Argus III: A Novel Image Optimization and Augmentation Framework to Enable an Improved Patient Experience for the Next Generation Epiretinal Prosthesis

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Q1: Problem or Question

Problem

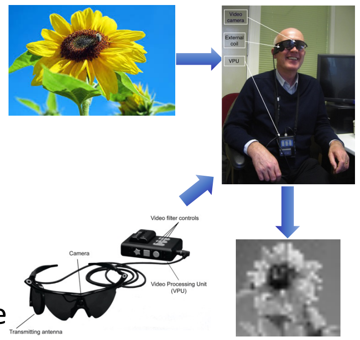
- ❑ Retinal prostheses are the current gold standard for vision restoration. However, retinal prostheses suffer from a low-image resolution, no color vision, and low adaptability.

Challenges

- ❑ Optimizing spatial and color information with a limited spatial constraint requires a novel computational solution.

Objectives

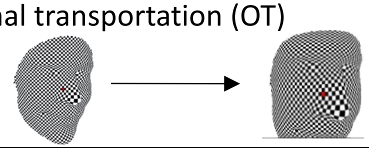
1. Localize and magnify regions of interest (ROIs) in an image frame while preserving areas of objects
2. Optimize the ROIs to encode the maximum amount of spatial and color information
3. Augment the optimized images and generate an image training library for new patients adapting to the prosthesis.



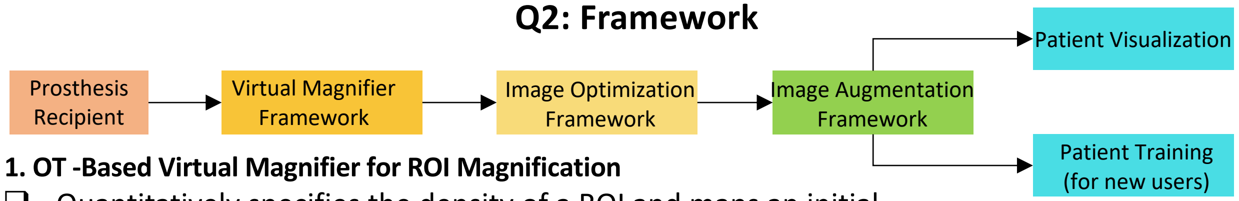
Low resolution images seen by patients. *Credit: Top right (Trinh et. al, 2020) & Bottom left (Farvardin et. al, 2018)*

The magnification of ROI's leads to a fundamental challenge in optimal transportation (OT) due to the highly non-linear nature of OT maps.

How can we efficiently compute OT maps at a large scale?

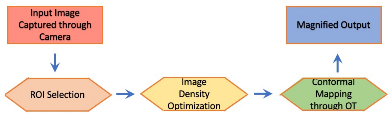


Q2: Framework



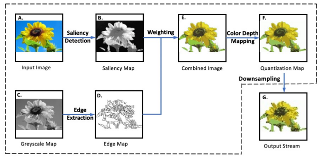
1. OT -Based Virtual Magnifier for ROI Magnification

- ❑ Quantitatively specifies the density of a ROI and maps an initial density to the desired density to best preserve the critical features of objects in ROIs before resolution reduction
- ❑ Accomplished through fixed point operator, obliqueness boundary condition, and fast Fourier transformation



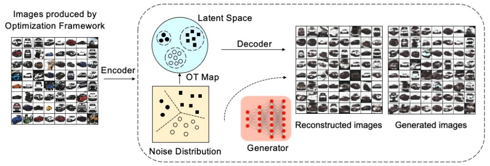
2. Image Optimization to Encode Spatial and Color Information

- ❑ Edge detection, developed region-contrast saliency maps, novel color quantization algorithm, and bicubic interpolation



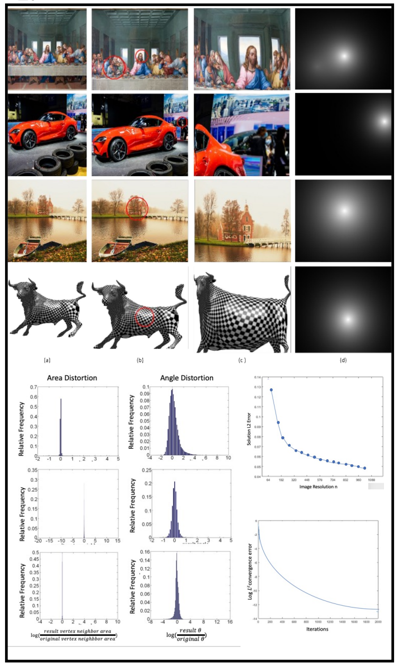
3. Autoencoder-OT for Patient Training

- ❑ Separate the manifold embedding and probability transformation step
- ❑ Manifold embedding: autoencoder
- ❑ Probability transformation: convex optimization framework

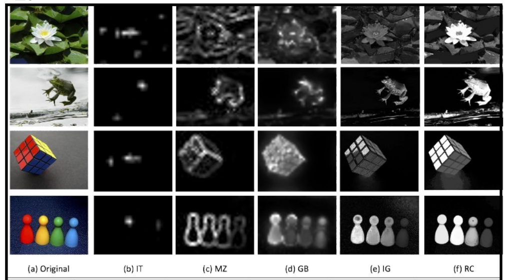


Q3: Findings

1.

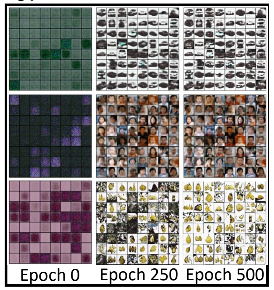


2.



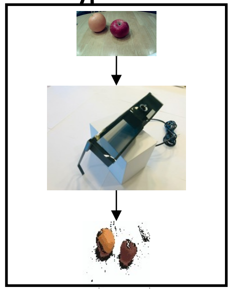
	IT		MZ		GB		IG		RC	
image	MSE	SSIM	MSE	SSIM	MSE	SSIM	MSE	SSIM	MSE	SSIM
lotus	7779.45	0.05	5906.95	0.2	3394.31	0.36	4426.91	0.25	728.21	0.58
frog	378707.37	0	39097.61	0.02	35239.6	0.02	36923.46	0.05	34303.75	0.16
rubik's cube	9927.65	0.01	8434.6	0.06	9575.38	0.15	8572.88	0.09	7849.32	0.16
pins	4285.96	0.04	3966.07	0.06	3184.76	0.25	2584.39	0.12	2242.94	0.25

3.



Epoch 0 Epoch 250 Epoch 500

Prototype



- ❑ The novel OT-based magnifier is scalable and has minimal angle & area distortions
- ❑ Optimization framework is more effective than state-of-the-art algorithms in salient object detection and color quantization
- ❑ AE-OT generated image libraries for new patient training
- ❑ Findings confirmed through prototype

Q4: Interpretations and Conclusions

Paper Contributions

- ❑ Existing strategies to improve the vision of patients do not address the absence of color vision. I designed and compared a novel image optimization framework that is the first to consider color perception for prosthesis users.
- ❑ Existing salient object detection algorithms are inaccurate when images have multiple objects. The virtual magnifier circumvents this issue by selecting a ROI, effectively removing unnecessary information.
- ❑ The existing conformal parametrization method for ROI enlargement may induce area shrinkage, which produces numerical instability. The optimal transport map is area-preserving, thus the robustness is improved.
- ❑ Existing image libraries and datasets only contain high-resolution images. (not suitable for retinal prosthesis). I initiate the idea to provide patients with a low-resolution image training library via an AE-OT model while avoiding mode collapse.

Applications and Future work

- ❑ Virtual magnifier can be applied to google maps, network graphs, medical imaging, etc.
- ❑ Develop algorithms for real-time video processing
- ❑ Integrate infrared thermography as an additional cue to improve saliency maps
- ❑ Integrate frameworks onto real prosthesis users