Final Presentation ADJOINT NONlINEAR RAYTRACING

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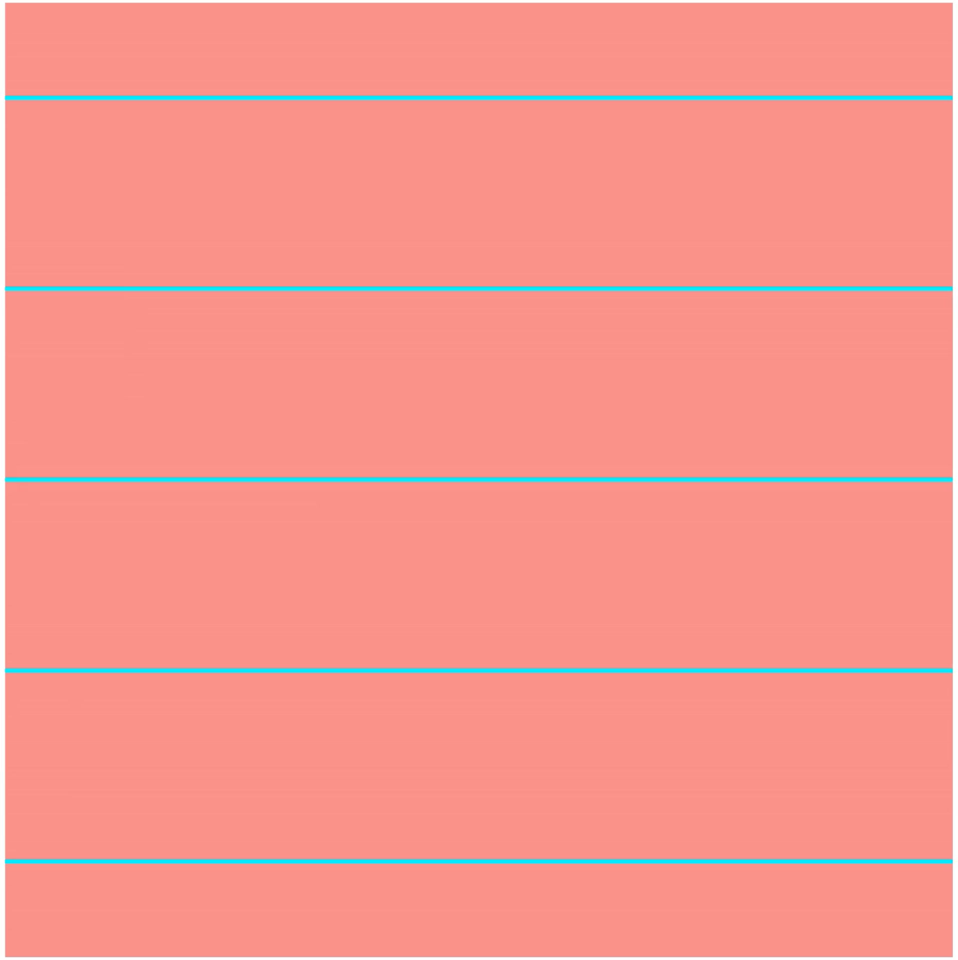
Recap

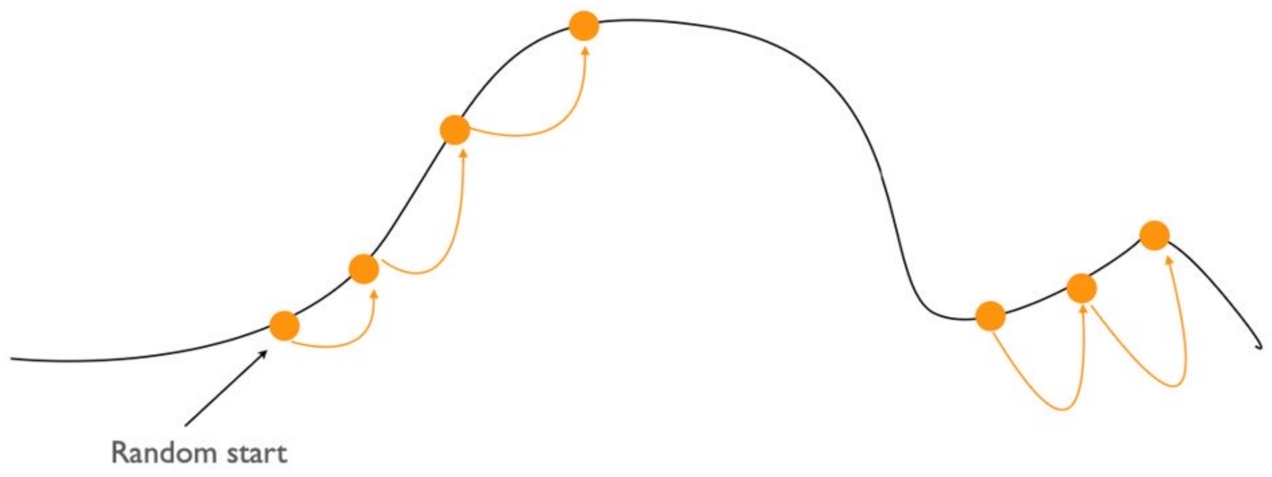

Continuous Refractive Materials
https://www.youtube.com/c/veritasium

Recap



Problem #1

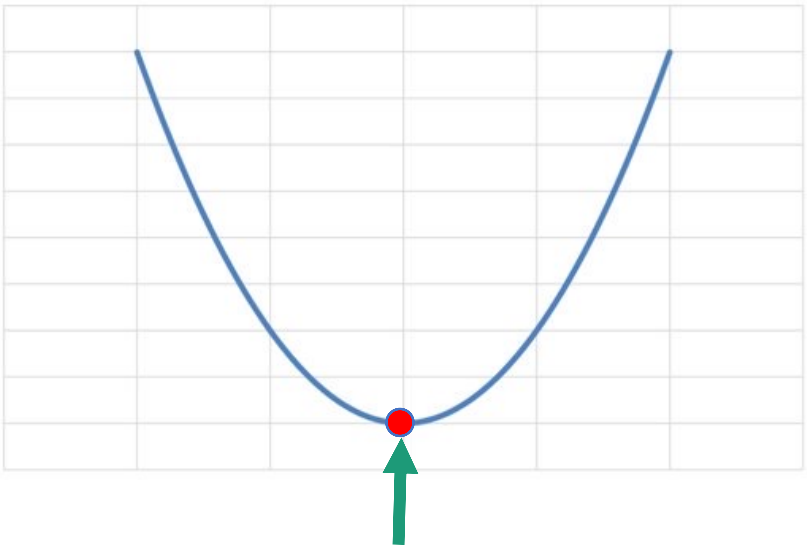
- Gradient-based optimization procedure requires a good **initialization**.
- Start from **randomly distributed** spatially varying medium.



Problem #1

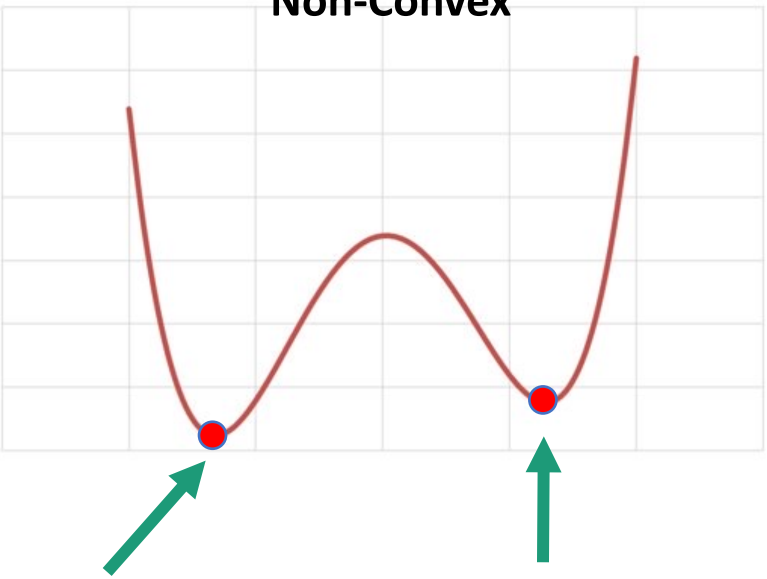
- Current method initializes a uniform **refractive index** of **1**.
- Can lead to wrong solution in non-convex cases.
- optimization landscape is highly non-convex

Convex



Global Minima(ok)

Non-Convex



Global Minima

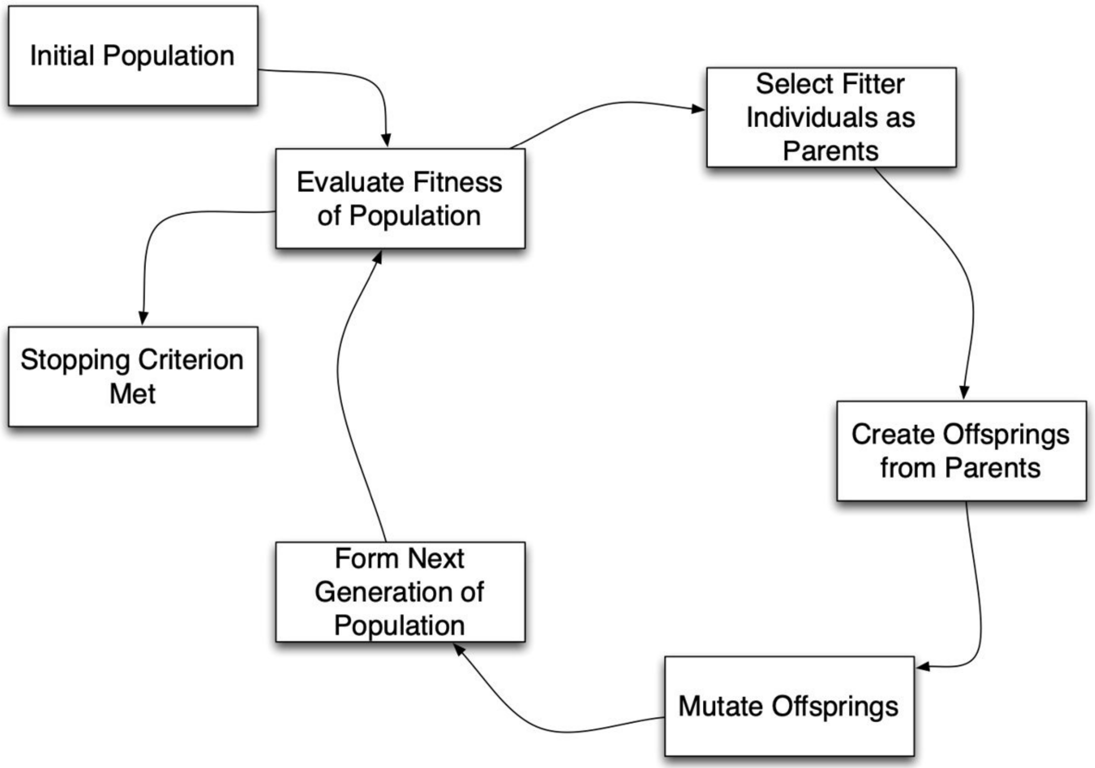
Local minima(wrong)

Problem #1

- Find better Initialization process
- gradient-based optimization procedure requires a good initialization

- **Paper implementation**:
  - initializing to a uniform refractive index field gave satisfactory results. η (x) = 1
  - To ensure that the recovered reconstruction is physically plausible, after every gradient descent iteration, we project η to be greater than or equal to 1 (projected gradient descent).

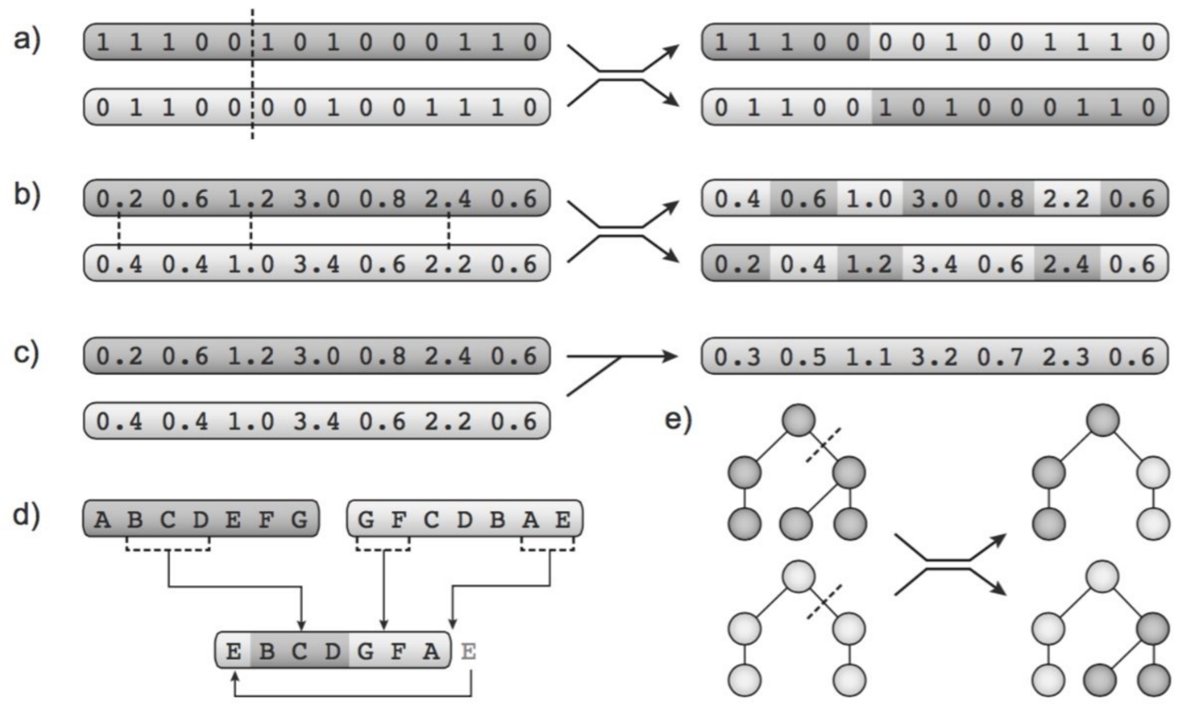
Problem #1



Initial Population
Evaluate Fitness of Population
Select Fitter Individuals as Parents
Create Offsprings from Parents
Mutate Offsprings
Form Next Generation of Population
Stopping Criterion Met

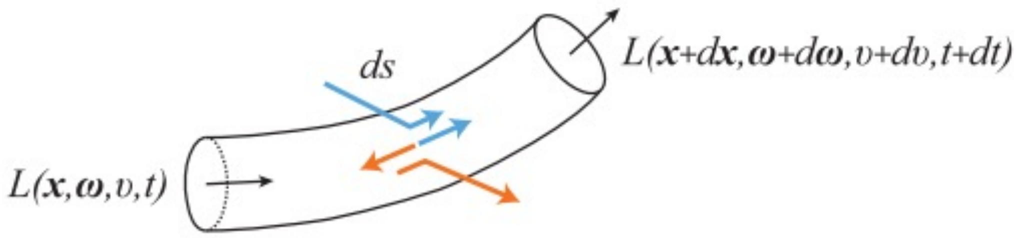
Problem #1

Crossover Operators



Problem #2

- Specifically apply to media where there is only continuous refraction and no volumetric scattering.
- The radiance varies through medium because of in-scattering(blue) and out-scattering(red).



Ament, Marco, Christoph Bergmann, and Daniel Weiskopf. "Refractive radiative transfer equation." *ACM Transactions on Graphics (TOG)* 33.2 (2014): 1-22.

Problem #2

- The paper introduces **Refractive Radiative Transfer Equation(RRTE)**.
- Estimation of basic radiance using photon mapping.

$$\begin{aligned}
\tilde{L}_i(\boldsymbol{x}, \boldsymbol{\omega}, \nu, t) &= \frac{\Lambda}{4\pi} \int_\Omega \tilde{L}(\boldsymbol{x}, \boldsymbol{\omega}_i, \nu, t) P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (34)\\
&= \frac{\Lambda}{4\pi n^2} \int_\Omega v_g h \nu f\, P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (35)\\
&= \frac{\Lambda}{4\pi n^2} \int_\Omega \frac{h\nu}{\sigma_s} v_g \sigma_s f\, P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (36)\\
&= \frac{\Lambda}{4\pi n^2} \int_\Omega \frac{1}{\sigma_s} \frac{d^4 W}{d\boldsymbol{x}\, d\boldsymbol{\omega}_i\, d\nu\, dt} P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (37)\\
&= \frac{\Lambda}{4\pi n^2} \int_\Omega \frac{1}{\sigma_s} \frac{d^3 \Phi}{d\boldsymbol{x}\, d\boldsymbol{\omega}_i\, d\nu} P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (38)\\
&= \frac{\Lambda}{4\pi n^2} \int_\Omega L(\boldsymbol{x}, \boldsymbol{\omega}_i, \nu, t) P(\boldsymbol{\omega}_i, \boldsymbol{\omega})\, d\omega_i && (39)\\
&=: \frac{1}{n^2} L_i(\boldsymbol{x}, \boldsymbol{\omega}_i, \nu, t). && (40)
\end{aligned}$$

Ament, Marco, Christoph Bergmann, and Daniel Weiskopf. "Refractive radiative transfer equation." *ACM Transactions on Graphics (TOG)* 33.2 (2014): 1-22.

Original Idea

- Random Search
- Genetic Algorithms:
  1. Start with a random population of refractive index field
  2. Evalute them give each one a score(fitness)
  3. Select different field and recombine to get new field(offspring)
  4. Random mutation
  5. Evalute new population
  6. Start from 2. again
- Refractive Radiative Transfer Equation:
  1. Start the refraction optimization process.
  2. Introduce scattering by measuring radiance for each step.

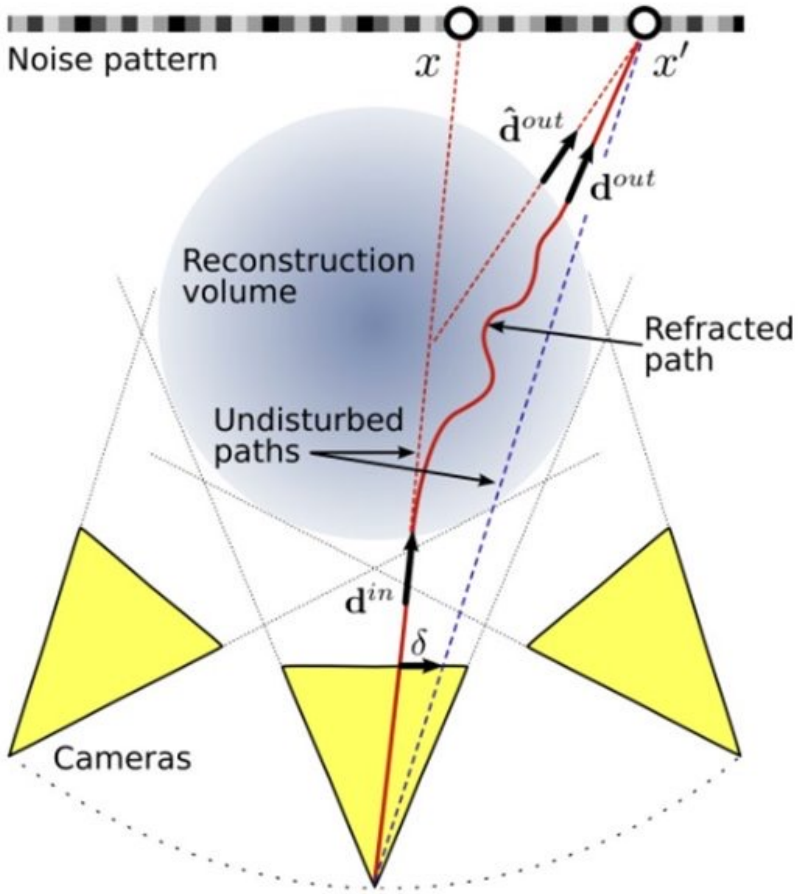
Expected Results

- **Benefits**
  - Faster convergence(i.e. less steps)
  - Will get stuck less in local optima
  - Can get a common refrative index field for different lenses and gas
  - Make ray behavior more realistic by introducing scattering.

- **Drawback**
  - Each step takes long time.
  - Not sure if result will be satisfactory
  - Refractive field can be hyper optimized for one lens(overfitting)

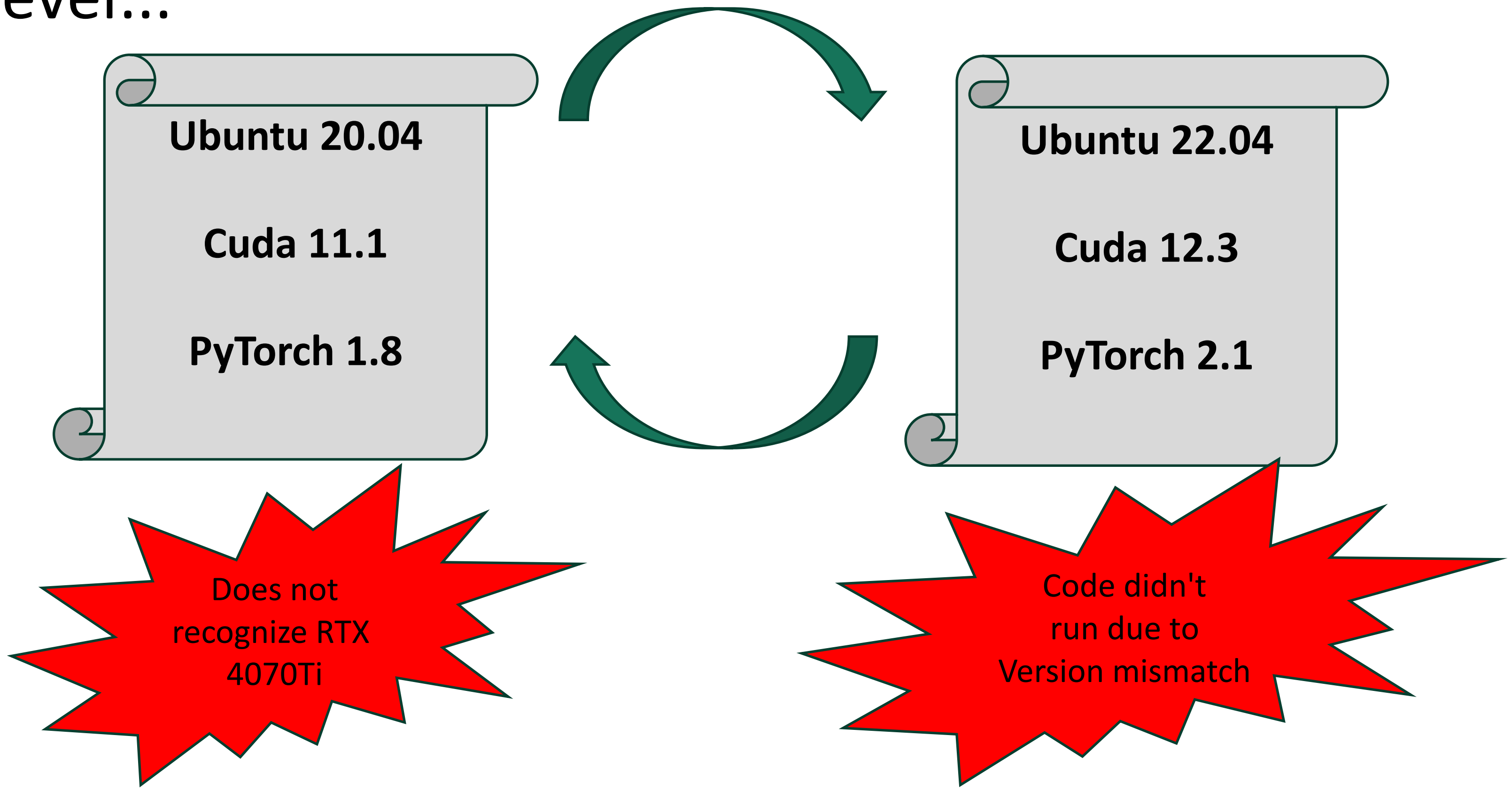
Other Methods

- Time-resolved 3D Capture of Non-stationary Gas Flows – SIGGRAPH Asia 2008
- reconstructions from techniques assuming a single refraction event
- Allows to make an approximation
- Background Oriented Schlieren BOS



Project failure...

- **Plan**: Make contribution to the existing code.
- However...



Roles

- **Jeong Uk Lee:**
  - Project setup
  - Scattering implementation

- **Philipp Derr:**
  - Finding possible solutions for problems.
  - GA Implementation

Source

- Teh, Arjun, Matthew O'Toole, and Ioannis Gkioulekas. "Adjoint nonlinear ray tracing." ACM Transactions on Graphics (TOG) 41.4 (2022): 1-13.
- CS454 AI Based Software Engineering: Shin Yoo
- https://www.cs.ubc.ca/labs/imager/tr/2008/GasCapture/gascapture.pdf
- Ament, Marco, Christoph Bergmann, and Daniel Weiskopf. "Refractive radiative transfer equation." ACM Transactions on Graphics (TOG) 33.2 (2014): 1-22.