Are All Pixels Equally Important?

by Dr. Gökhan Yıldırım

Supervisor: Prof. Sabine Süsstrunk

Images and Visual Representation Laboratory (IVRL)

IVRL - Our Lab

EPFL Campus

Prof. Sabine Süsstrunk

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EPFL Campus

Prof. Sabine Süsstrunk

Image Processing

- Image Enhancement
- Image Segmentation

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Image Processing

- Image Enhancement
- Image Segmentation

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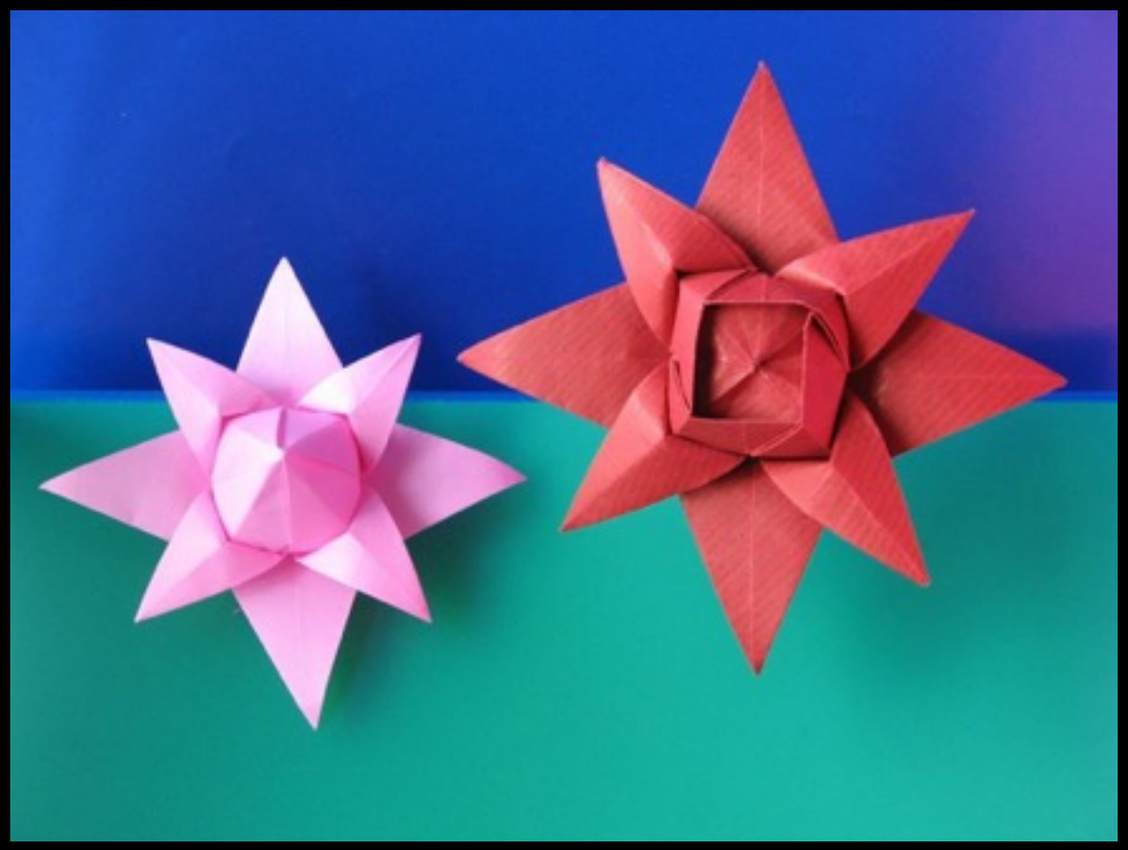

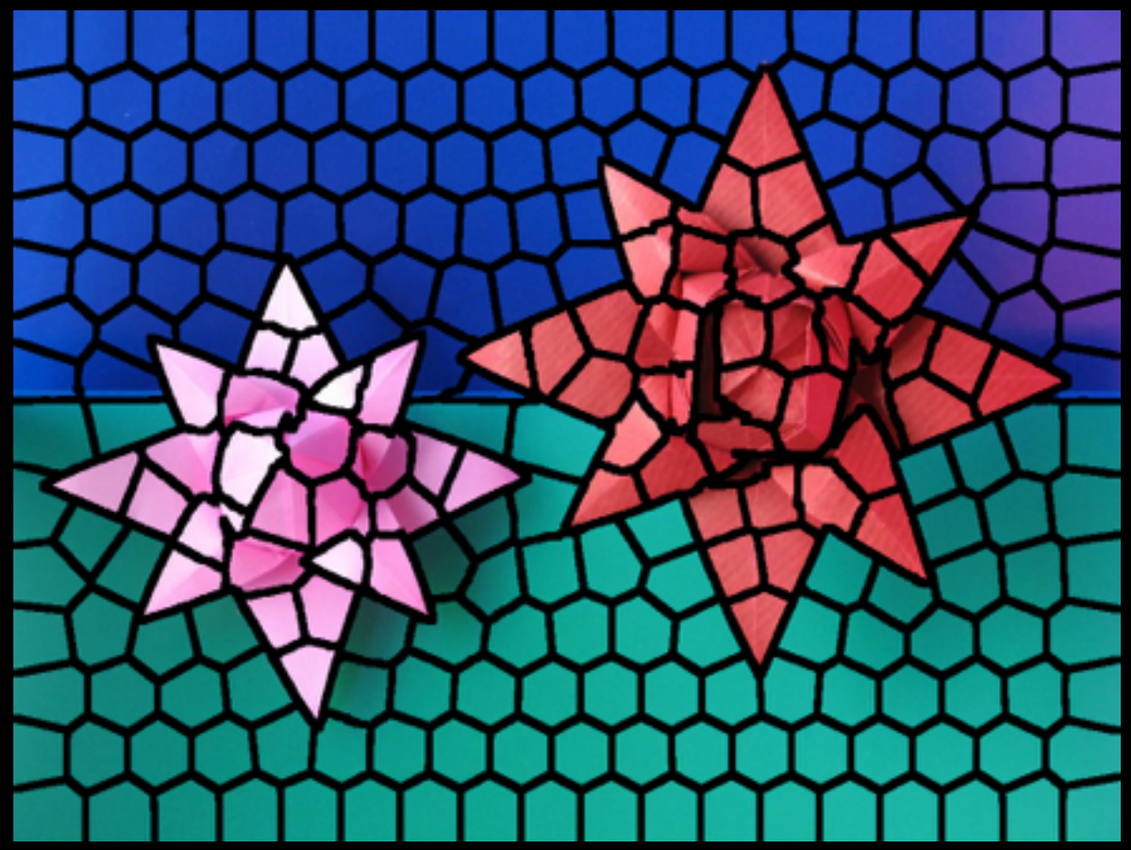

Image Processing

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- Image Segmentation

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Image Processing

- Image Enhancement
- Image Segmentation

IVRL - Our Lab

Image Processing

- Image Enhancement
- Image Segmentation

Computer Vision

- Object Detection
- Object Recognition

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Seagull

Image Processing

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Computer Vision

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Salient Object Detection

Image Processing

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Computer Vision

- Object Detection
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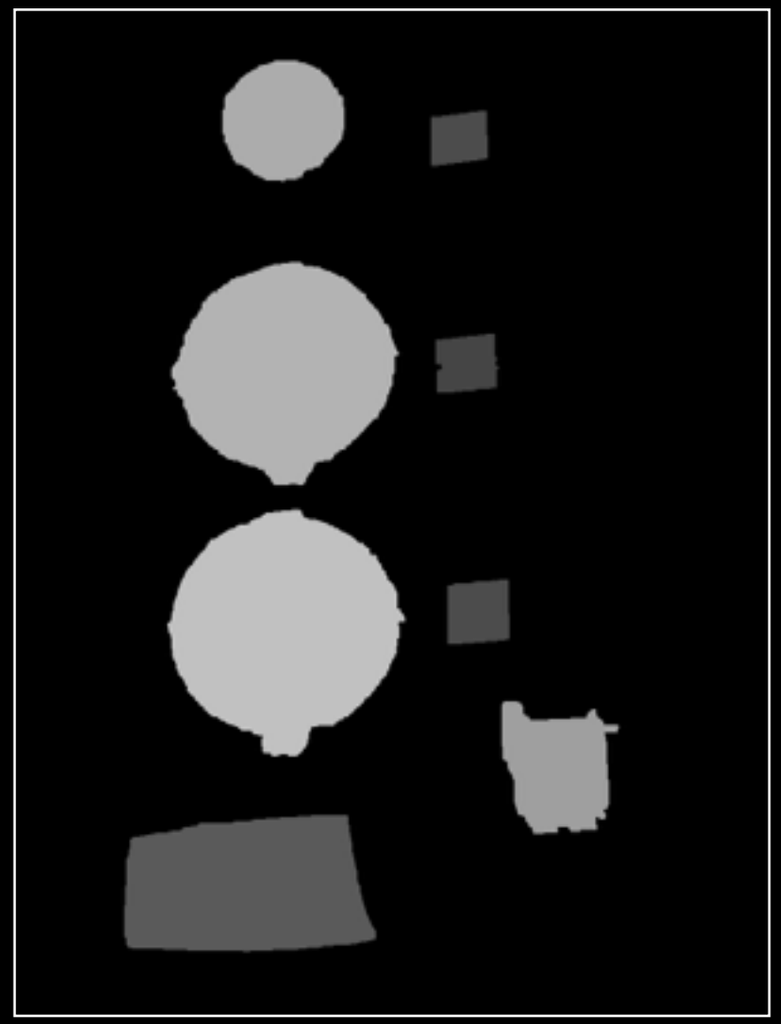

Salient Object Detection

Image Processing

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- Object Recognition

What is “Salient”?

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Something that stands out relative to its neighbors

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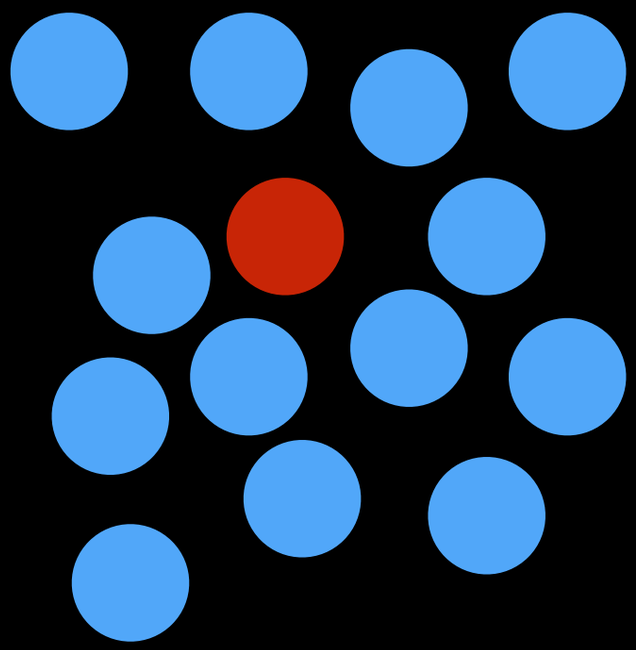
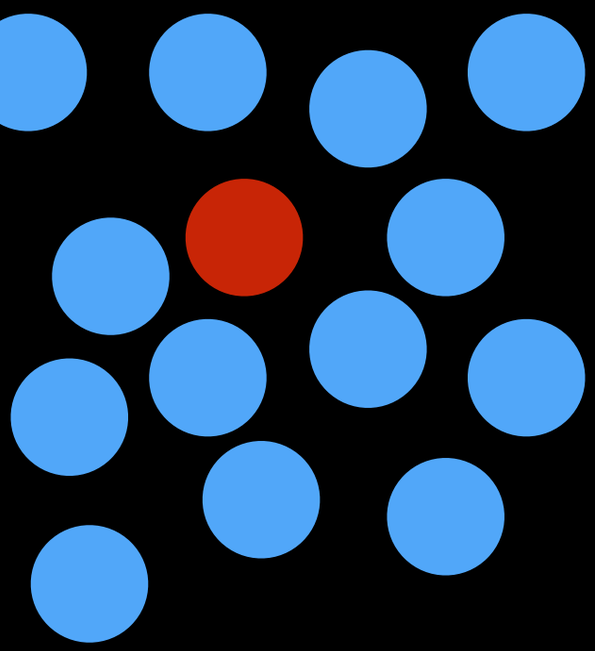


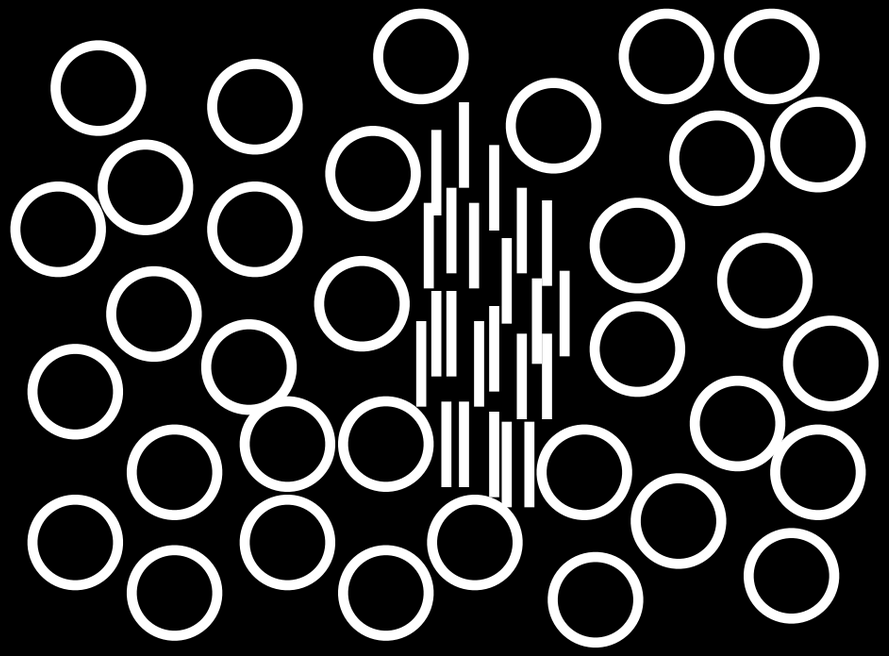
Color

What is “Salient”?

Something that stands out relative to its neighbors



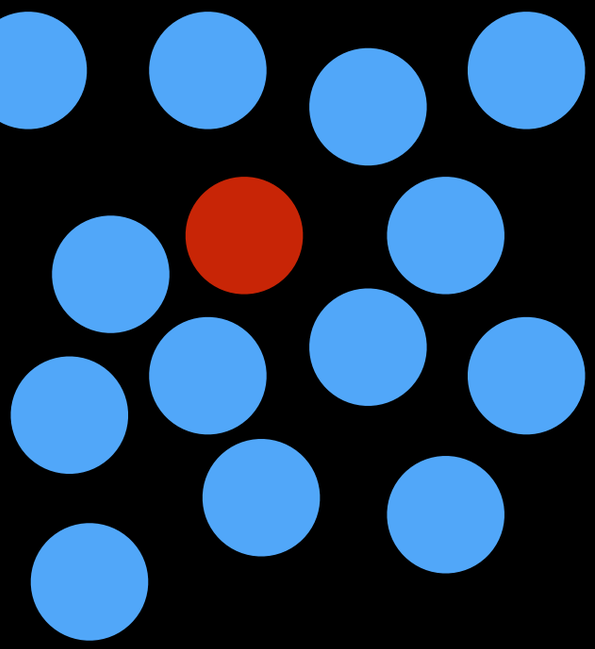
Color



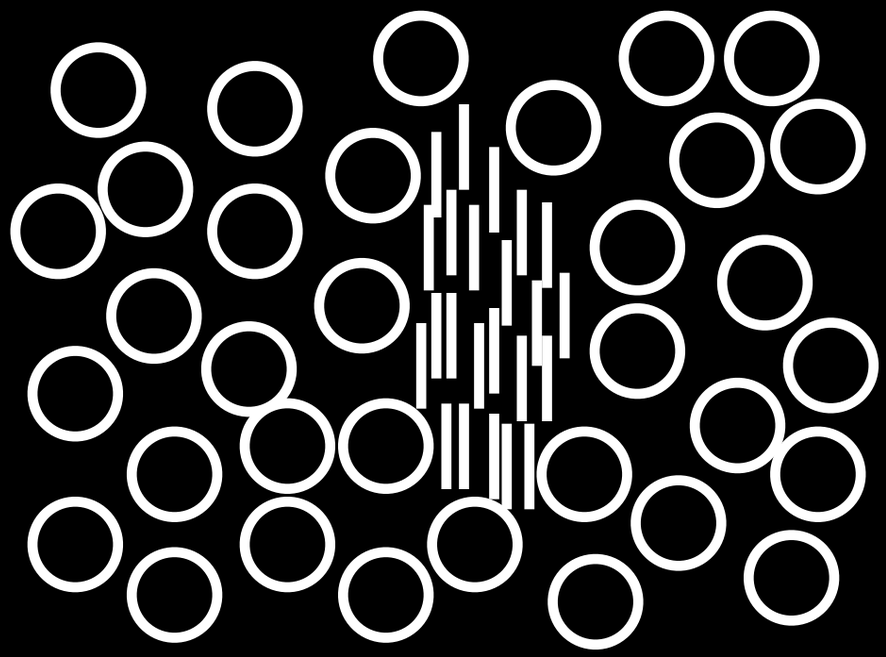
Texture

What is “Salient”?

Something that stands out relative to its neighbors



Color



Texture

Orientation

Outline

- Saliency in the Human Visual System
- Measuring Object Saliency
- Detecting Salient Objects
- Estimating Object Saliency Level
- Data Saliency

Why Visual Saliency?

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Do we need to process all pixels?

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Are All Pixels Equally Important?

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Why Visual Saliency?

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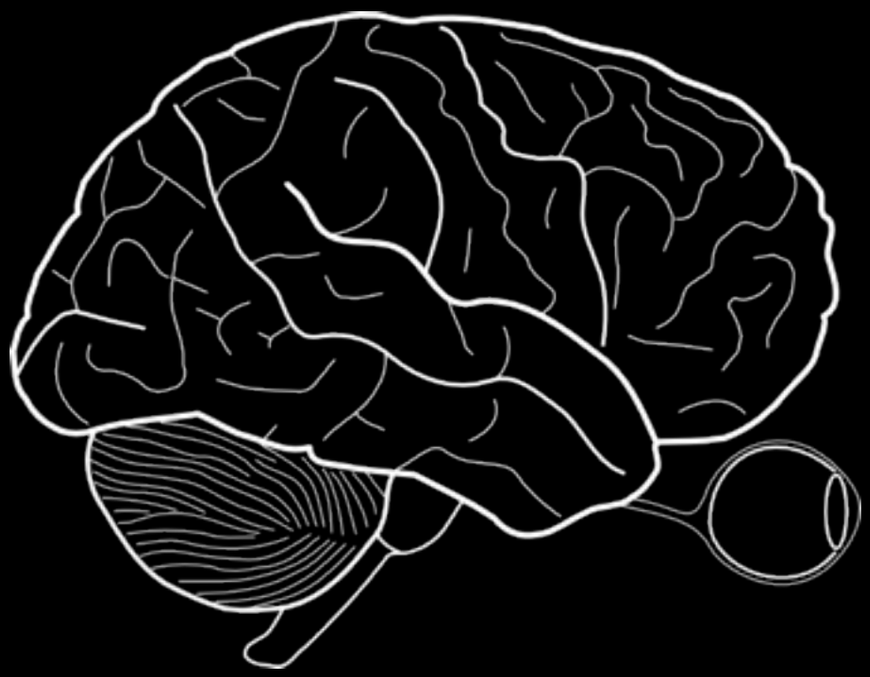
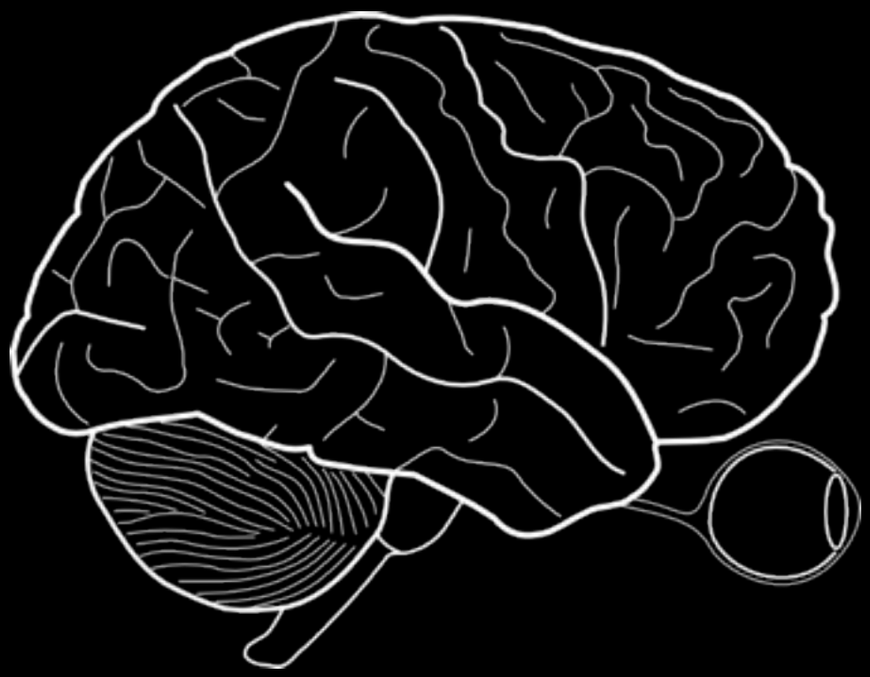
Are All Pixels Equally Important?

Resource Allocation

Human Visual System



Human Visual System



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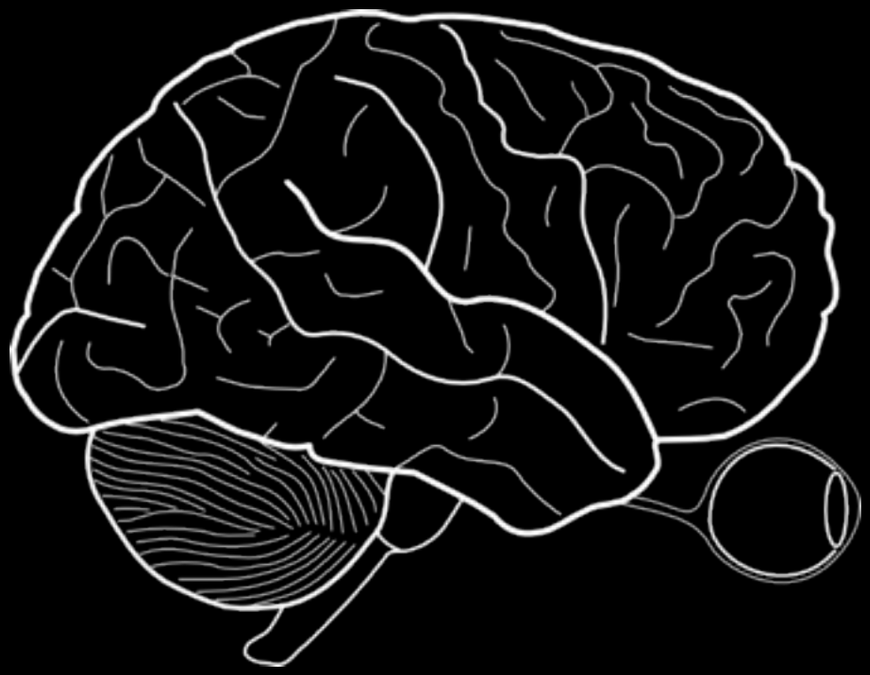
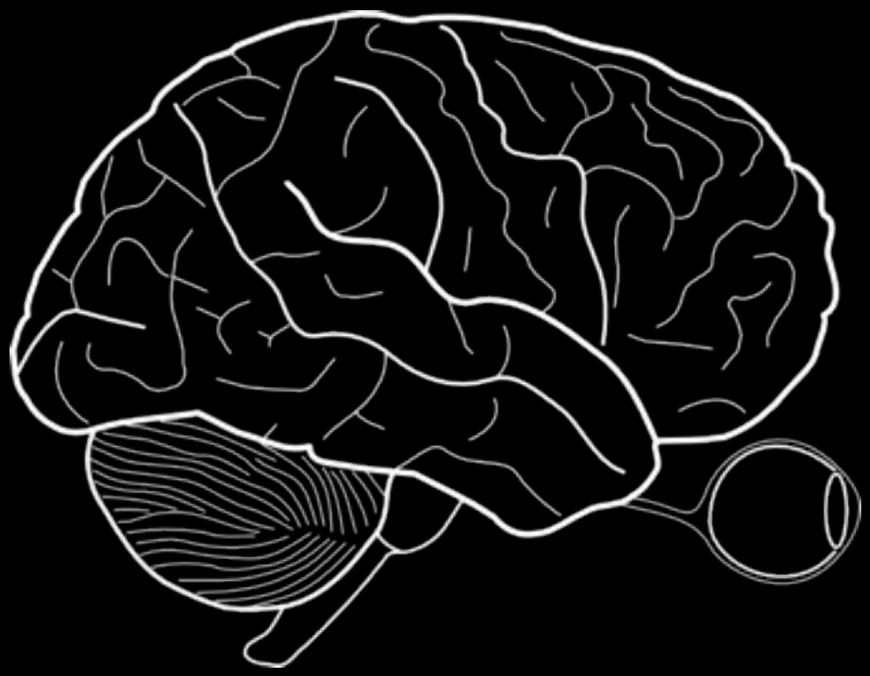
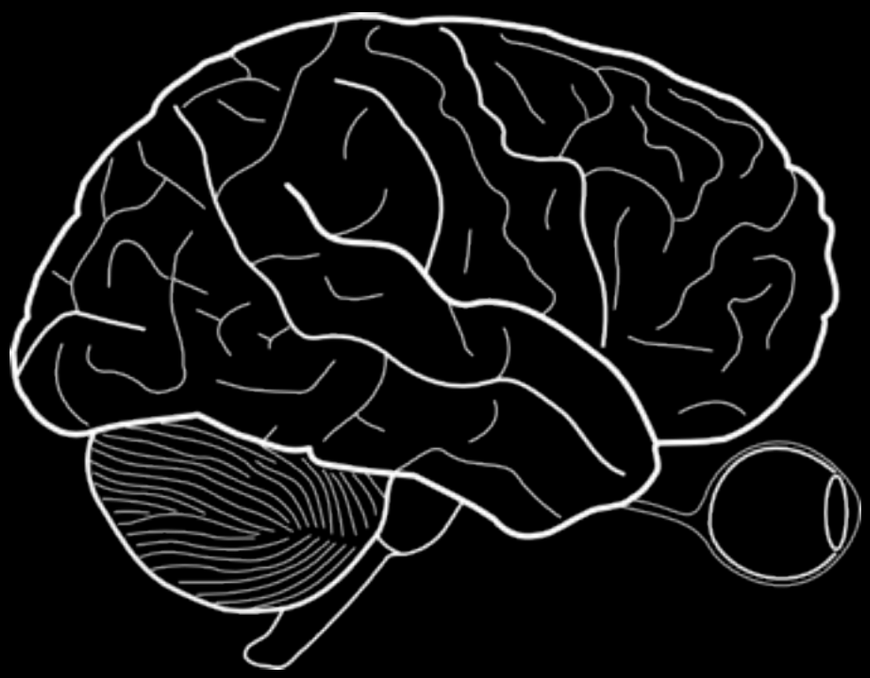


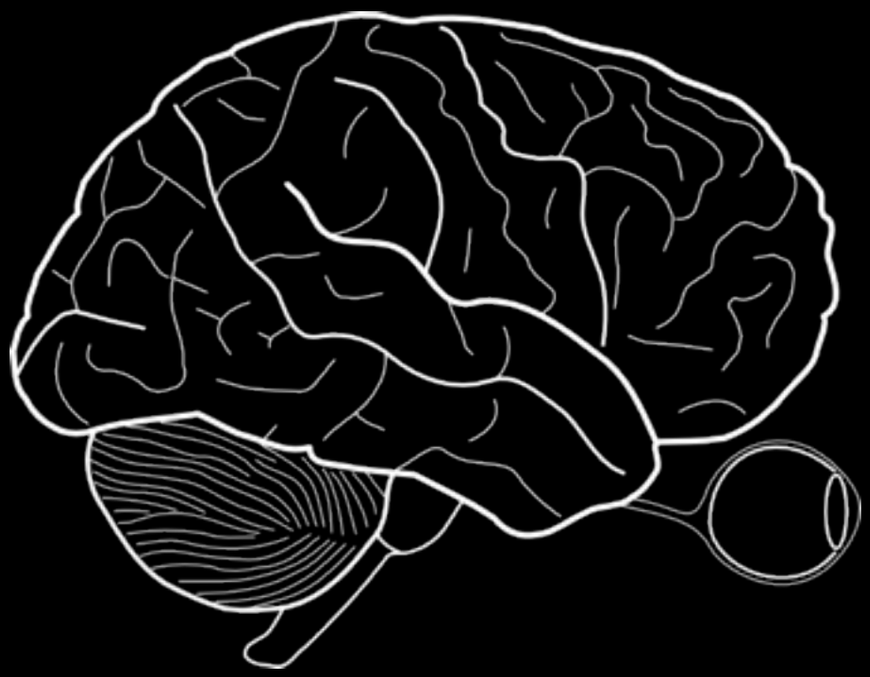
Human Visual System



Human Visual System



Allocation in Human Visual System



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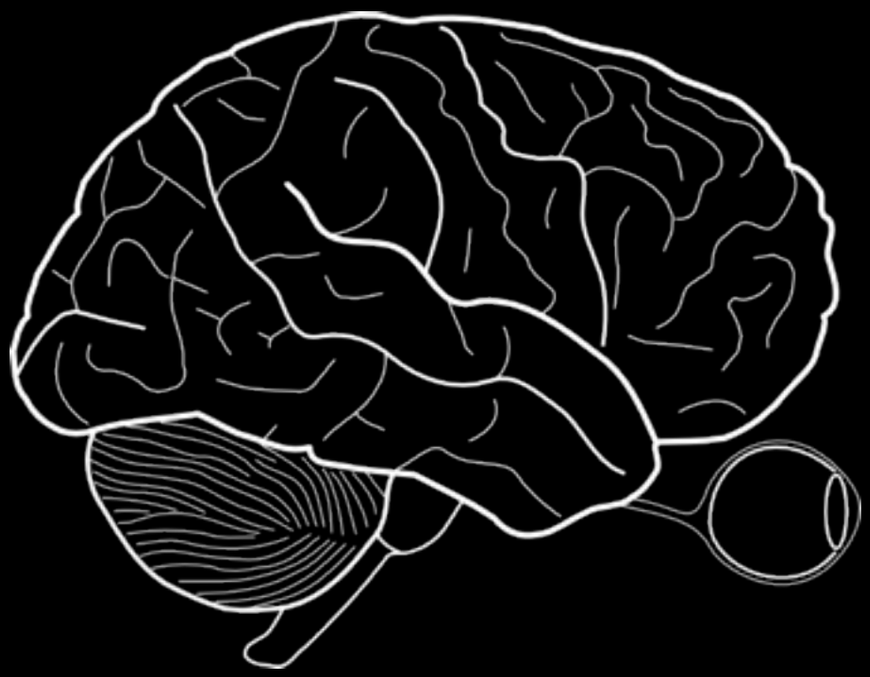
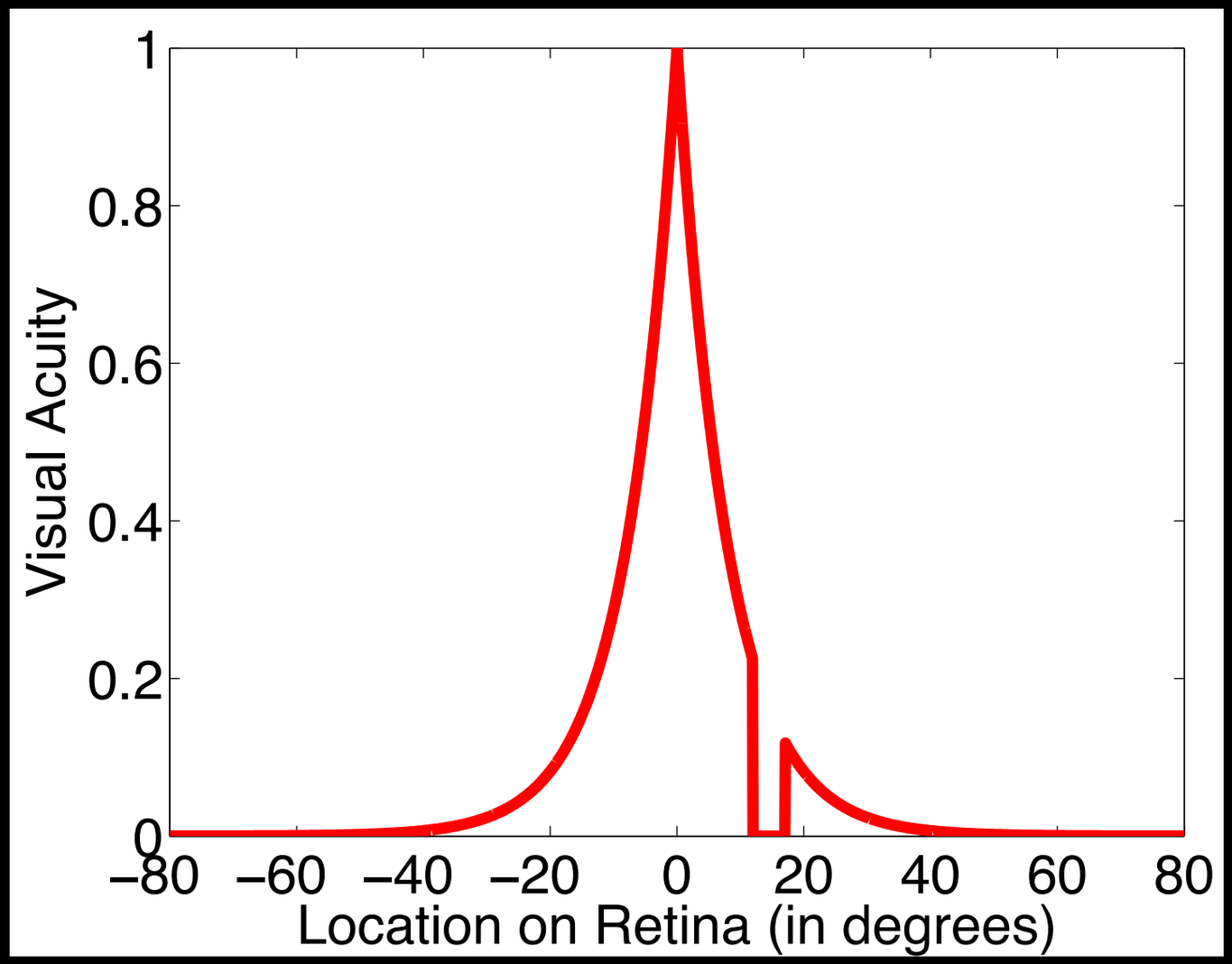
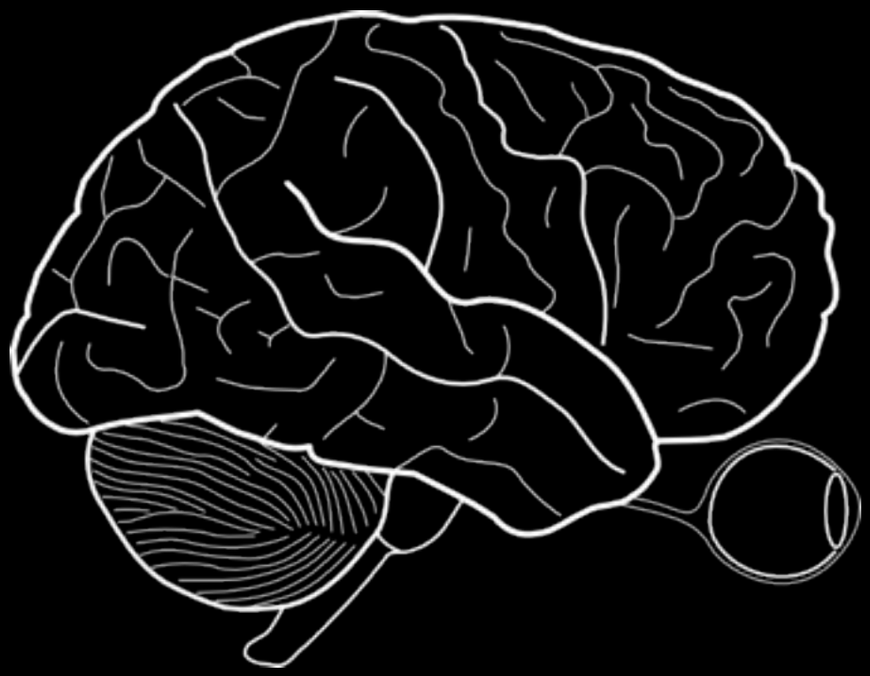
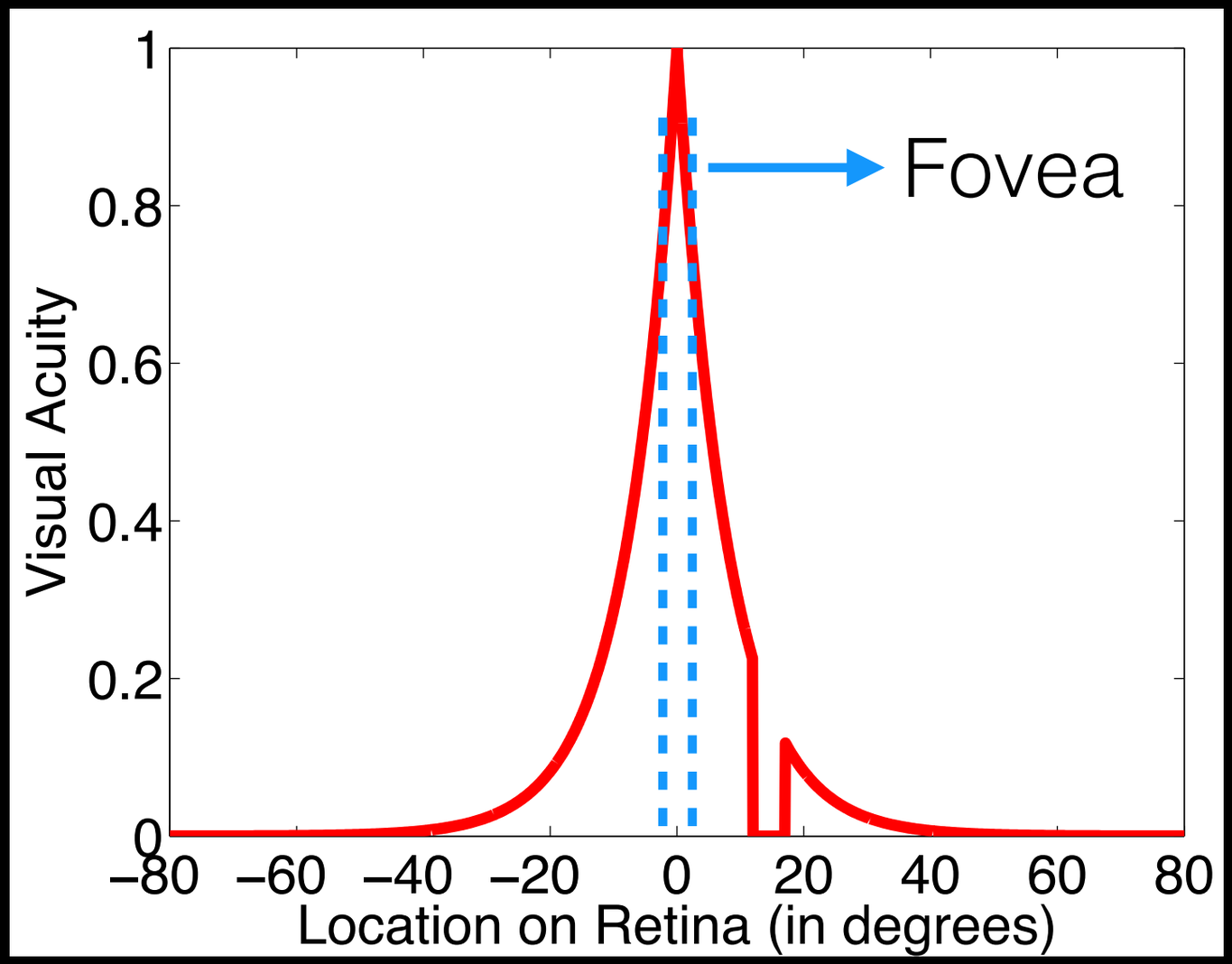


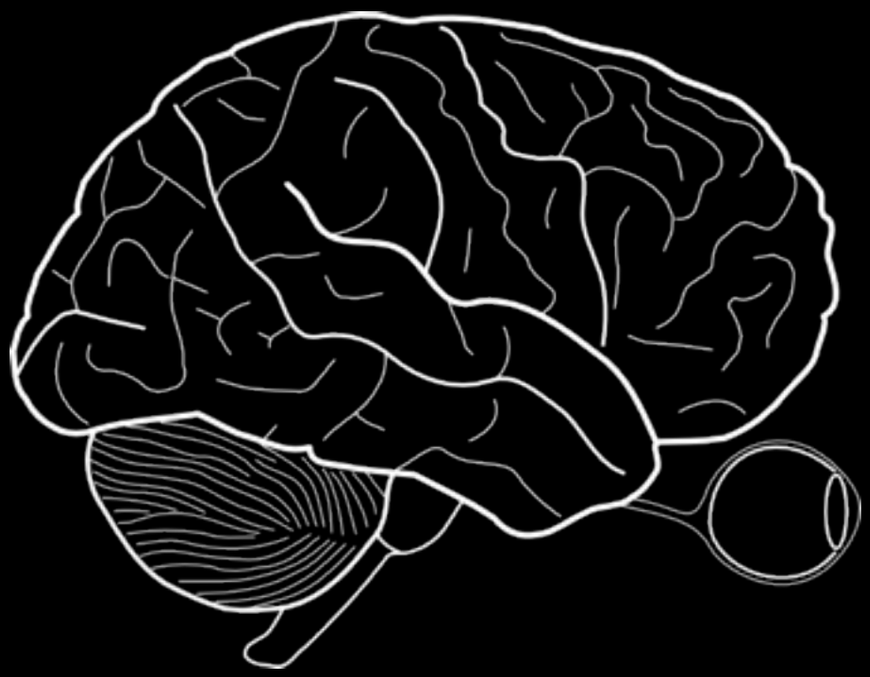


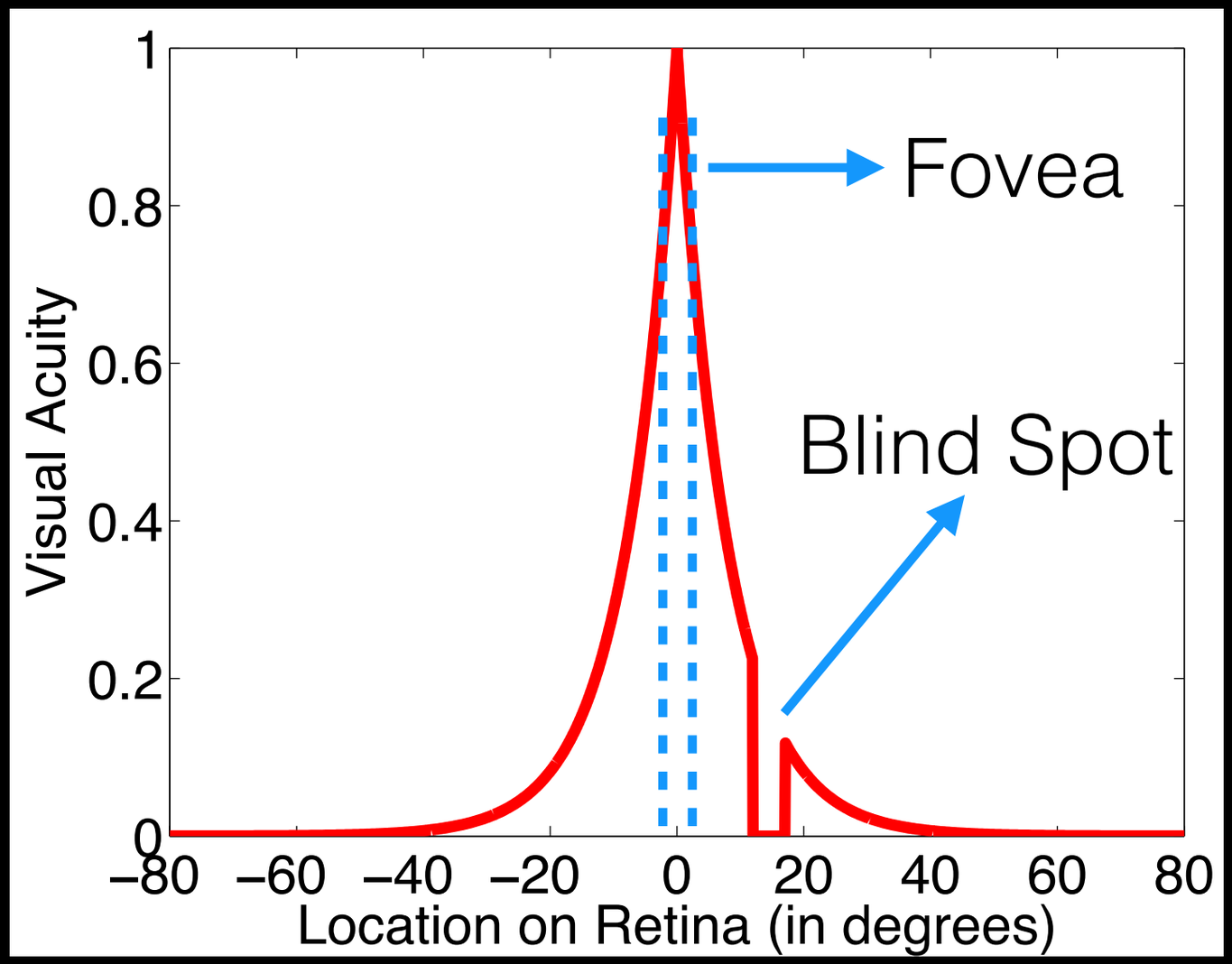
Allocation in Human Visual System



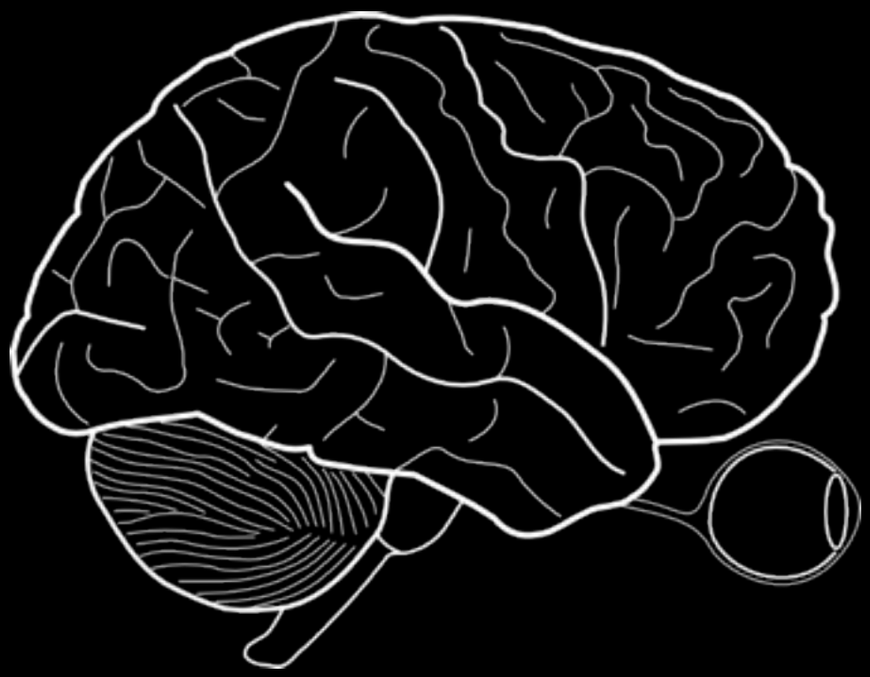


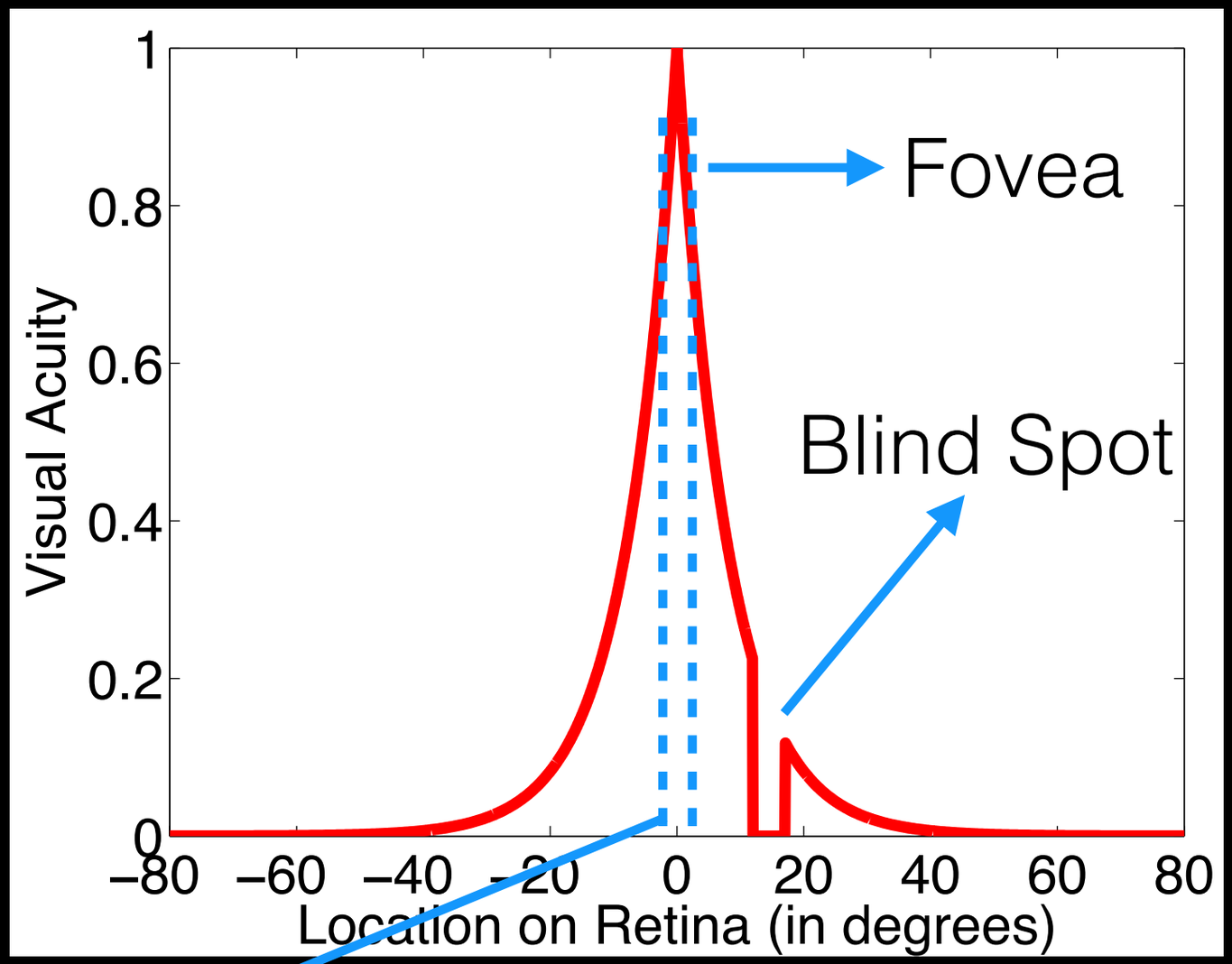
Allocation in Human Visual System





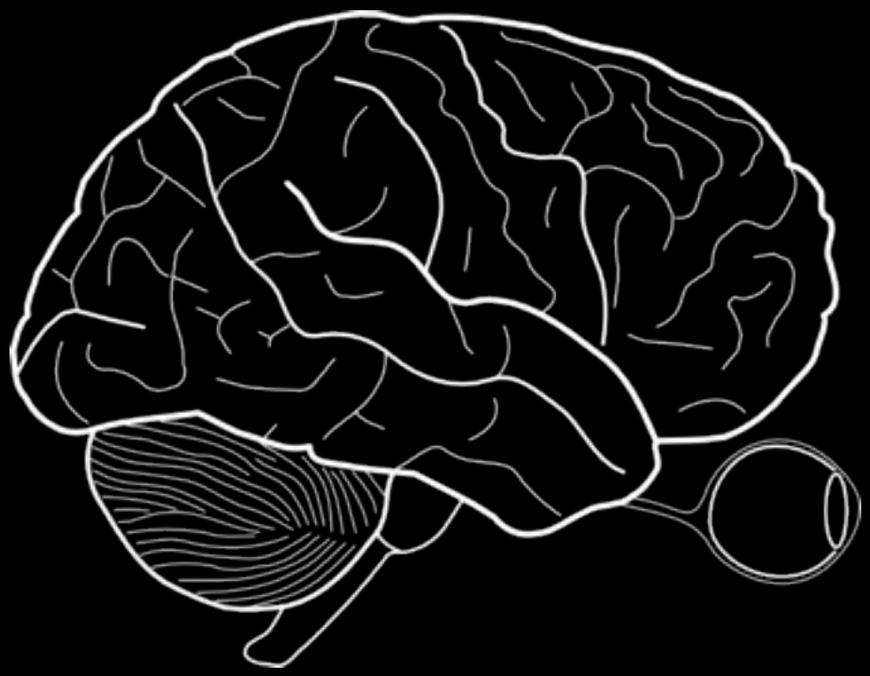
Allocation in Human Visual System

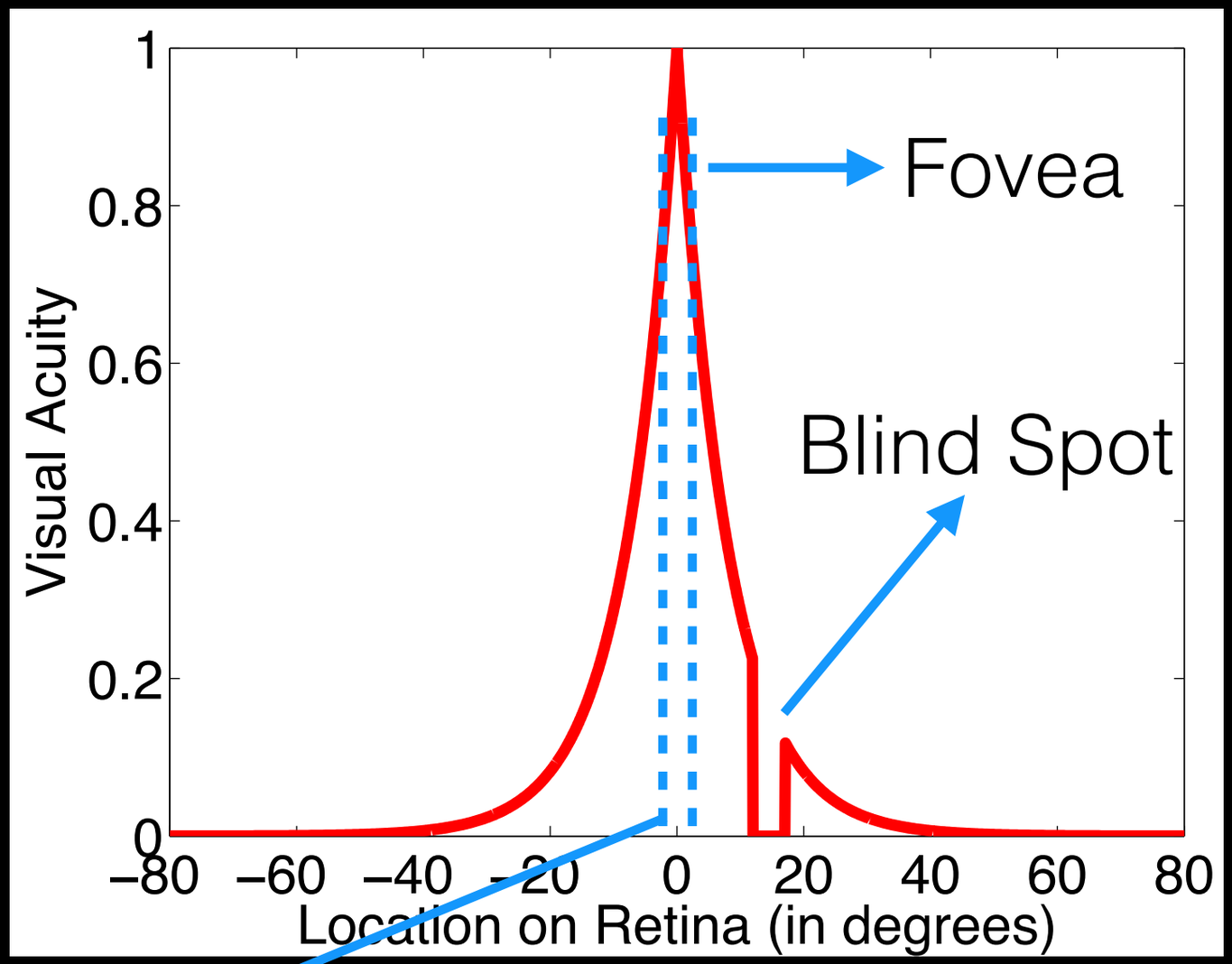




50% of the processing resources (Kandel et al., 1991)

Allocation in Human Visual System

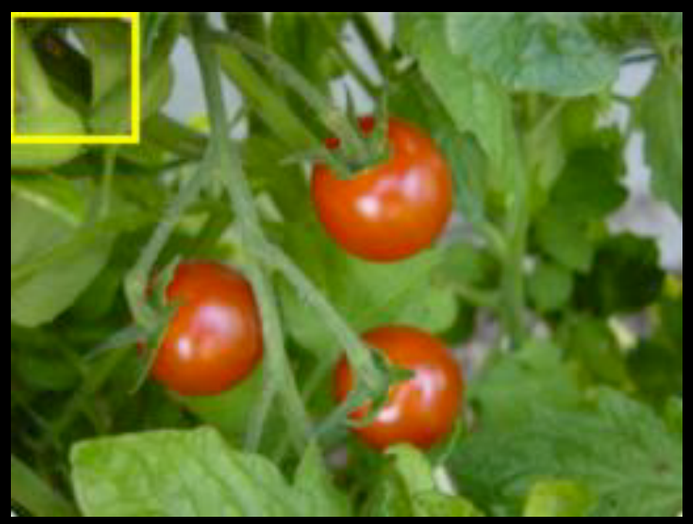




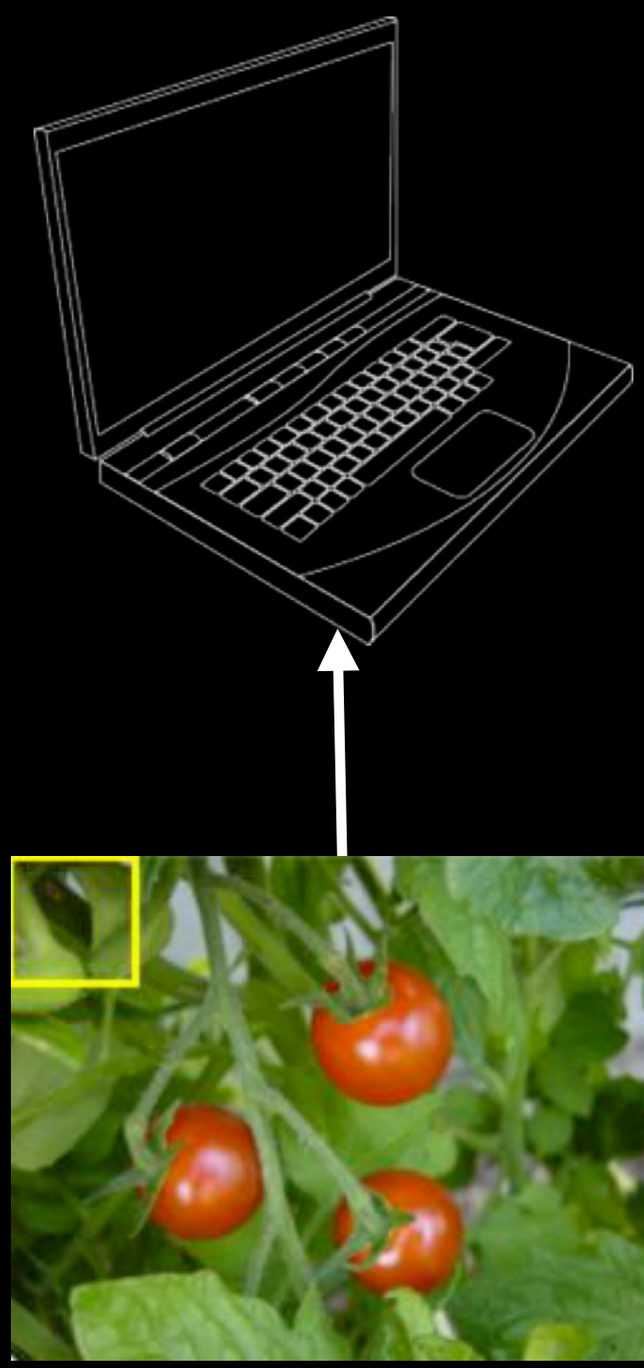
50% of the processing resources (Kandel et al., 1991)

Asymmetric resource allocation!

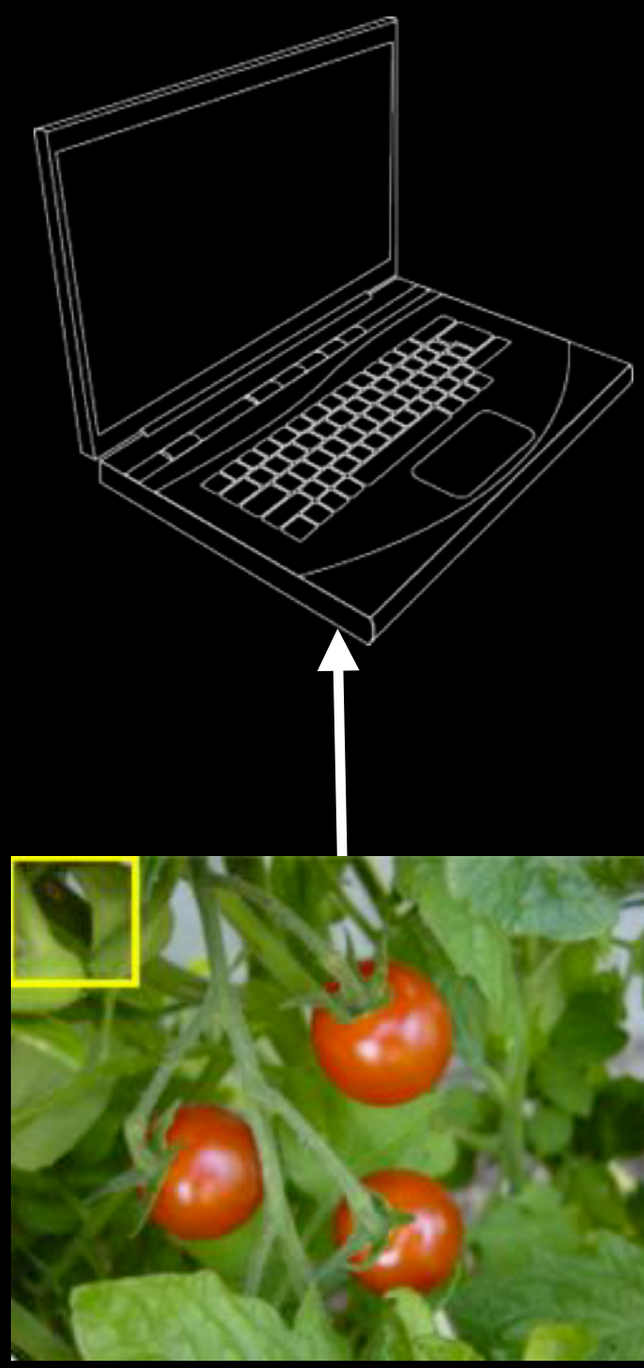
Allocation in Computers



Allocation in Computers

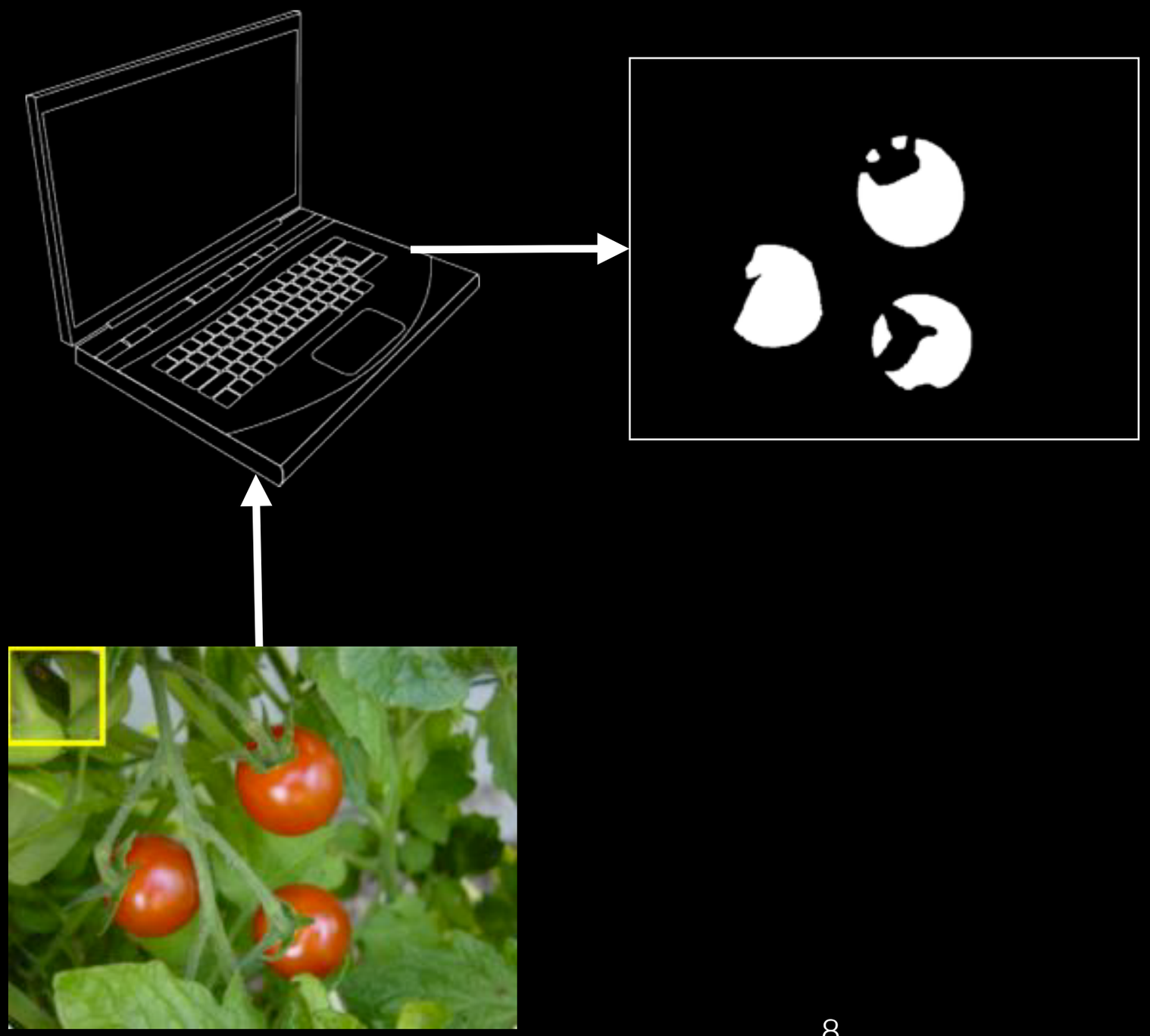


Allocation in Computers



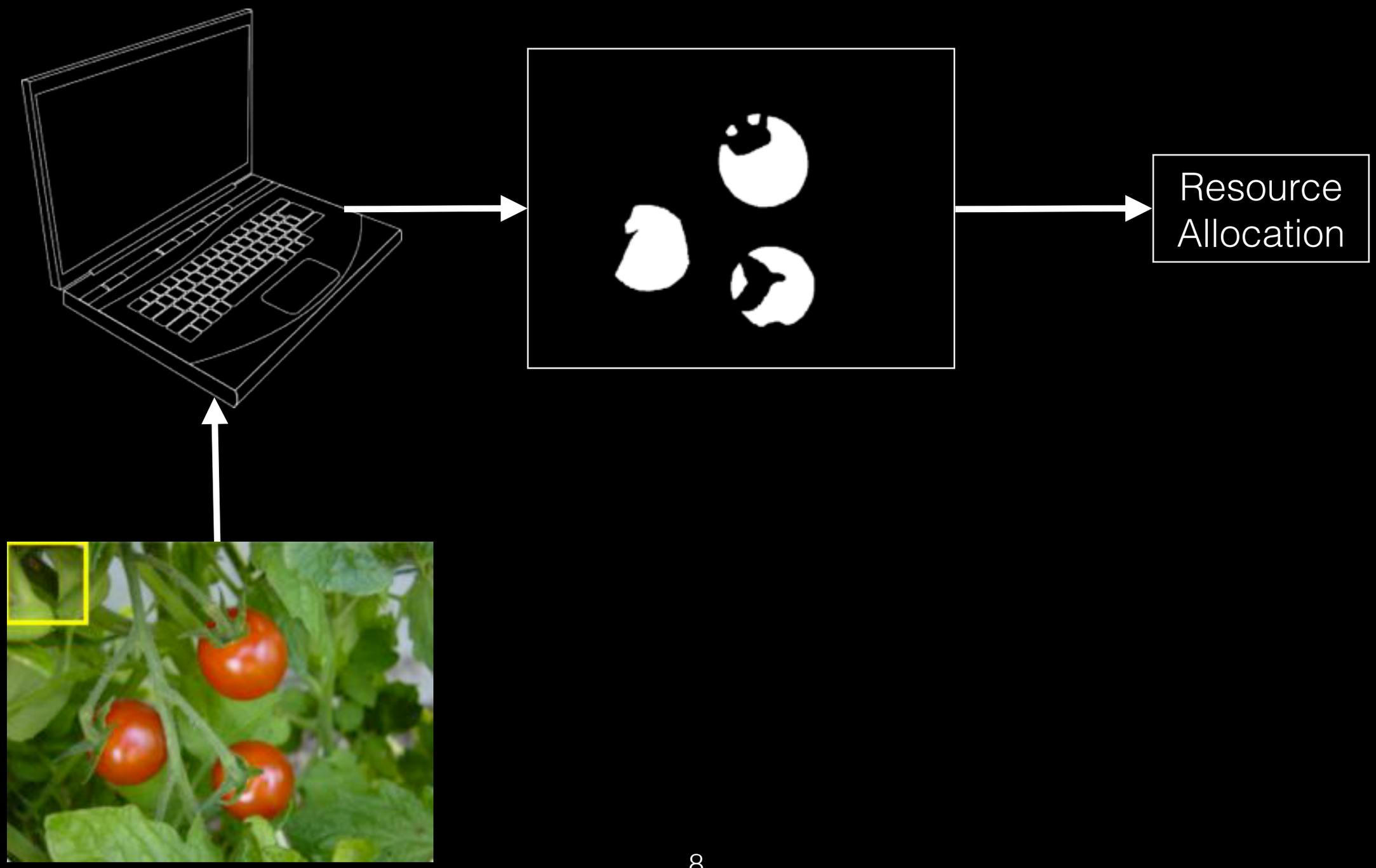
Allocation in Computers

Salient-Object Detection



Allocation in Computers

Salient-Object Detection



Allocation in Computers

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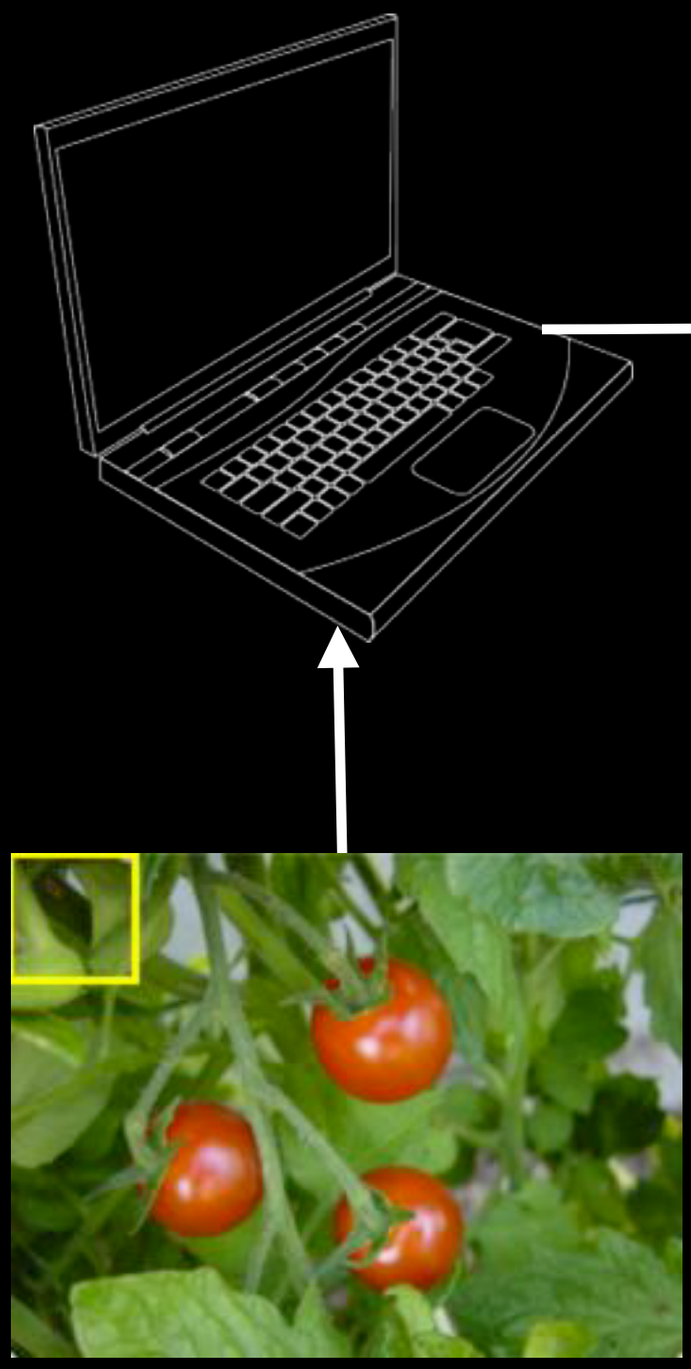
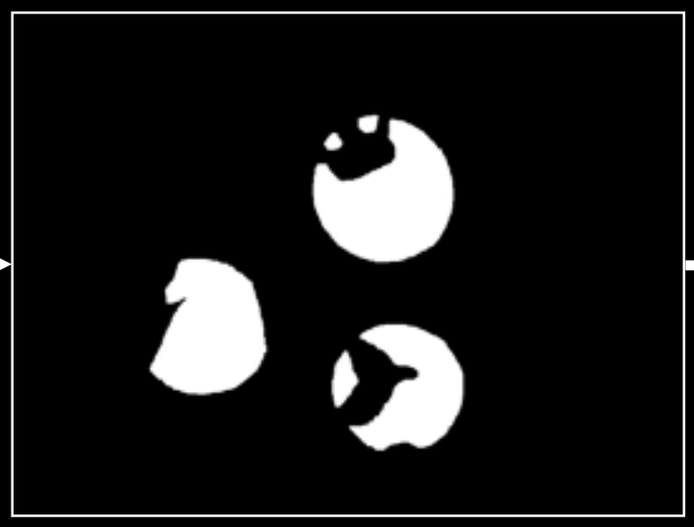




Resource Allocation

Computer Vision Applications

- Image Tagging
- Object Recognition

Outline

- Saliency in the Human Visual System
- Measuring Object Saliency
- Detecting Salient Objects
- Estimating Object Saliency Level
- Data Saliency

COS Dataset

Comprehensive **O**bject **S**aliency

COS Dataset

Comprehensive **O**bject **S**aliency

- 588 Images

COS Dataset

Comprehensive **O**bject **S**aliency

- 588 Images
- ImageNet and Flickr

http://www.image-net.org/

https://www.flickr.com/

COS Dataset

Comprehensive **O**bject **S**aliency

- 588 Images
- ImageNet and Flickr
- Image Tags

"Bull Terrier"

http://www.image-net.org/

https://www.flickr.com/

COS Dataset

2434 Objects

COS Dataset

2434 Objects

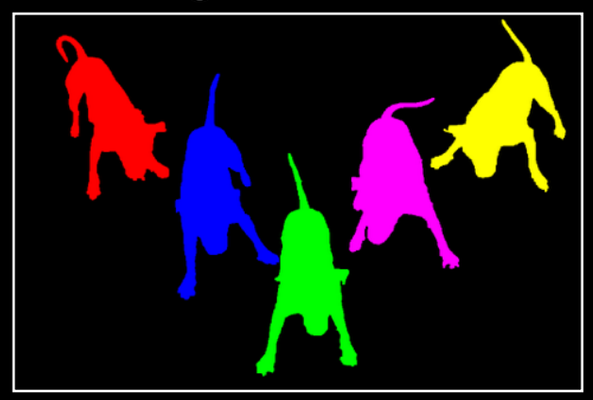
Manual Object Segmentation

Required for measuring object saliency!

COS Dataset Overview

Image

Manual Object Segmentation

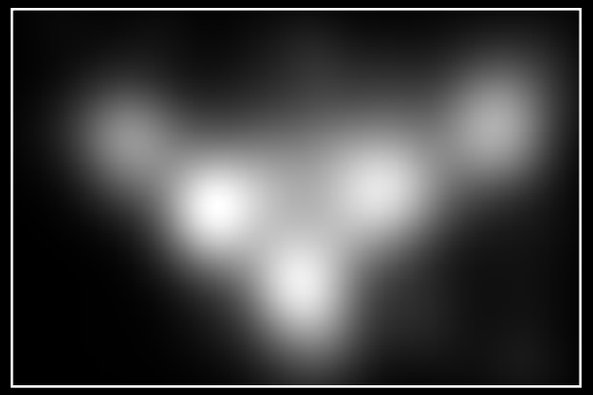


COS Dataset Overview

Three Subjective Experiments

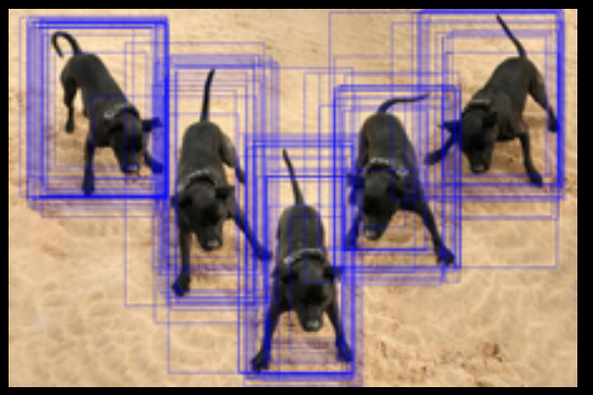
Image

Eye Tracking

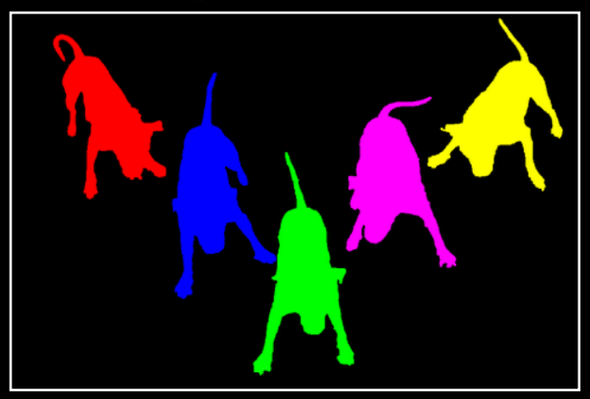


Point Clicking

Rectangle Drawing



Manual Object Segmentation



COS Dataset Overview

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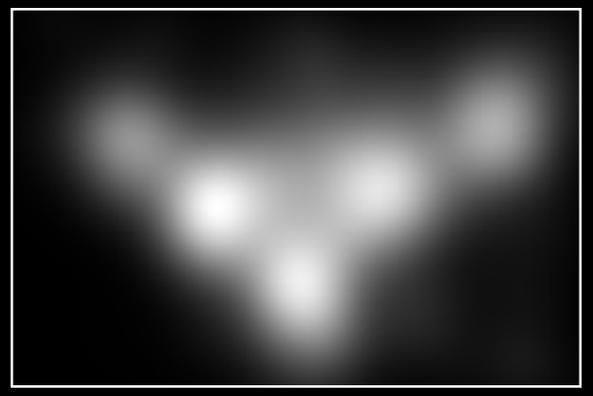
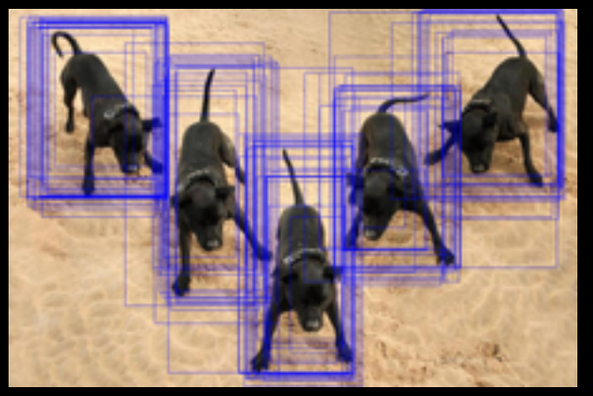
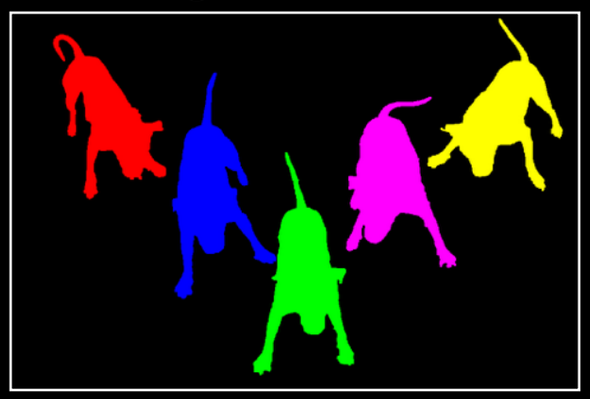


Point Clicking

Rectangle Drawing



Manual Object Segmentation



Eye-Tracking GT

Point-Clicking GT

Rectangle-Drawing GT

Three Types of Multi-Level Object Saliency & Ground Truth

GT: Ground Truth

Subjective Experiment

Experimental Data

Subjective Experiment

Measuring Object Saliency

Experimental Data

Subjective Experiment

Measuring Object Saliency

Experimental Data

Object Saliency is Multi-Level

Eye-Tracking Experiments

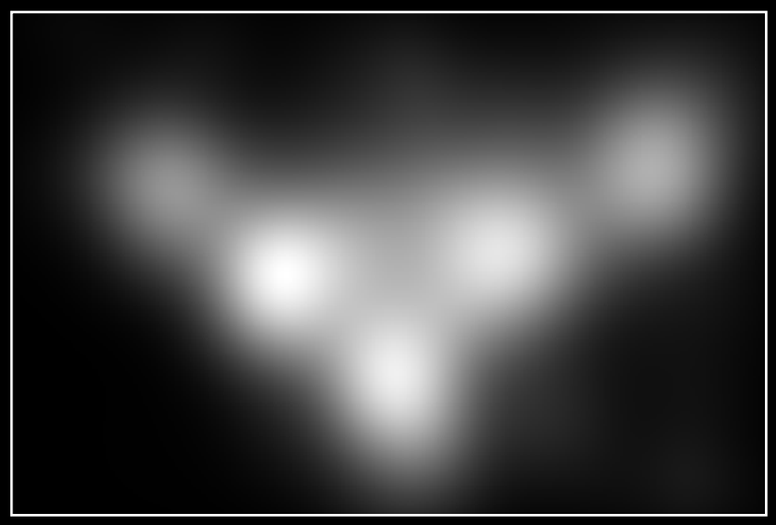
Subject

Eye Tracker

Directive

“Freely View the Images”

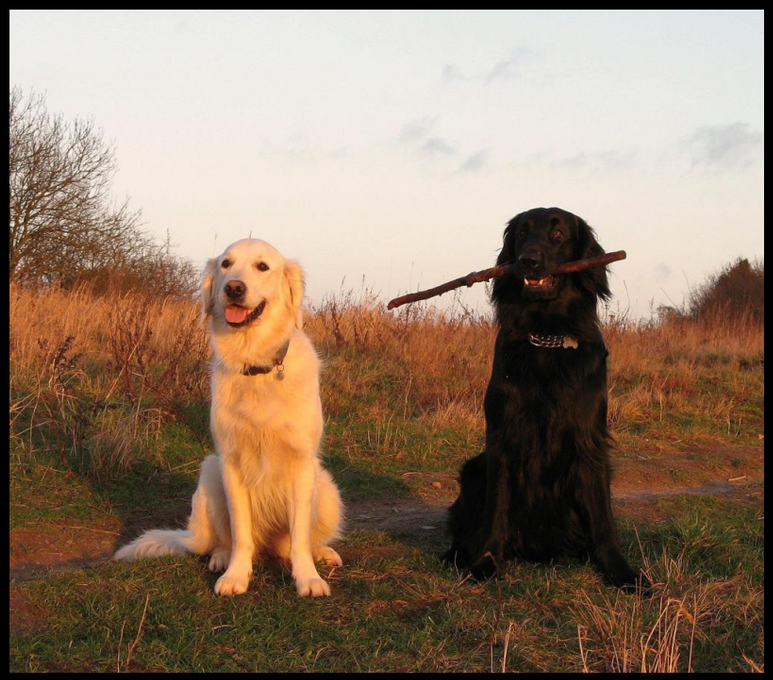
Input Image



Experimental Data

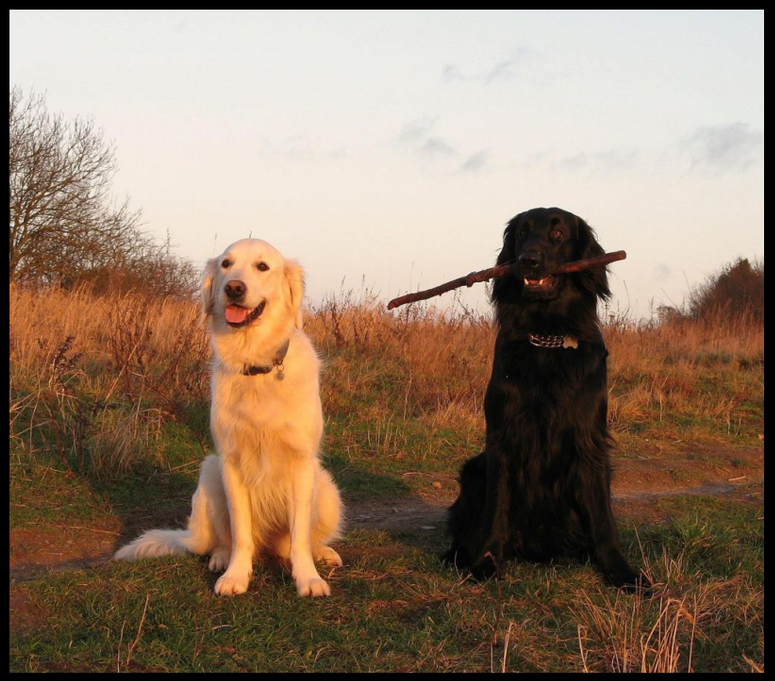
Eye-Tracking Saliency

Original Image

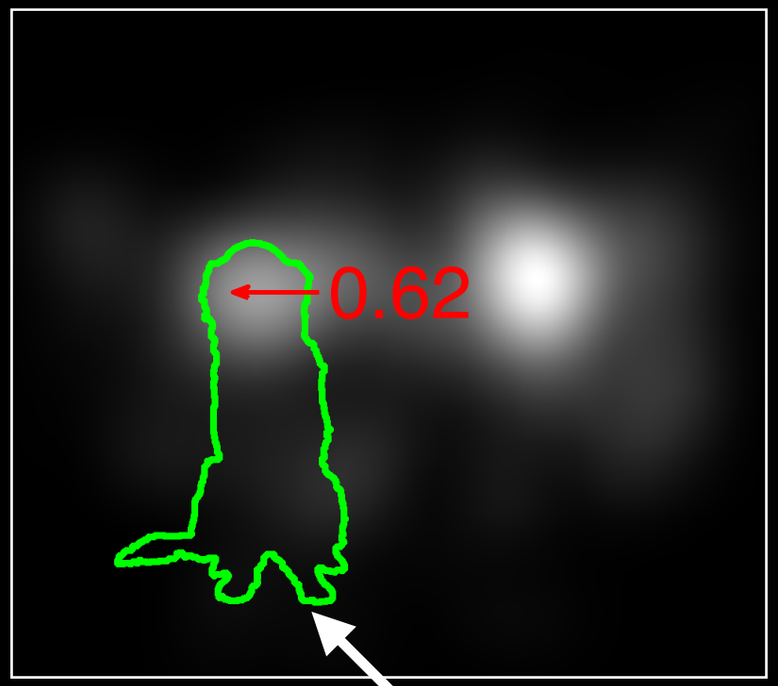


Eye-Tracking Saliency

Original Image



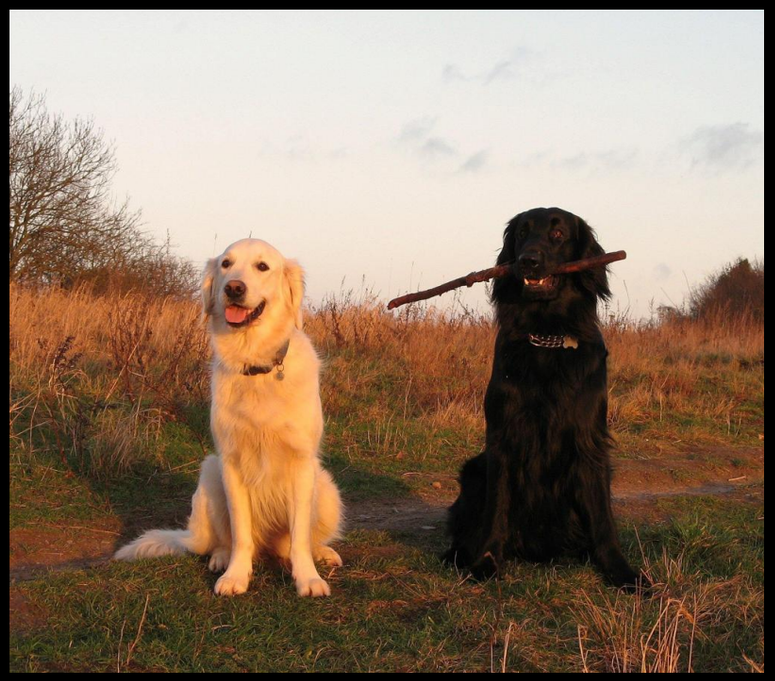
Average
Experimental Data



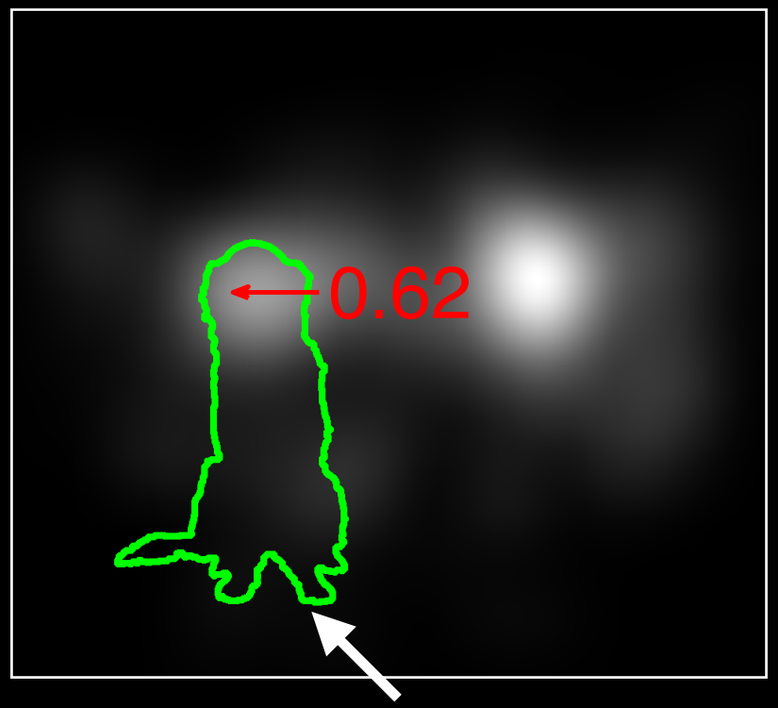
Manual Object
Segmentation

Eye-Tracking Saliency

Original Image



Average
Experimental Data

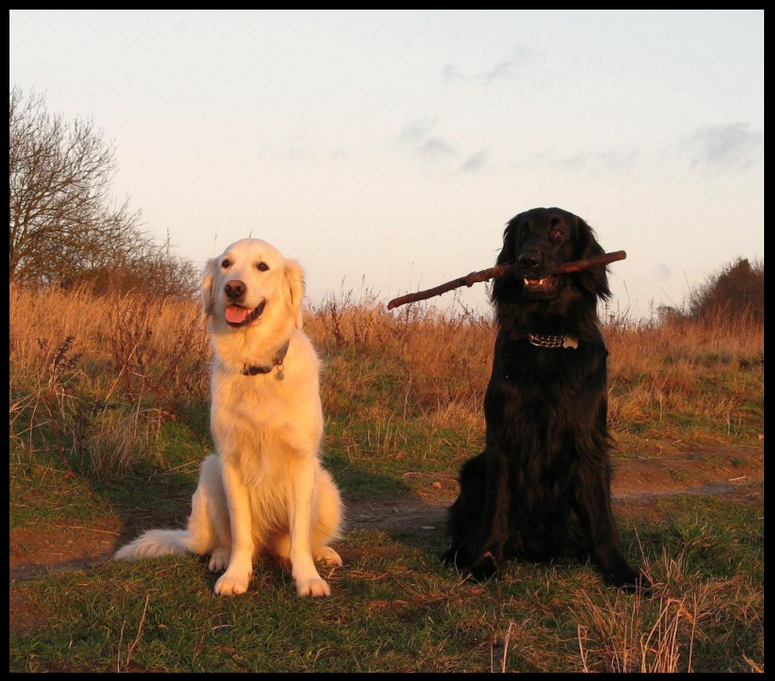


Manual Object
Segmentation

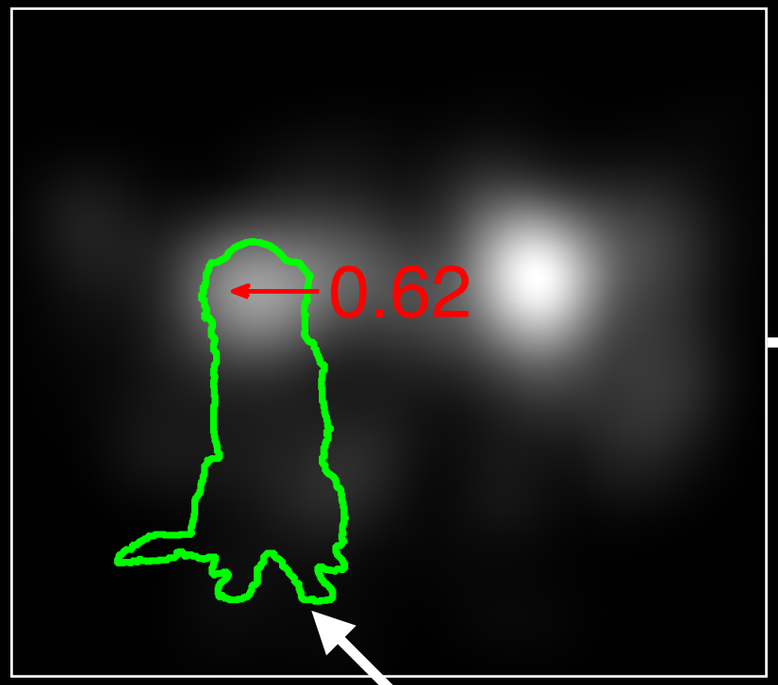
Multi-Level Object Saliency = Average Experimental Data

Eye-Tracking Saliency

Original Image

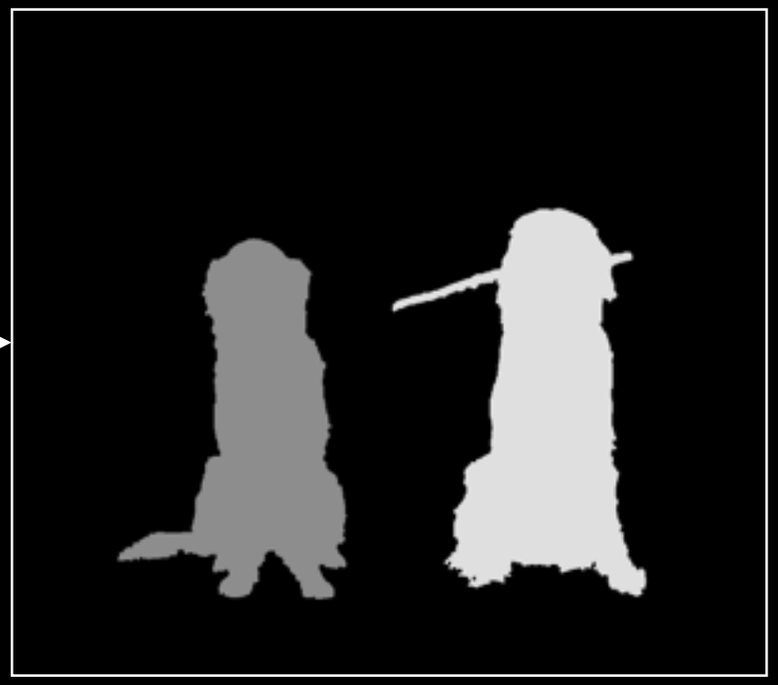


Average
Experimental Data



Manual Object
Segmentation

Eye-Tracking GT



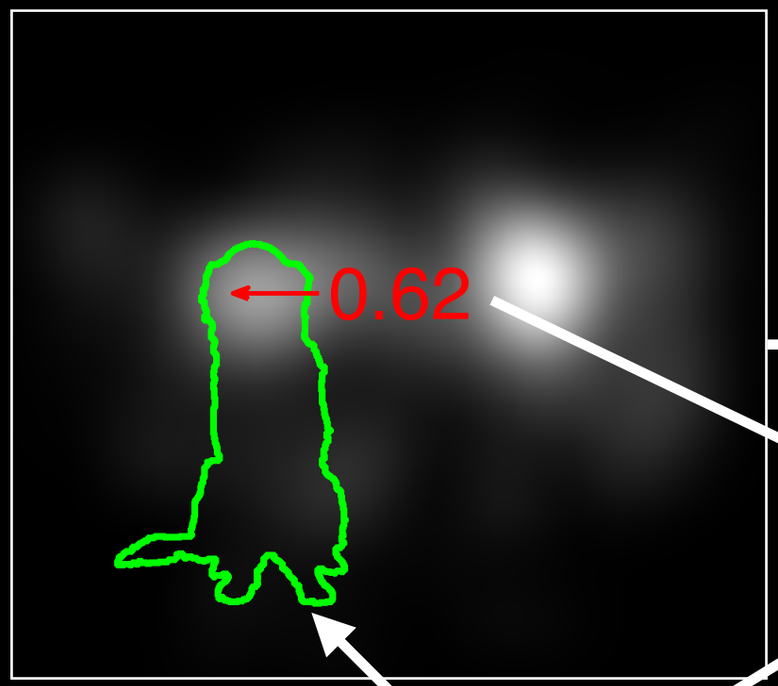
Multi-Level
Ground Truth

Multi-Level Object Saliency = Average Experimental Data

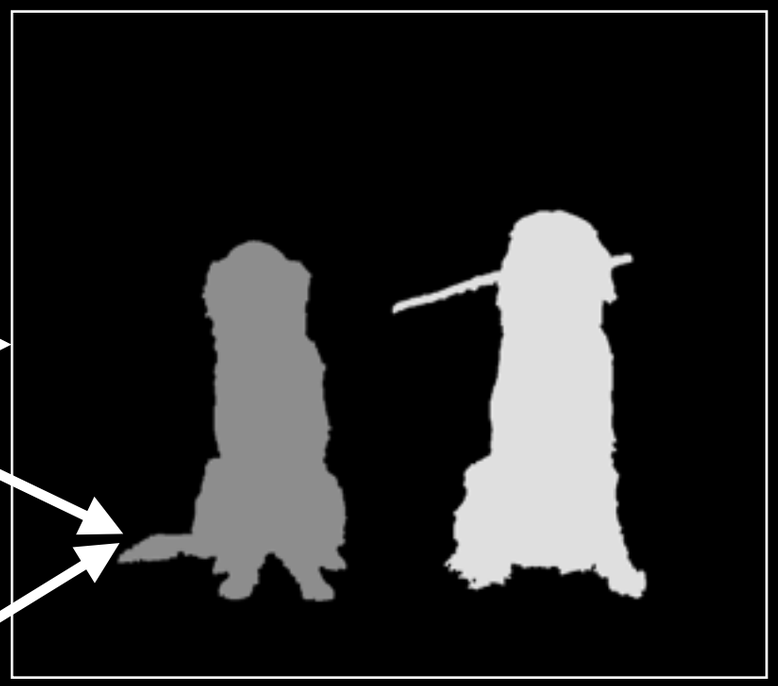
Eye-Tracking Saliency

Original Image

Average
Experimental Data



Eye-Tracking GT



Manual Object
Segmentation

Multi-Level
Ground Truth

Multi-Level Object Saliency = Average Experimental Data

Point-Clicking Experiments

Directive

Subject “Click on the Noticeable Objects”

Input Image

Experimental Data

Point-Clicking Saliency

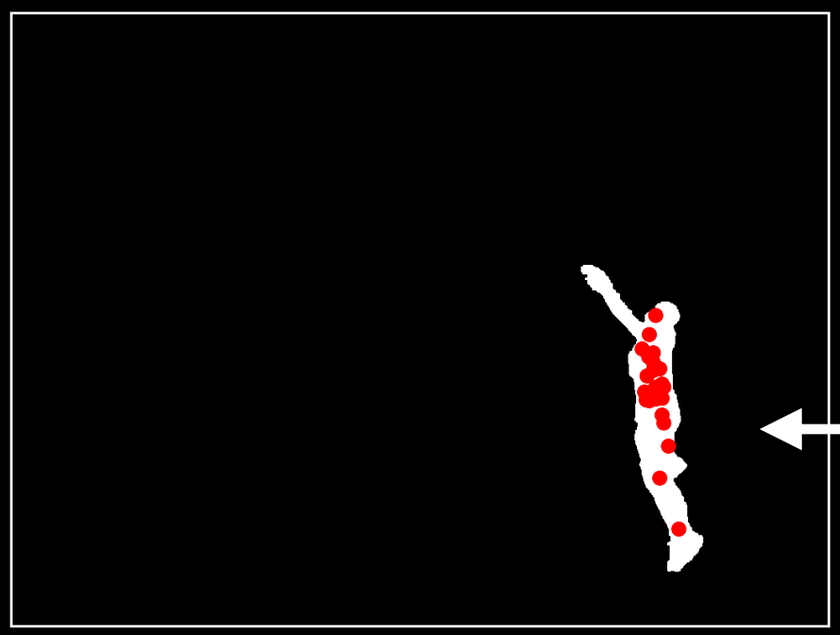
Original Image

Experimental Data

Point-Clicking Saliency

Original Image

Valid Clicks



Multi-Level
Object Saliency

$$\frac{\#\text{ of Valid Clicks}}{\#\text{ of Subjects}}$$

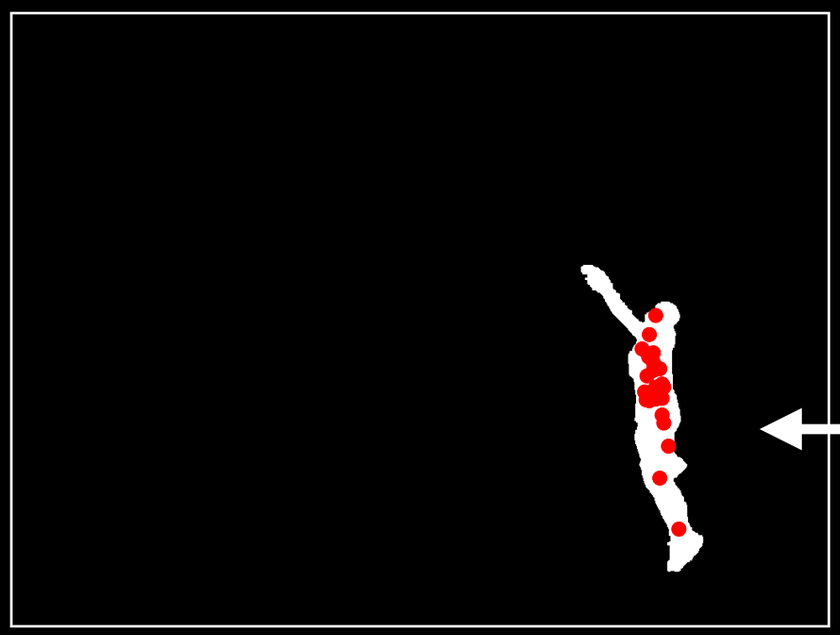
Manual Object
Segmentation

Experimental Data

Point-Clicking Saliency

Original Image

Valid Clicks



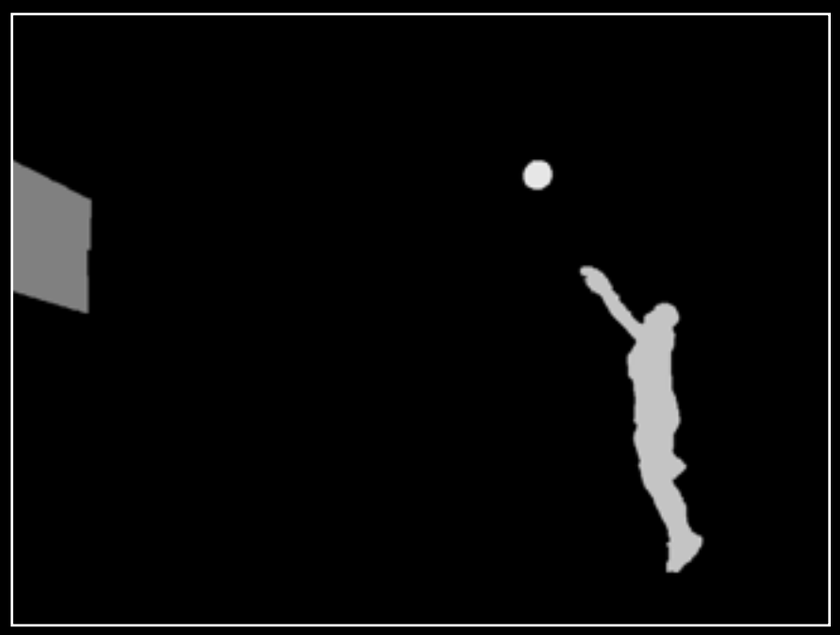
Multi-Level
Object Saliency

$$\frac{\#\text{ of Valid Clicks}}{\#\text{ of Subjects}}$$

Manual Object
Segmentation

Experimental Data

Point-Clicking GT



Multi-Level Ground Truth

Point-Clicking Saliency

Original Image

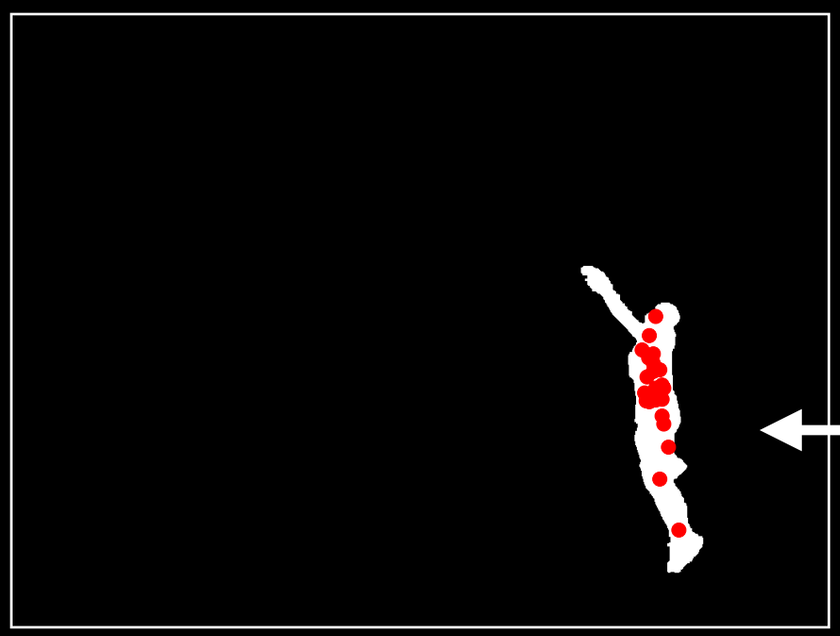
Valid Clicks

Multi-Level
Object Saliency

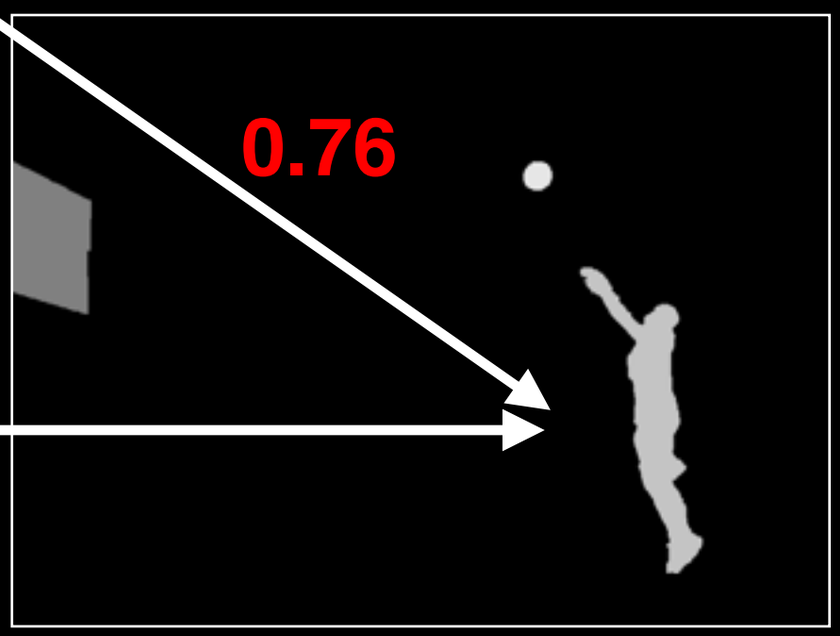
$$\frac{\text{\# of Valid Clicks}}{\text{\# of Subjects}} = \frac{23}{30}$$

Experimental Data

Point-Clicking GT



Manual Object
Segmentation



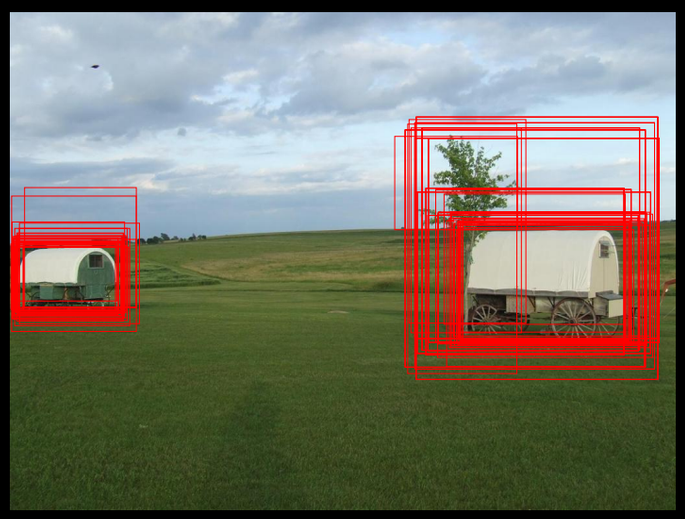
Multi-Level Ground Truth

Rectangle-Drawing Experiments

Subject

Directive
"Draw Rectangles on the Noticeable Objects"

Input Image

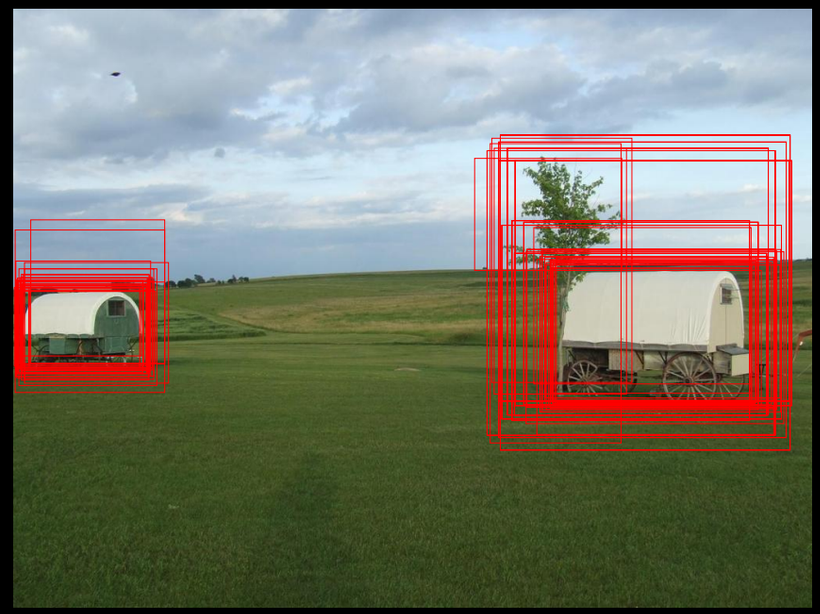


Experimental Data

Rectangle-Drawing Experiments

Original Image

Experimental Data



Rectangle-Drawing Experiments

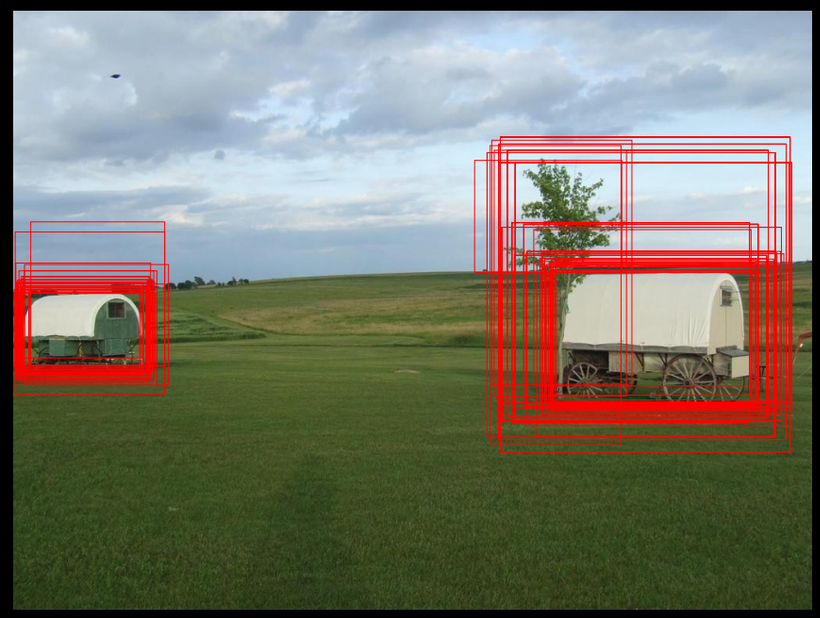
Original Image

Multi-Level
Object Saliency

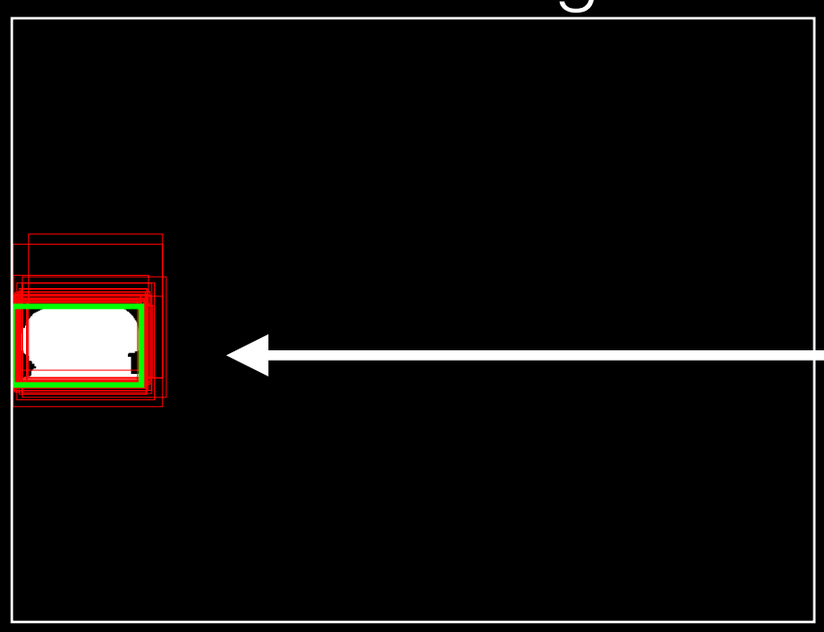
# of Valid Rectangles

# of Subjects

Experimental Data



Valid Rectangles



Manual Object
Segmentation

Rectangle-Drawing Experiments

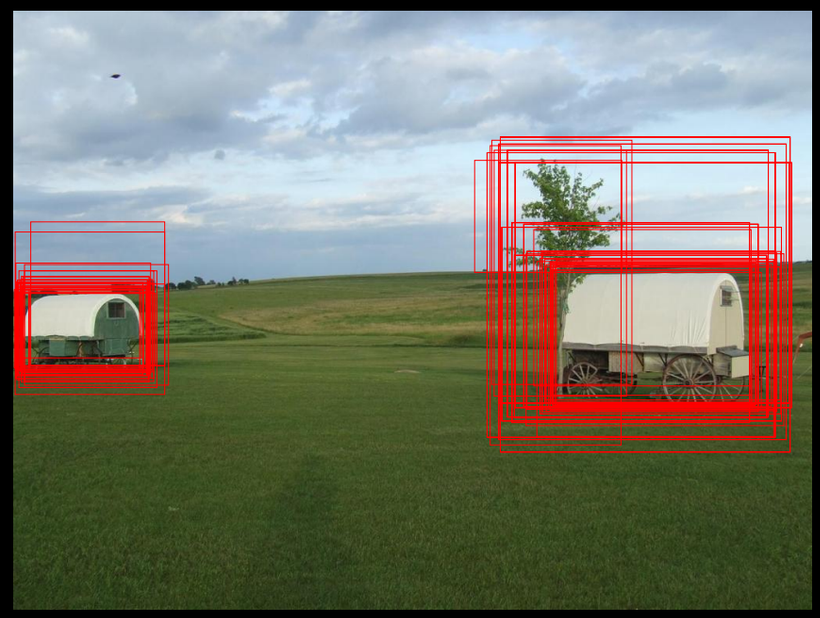
Original Image

Multi-Level
Object Saliency

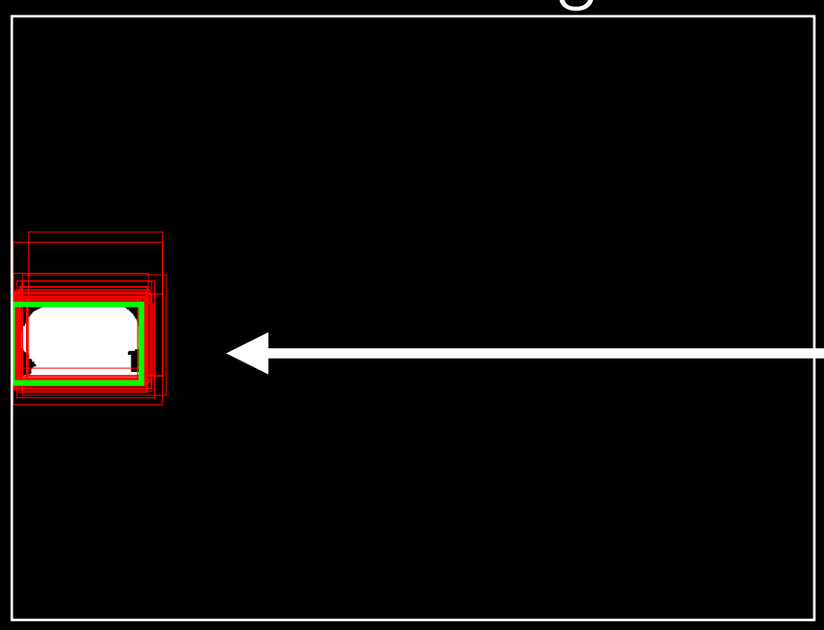
# of Valid Rectangles

# of Subjects

Experimental Data

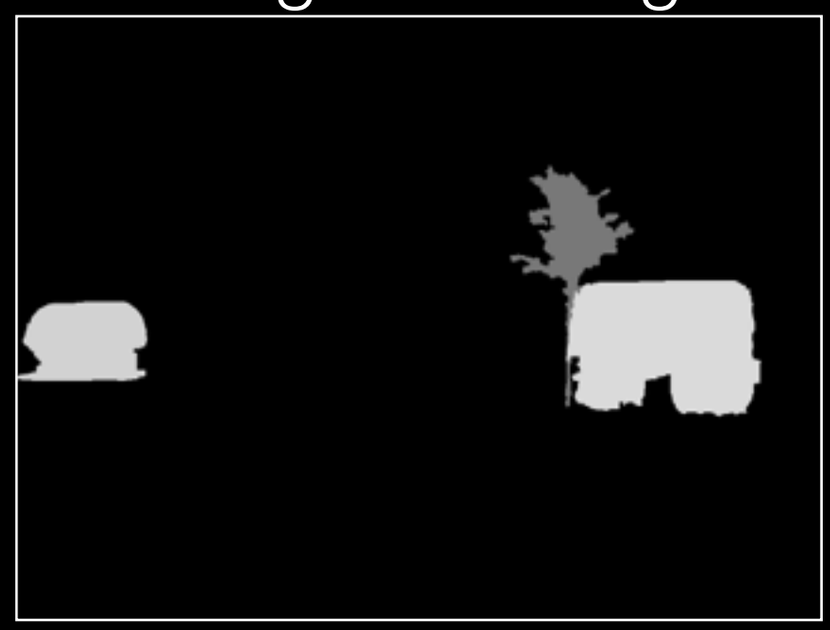


Valid Rectangles



Manual Object
Segmentation

Rectangle-Drawing GT



Multi-Level Ground Truth

Rectangle-Drawing Experiments

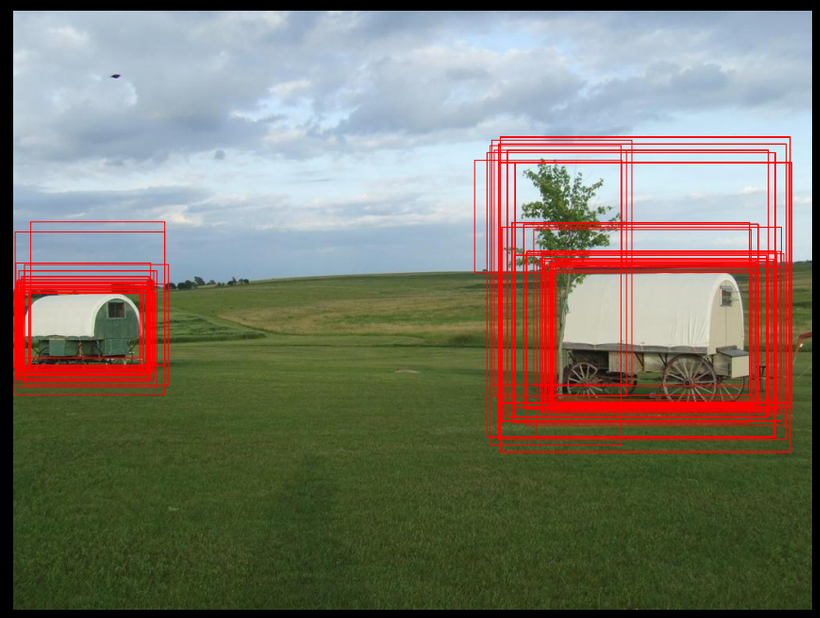
Original Image

Multi-Level
Object Saliency

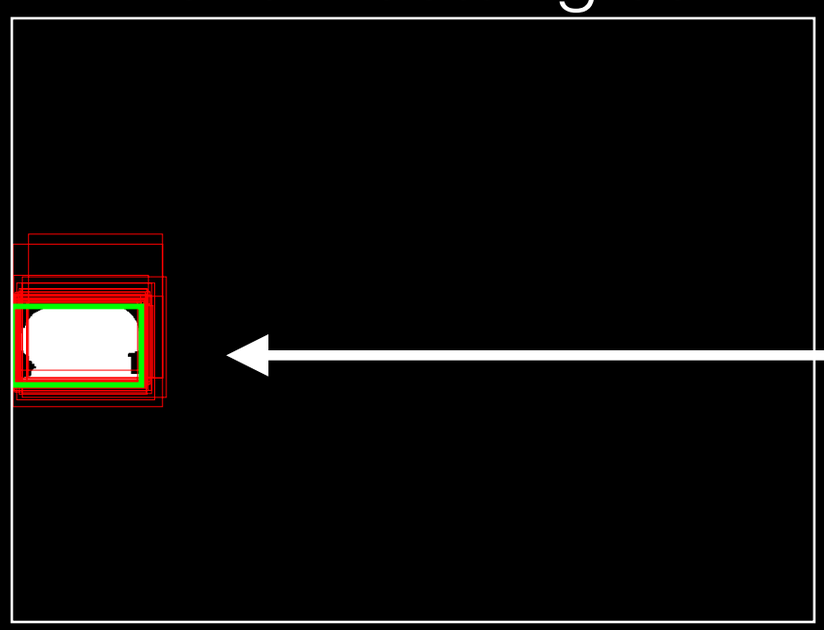
# of Valid Rectangles = 28

# of Subjects = 34

Experimental Data

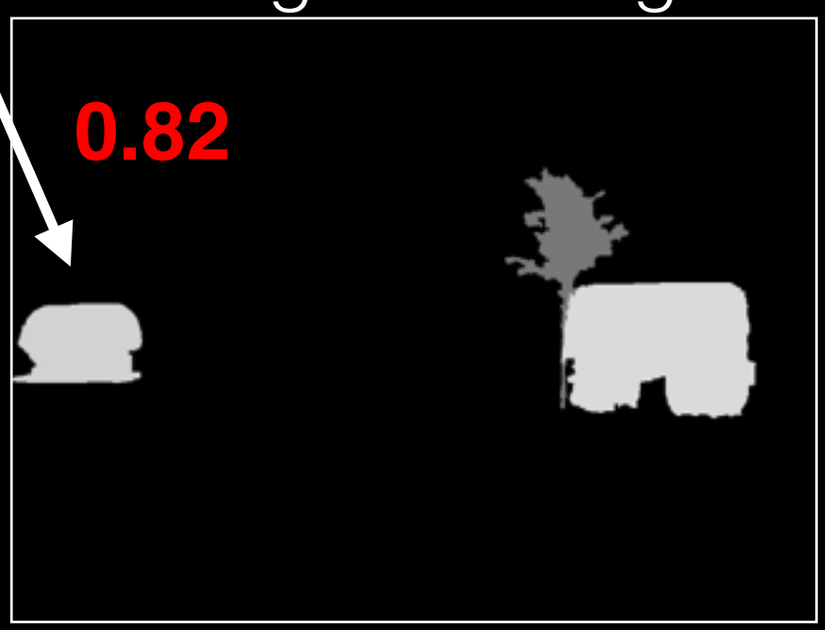


Valid Rectangles



Manual Object
Segmentation

Rectangle-Drawing GT



Multi-Level Ground Truth

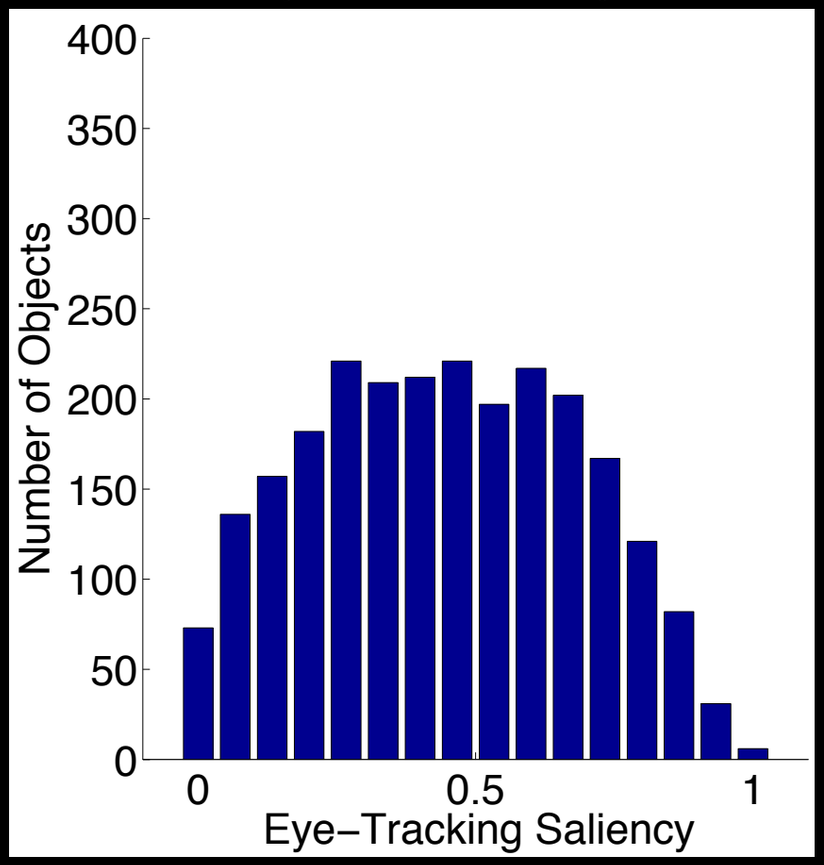
All Objects Are Not Equally Important!

Object Saliency Values in COS Dataset

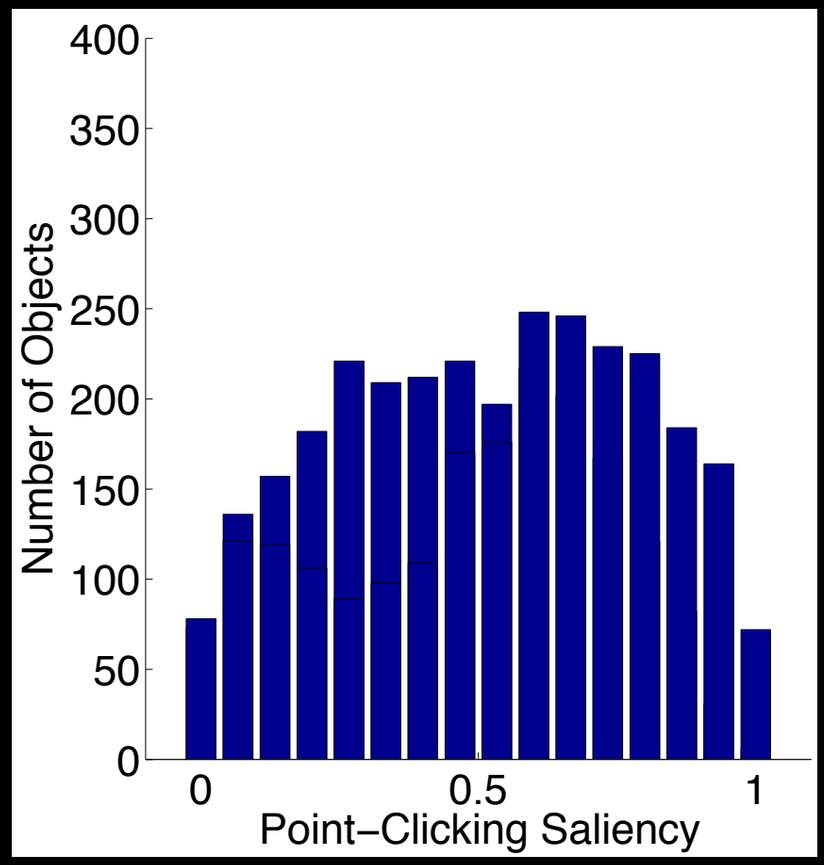
All Objects Are Not Equally Important!

Object Saliency Values in COS Dataset

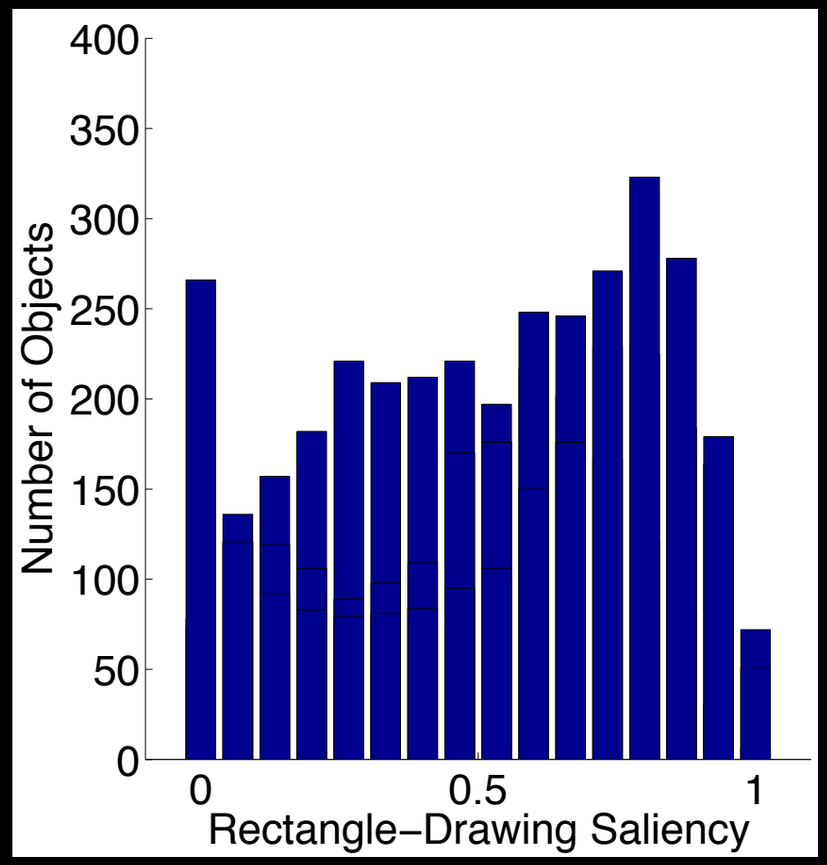
Eye-Tracking Object Saliency



Point-Clicking Object Saliency



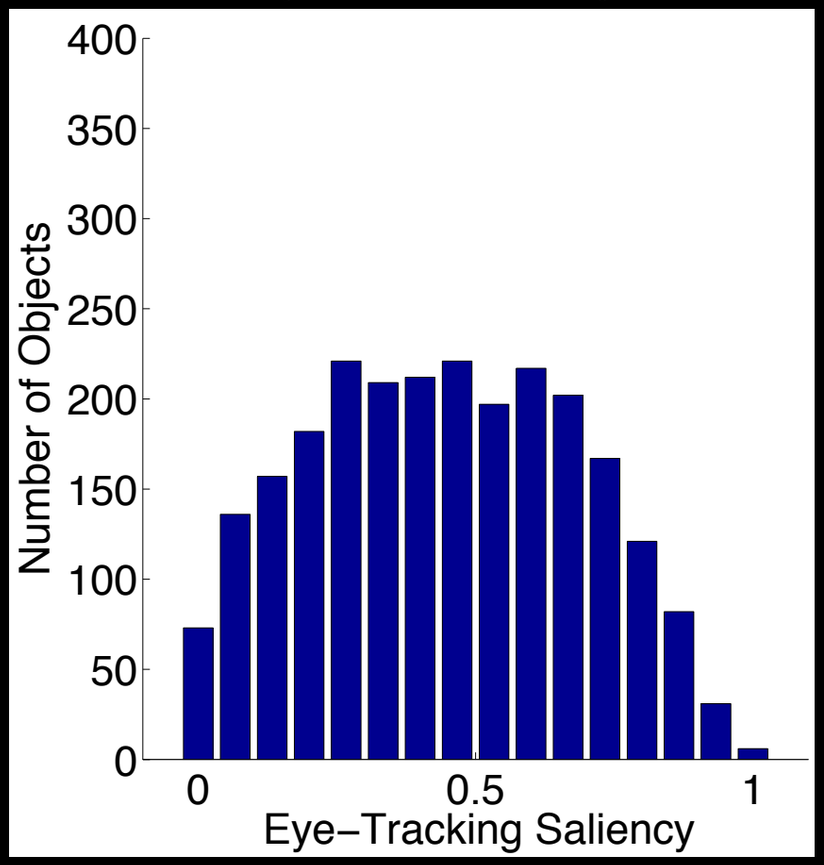
Rectangle-Drawing Object Saliency



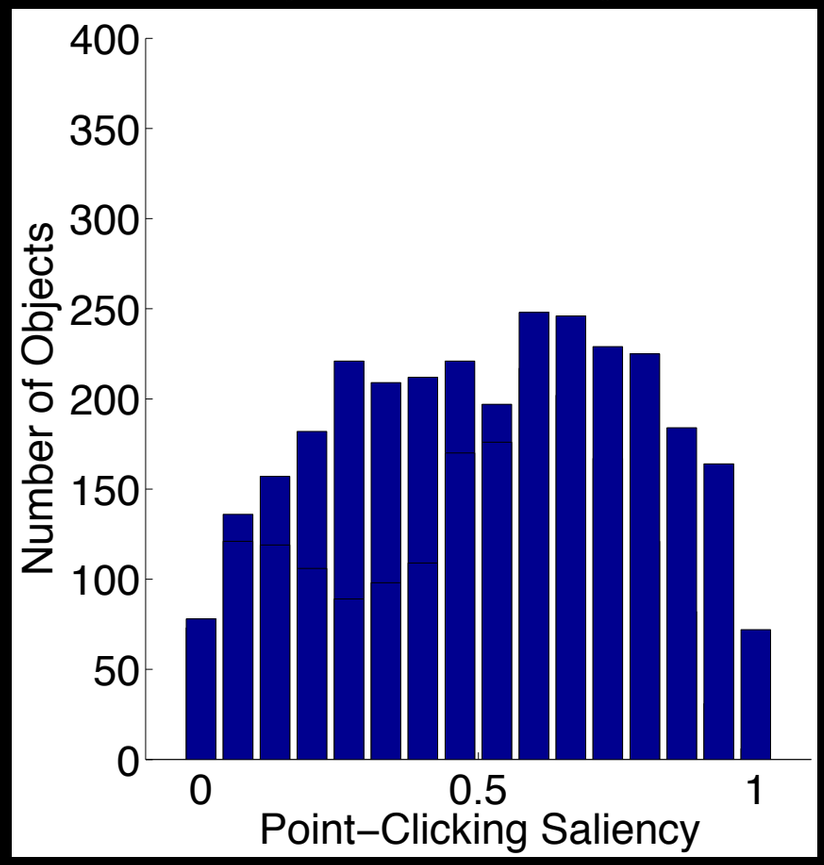
All Objects Are Not Equally Important!

Object Saliency Values in COS Dataset

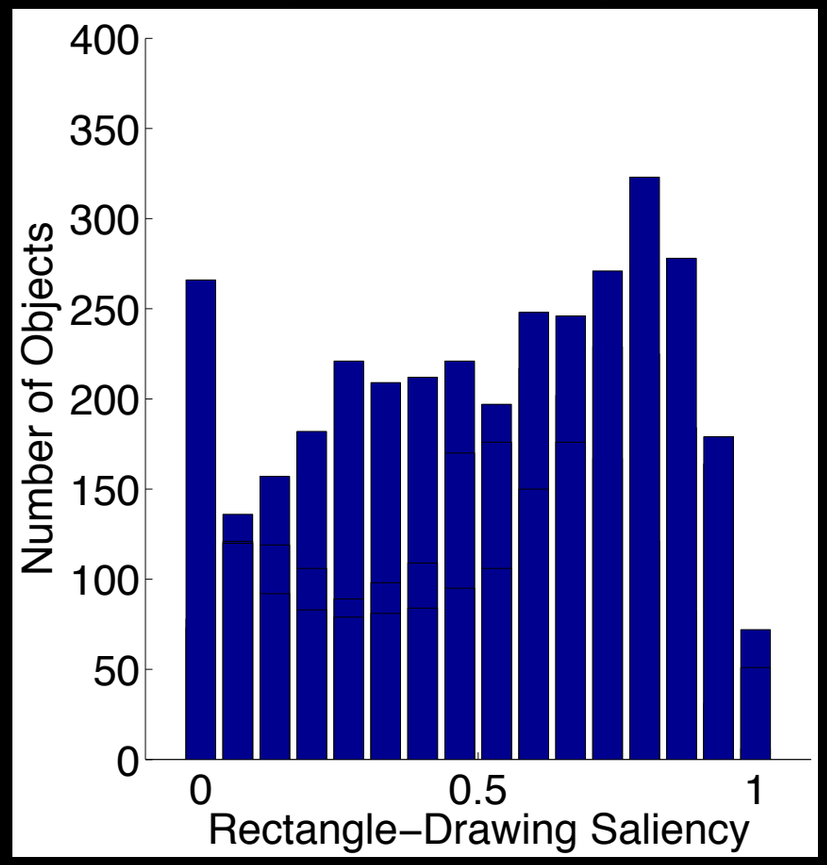
Eye-Tracking Object Saliency



Point-Clicking Object Saliency



Rectangle-Drawing Object Saliency



Object Saliency is Multi-Level!

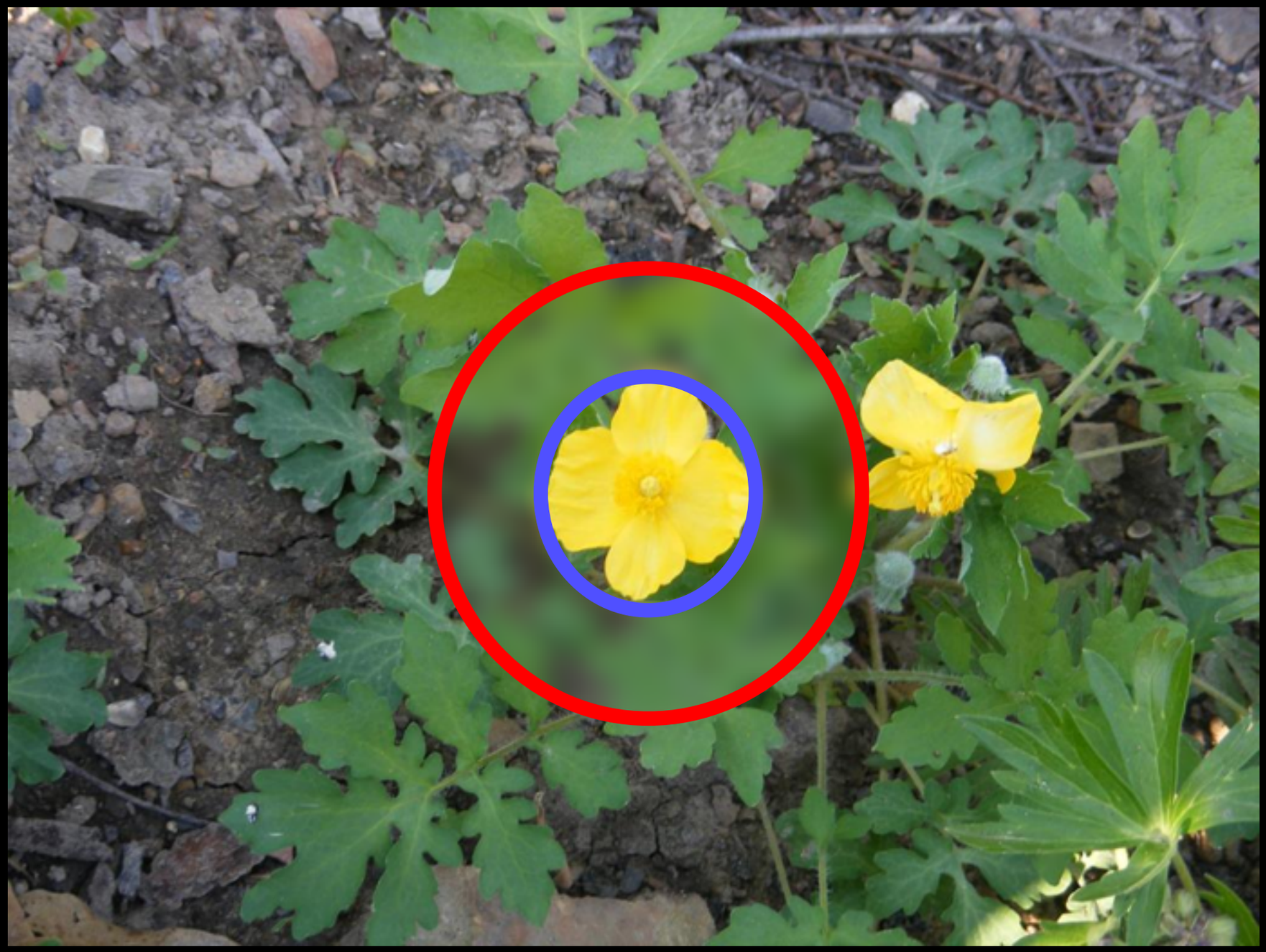
Outline

- Saliency in the Human Visual System
- Measuring Object Saliency
- Detecting Salient Objects
- Estimating Object Saliency Level
- Data Saliency

Detecting Salient Objects

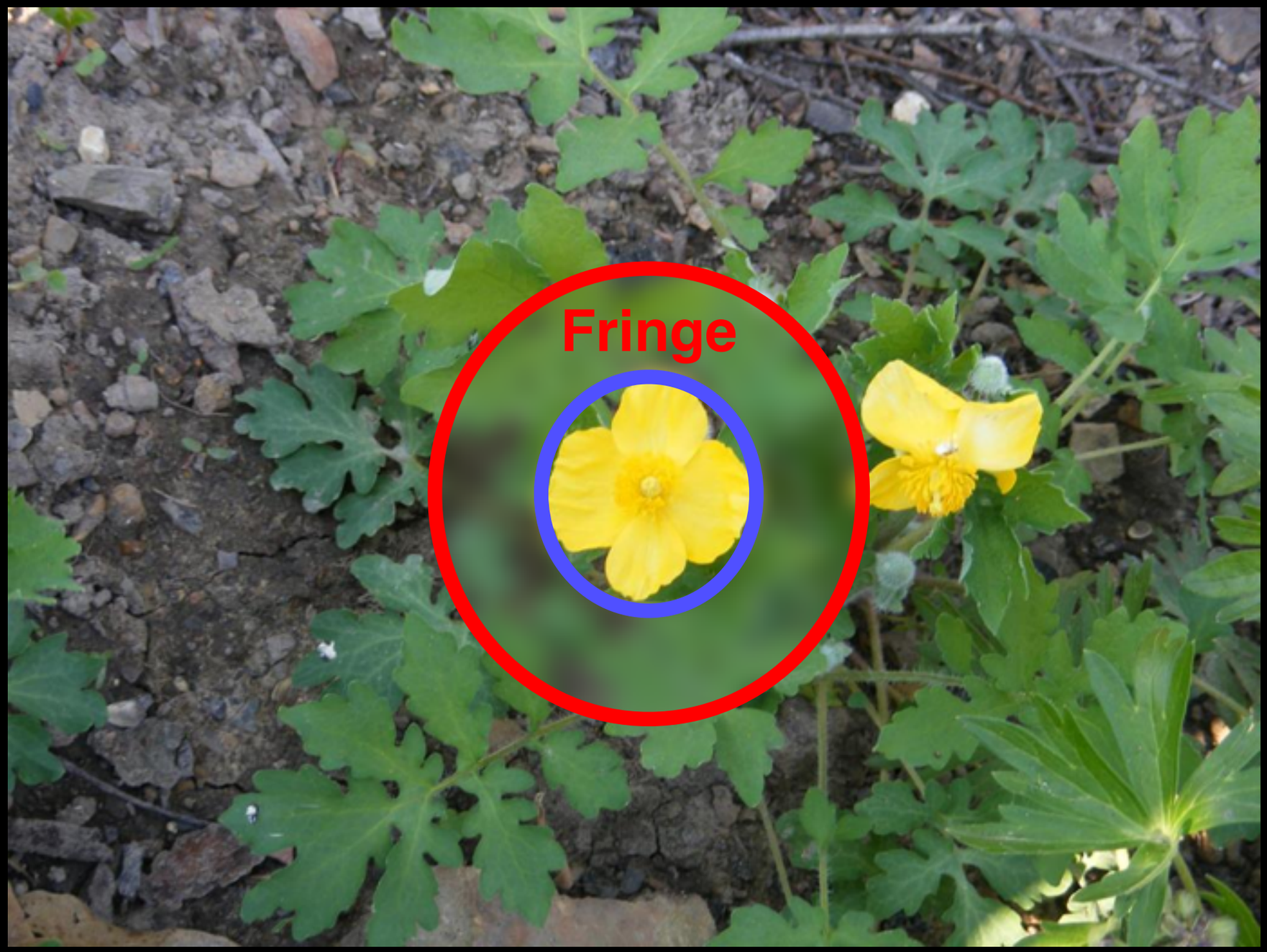
(Eriksen and James, 1986)

Detecting Salient Objects



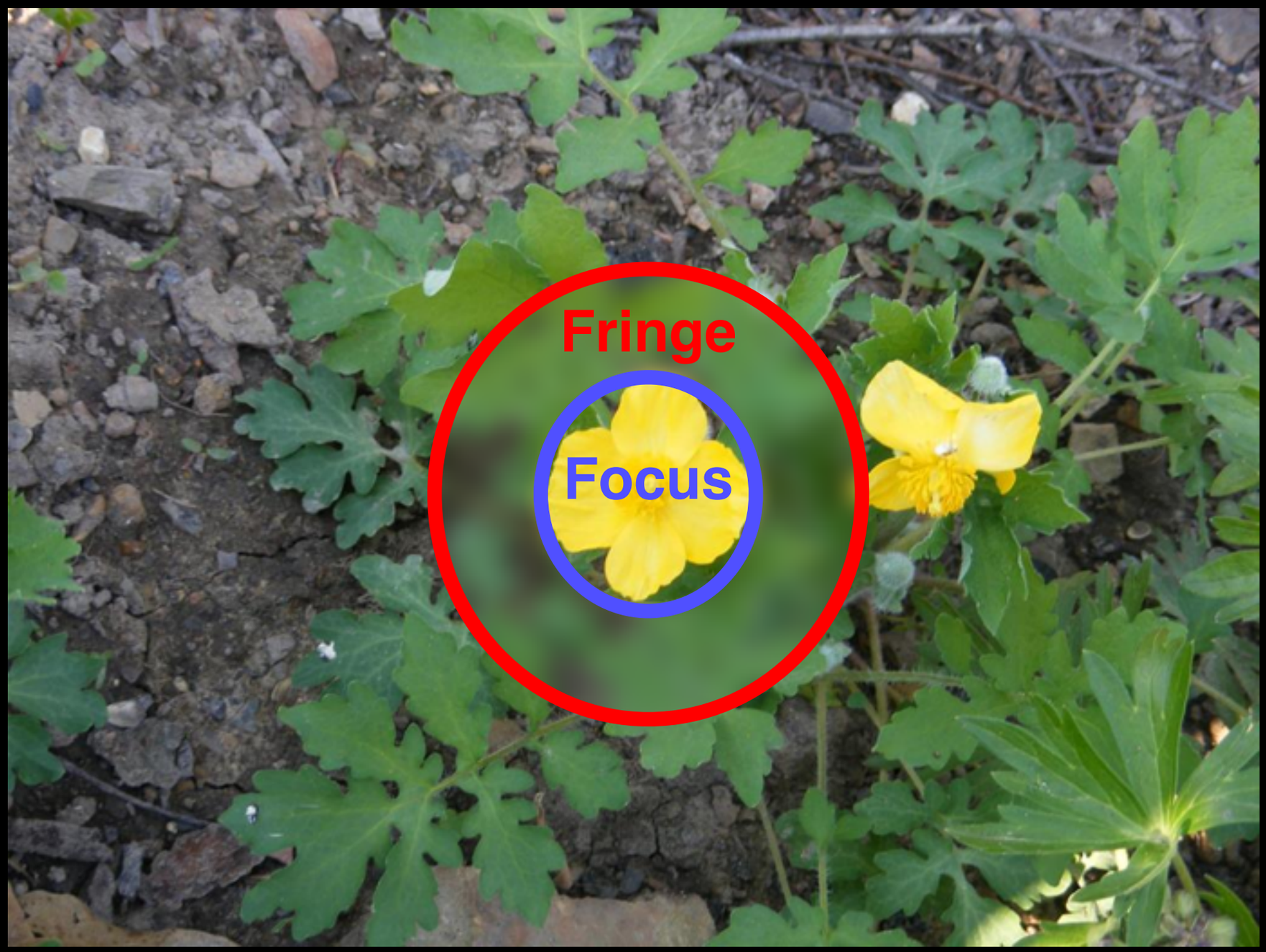
(Eriksen and James, 1986)

Detecting Salient Objects



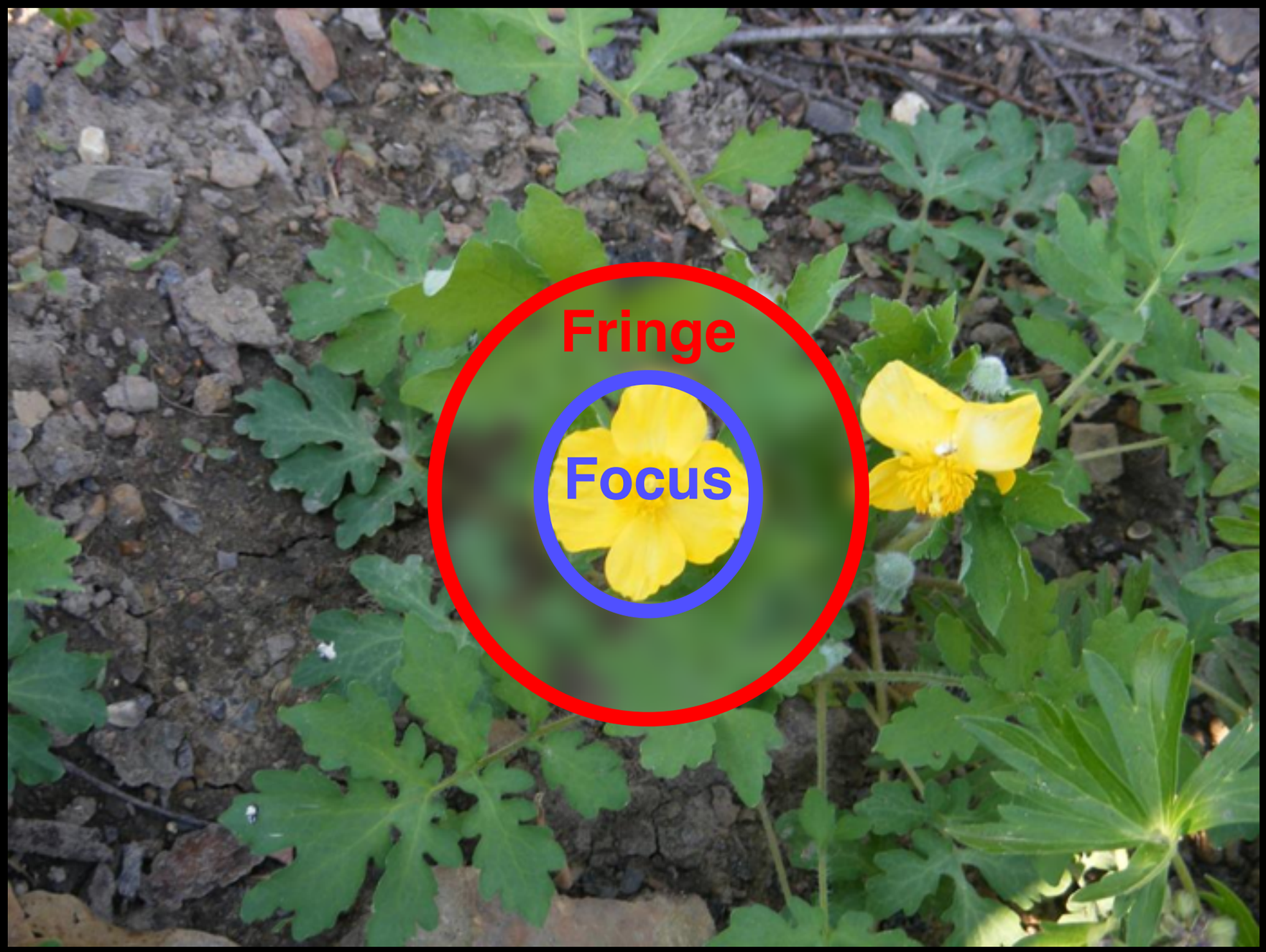
(Eriksen and James, 1986)

Detecting Salient Objects



(Eriksen and James, 1986)

Detecting Salient Objects



Object Saliency

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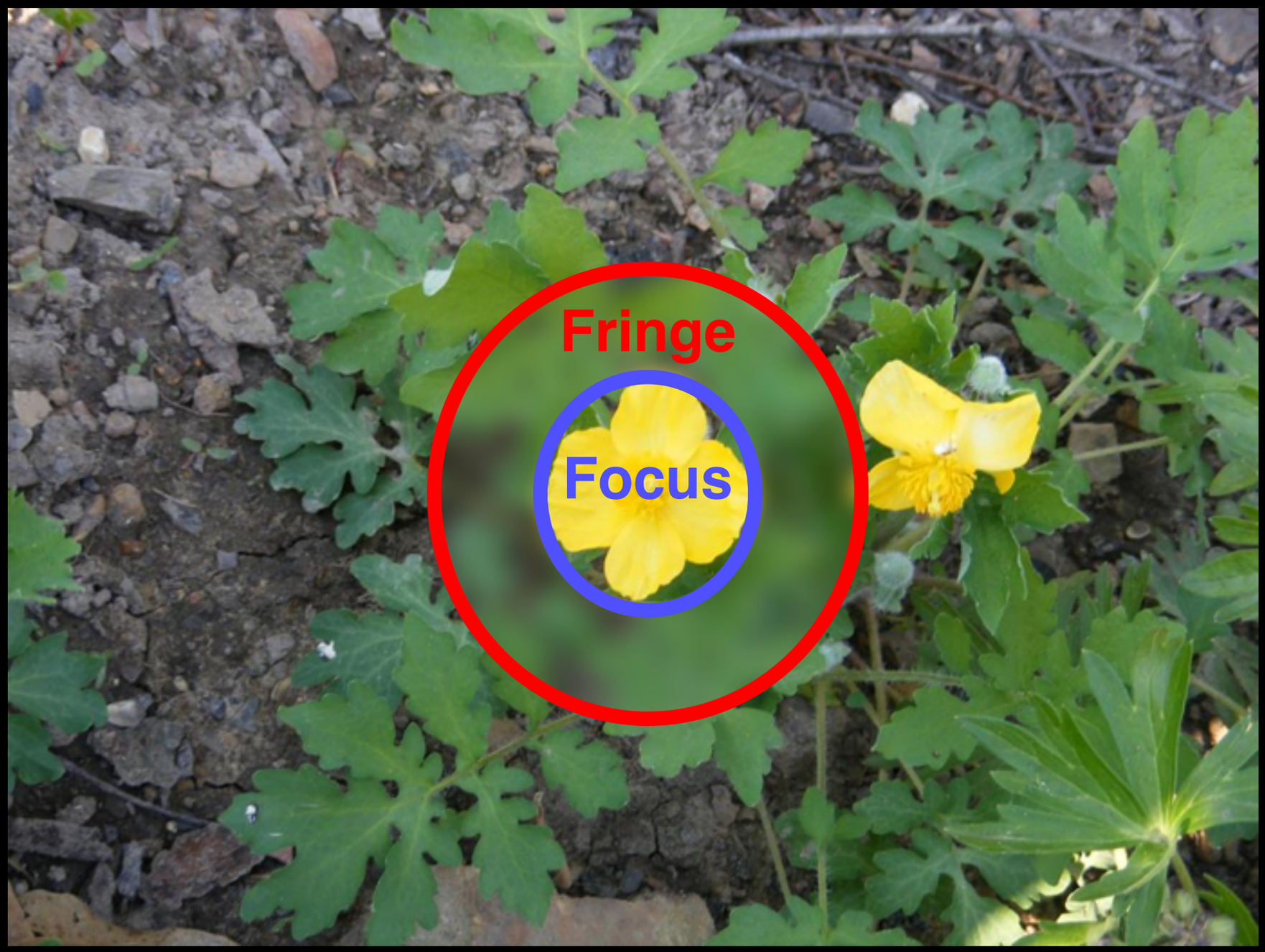
Detecting Salient Objects



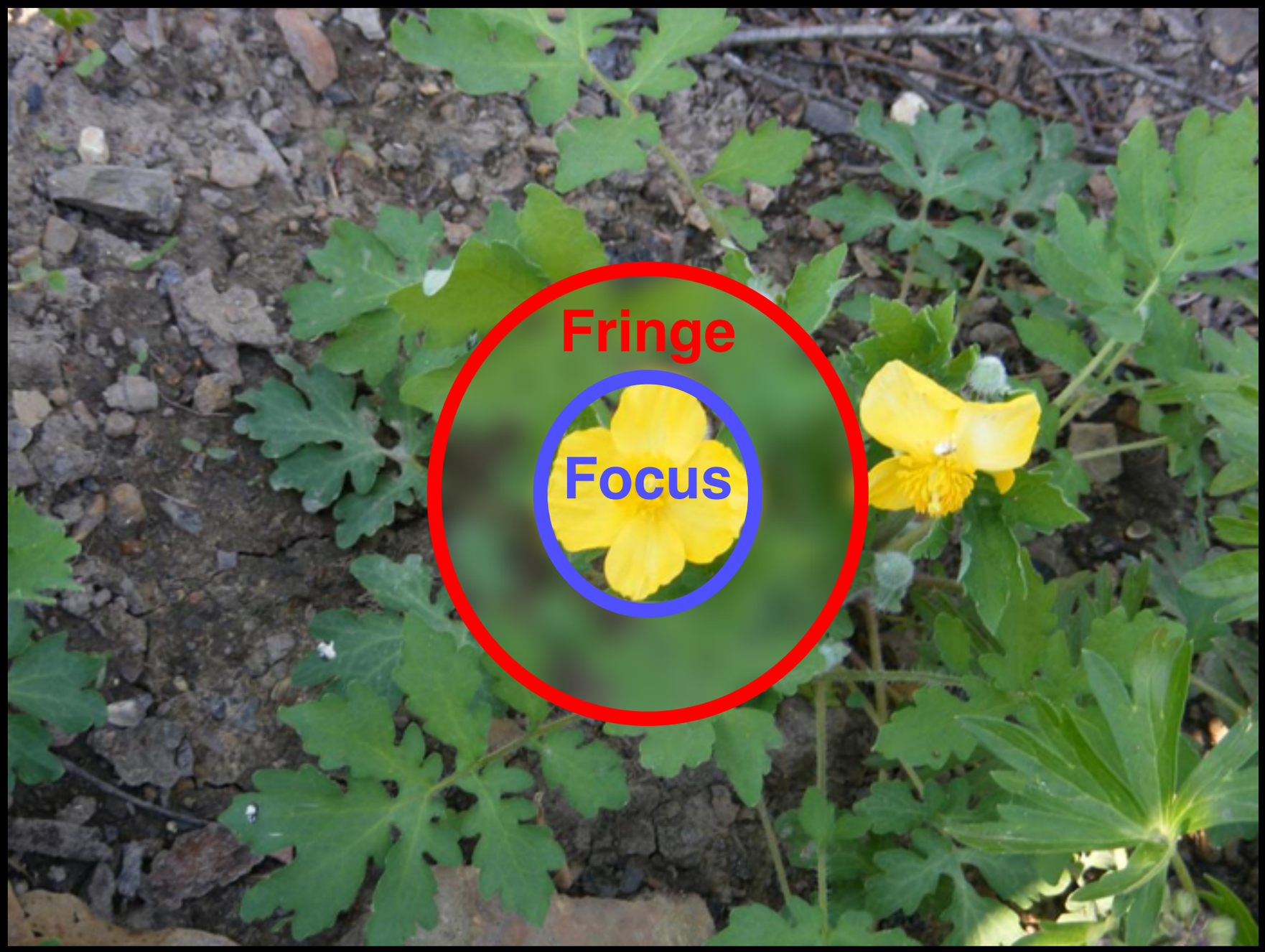
Object Saliency

Color
Texture
Orientation
…

Contrast
|**Focus** - **Fringe**|

(Eriksen and James, 1986)

Detecting Salient Objects



Object Saliency

Color
Texture
Orientation
…

Contrast
|**Focus** - **Fringe**|

(Eriksen and James, 1986)

(Treisman et al., 1980)
(Itti et al., 1998)
(Neibur and Koch, 1998)
…

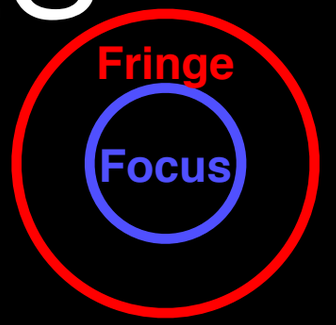
Finding Salient Objects

Finding Salient Objects

Designed for Binary Salient Object Detection!

Finding Salient Objects

Designed for Binary Salient Object Detection!

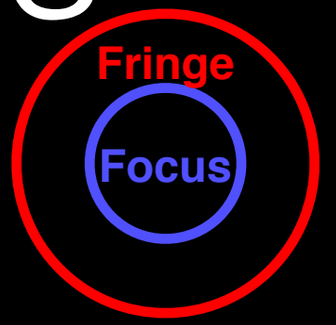


Single-Scale Filtering

(Achanta et al., 2009)

Finding Salient Objects

Designed for Binary Salient Object Detection!



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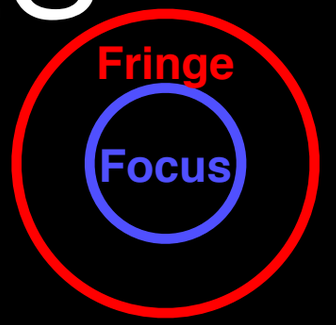


Single-Scale Filtering

(Achanta et al., 2009)

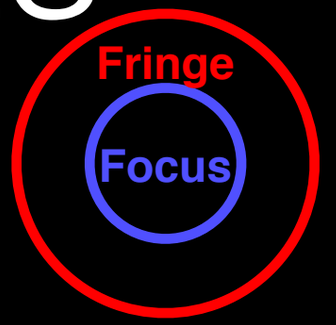
Multi-Scale Filtering

(**Yildirim** et al., 2013)

Our Methods

Finding Salient Objects

Designed for Binary Salient Object Detection!



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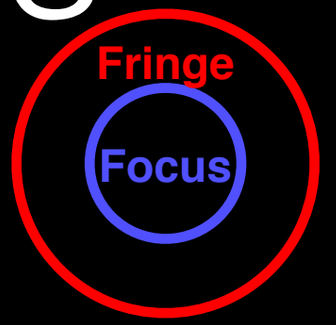

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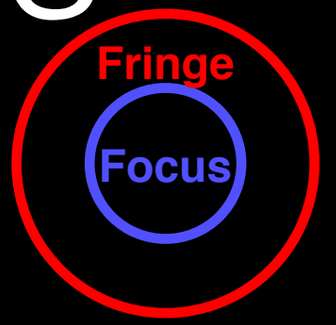

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Finding Salient Objects

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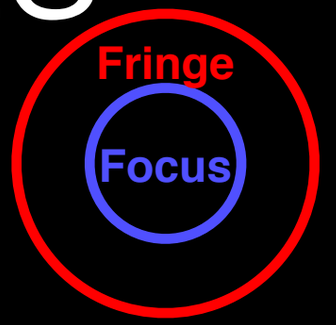

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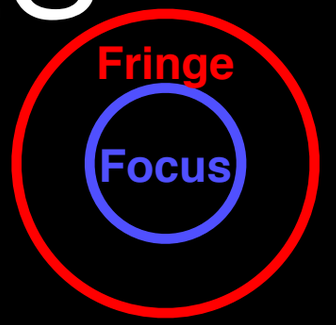
Finding Salient Objects

Designed for Binary Salient Object Detection!



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(Achanta et al., 2009)

Multi-Scale Filtering

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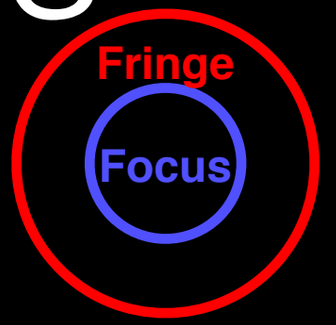
Our Methods

Finding Salient Objects

Designed for Binary Salient Object Detection!



Single-Scale Filtering

(Achanta et al., 2009)

Multi-Scale Filtering

(**Yildirim** et al., 2013)

Our Methods

Finding Salient Objects

Designed for Binary Salient Object Detection!

Single-Scale Filtering

(Achanta et al., 2009)

Multi-Scale Filtering

(**Yildirim** et al., 2013)

Bilateral Filtering

(**Yildirim** et al., 2014)

Our Methods

Finding Salient Objects

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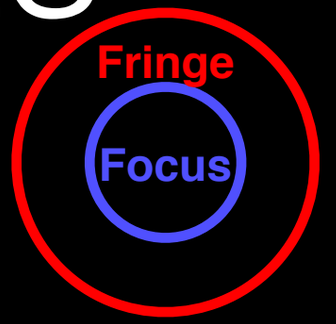


Single-Scale Filtering

(Achanta et al., 2009)

Multi-Scale Filtering

(**Yildirim** et al., 2013)

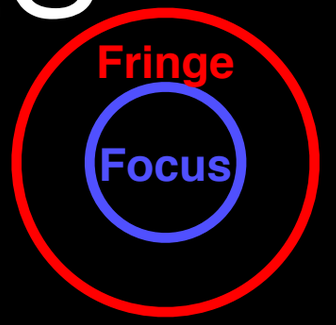
Bilateral Filtering

(**Yildirim** et al., 2014)

Our Methods

Finding Salient Objects

Designed for Binary Salient Object Detection!



Single-Scale Filtering

Multi-Scale Filtering

Bilateral Filtering

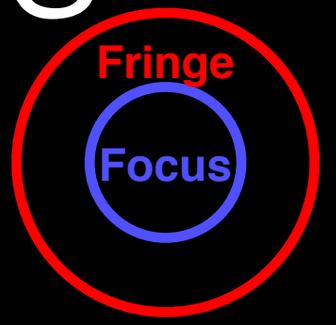
Segmentation & Learning Based

(Achanta et al., 2009) (**Yildirim** et al., 2013) (**Yildirim** et al., 2014) (**Yildirim** et al., 2014)

Our Methods

Finding Salient Objects

Designed for Binary Salient Object Detection!



Single-Scale Filtering

(Achanta et al., 2009)

Multi-Scale Filtering

(**Yildirim** et al., 2013)

Bilateral Filtering

(**Yildirim** et al., 2014)

Segmentation & Learning Based

(**Yildirim** et al., 2014)

Our Methods

Outline

- Saliency in the Human Visual System
- Measuring Object Saliency
- Detecting Salient Objects
- Estimating Object Saliency Level
- Data Saliency

Multi-Level Object Saliency

Natural Image

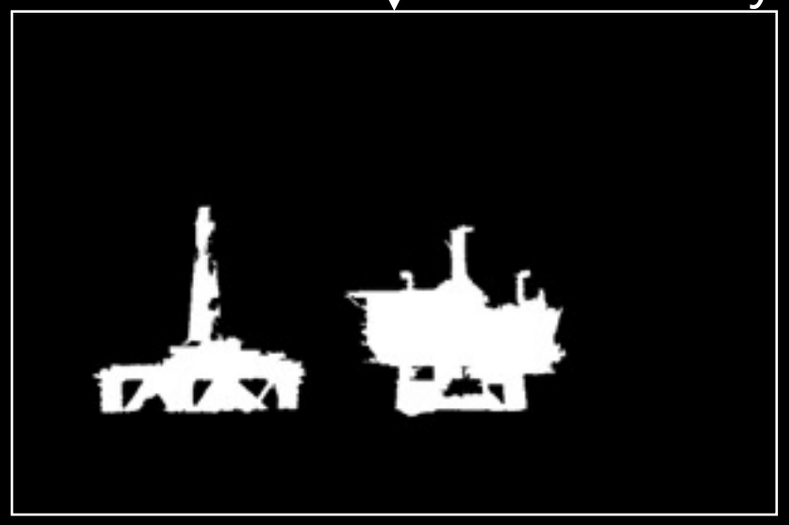
Multi-Level Object Saliency

Natural Image

Multi-Level Object Saliency

Natural Image

Binary



Segmentation-Based*

Multi-Level Object Saliency

Natural Image

Binary

Segmentation-Based*

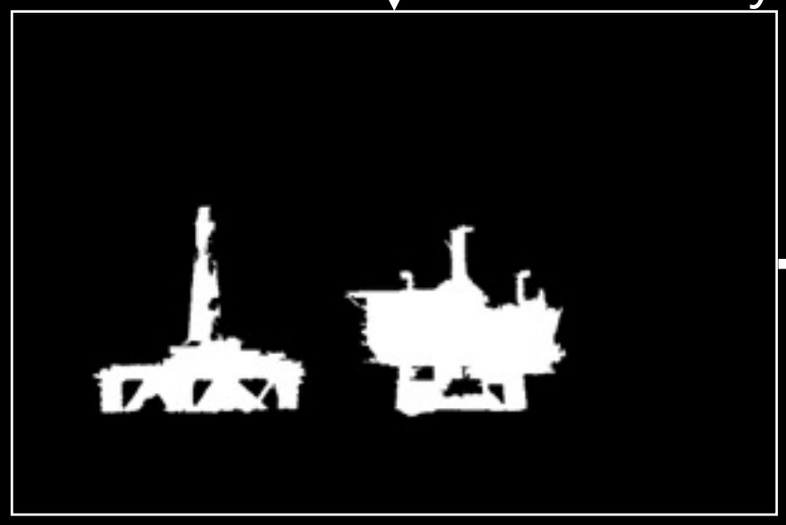
?

Multi-Level

Multi-Level Object Saliency

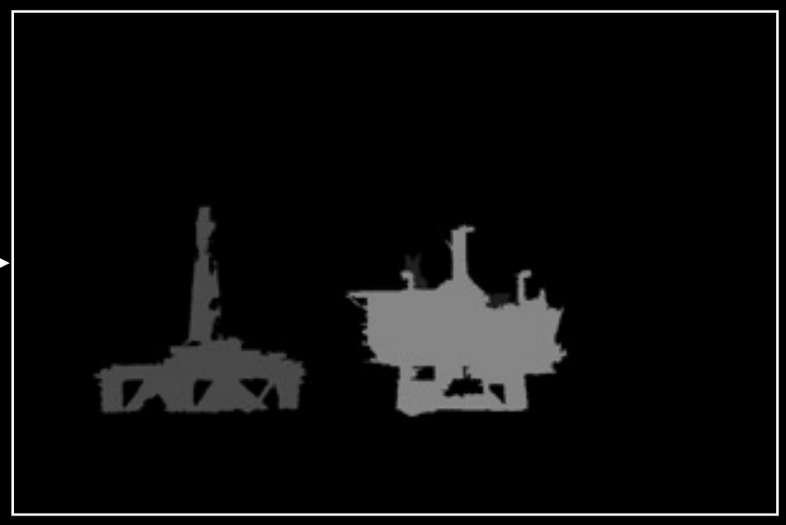
Natural Image

Binary



Segmentation-Based*

Object Awareness Model

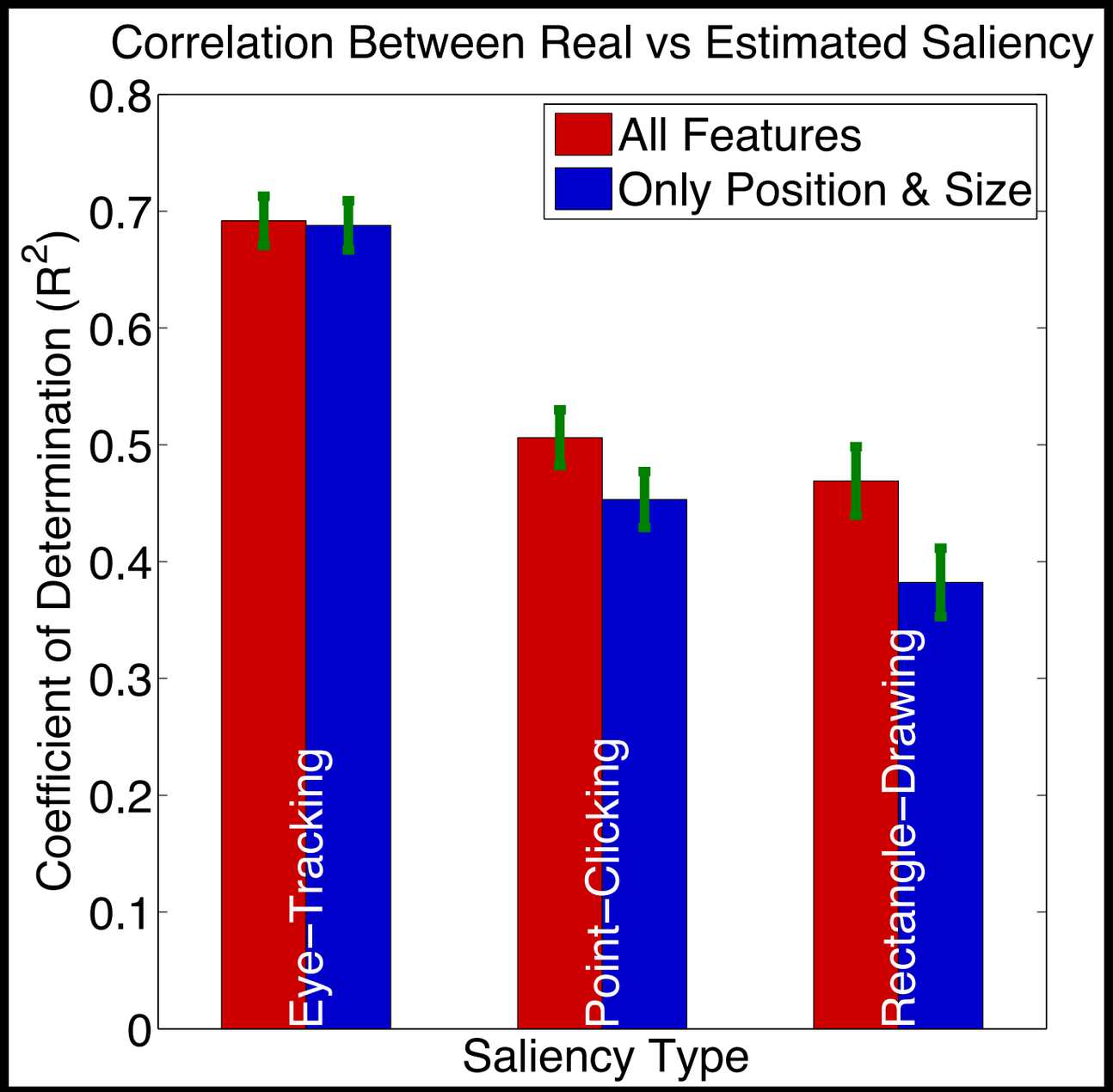


Multi-Level

Object Awareness

To be aware of the **position** and the **size** of objects

Object Awareness

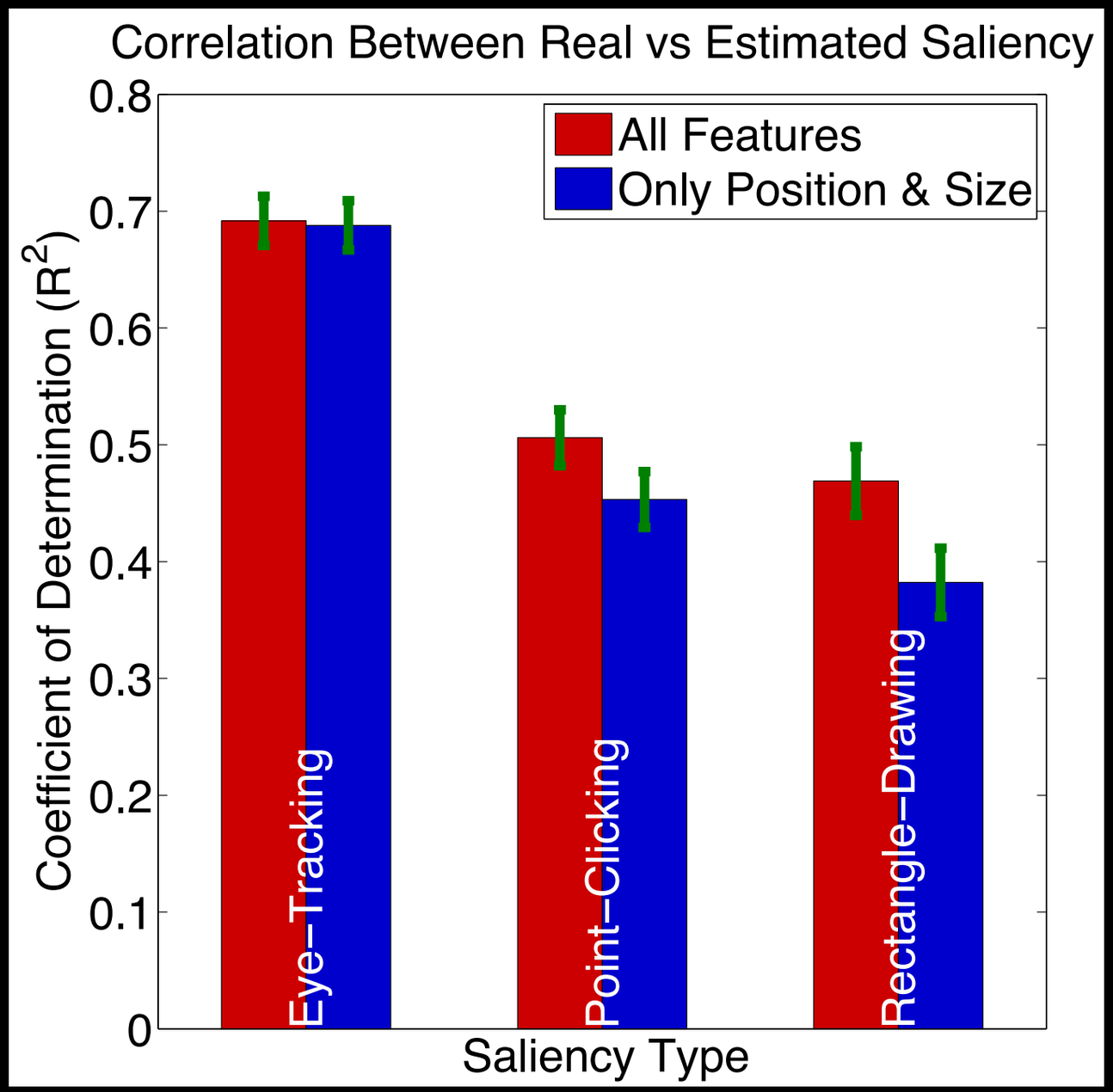


Visual Features

- Local Color Contrast
- Global Color Contrast
- Local Texture Contrast
- Global Texture Contrast
- Object Size
- Object Position

Object Awareness: To be aware of the position and the size of objects

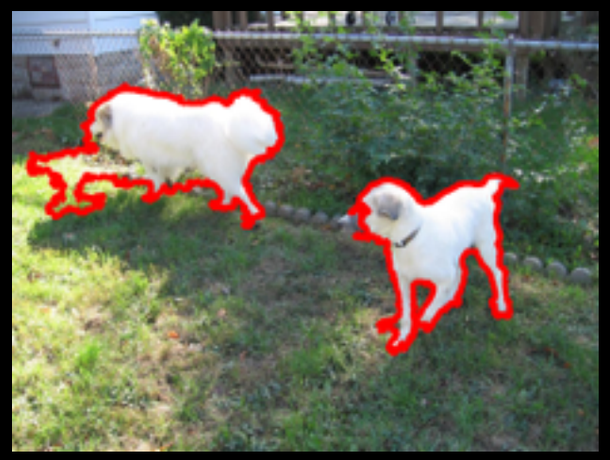
Object Awareness



Visual Features

- Local Color Contrast
- Global Color Contrast
- Local Texture Contrast
- Global Texture Contrast
- Object Size
- Object Position

Contrast Features



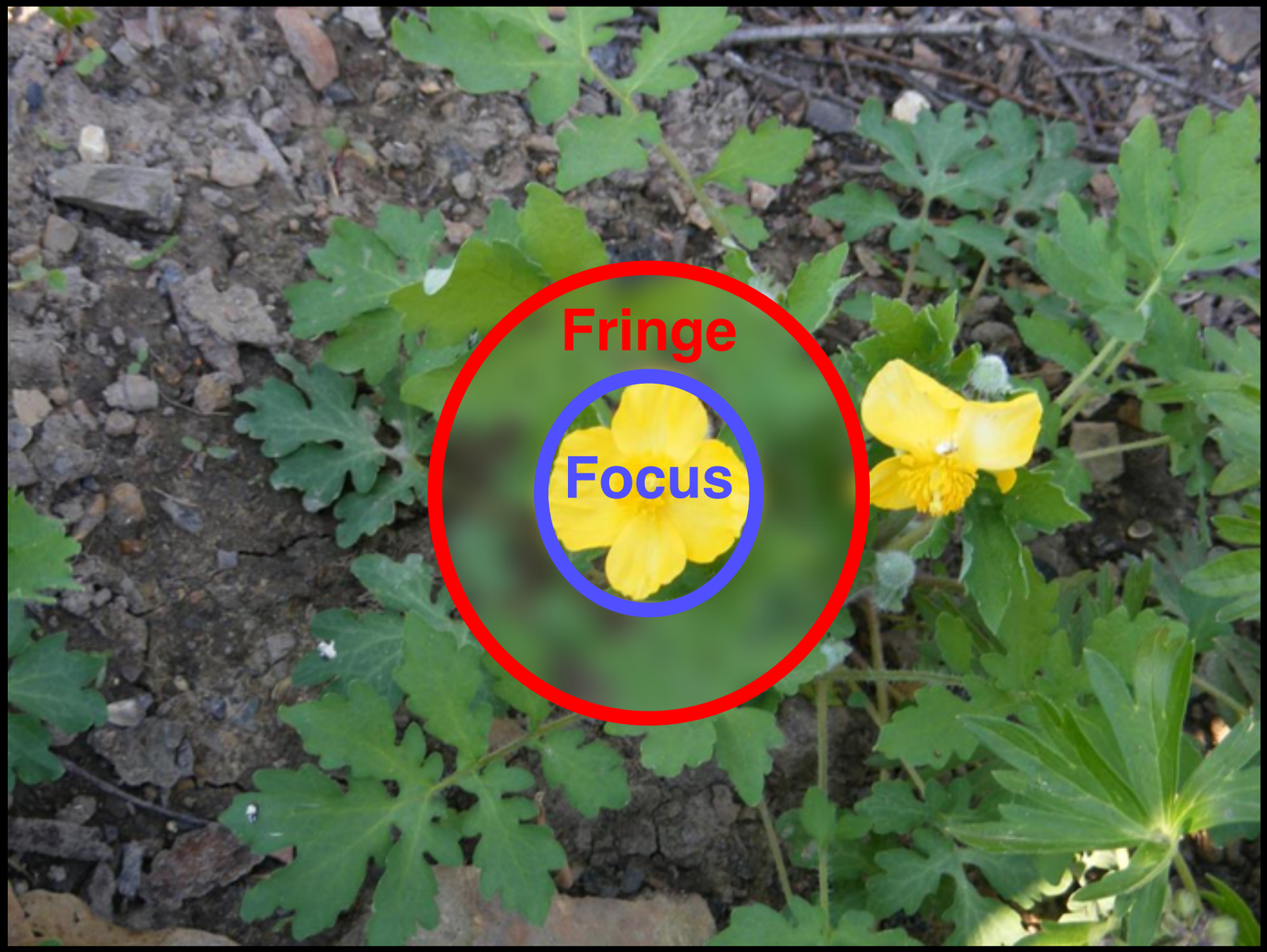
Position & Size

Object Awareness: To be aware of the position and the size of objects

Outline

- Saliency in the Human Visual System
- Measuring Object Saliency
- Detecting Salient Objects
- Estimating Object Saliency Level
- Data Saliency

Visual Saliency



Object Saliency

Color
Texture
Orientation
…

Contrast
|**Focus** - **Fringe**|

Data Saliency

Data

Data Saliency

Measure Data Saliency
- Probably involves experts

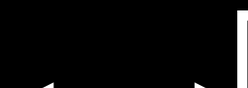
Data Saliency

Detecting Salient Data

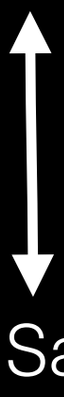
- Identify the key differences
- Design a feature

Data Saliency

Measure Data Saliency
- Probably involves experts



Data



Detecting Salient Data
- Identify the key differences
- Design a feature

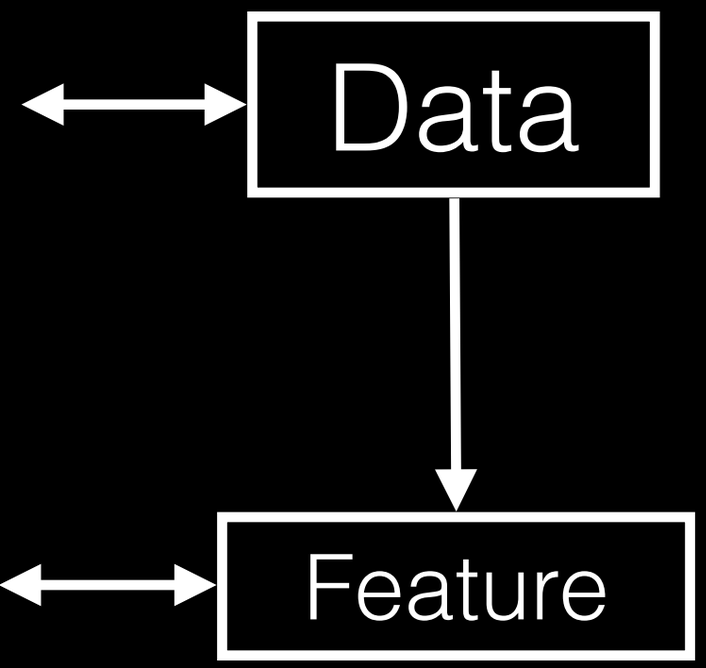
Interesting Data

Uninteresting Data

Data Saliency

Measure Data Saliency
- Probably involves experts

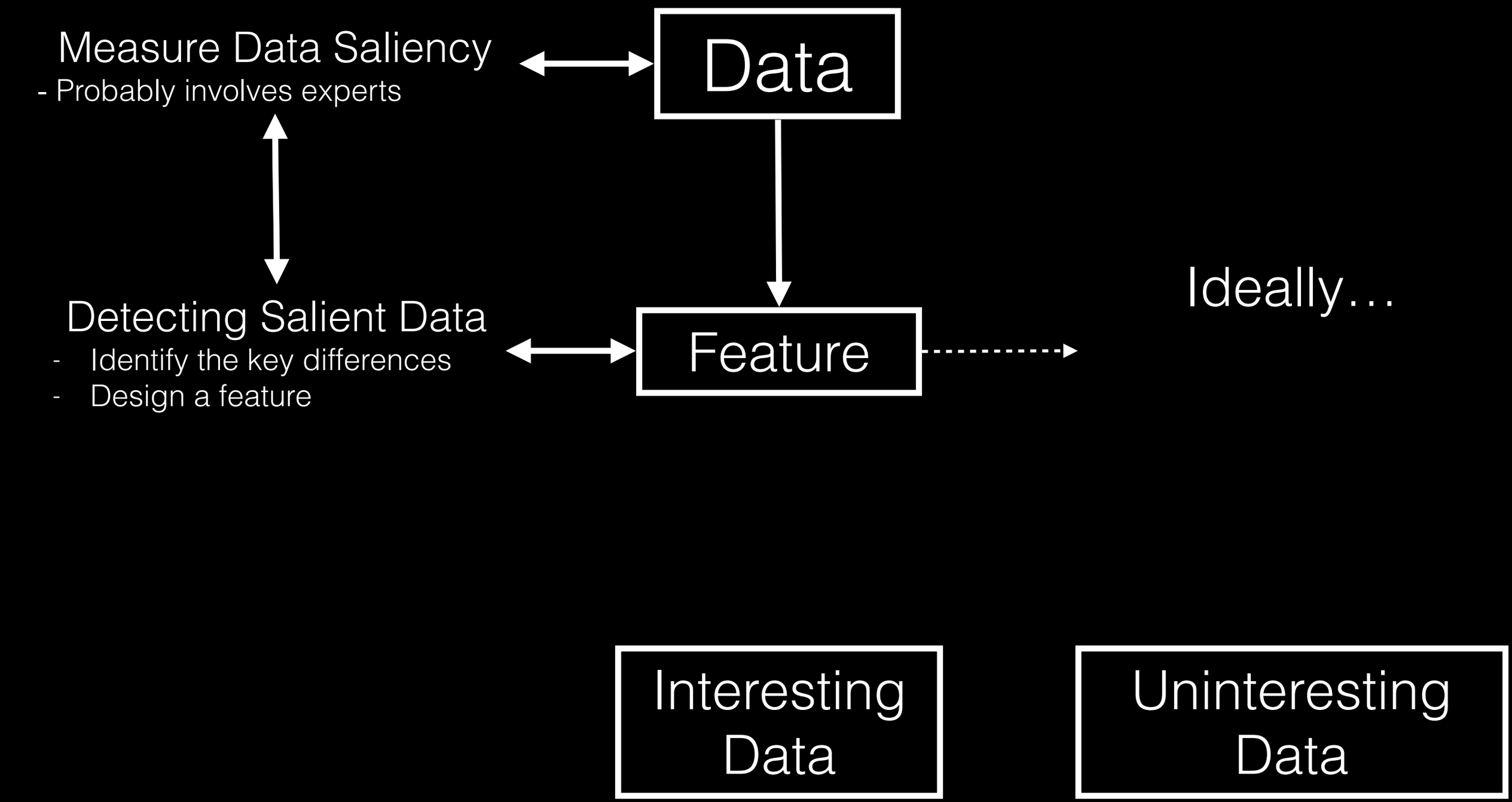
Detecting Salient Data
- Identify the key differences
- Design a feature



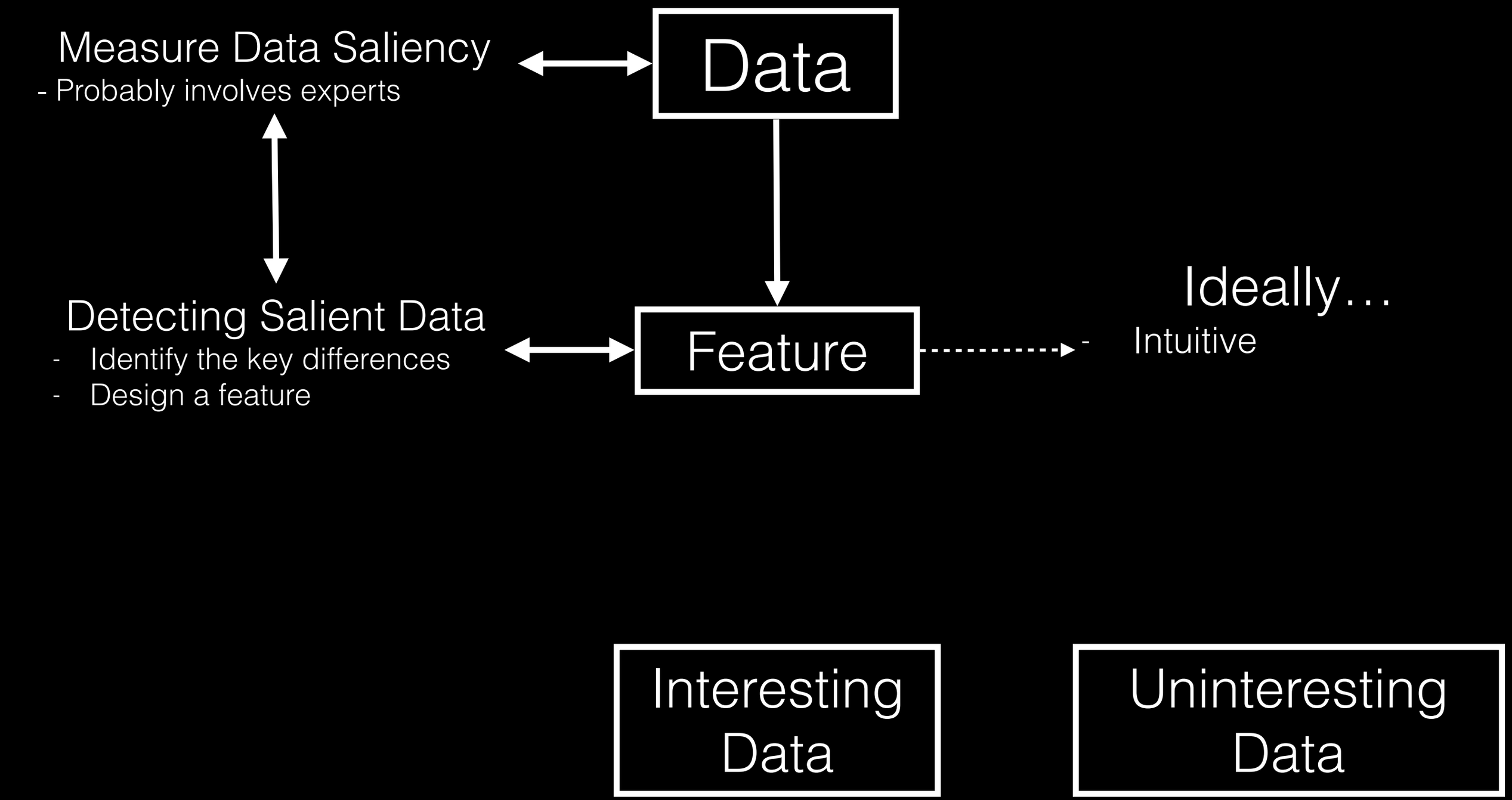
Interesting Data

Uninteresting Data

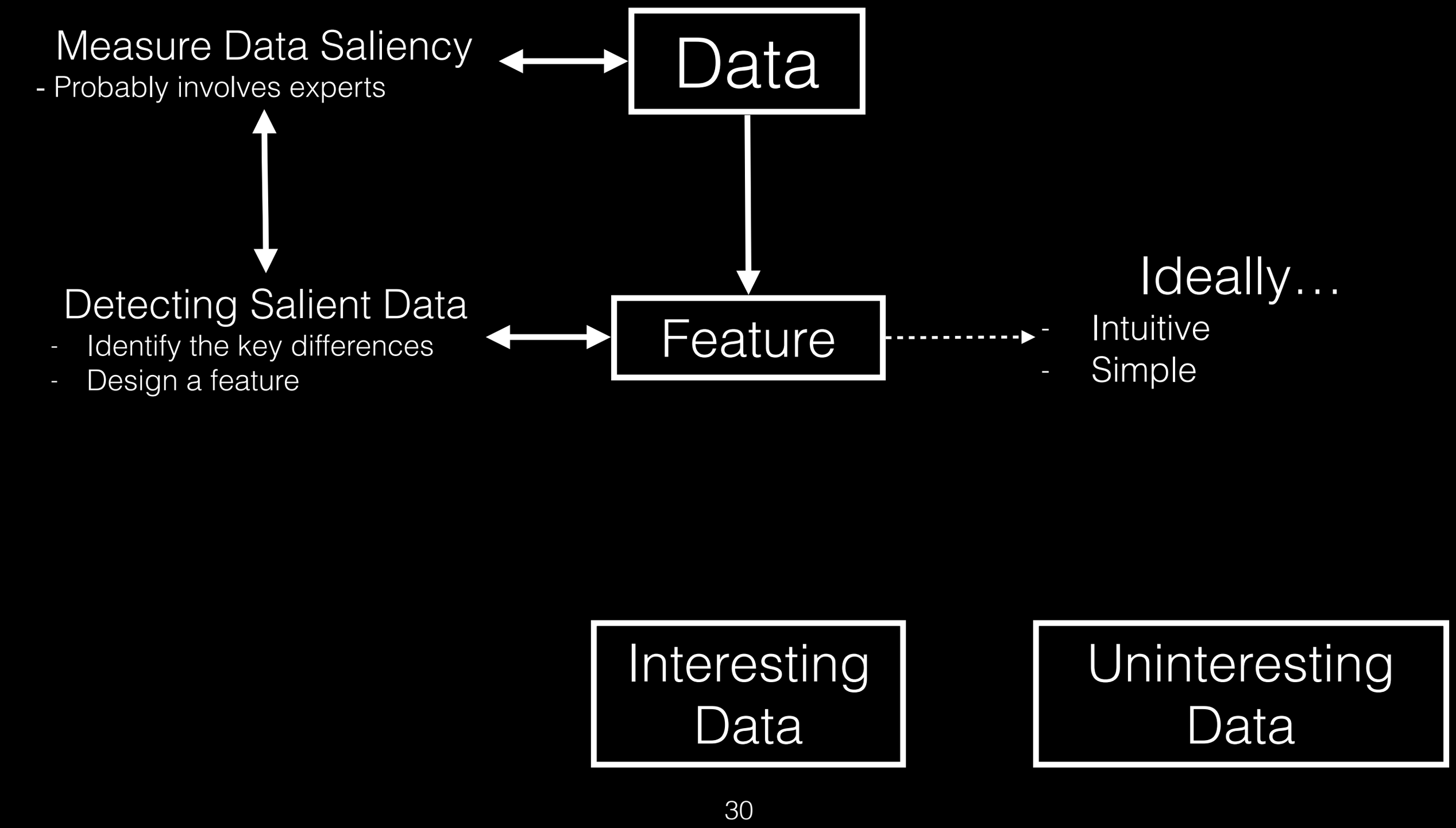
Data Saliency



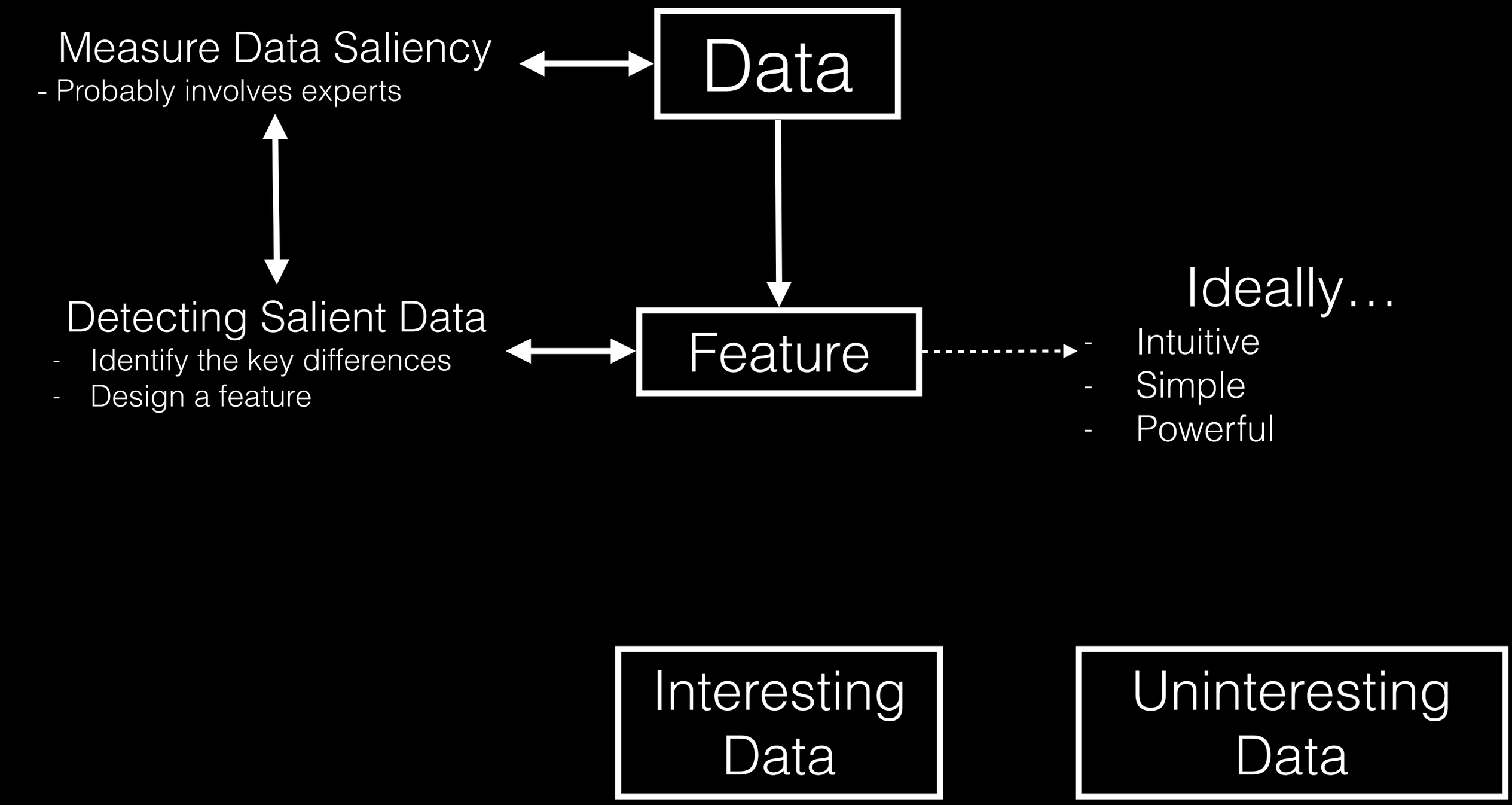
Data Saliency



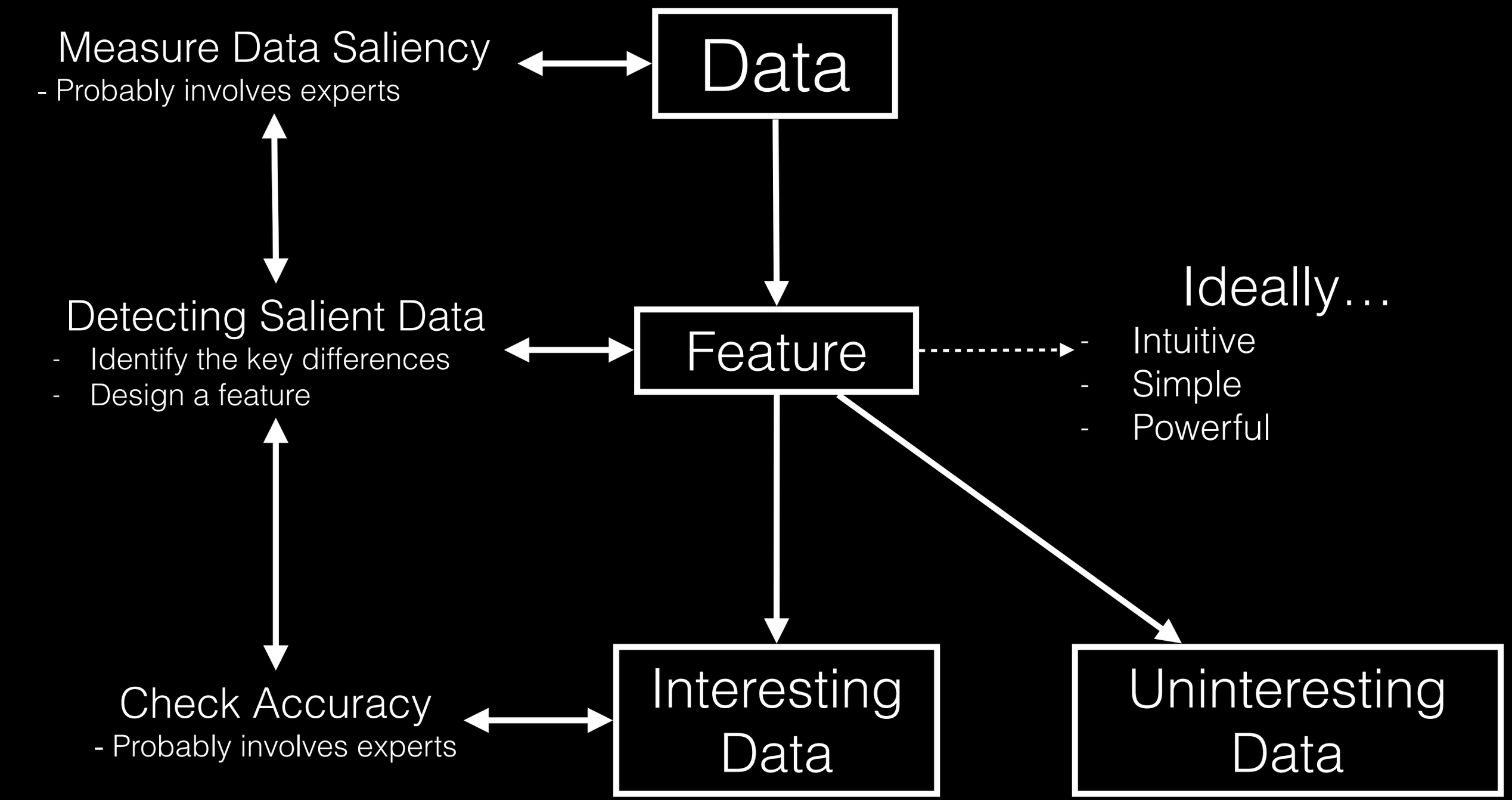
Data Saliency



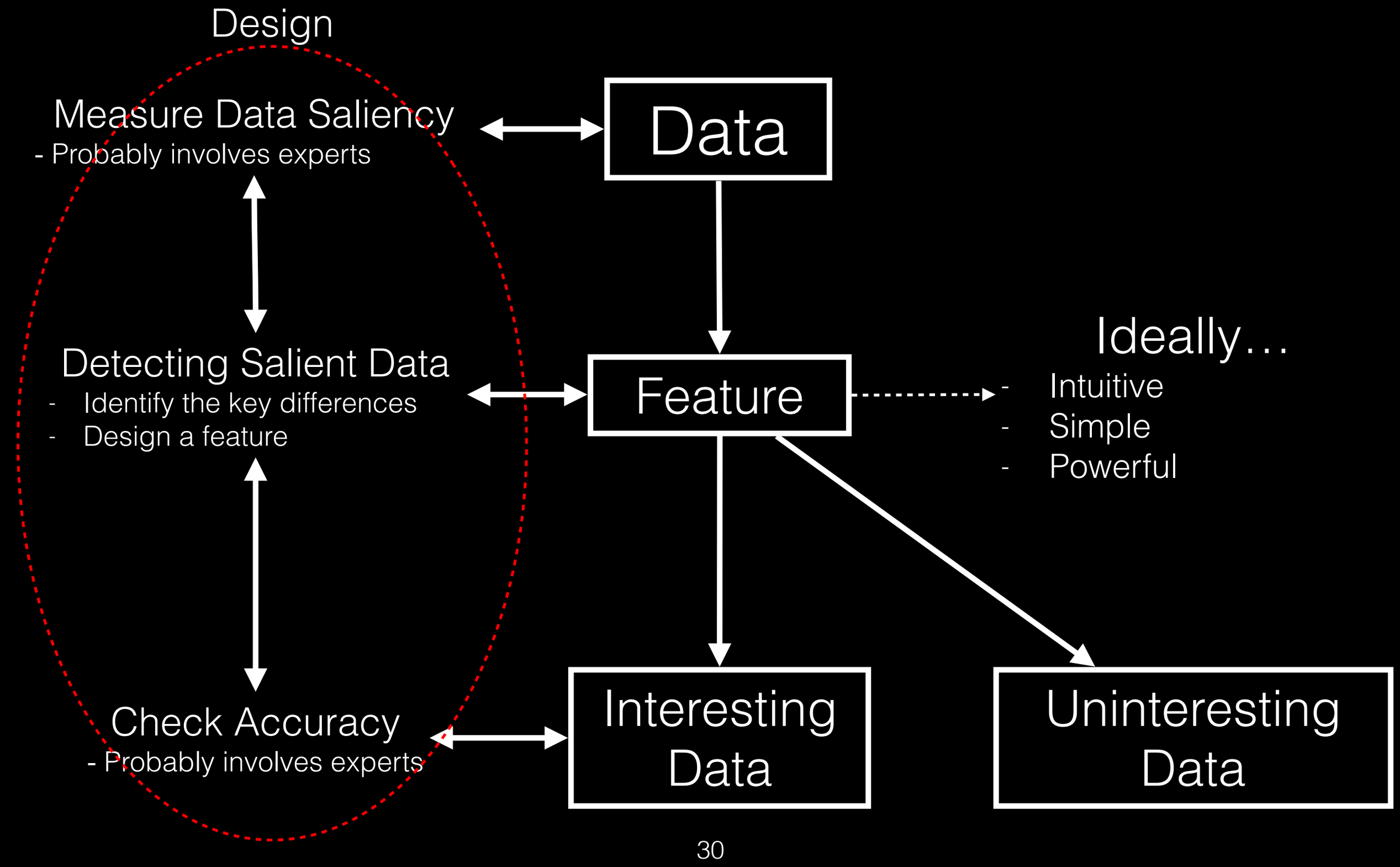
Data Saliency



Data Saliency



Data Saliency



Thank You!

Acknowledgements

- Thesis Supervisor
  - Prof. Sabine Süsstrunk
- Advisors
  - Dr. Appu Shaji
  - Dr. Radhakrishna Achanta
- International Collaborators
  - Prof. Debashis Sen (IIT - Kharagpur)
  - Prof. Mohan Kankanhalli (NUS)

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