Simulation of Light Field Camera for Retina Imaging

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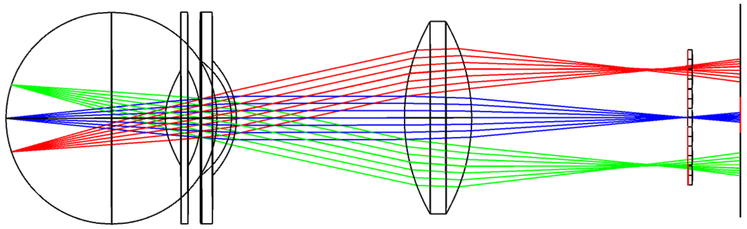
Motivation

- Retina imaging presents unique challenges
  - Very weak S/N ratio due to absorptive and scattering nature of retina
  - Near spherical retina conjugates to planar sensor with 2X~3X magnification, FOV and DOF tradeoff
  - Need to accommodate various optical aberrations from mass population
  - Difficult to construct 3D due to depth and non-uniform tissue lighting response
- Light field camera has potential capabilities to address these challenges through 4D light field recording and image reconstruction
- We want to explore the feasibility of using light field camera to record retina imaging and compare its performance to traditional camera

Related Work

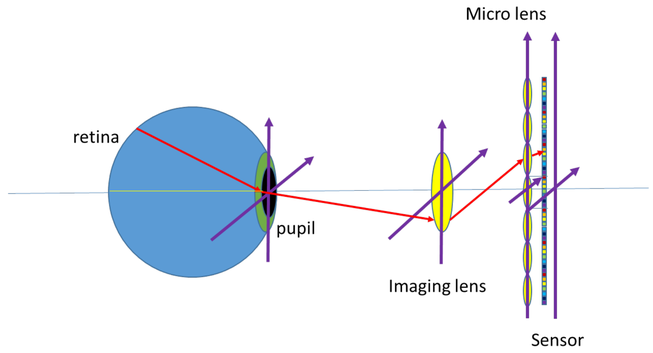
- Little peer reviewed research work in this area
- A couple of patents (US 8998411, etc)
- One FDA study initiated in Feb'17 (https://clinicaltrials.gov/ct2/show/NCT03037268)

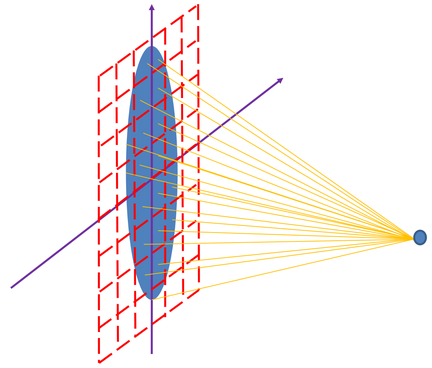
Camera Schematic



- Retina is the objective and final "image" is on the sensor array
- Gullstrand's eye model used in study, retina is imaged at near ∞
- Ray is focused by camera imaging lens, the focal plane is spherical due to field curvature (a big problem for normal camera!)
- Micro lens is located at focal length behind imaging lens and sensor is micro_f behind the micro lens
- NA matched between micro lens and imaging lens, each micro lens is assumed to have dia=20μm and f=40 μm
- No other aberration is added except field curvature

Camera Simulation

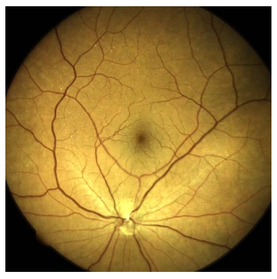




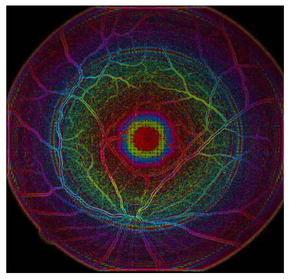
- Use ray tracing to establish point to point mapping between 3D retina and 2D sensor
- Eye model is simulated in Zemax and the camera is simulated in Matlab with own ray tracing algorithm
- Each ray has 4 DOF (2 position and 2 angle)
- 3 lens elements alternate angle and 3 free space changes position with multiple apertures in the system
- Lens is discretized into 2D grids correspond to #s of rays/pixel
- Billions of rays in our simulation
- The final result is a 5D light field matrix (micro lens XY, sensor XY and color)

Experimental Results & Conclusions

Normal camera

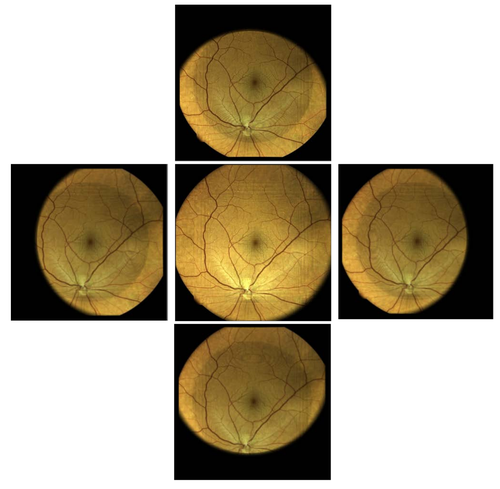


Light Field camera through focal stack



Depth map

- Demonstrated the potential advantage of light field camera, decent image can be obtained even with very unsophisticated optical design
- The center view image is actually the all in focus image with the largest FOV in this particular optical configuration (no need to run focal stack)
- By picking corresponding pixels in forming pictures with different perspective, you are actually spatially resolving the light from different locations of retina



Different viewing perspectives