What I review and why

**Background:** ISETBio (Image Systems Engineering Tools for Biology) provides computational tools that implement the ideas developed by vision scientists.

**What:** ISET3d is a tool that extends ISETBio from planar images into three-dimensional scenes. My goal today is to explain ISET3d.

**Why:** The extension to 3D may be relevant to scientists and engineers who aim to
  - Model and understand the visual encoding of natural images and stereo vision,
  - Optimize devices, including cameras and displays, for capturing and rendering 3D scenes.
3D scene spectral radiance in the world and at the eye

Gershun (1936)

Ray intensities: $L(x,y,z,\alpha,\beta,\lambda,\theta)$
- Position $(x,y,z)$
- Azimuth and elevation $(\alpha, \beta)$
- Wavelength $(\lambda)$
- Polarization $(\theta)$

Adelson and Bergen (1991)

Ray intensities: $L(u,v,\alpha,\beta,\lambda)$
- Position $(u,v)$
- Azimuth and elevation $(\alpha, \beta)$
- Wavelength $(\lambda)$

Light field

The world beyond the RGB image representation must be accounted for in the simulation
There are many tools for creating realistic 3D scene geometries.

We use Cinema 4D from Maxon because it integrates well with ray tracing methods.

Maxon offers free Cinema 4D licenses to students and teachers, and low- or no-cost “lab” licenses for schools.
Graphics tools: Quantitative computer graphics is a necessary component

- Progress in computer graphics enables us to create synthetic and yet highly realistic input data.

- We use PBRT because it is open-source, extensible, and taught at Stanford

- The simulations can maintain meaningful units; quantitative computer graphics

- A GPU version is scheduled to be released by Pharr et al. in about 2 months
In the next 15 minutes I illustrate the ISET3d computational framework.

I will show you:
- The **kinds of stimuli** that we are producing and
- The programming approach in the specific case of simulating human physiological optics (image formation).

David and I are producing videos of the tools that illustrate many more computations.

We use ISET3d for camera design, autonomous driving, underwater imaging, and medical imaging.
Use computer graphics and ray-tracing to model how spectral, 3D scenes are transformed by human optics to the retinal irradiance.
Comparison of eye models

The code flexibility accommodates the major human eye models (Lian et al. 2019, Journal of Vision).

Remember: these images represent underlying spectral irradiance.
Example code: User’s perspective

• We aim to make the top-level code easily understood. The computations are embedded in methods, often the set/get methods

• The sceneEye models a spherical eyeball and a curved retina, with inert pigments

```
thisSE = sceneEye('letters at depth', 'human eye', 'legrand');
```

PBRT files Human eye model

```
>> thisSE
```

```
thisSE =

sceneEye with properties:

name: 'lettersAtDepth'
modelName: 'legrand'
usePinhole: 0
recipe: [1×1 recipe]
lensDensity: 1
```
Example code

- The code doing the computational work in ISET3d is managed within
  - The set/get methods
  - PBRT calculations
- You can ‘set’ many camera, rendering, and scene parameters
- You can ‘get’ many more parameters by calculation
- There are a number of methods ‘render’, ‘summary’ and others

```matlab
% Suppose you are in focus at the proper distance to the edge. And we turn % on chromatic aberration. That will slow down the calculation, but makes % it more accurate and interesting. We only use 8 spectral bands for % speed. You can use up to 31.
nspectralbands = 8;
thisSE.set('chromatic aberration', nspectralBands);

% This is the distance we calculate above
thisSE.set('focal distance', 1);

% Controls the rendering noise vs. speed by setting the number of rays.
thisSE.set('rays per pixel', 128);

% Increase the spatial resolution by adding more spatial samples.
thisSE.set('spatial samples', 384);

% This takes longer than the pinhole rendering, so we do not bother with % the depth.
oi = thisSE.render('render type', 'radiance');
oiWindow(oi);
```
This is the position of the left eye

from = thisEye.get('from')

It is the ‘from’ parameter in the recipe
Move the camera position by 6 cm to the right

newFrom = from + (0.060, 0, 0)

thisEye.set('from', newFrom)

oiRight = thisEye.render;
This ISET3d code makes the stereo pair of the Chess retinal irradiance, imaged through the Navarro model eye.

I set the lens density to 0 so the scene would not look very yellow. I will explain this in a moment.
Inert pigments (e.g. lens transmission) are included and controlled.

Remember: these images represent underlying spectral irradiance.
Vergence and Accommodation

Where the eye (or eyes) is looking is controlled

\[ \text{thisEye.set('to', loc)} \]

Remember: these images represent underlying spectral irradiance
Calculating cone responses and eye movements


GitHub wiki video pages

https://github.com/iset/isetcam/wiki/ISETCam-Videos
Scenes can be quite complex and realistic

- We have more than 25 high quality scenes like these
- The geometry, reflectance, lighting and textures can be edited (ask me)
- This collection will grow and already includes HDR, inter-reflections, many types objects, materials, textures, shadows, occlusions
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ISETBio Team and Funding

Brian Wandell  Trisha Lian  Haomio Jiang  James Golden
David Brainard  Nicolas Cottaris  Xiaomao Ding  Lingqi Zhang
E.J. Chichilnisky  Fred Rieke  Joyce Farrell  Jon Winawer

facebook research

SIMONS FOUNDATION

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