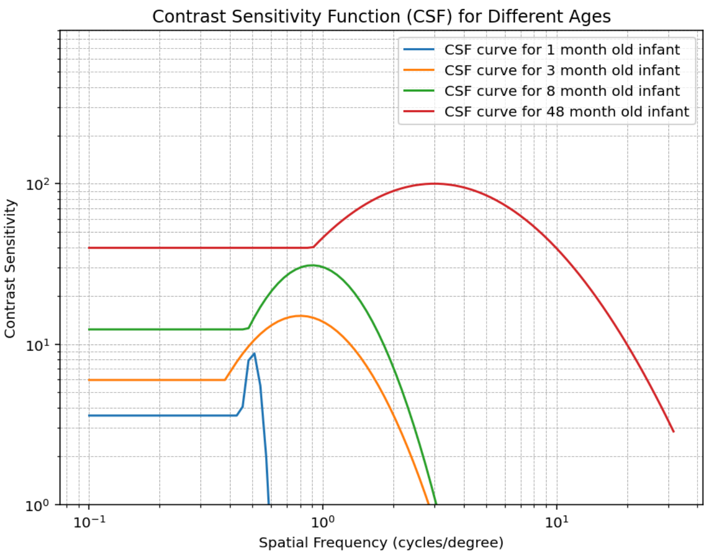
Project: Computational Visual Perception

Introduction

The study and assessment of infant visual function demonstrate that early visual experience partly determines the eventual state of adult visual function. This report expands on studies conducted on "Potential downside of high initial visual acuity"[1], "Butterfly effects in perceptual development: A review of the 'adaptive initial degradation' hypothesis"[2], and "Acuity and contrast sensitivity in 1-, 2-, and 3-month-old human infants"[3]. Emphasis is laid on implementing the infant vision parameters - Visual acuity and Contrast sensitivity, through image transformations. While visual acuity provides insights into stimulus-response towards spatial frequencies over ages, contrast sensitivity helps us study the progressive relation between the spatial frequencies and the associated contrast range. In the study by *(Banks and Salapatek, 1978)*[3], contrast sensitivity was measured using a fixation-preference paradigm, where several test stimuli (vertical sinewave grating and unpatterned stimuli) of varying spatial frequencies and contrast levels were presented. The ability to discriminate between patterned and unpatterned stimuli was observed and the results were expressed as contrast sensitivity functions (CSF), showing sensitivity across different spatial frequencies. These studies[2][3] establish that developments in contrast sensitivity reflect maturation in visual capabilities, with potential implications for addressing early visual abnormalities. With the help of these studies[2][3], this report attempts to implement the progressive development of the above-discussed vision parameters through image transformation.

Implementation



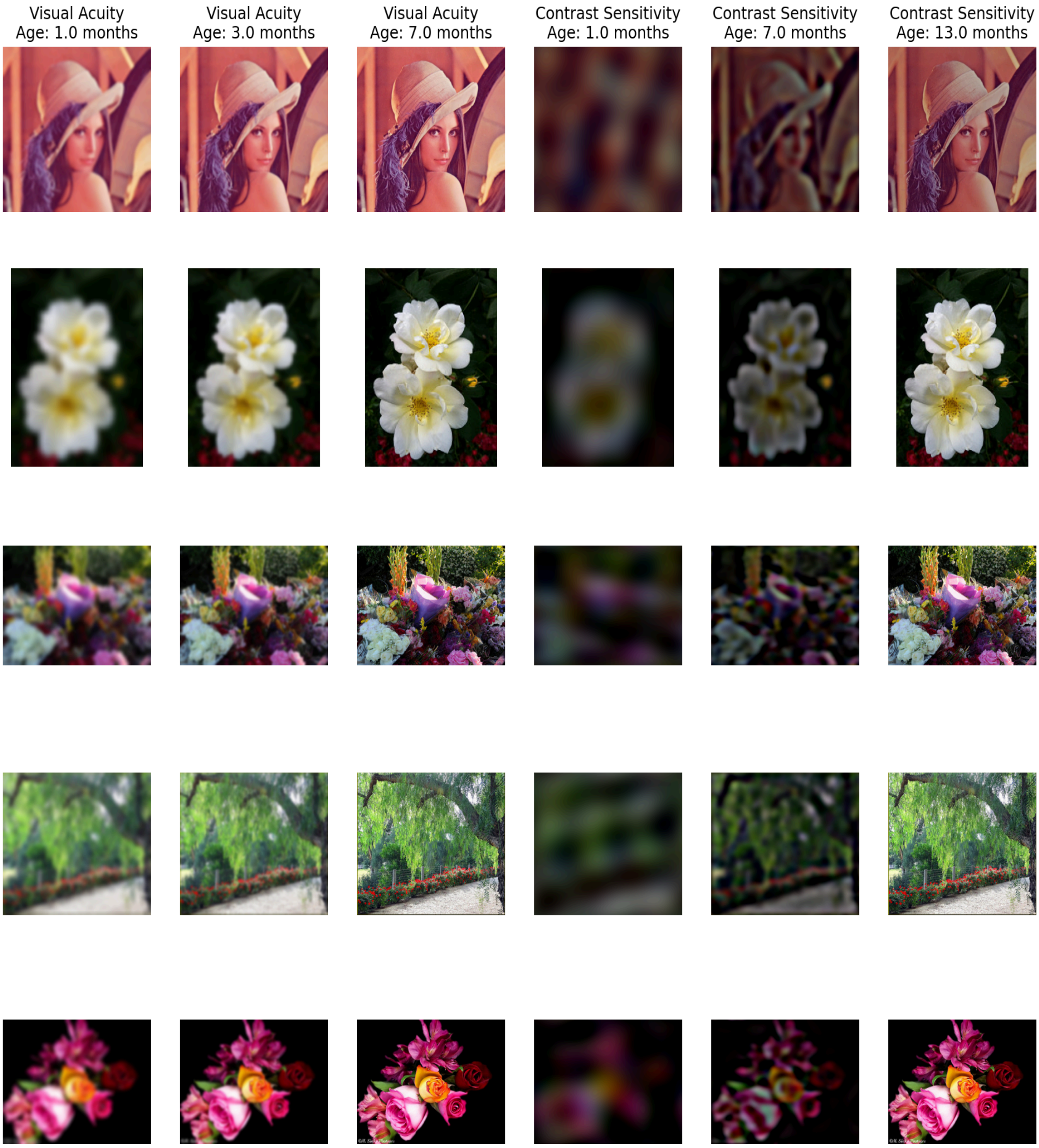
A custom PyTorch Dataset class is utilized to transform a collection of 100 JPEG images. Images were subjected to visual acuity and contrast sensitivity transformations reflecting experimental conditions discussed in the studies mentioned above. Implementation of **visual acuity** was based on the work by *(Vogelsang et al., 2018)*[1]. Gaussian filters with age-specific sigma values (σ) are applied. The **contrast sensitivity function** (CSF), adapted from the truncated log-parabola model discussed in *(Min and Reynaud, 2024)*[4], is implemented via *compute_CSF()* with the model parameters - peak gain (γ_{max}), peak spatial frequency (f_{max}), bandwidth (β), and truncation value (δ). These parameter values are approximated based on the data extracted from *Fig.1.A*[2]. When provided with spatial frequency and contrast sensitivity data, the CSF curves for different ages *(see above figure)* are obtained, which are then applied to the Fourier domain of the input images across all three color channels. This modifies the contrast values for particular frequencies of the input image, ultimately mimicking the perception of an infant's vision.

Performance evaluation

The tabulated runtime was measured in a local system under the following conditions: Number of images - 100; File type - "JPEG"; Total file size - 5.57MB

Run Description	Measured runtime (ms)
Visual acuity	0.50329
Contrast sensitivity	0.53940
No transforms	0.555

Output images



The first 3 columns demonstrate **visual acuity** at ages - 1, 3, and 7 months; Interpolation: { (age): sigma } = { (0,1.5]:σ=4, (1.5,2.5]:σ=3, (2.5,4.5]:σ=2, (4.5,6.0]:σ=1, (>6.0):σ=0 }. The last 3 columns demonstrate **contrast sensitivity** at ages - 1, 7, and 13 months; Interpolation: { (age): CSFcurve } = { (0.0,2.5):'1-month-CSF', (2.5,6.0):'3-months-CSF', (6.0,12.0):'8-months-CSF', (>12.0):'48-months-CSF' }.

[1] L. Vogelsang, S. Gilad-Gutnick, E. Ehrenberg, A. Yonas, S. Diamond, R. Held, P. Sinha, Potential downside of high initial visual acuity, Proc. Natl. Acad. Sci. U.S.A. 115 (44) 11333-11338, https://doi.org/10.1073/pnas.1800901115

[2] Lukas Vogelsang, Marin Vogelsang, Gordon Pipa, Sidney Diamond, Pawan Sinha, Butterfly effects in perceptual development: A review of the 'adaptive initial degradation' hypothesis (Developmental Review, Volume 71, March 2024, 101117), https://doi.org/10.1016/j.dr.2024.101117

[3] Banks MS, Salapatek P, Acuity and contrast sensitivity in 1-, 2-, and 3-month-old human infants, Invest Ophthalmol Vis Sci. 1978 Apr;17(4):361-5.

[4] Min SH, Reynaud A. Applying Resampling and Visualization Methods in Factor Analysis to Model Human Spatial Vision. Invest Ophthalmol Vis Sci. 2024 Jan 2;65(1):17. PMID: 38180771; PMCID: PMC10785955, https://doi.org/10.1167/iovs.65.1.17