/conflict-of-interest/coiandpob.html**

Conflict Resolution Process

The Society leadership will create an ad hoc committee to handle each matter requiring conflict resolution.

1. **Composition.** The composition of each ad hoc committee will include area experts. The experts should be chosen based on mediation experience or subject area experience. All members of the ad hoc committee should be non-conflicted, e.g., no prior involvement in the situation, no collegial work relationship, etc. The committee may be augmented with the agreement of all members of the ad hoc committee. The committee will select its own chair.

2. **Process.** During the first meeting of the ad hoc committee, the committee shall create a timeline detailing the conflict resolution process, as well as determine any operational rules for the ad hoc committee's operation (e.g., length of final report; length of statement of dissent, etc.) The individual who brought the conflict matter forward shall be informed of the timeline. All discussions and information presented to the ad hoc committee shall be handled in a confidential manner.

Decisions need not be unanimous; final outcomes may be determined by majority vote of the membership of the ad hoc committee. Dissenting members may include their dissenting opinion as part of the report; the length of such dissent will be determined as part of the committee's operational rules.

After the ad hoc committee has determined its final ruling, the ad hoc committee chair shall be responsible for preparing a short report documenting the committee's findings. The report shall be provided to the individual who brought the conflict matter forward.

3. **Appeal.** If the individual who brought the conflict matter forward feels that the matter has not been adequately resolved by the ad hoc committee at the Society level, the individual may escalate the matter further to TAB or IEEE. The ad hoc committee report shall be shared with TAB and/or IEEE.

5.4 Prizes for Finalists

The three teams with the highest performance in the open competition based on the judging criteria will be selected as finalists and invited to participate in the final competition at ICASSP (SP Cup) or ICIP (VIP Cup). The 1st place (Champion) team will receive a grand prize of US$5,000. The teams placing 2nd (First Runner-Up) and 3rd (Second Runner-Up) will receive a prize of US$2,500 and US$1,500, respectively, in addition to travel grants and complimentary conference registrations for up to three undergraduate team members.

- Up to three undergraduate student members from each finalist team will be provided limited travel support to attend the conference in-person. In-person attendance of the physical conference is required for reimbursement.
  - Travel grant funds are offered on a reimbursement basis of up to $1,200 for continental travel and $1,700 for intercontinental travel; there are no exceptions.
  - Undergraduate team members receiving travel support must be SPS student members.
  - Funds will be issued by way of a bank transfer after the competition via IEEE's NextGen Expense Reimbursement (Concur) tool. *Detailed information on this step will be sent via email to the finalist team members that will be receiving reimbursement.*
  - Receipts are required for all expenses reimbursed under the travel support..

- Prior to claiming your travel grant award, you must submit receipts of your travel expenses that are equal to or exceed the grant amount in order to receive the full travel grant payment. Travel expenses include: air fare, train tickets, hotel, visa fees, transit, meals, and conference registration. Receipts are required for all items and must equal to or exceed the total reimbursement amount. **The receipts must show** form of payment used, name, date, and amount paid. Hotel reservation confirmations or bookings, invoices, or quotes for airfare are not acceptable receipts unless the proof of payment is also provided with the document.
- All travel expenses must be submitted through IEEE's NextGen Expense Reimbursement (Concur) tool. *Detailed instructions on how to create an account and properly input receipts will be shared with the (up to) 3 undergraduate members from finalist teams receiving travel support.*

- Complimentary conference registration for up to three undergraduate team members of finalist teams.
  - These complimentary conference registrations **cannot** be used to cover any papers accepted by the conference.
  - You must notify Jaqueline Rash, Jaqueline.rash@ieee.org, via email of the three team members who have been chosen to receive complimentary registration. Provide the team member's Name and Email Address.
  - VISA: **Once registered for the conference**, each individual will have the opportunity to request an invitation letter **through the conference website** to be used for the visa application process. This is the **only** way to receive a letter, please follow instructions given on the conference website. *To prevent delays, please do not request an invitation letter via email to SPS Staff.*
- The finalist teams will also be invited to join the Conference Banquet and the SPS Student Job Fair, so that they can meet and talk to SPS leaders and global experts. Please note registration for the Conference Banquet and Student Job Fair is limited and based on availability. You must add these events to your registration. If you are unable to add these events, then maximum capacity has been reached. *There may be additional availability for the Student Job Fair, but not the Conference Banquet. If unable to add the Student Job Fair to your conference registration, you can inquire by emailing Jaqueline.Rash@ieee.org.*

5.5 Terms and Conditions Agreement Form

The team must sign an acknowledgement and agreement form before they can be considered as a finalist team. Please upload the Agreement Form during the team registration process. You can access the full Terms and Conditions Document with the Agreement Form located on the last page at the following link:

6. Important Dates

- Challenge announcement: January 2024
- Release of the training dataset: 31 January 2024
- **Team Registration Deadline:** 29 February 2024 [Register here]
- Release of the test-dataset 1: 30 April 2024.
- **Final Submission of Team's Work Deadline:** 15 June 2024
- Announcement of 3 finalist teams: 15 July 2024
- Final competition in-person at ICIP 2024: 27-30 October 2024

7. Registration and Important Resources

7.1 Official VIP Cup Team Registration

All teams MUST be registered through the official competition registration system in order to be considered as a participating team. Teams also MUST acknowledge, agree to the SPS Student Terms and Conditions, and meet all eligibility requirements at the time of team registration as well as throughout the competition.

Register your team for the 2024 VIP Cup before **29 February 2024** and submit work before **15 July 2024** at the following link: **2024 VIP Cup Team Registration**

8. Competition Organizers

Medical Image and Signal Processing Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
Professor Hossein Rabbani, Medical Image and Signal Processing Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
Dr.Azhar Zam, Tandon School of Engineering, New York University, Brooklyn, NY, 11201, USA and Division of Engineering, New York University Abu Dhabi (NYUAD), Abu Dhabi, United Arab Emirates
Dr. Farnaz Sedighin, Medical Image and Signal Processing Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
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Mohammadreza Ommani, Didavaran Eye Clinic, Isfahan, Iran
Arsham Hamidi, Biomedical Laser and Optics Group (BLOG), Department of Biomedical Engineering, University of Basel, Basel, Switzerland

9. Contacts

Competition Organizers (technical, competition-specific inquiries):

Medical Image and Signal Processing Research Center, Isfahan University of Medical Sciences, Isfahan, Iran
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SPS Staff (Terms & Conditions, Travel Grants, Prizes):

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SPS Student Services Committee

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