Midterm Exam Discussion

Computer Vision

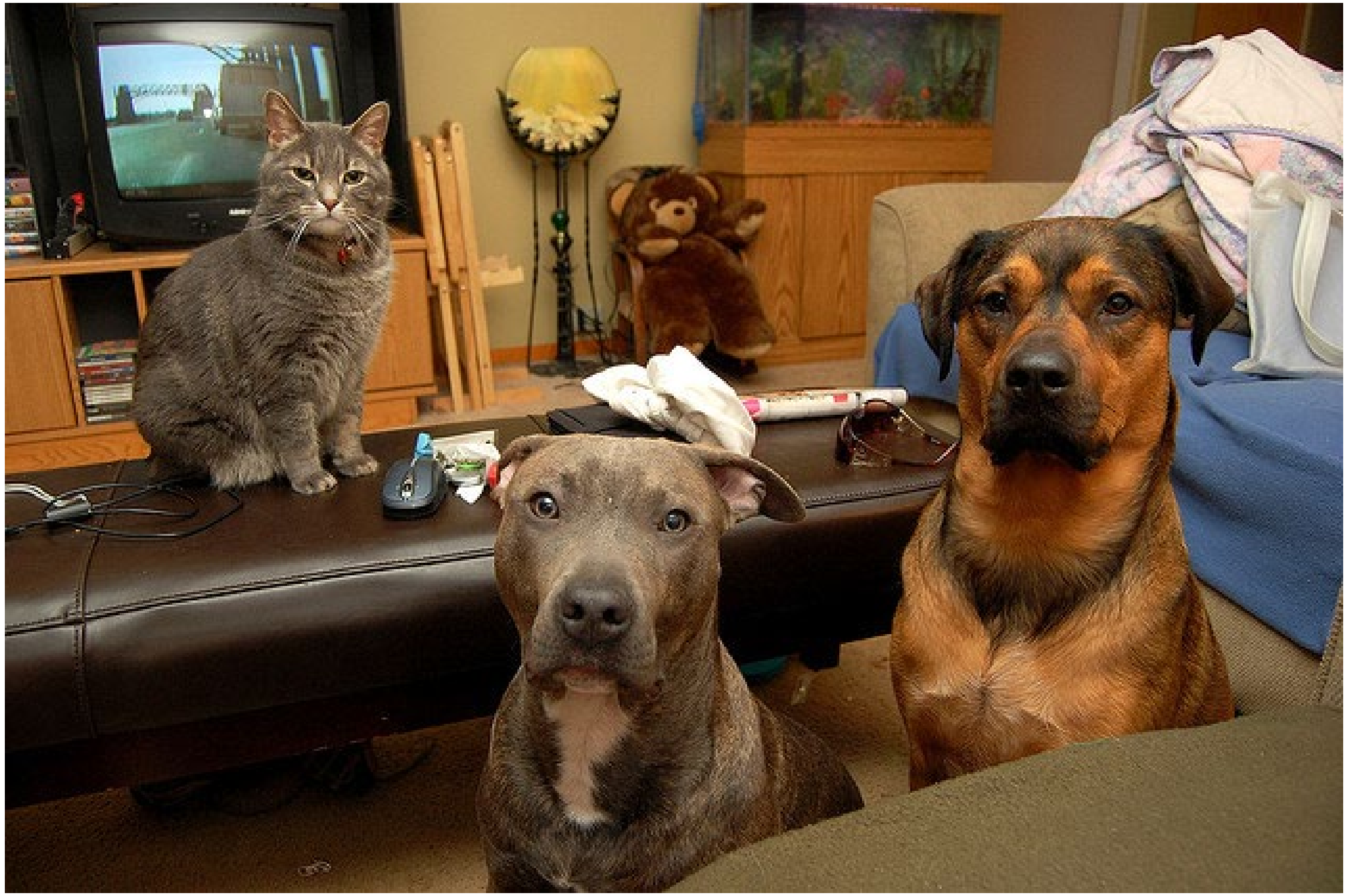
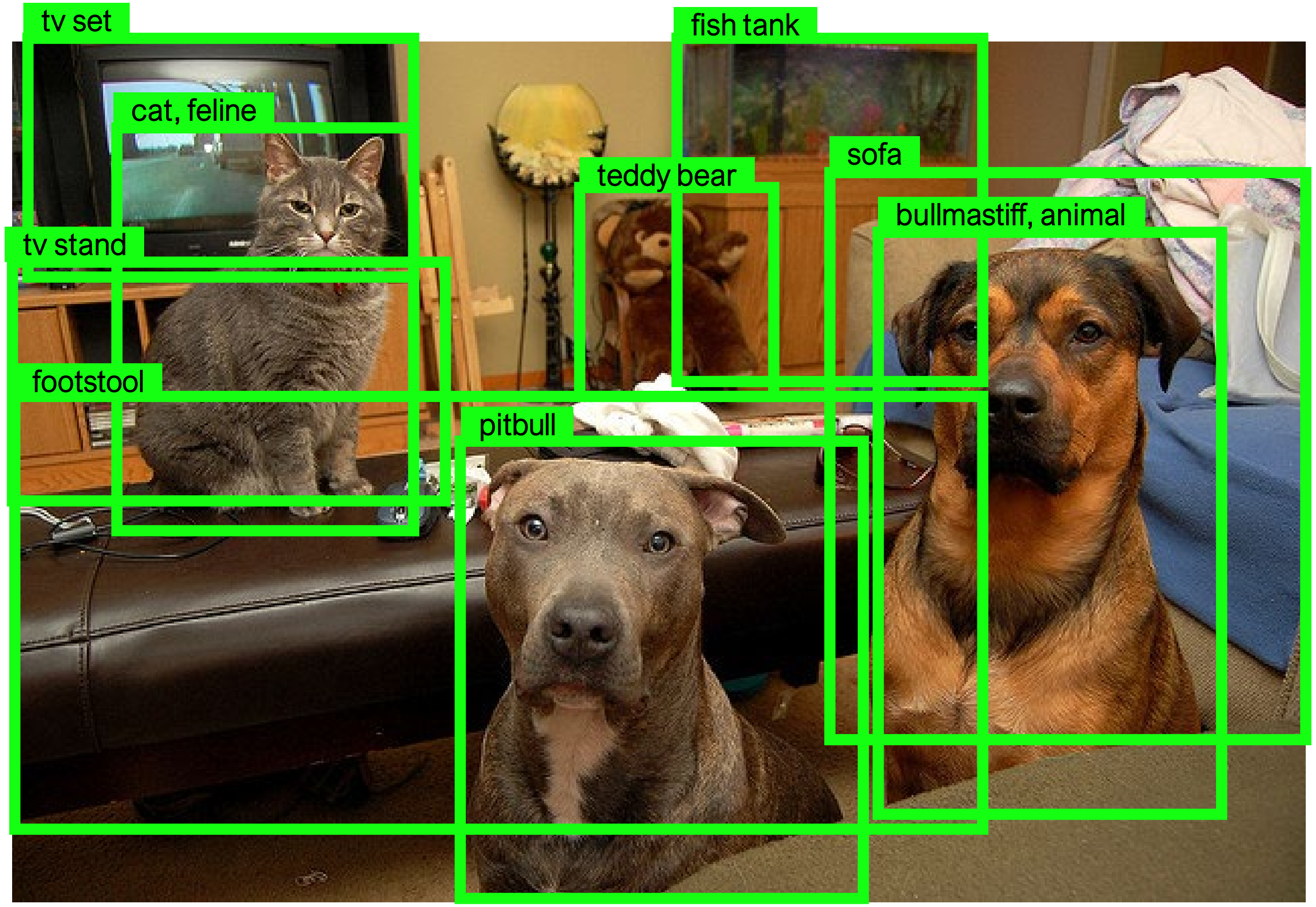


Image tagging / Image classification

- feline
- tv set
- teddy bear
- pitbull
- bullmastiff
- cat
- tv stand
- group of dogs
- fish tank
- room
- indoor
- man-made
- footstool
- furniture

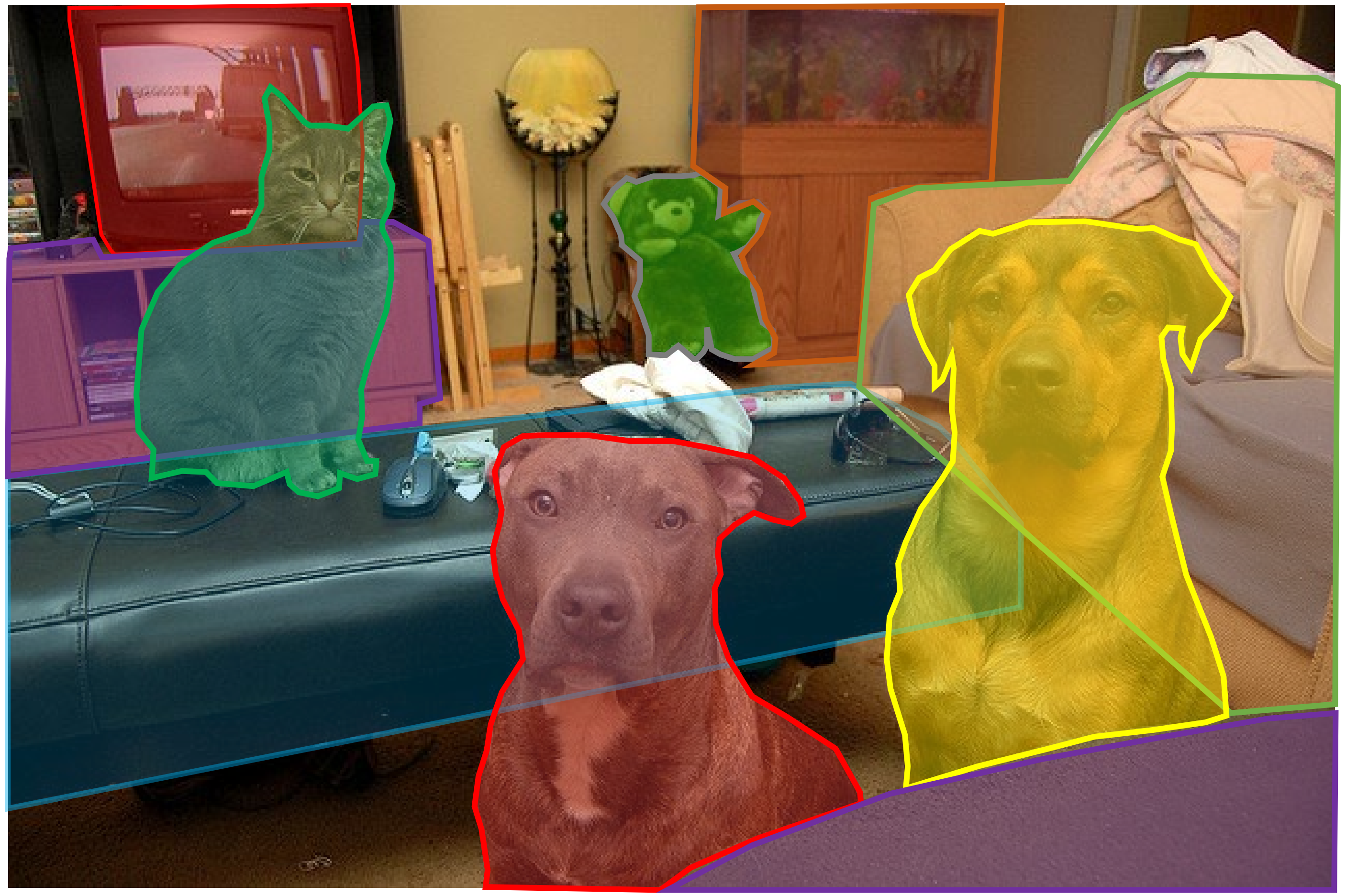
Computer Vision



Object Detection

feline
tv set
teddy bear
pitbull
bullmastiff
cat
tv stand
group of dogs
fish tank
room
indoor
man-made
footstool
furniture

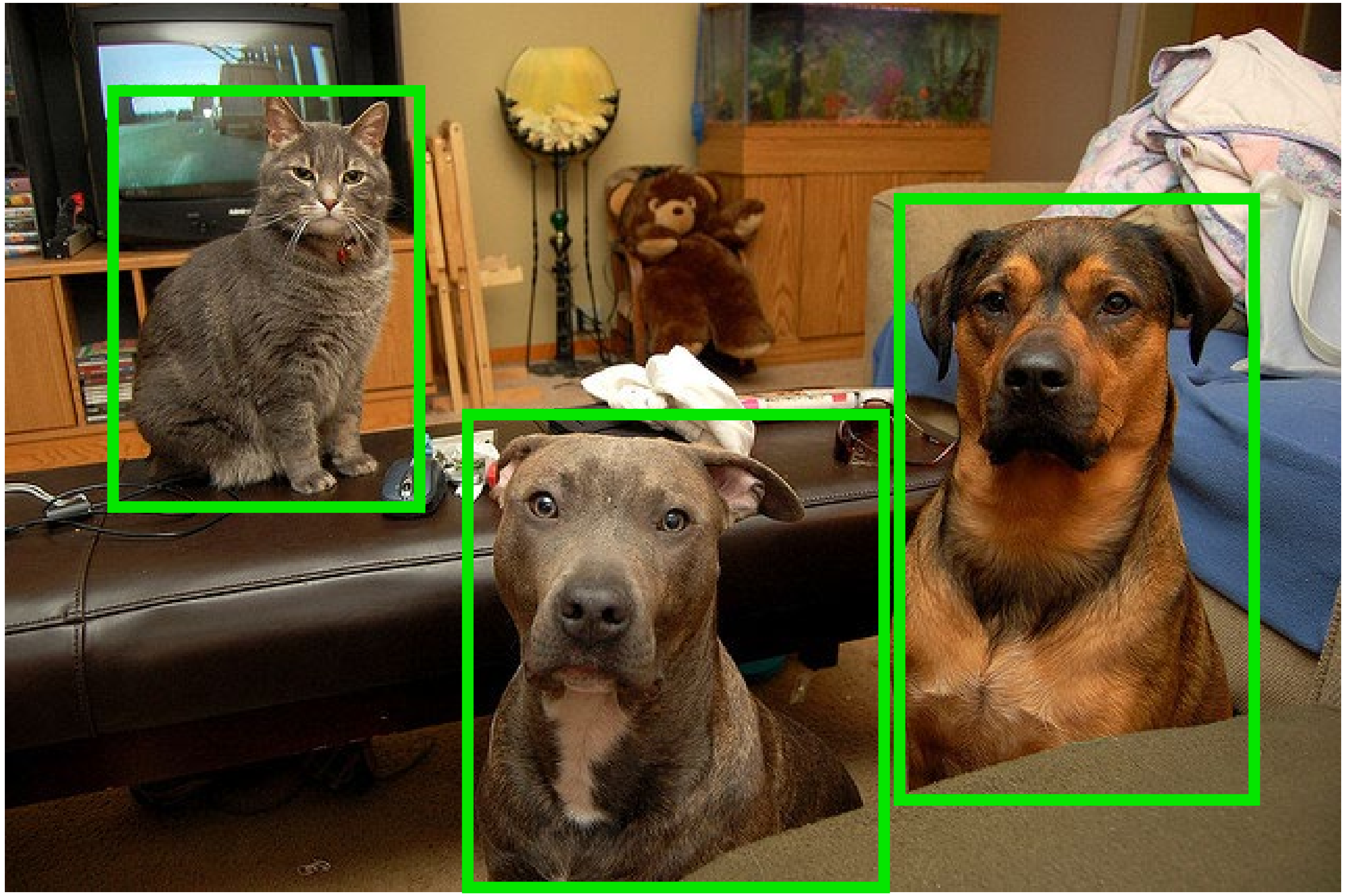
Computer Vision



- 🟩 feline
- 🟥 tv set
- 🟩 teddy bear
- 🟥 pitbull
- 🟨 dog
- 🟩 cat
- 🟪 tv stand
- group of dogs
- 🟩 fish tank
- room
- indoor
- man-made
- 🟦 footstool
- 🟧 furniture

Image Parsing / Image Segmentation

How do we describe images?



A cat and two big dogs staring at the camera

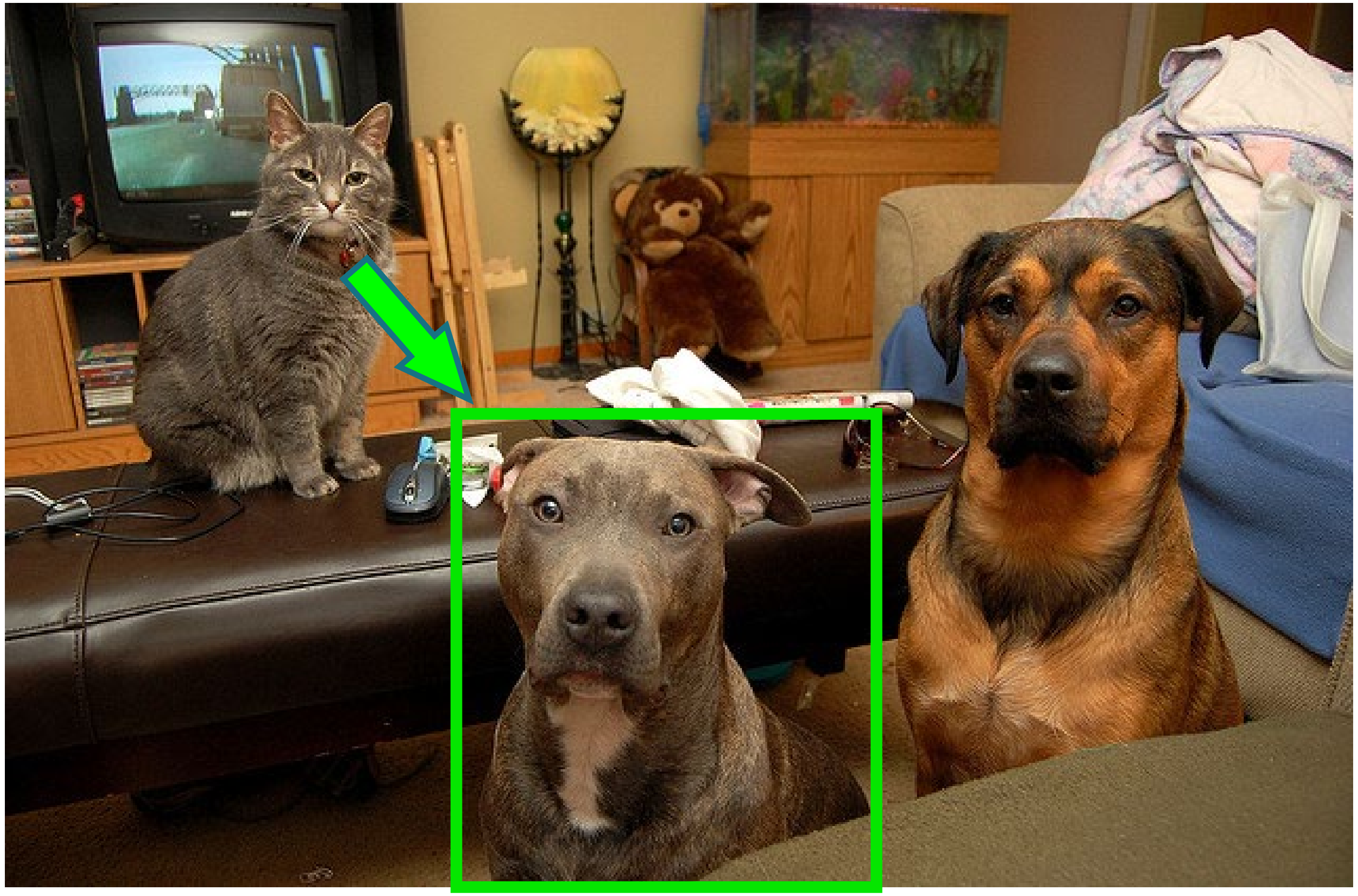
Object Importance

Attribute Importance

Action Importance

World knowledge

Referring to objects



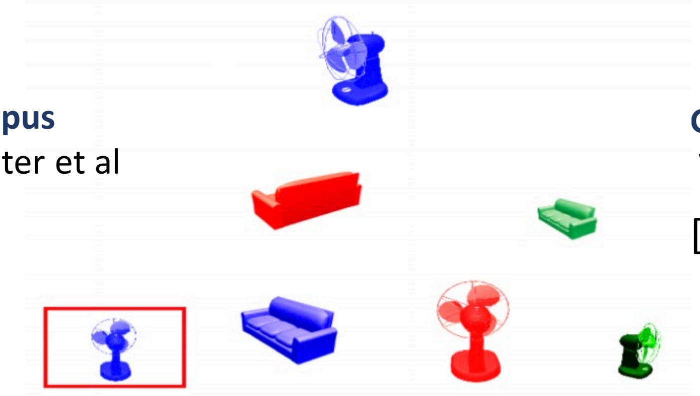
The dog in the middle

The gray dog in the middle

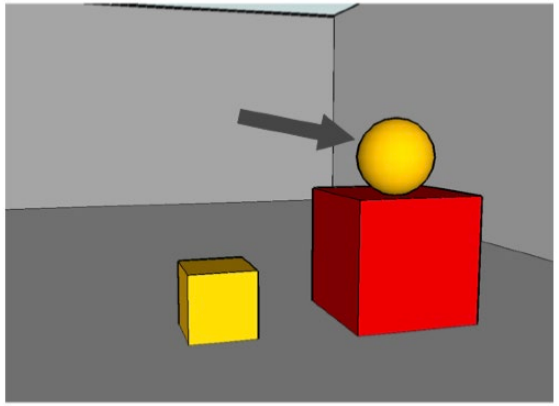
The gray dog

Work on Referring Expression

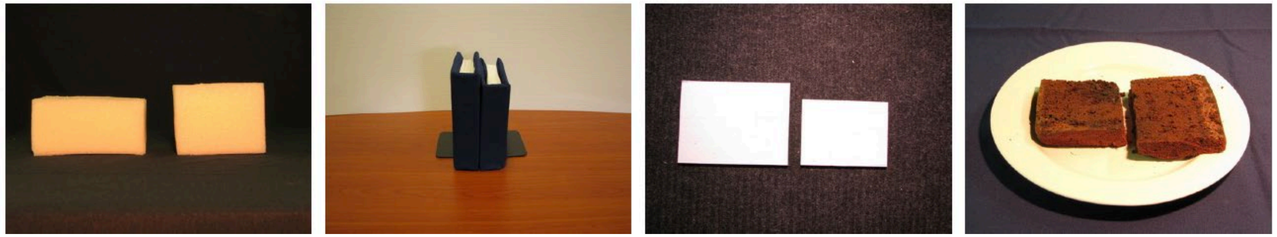
TUNA Corpus
van Deemter et al 2006



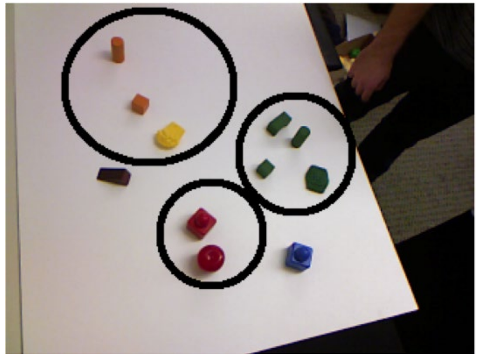
GRE3D3 Corpus
Viethen and Dale 2008
[20 scenes]



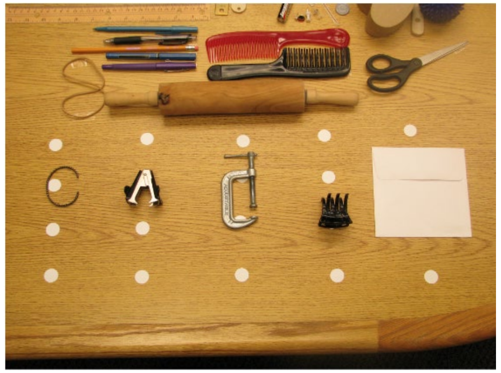
Size Corpus
Mitchell et al 2011
[96 scenes]



GenX Corpus
FitzGerald et al 2013
[269 scenes]

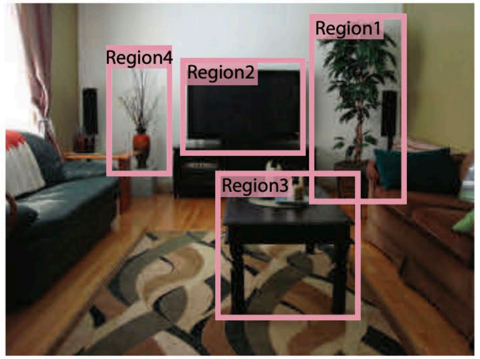


Typicality Corpus
Mitchell et al 2013
[35 scenes]



Referring Expression Comprehension

The plant on the
right side of the TV

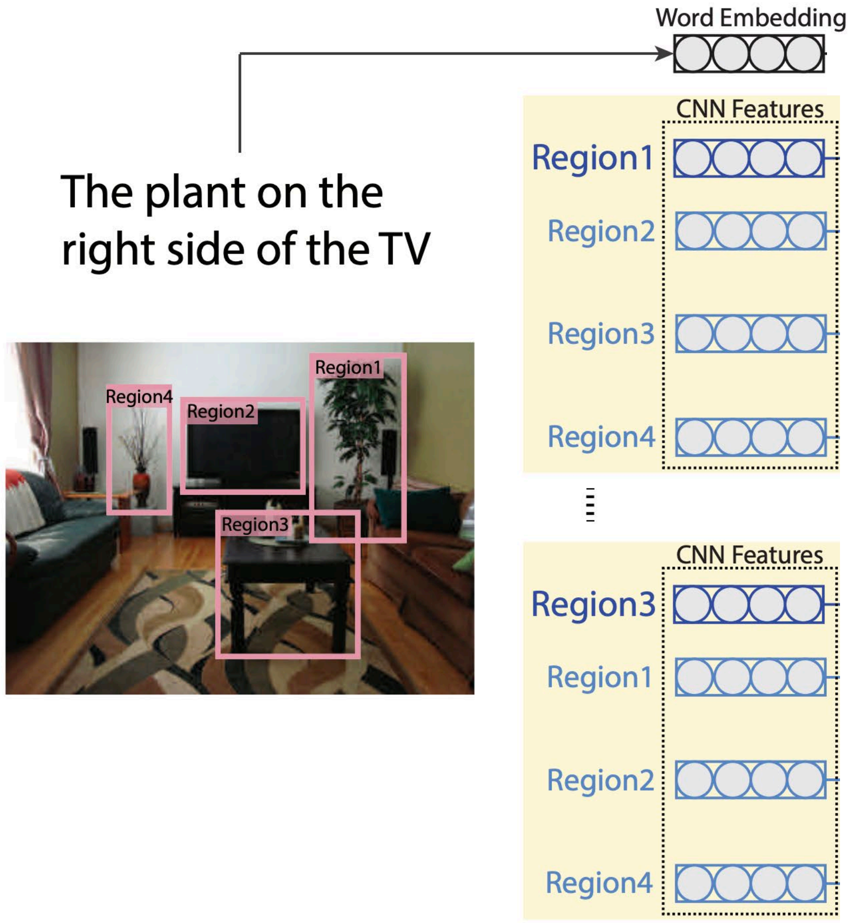


Modeling Context Between Objects for Referring Expression Understanding

Varun K. Nagaraja Vlad I. Morariu Larry S. Davis

University of Maryland, College Park, MD, USA.
{varun,morariu,lsd}@umiacs.umd.edu

Referring Expression Comprehension



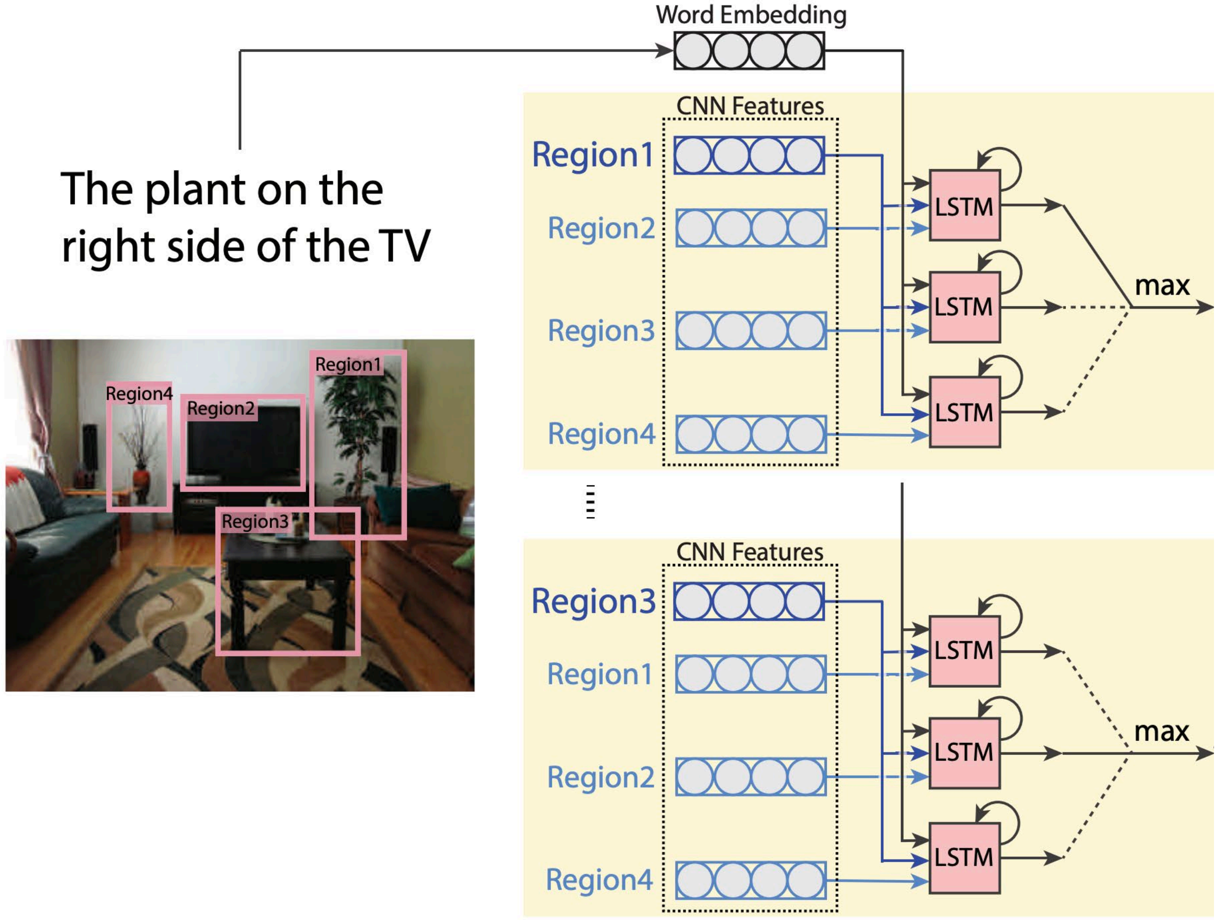
The plant on the right side of the TV

Modeling Context Between Objects for Referring Expression Understanding

Varun K. Nagaraja Vlad I. Morariu Larry S. Davis

University of Maryland, College Park, MD, USA.
{varun,morariu,lsd}@umiacs.umd.edu

Referring Expression Comprehension

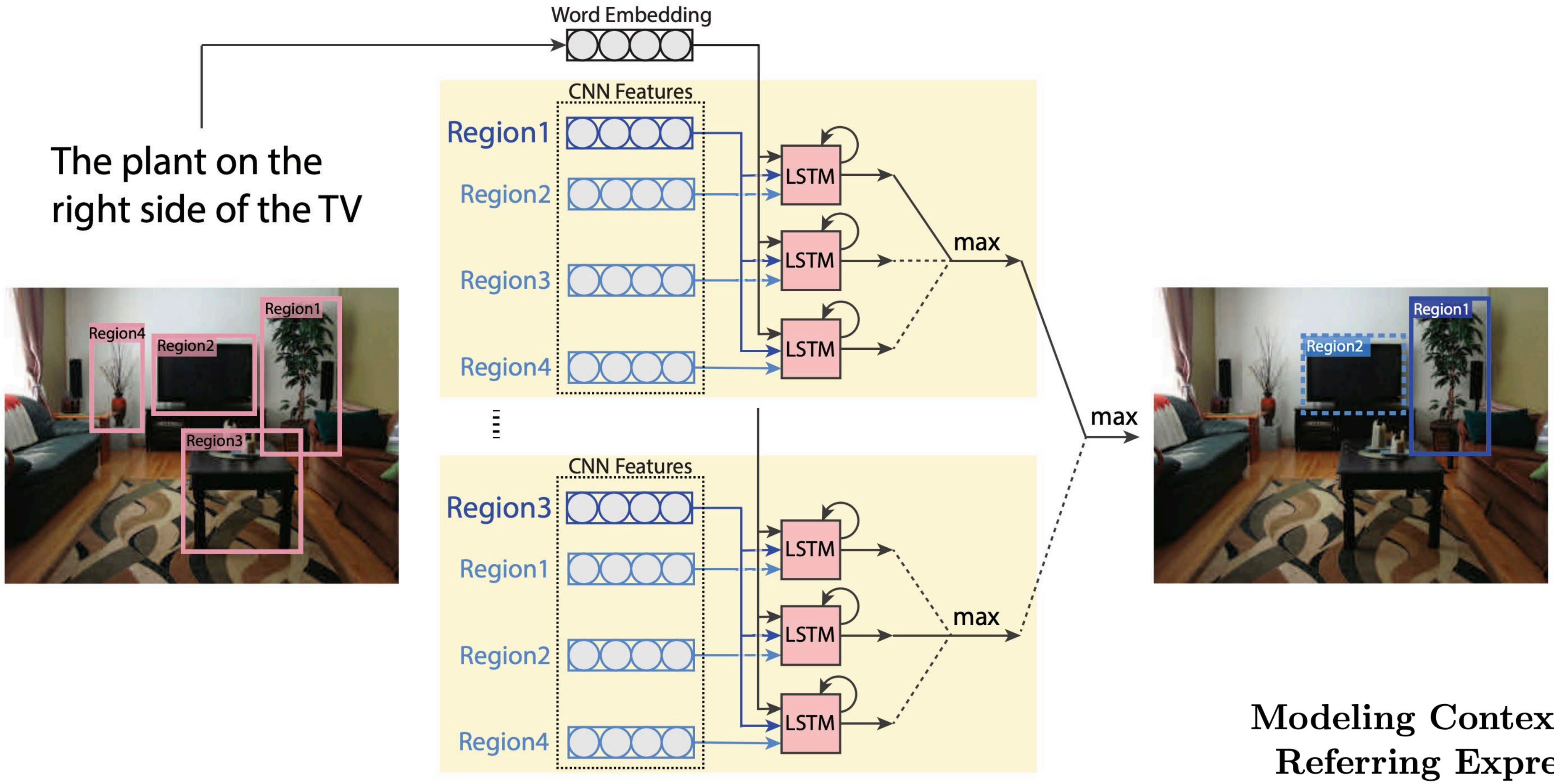

The plant on the right side of the TV

Modeling Context Between Objects for Referring Expression Understanding

Varun K. Nagaraja   Vlad I. Morariu   Larry S. Davis

University of Maryland, College Park, MD, USA.
{varun,morariu,lsd}@umiacs.umd.edu

Referring Expression Comprehension

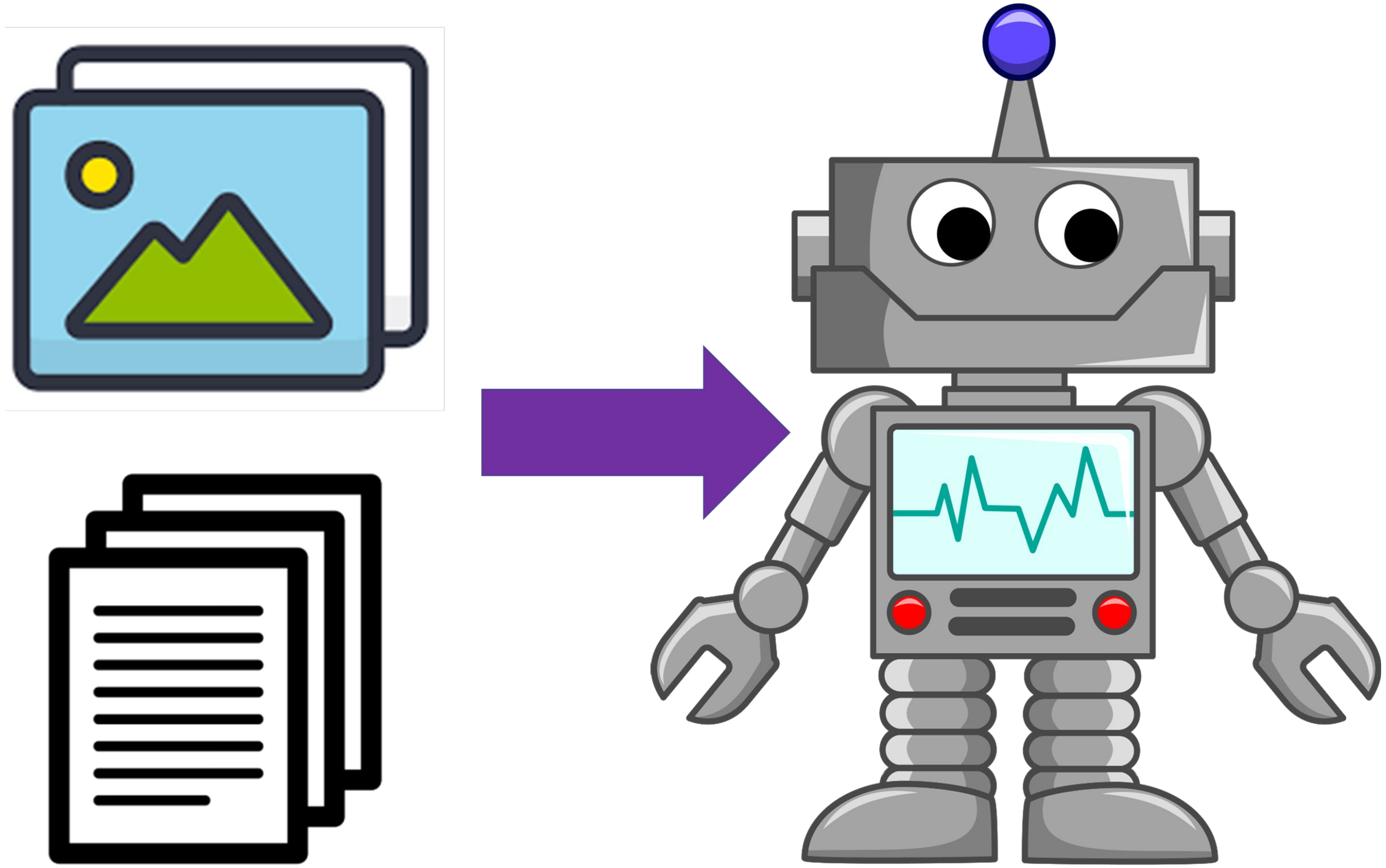


Modeling Context Between Objects for Referring Expression Understanding

Varun K. Nagaraja Vlad I. Morariu Larry S. Davis

University of Maryland, College Park, MD, USA.
{varun,morariu,lsd}@umiacs.umd.edu

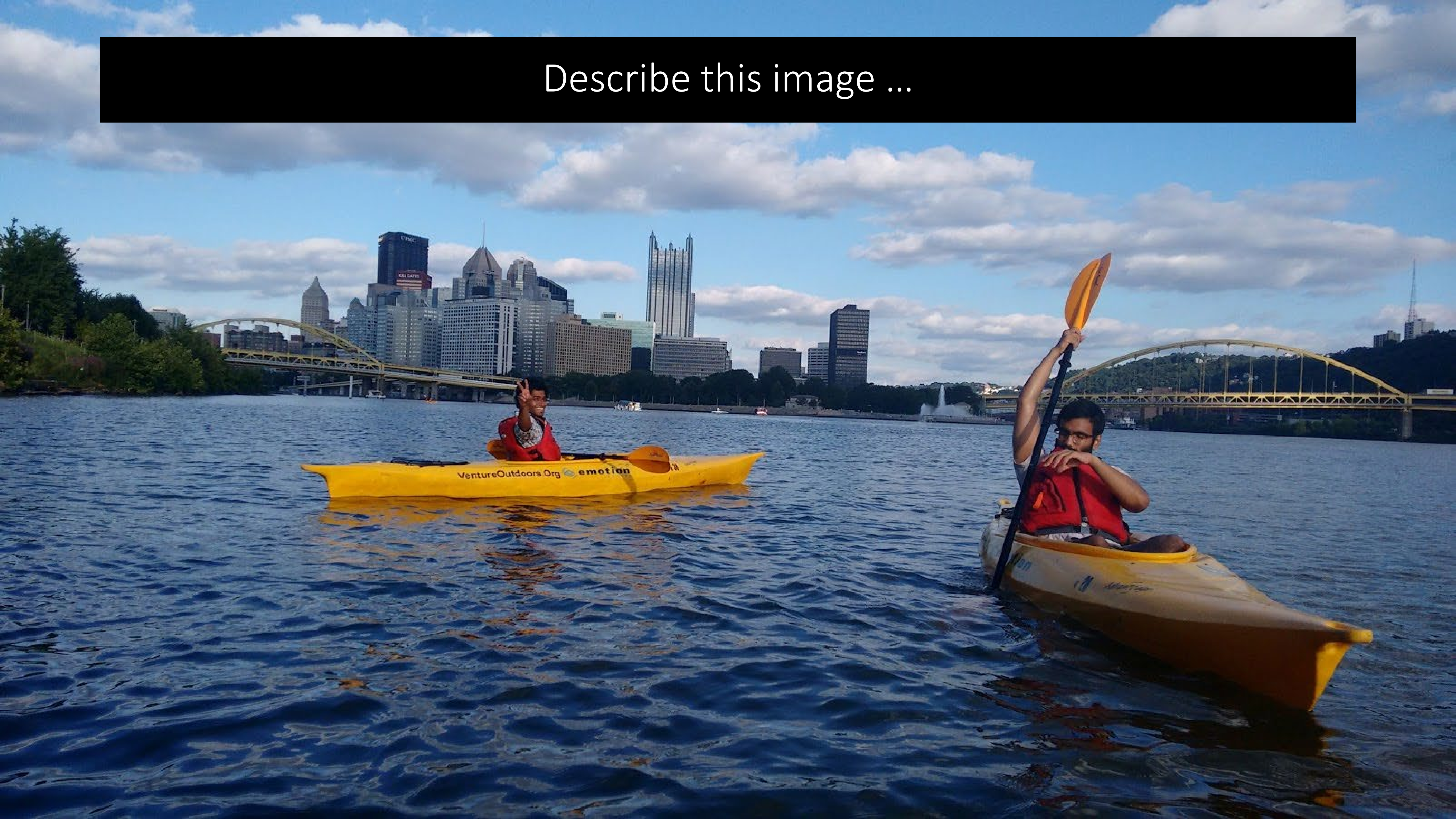
2016



Vision + Language

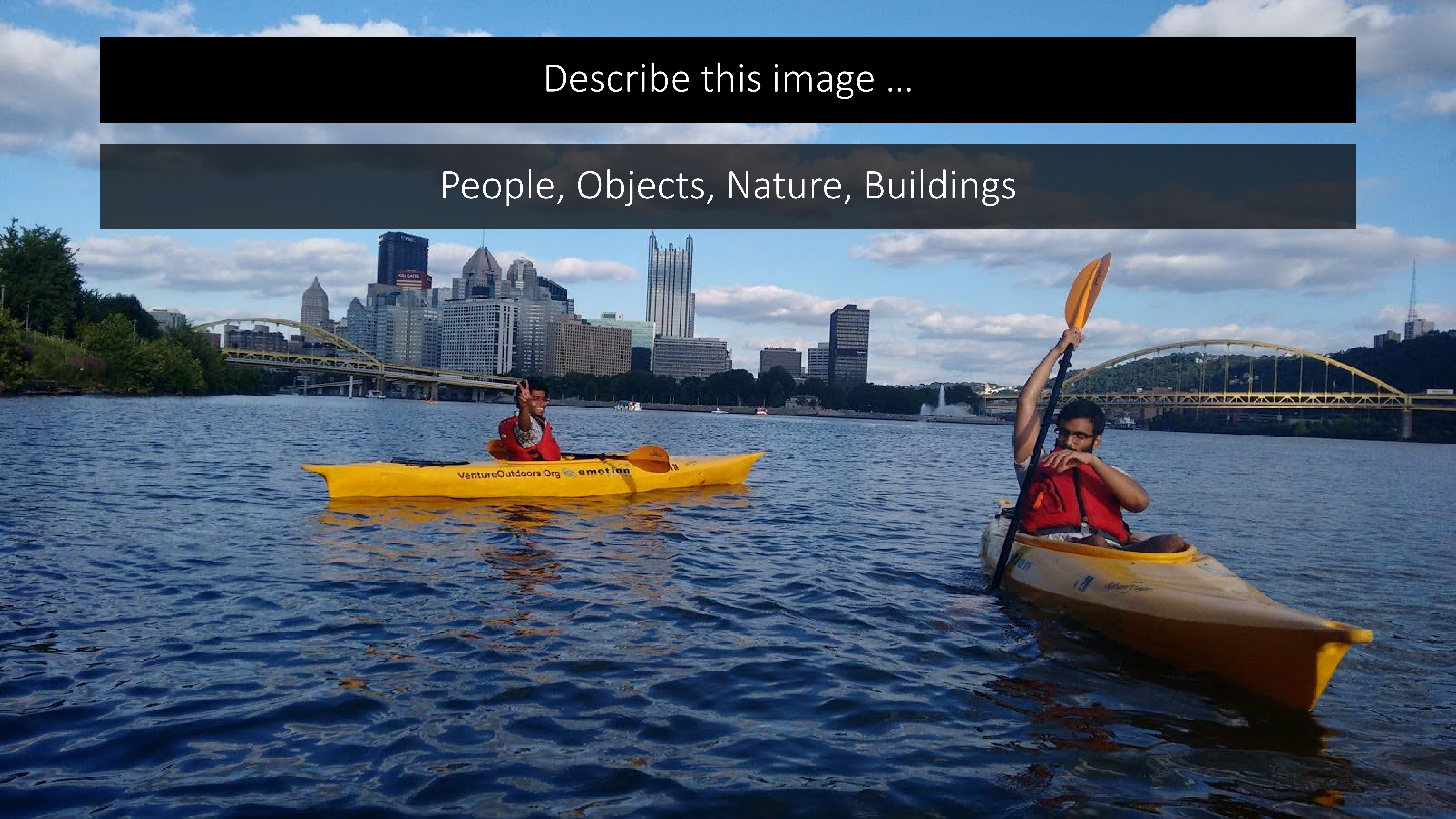
A brand new era for computer vision!

Describe this image …



Describe this image …

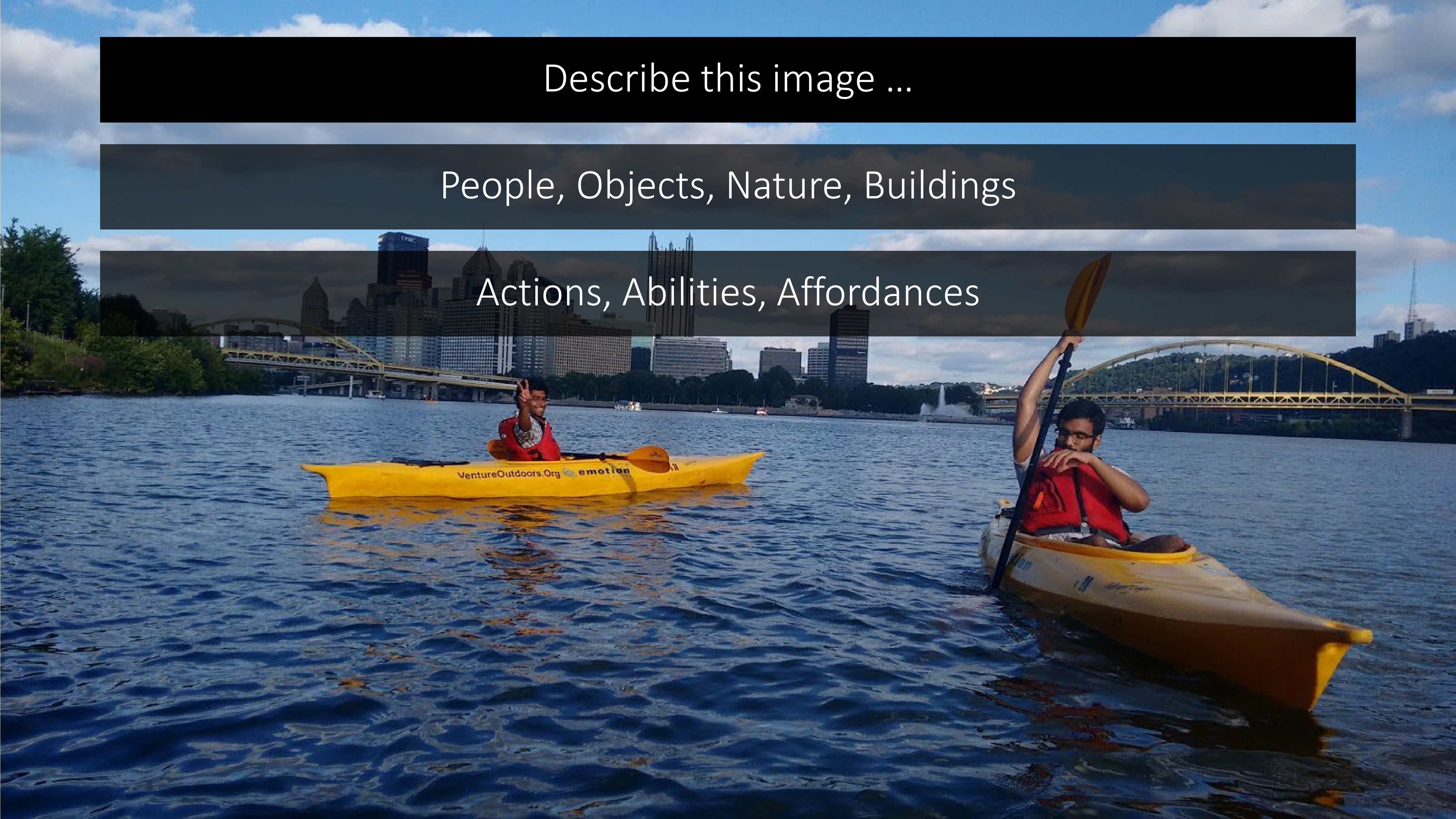
People, Objects, Nature, Buildings



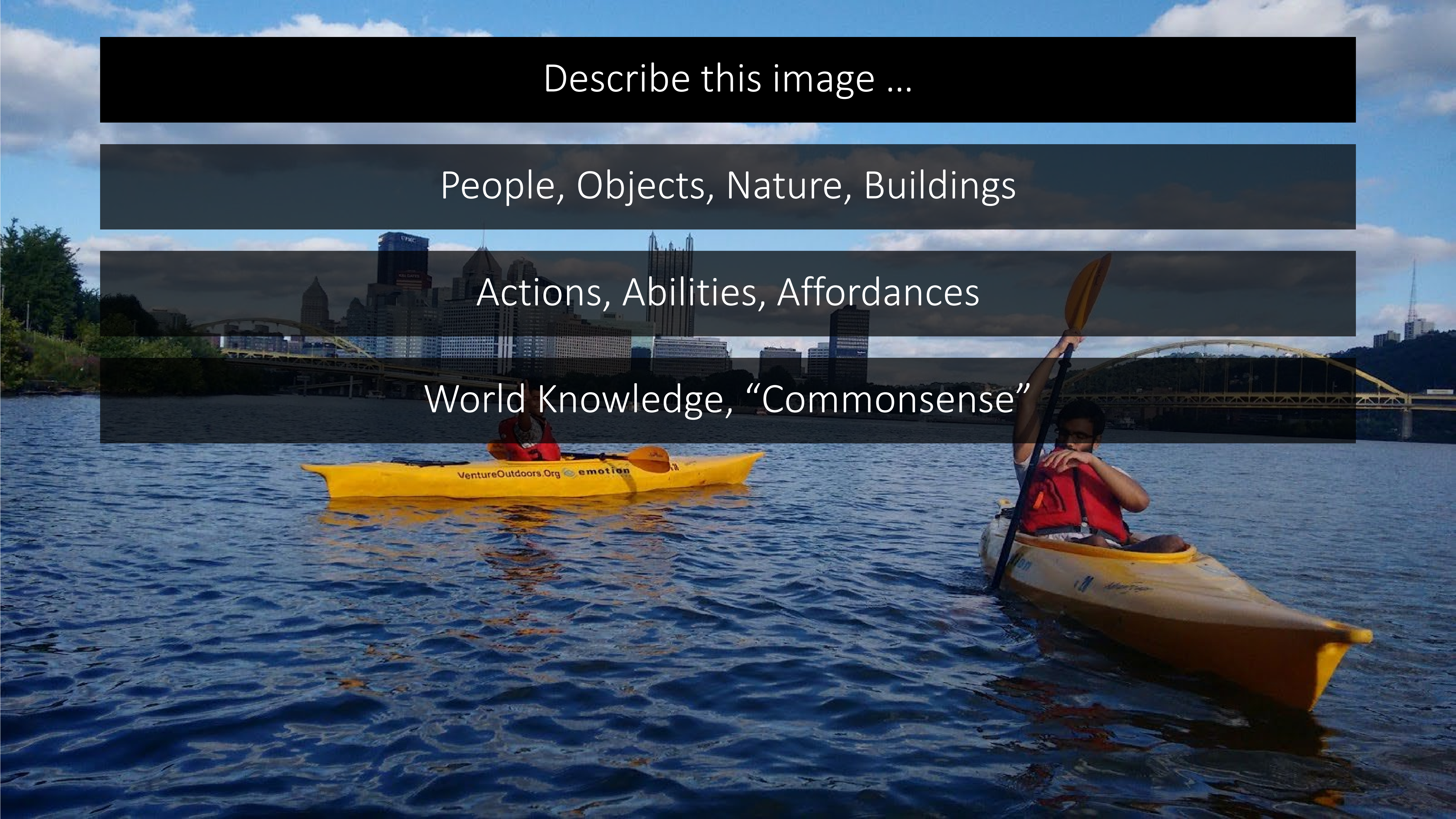
Describe this image …

People, Objects, Nature, Buildings

Actions, Abilities, Affordances



Describe this image …

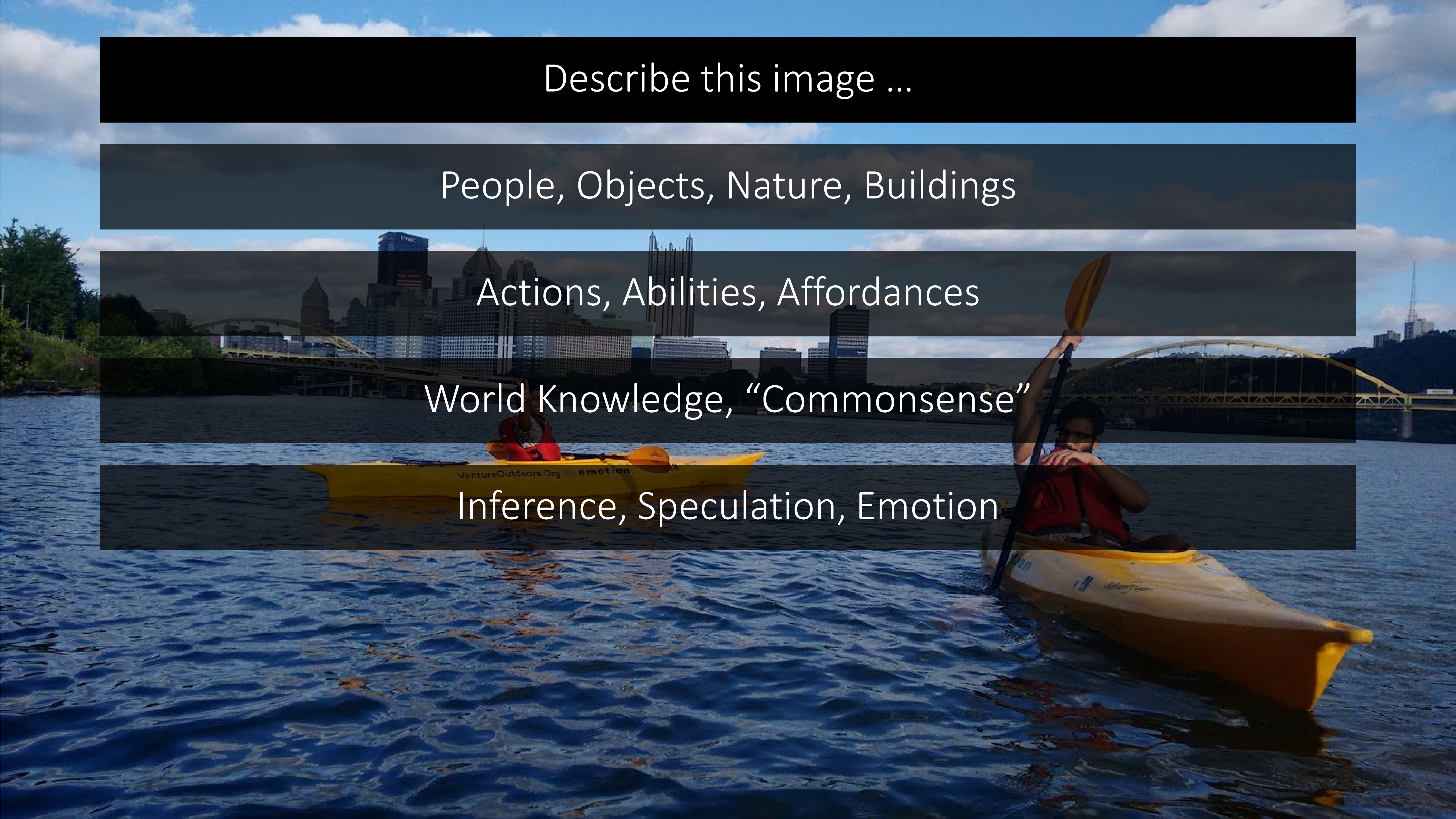


People, Objects, Nature, Buildings

Actions, Abilities, Affordances

World Knowledge, “Commonsense”

Describe this image …



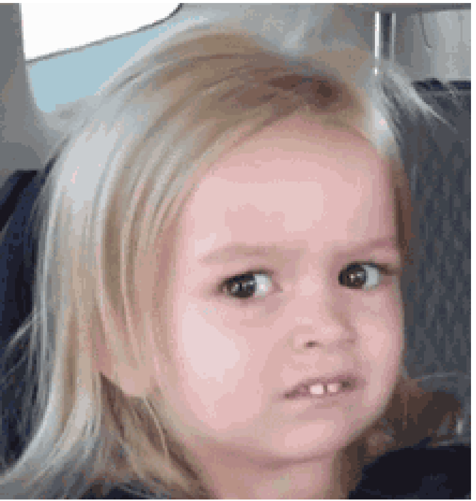
People, Objects, Nature, Buildings

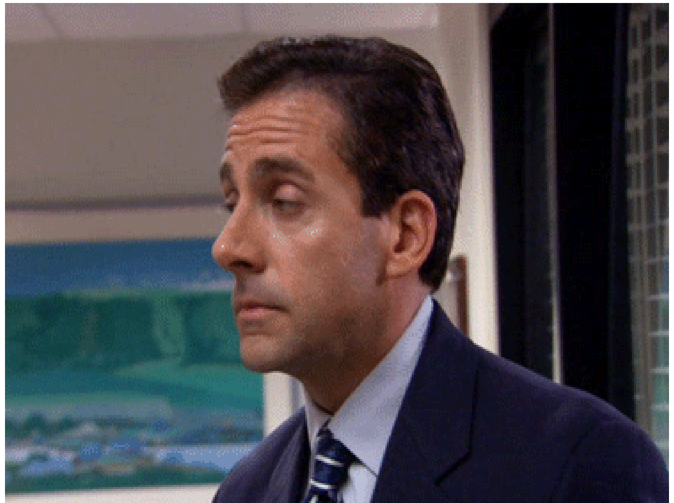
Actions, Abilities, Affordances

World Knowledge, “Commonsense”

Inference, Speculation, Emotion

Images convey emotions





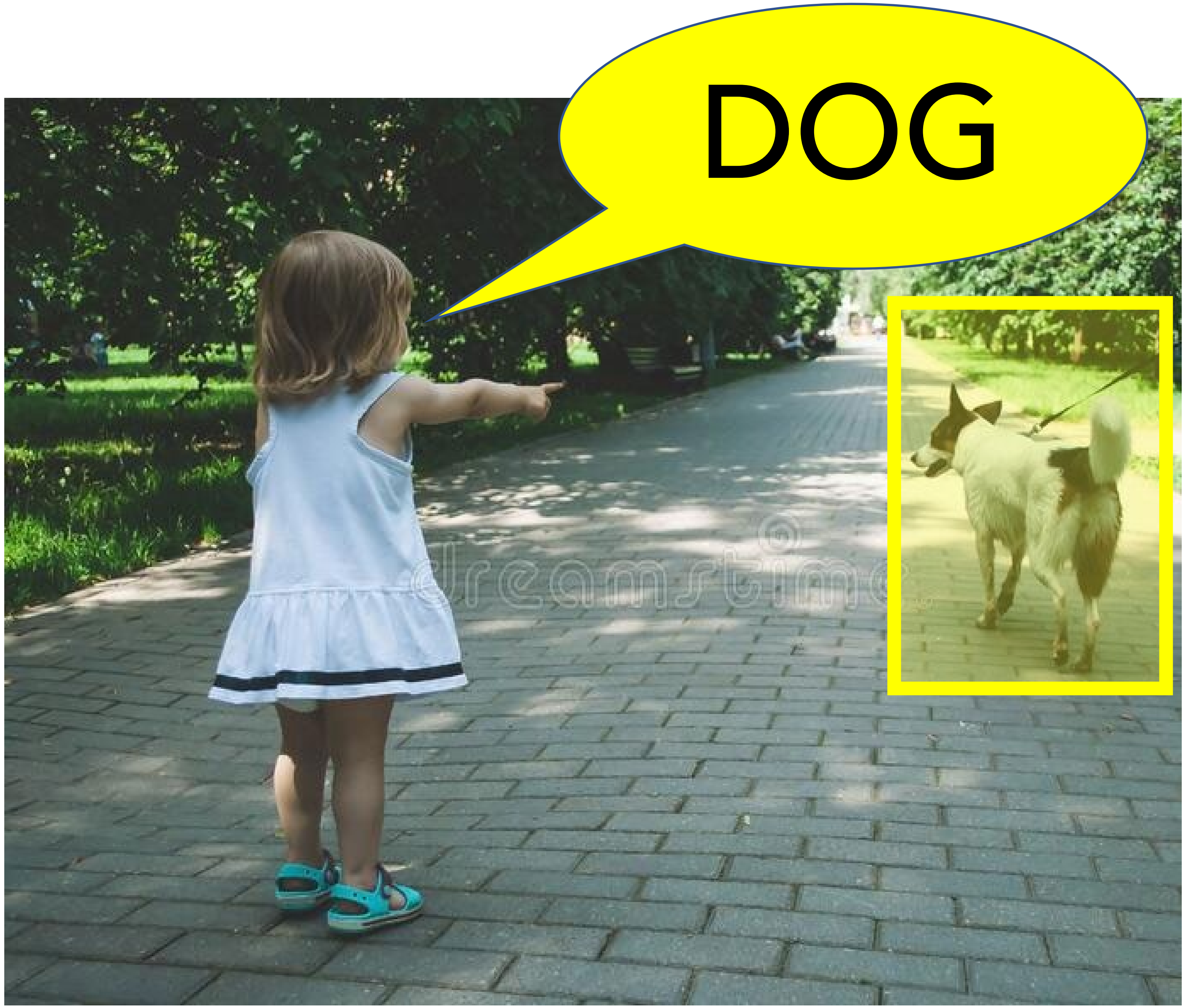
Vision + Language

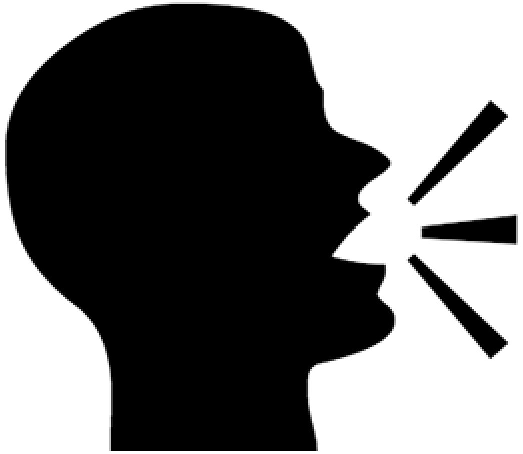
A brand new era for computer vision!

Vision + Language

A brand new era for computer vision!

Perception+Reasoning needs Vision+Language

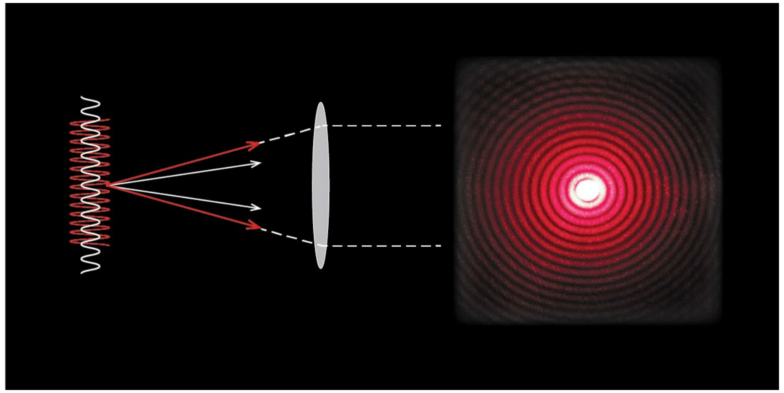




Computer Vision: A Pyramid

PHYSICS-BASED

- Optics
- Computational Imaging



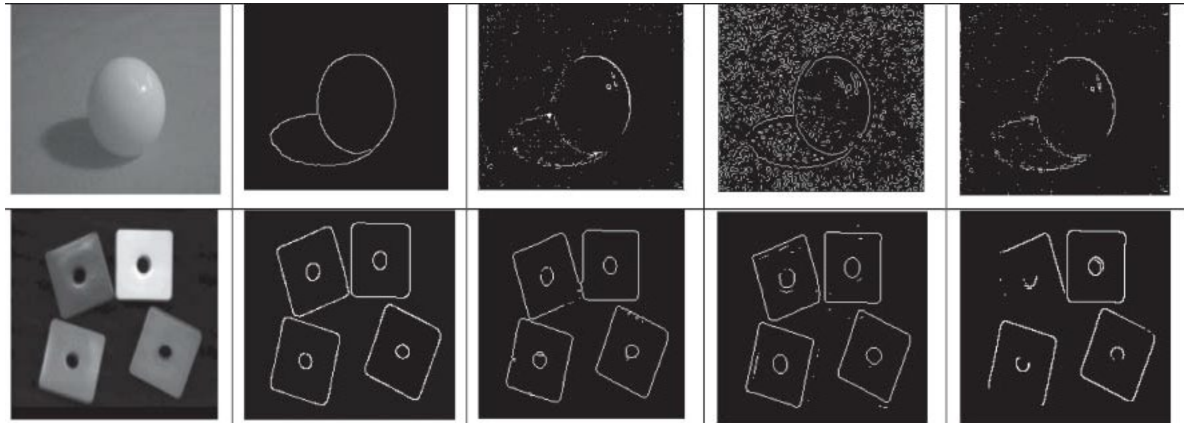
GEOMETRIC

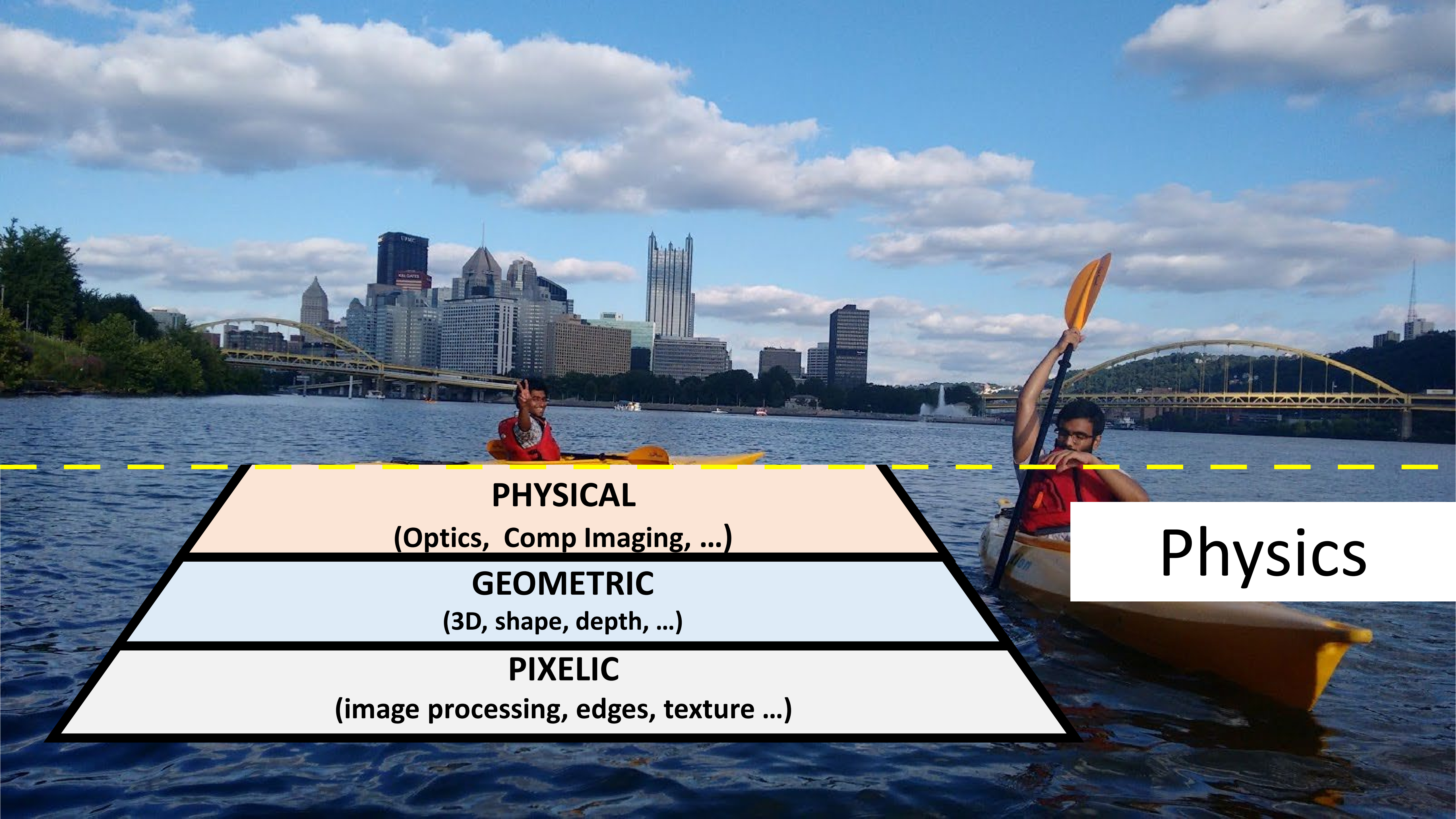
- 3D Reconstruction
- Shape, Depth, …

CoReNet
Points2Objects (Ours)

PIXELIC

- Image Processing
- Edge Detection





PHYSICAL

(Optics, Comp Imaging, …)

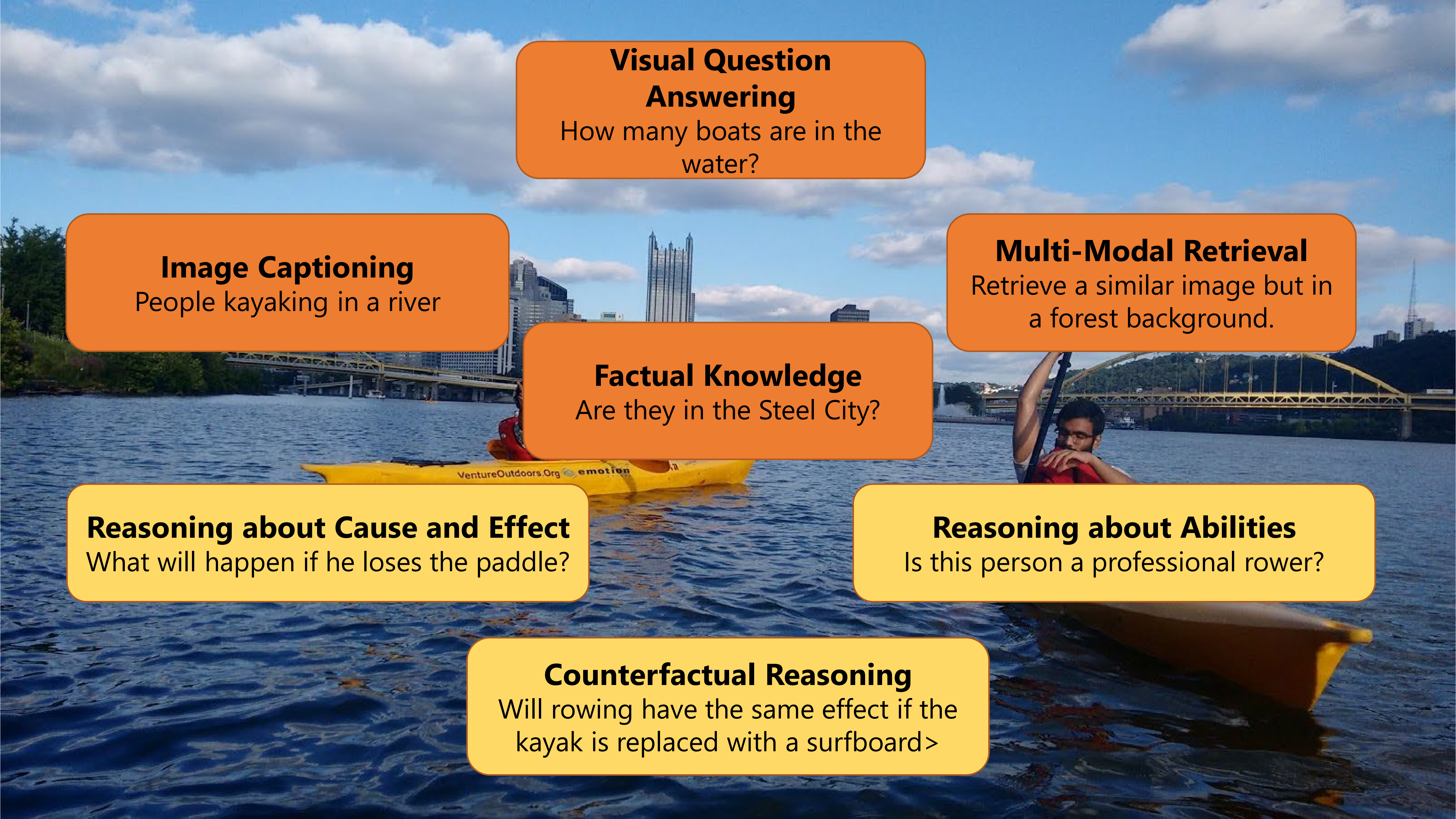
GEOMETRIC

(3D, shape, depth, …)

PIXELIC

(image processing, edges, texture …)

Physics



Visual Question Answering
How many boats are in the water?

Image Captioning
People kayaking in a river

Multi-Modal Retrieval
Retrieve a similar image but in a forest background.

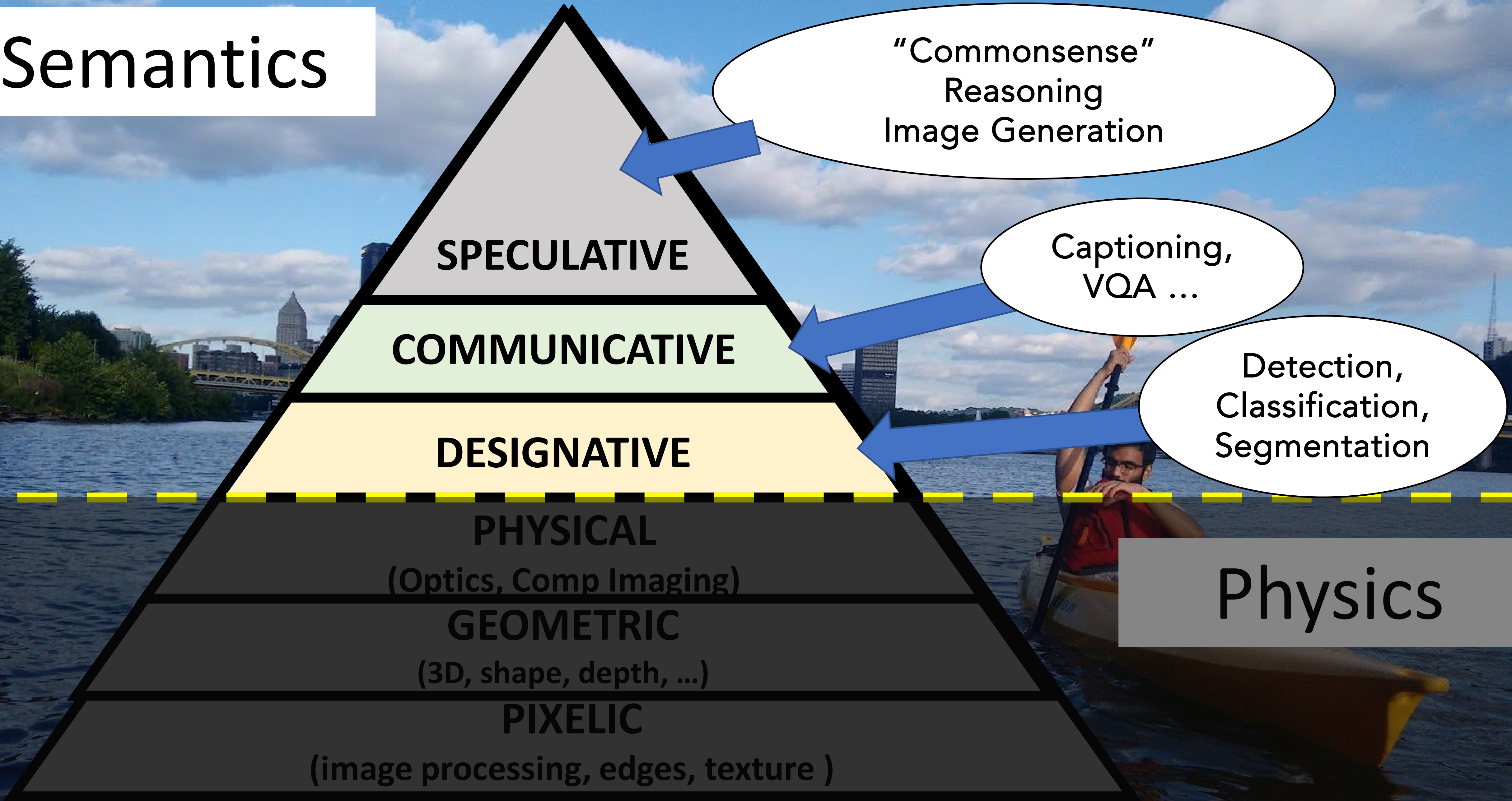
Factual Knowledge
Are they in the Steel City?

Reasoning about Cause and Effect
What will happen if he loses the paddle?

Reasoning about Abilities
Is this person a professional rower?

Counterfactual Reasoning
Will rowing have the same effect if the kayak is replaced with a surfboard>

Semantics



SPECULATIVE

COMMUNICATIVE

DESIGNATIVE

PHYSICAL

(Optics, Comp Imaging)

GEOMETRIC

(3D, shape, depth, …)

PIXELIC

(image processing, edges, texture)

“Commonsense”
Reasoning
Image Generation

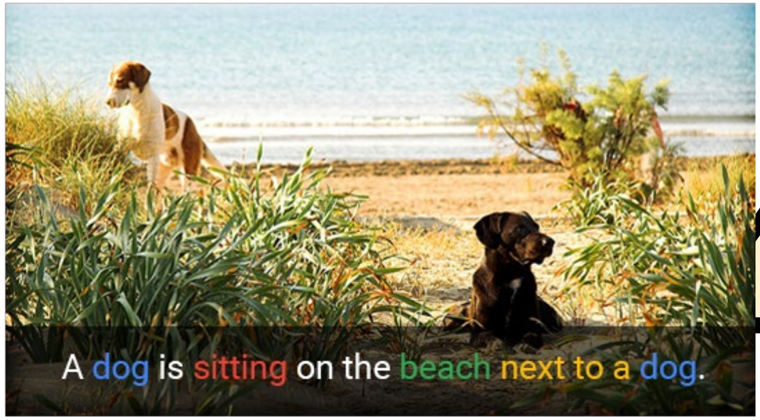
Captioning,
VQA …

Detection,
Classification,
Segmentation

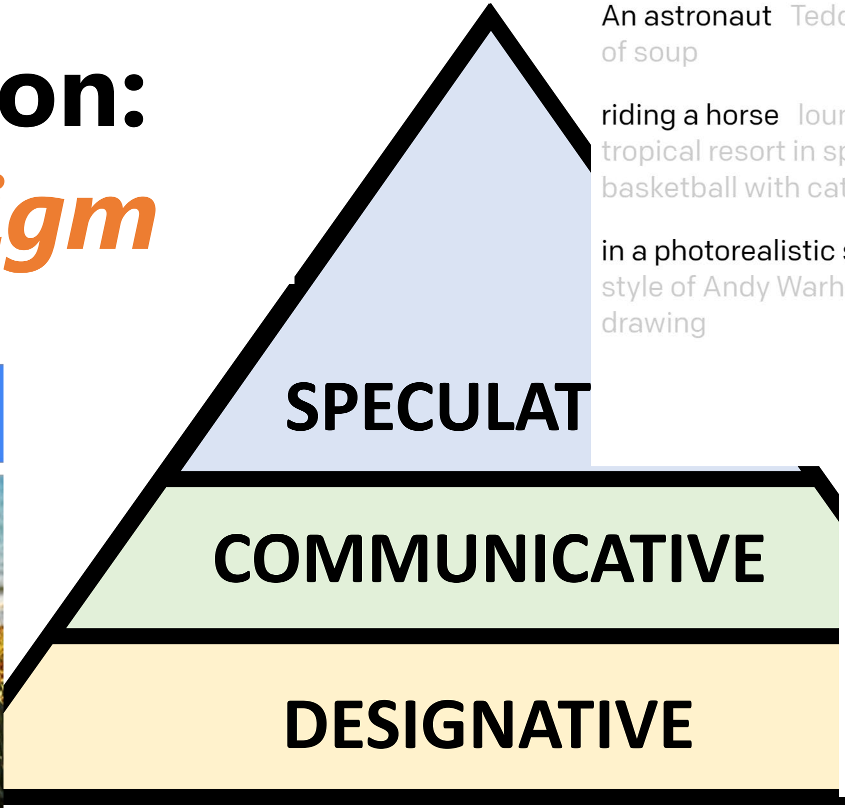
Physics

Semantic Vision:
A New Paradigm

Automatically captioned



A dog is sitting on the beach next to a dog.



TEXT DESCRIPTION

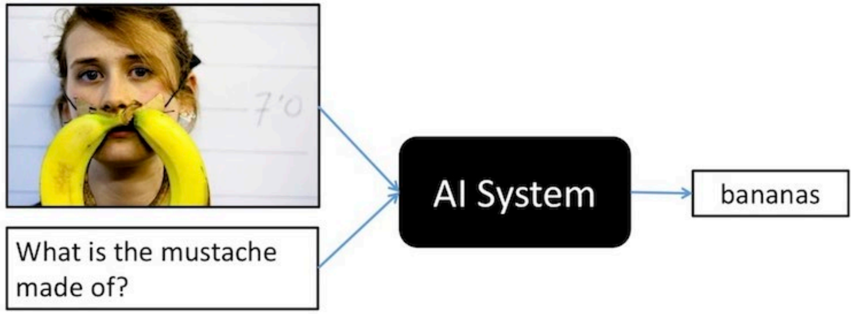
An astronaut Teddy bears A bowl of soup

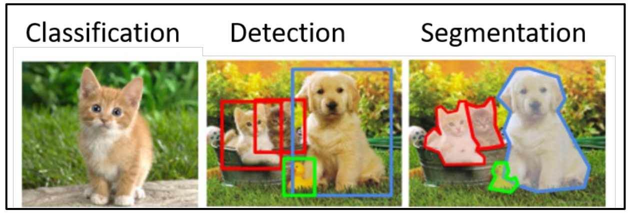
riding a horse lounging in a tropical resort in space playing basketball with cats in space

in a photorealistic style in the style of Andy Warhol as a pencil drawing

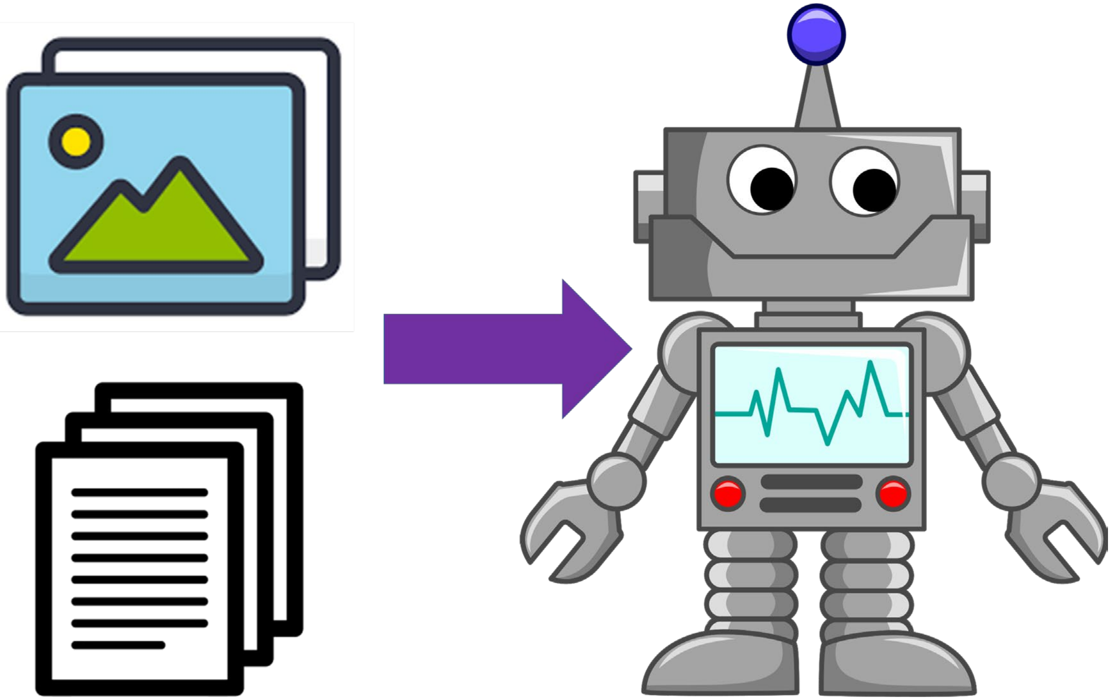
→

DALL·E 2





Multi-Modal (Vision + Language) Learning

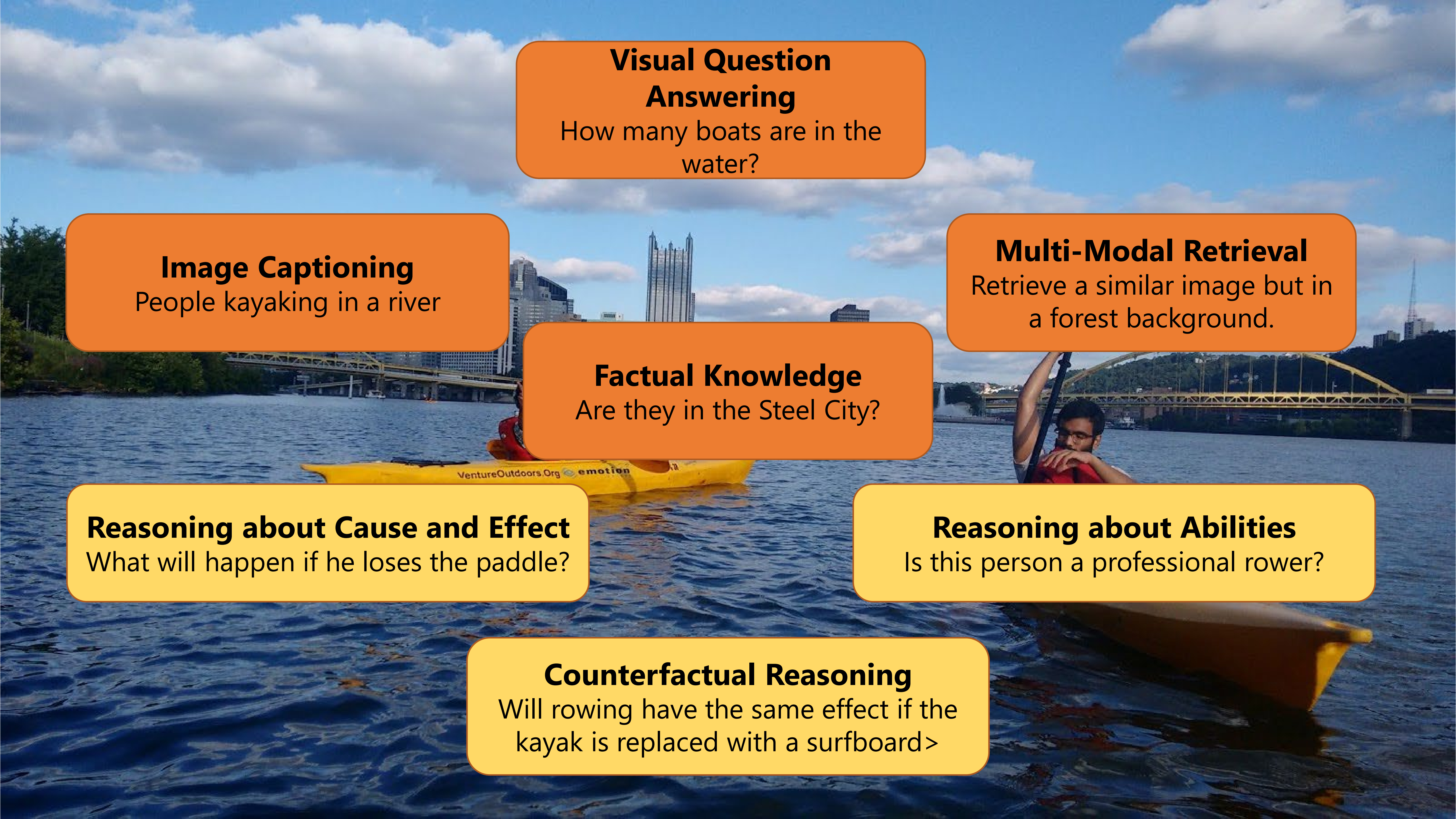


Multimodal Learning:
Tremendous potential in

- Robotics
- Embodied AI
- Graphics , AR / VR
- Human-Computer Interaction

Learning jointly from images and text has caused a **paradigm shift** in AI

VentureOutdoors.Org
emotion



Visual Question Answering
How many boats are in the water?

Image Captioning
People kayaking in a river

Multi-Modal Retrieval
Retrieve a similar image but in a forest background.

Factual Knowledge
Are they in the Steel City?

Reasoning about Cause and Effect
What will happen if he loses the paddle?

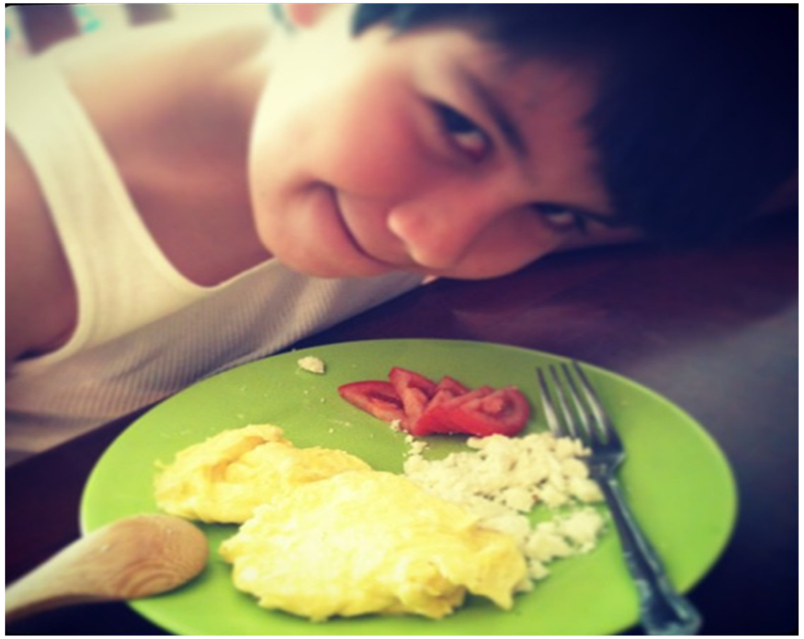
Reasoning about Abilities
Is this person a professional rower?

Counterfactual Reasoning
Will rowing have the same effect if the kayak is replaced with a surfboard>

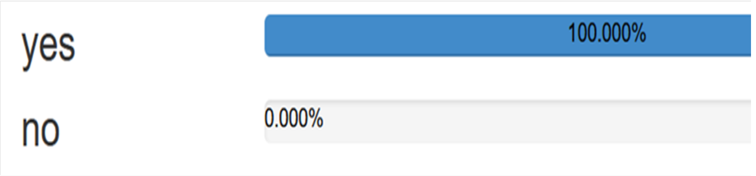
Some popular tasks in Vision + Language

Visual Question Answering

Given an image and a question about it, produce an answer to that question.



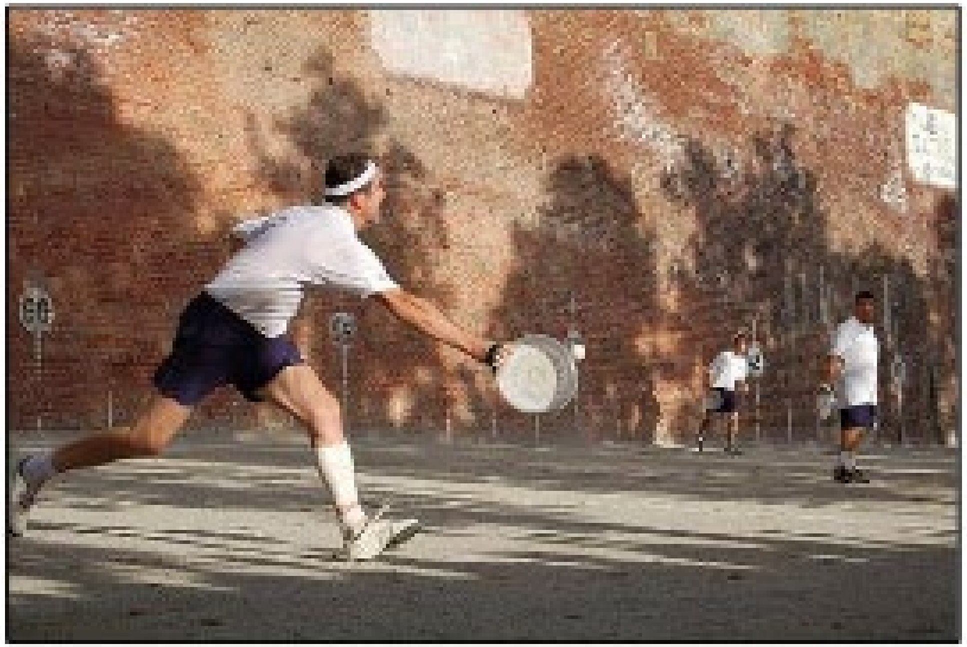
Is the food made of eggs?



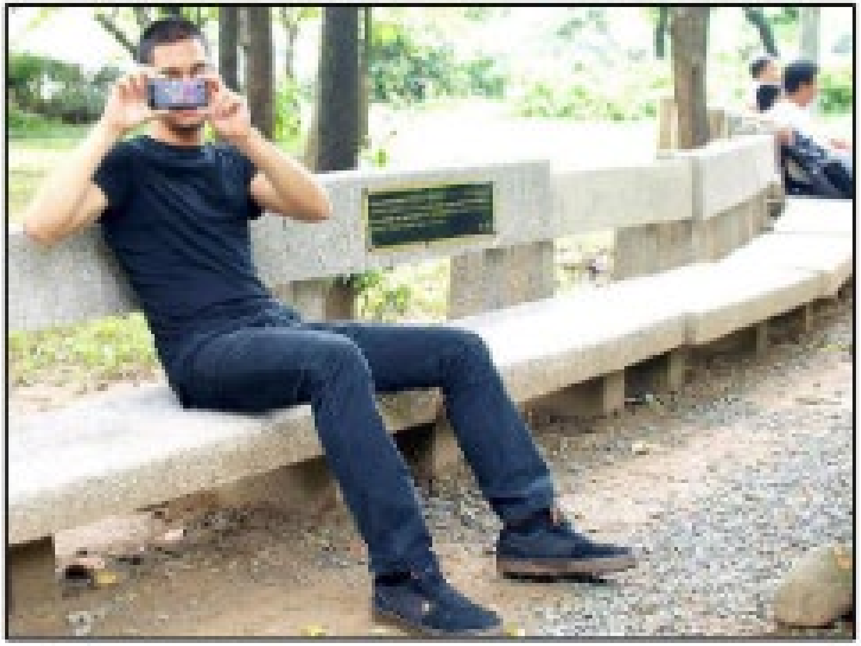
VQA: Visual Question Answering

www.visualqa.org

Aishwarya Agrawal*, Jiasen Lu*, Stanislaw Antol*,
Margaret Mitchell, C. Lawrence Zitnick, Dhruv Batra, Devi Parikh

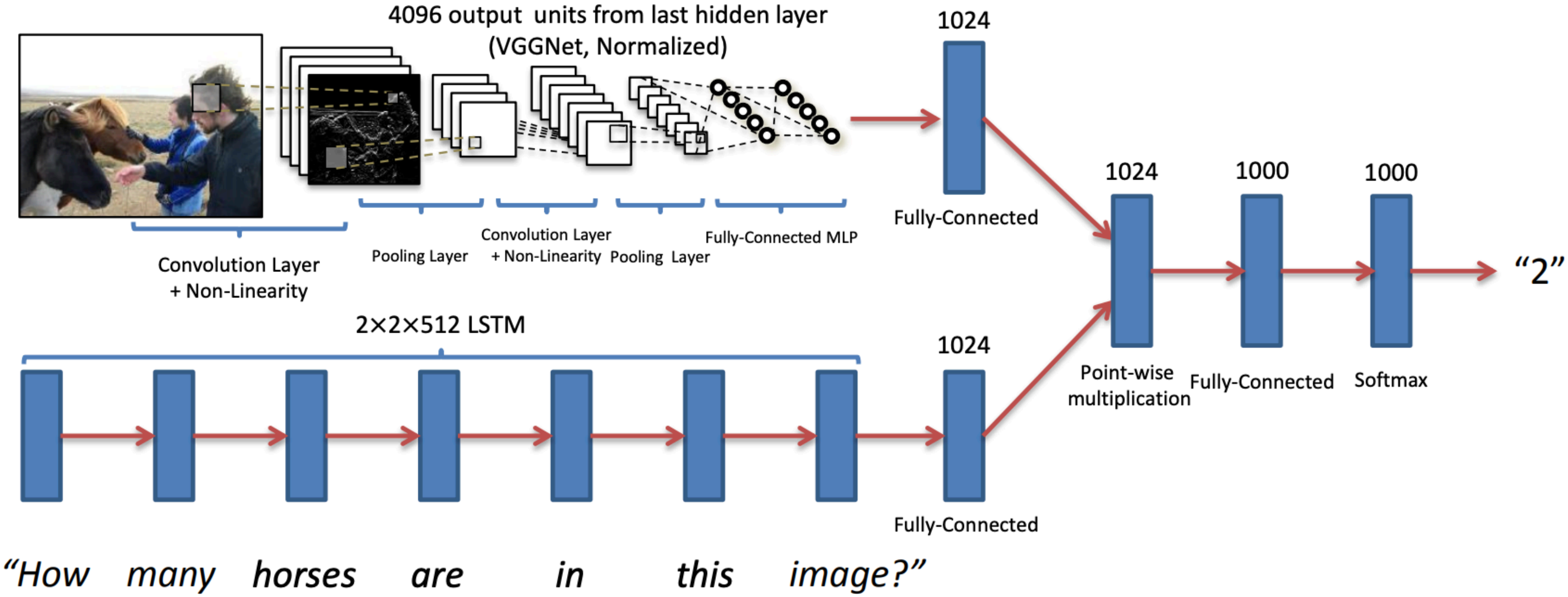


Is this person trying to hit a ball?	yes yes yes	yes yes yes
What is the person hitting the ball with?	frisbie racket round paddle	bat bat racket

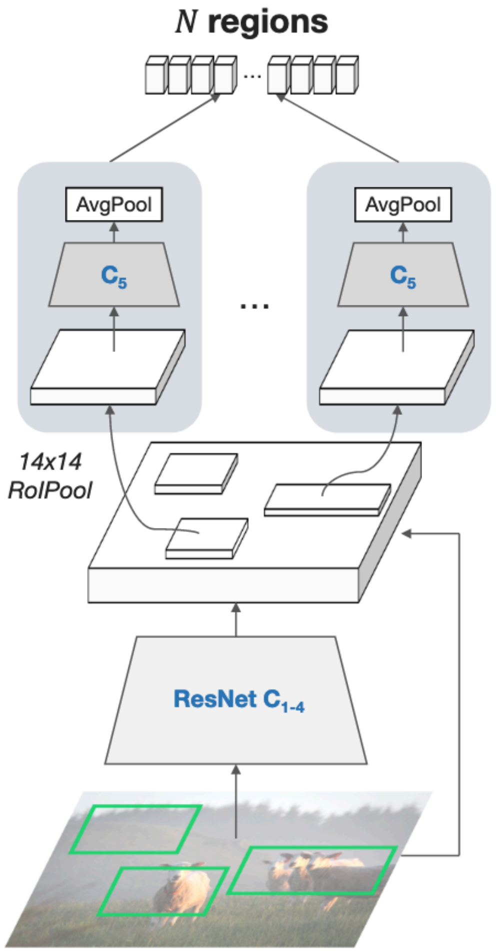


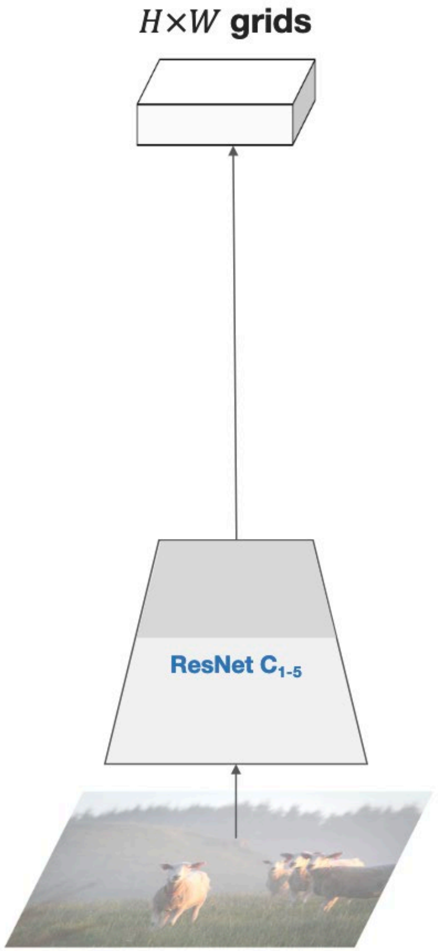
What is the guy doing as he sits on the bench?	phone taking picture taking picture with phone	reading reading smokes
What color are his shoes?	blue blue blue	black black brown

Visual Question Answering: Naïve Approach



What Features to use as input visual features?

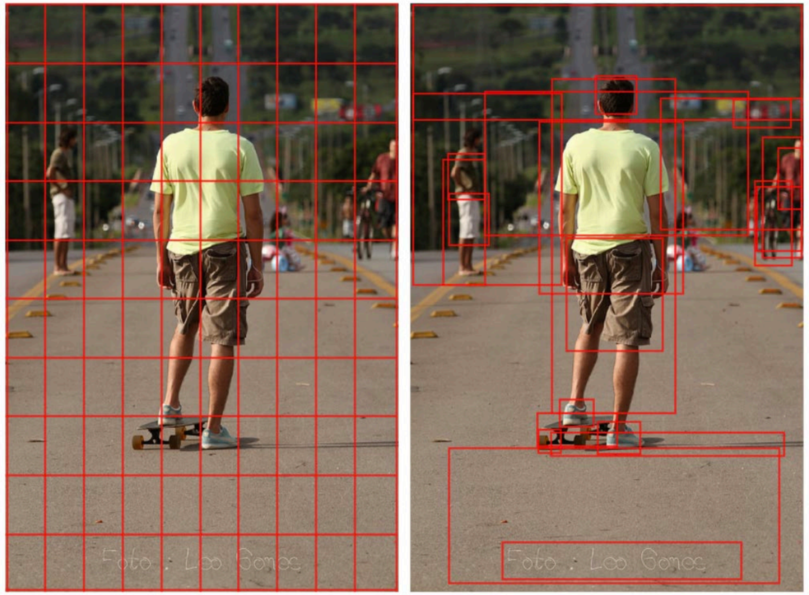


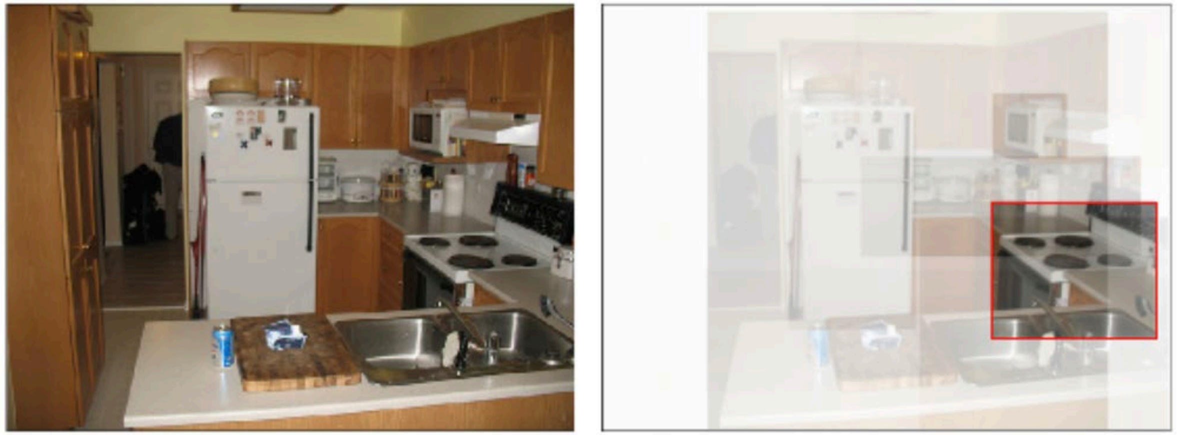


CVPR 2017

Bottom-Up and Top-Down Attention for Image Captioning and Visual Question Answering

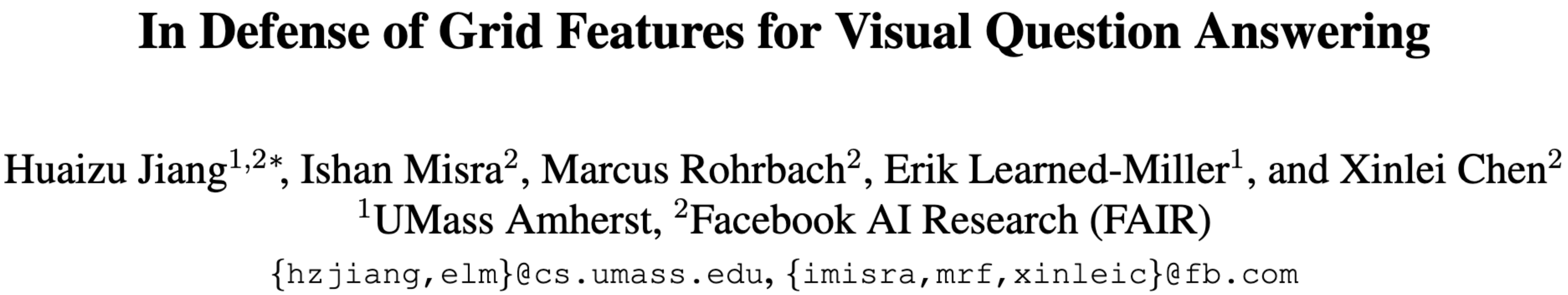
Peter Anderson[1]* Xiaodong He[2] Chris Buehler[3] Damien Teney[4]
Mark Johnson[5] Stephen Gould[1] Lei Zhang[3]
[1]Australian National University [2]JD AI Research [3]Microsoft Research [4]University of Adelaide [5]Macquarie University
[1]firstname.lastname@anu.edu.au, [2]xiaodong.he@jd.com, [3]{chris.buehler,leizhang}@microsoft.com
[4]damien.teney@adelaide.edu.au, [5]mark.johnson@mq.edu.au





Question: What room are they in? Answer: kitchen

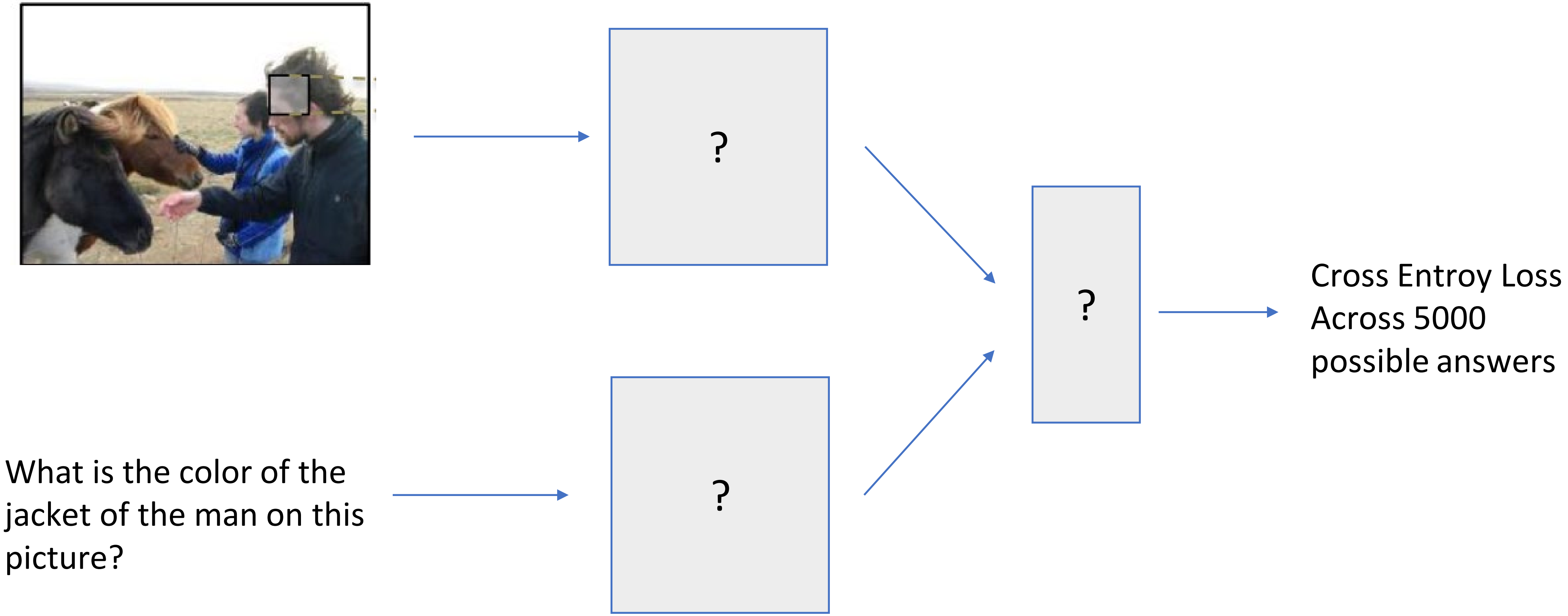
CVPR 2020



In Defense of Grid Features for Visual Question Answering

Huaizu Jiang[1,2]*, Ishan Misra[2], Marcus Rohrbach[2], Erik Learned-Miller[1], and Xinlei Chen[2]
[1]UMass Amherst, [2]Facebook AI Research (FAIR)
{hzjiang,elm}@cs.umass.edu, {imisra,mrf,xinleic}@fb.com

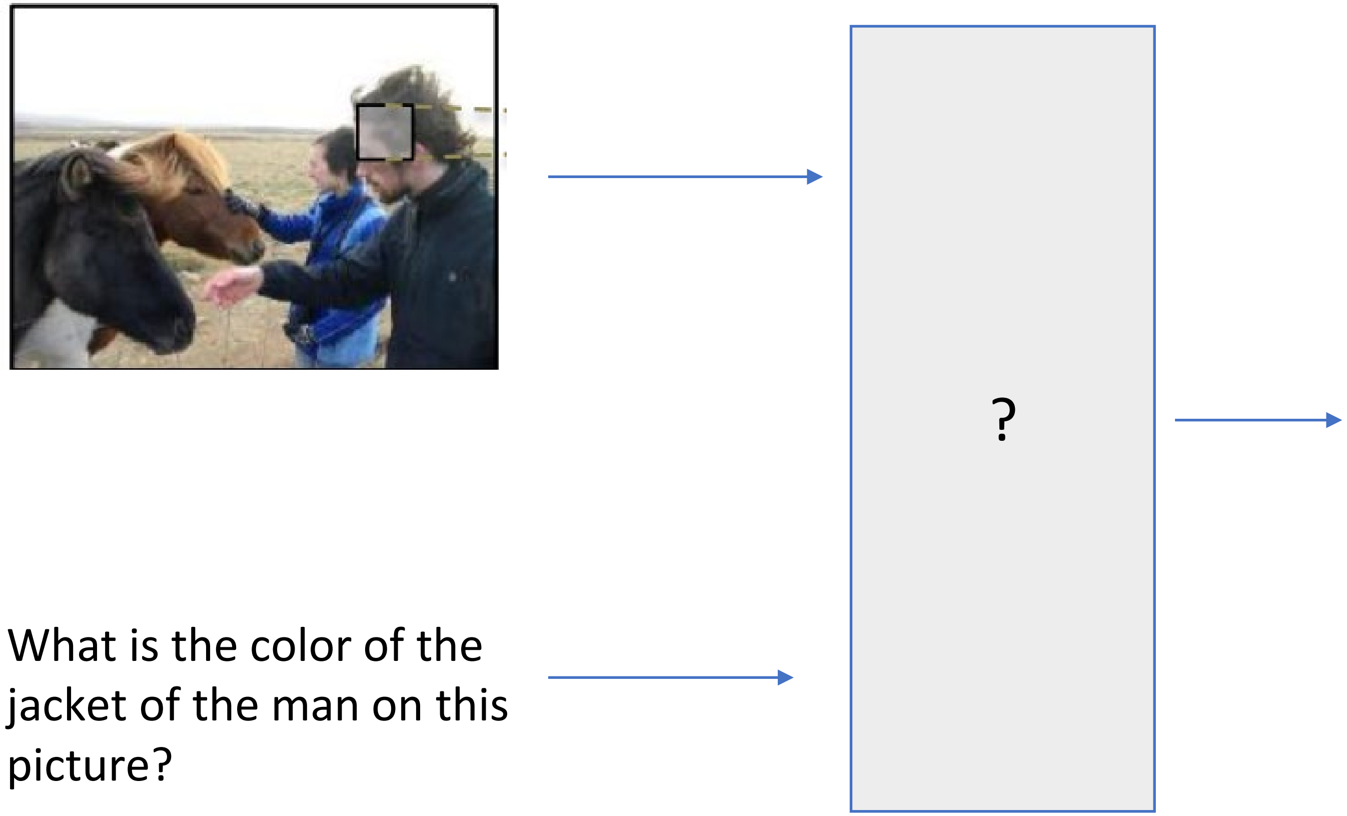
VQA Solution 5 years ago:
Learn V and L features separately, and fuse.



What is the color of the jacket of the man on this picture?

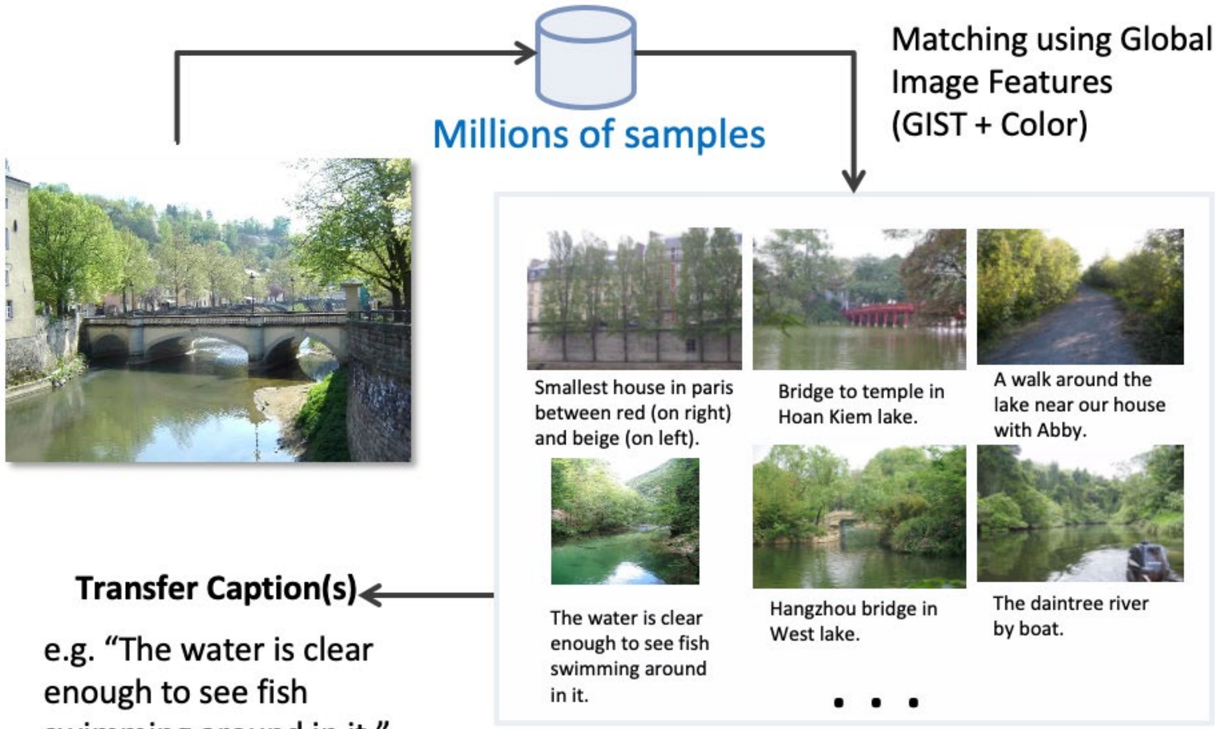
Cross Entroy Loss
Across 5000
possible answers

VQA Solution today? Multimodal Pretraining (typicall using masked language modeling)



What is the color of the jacket of the man on this picture?

Describing images with language (Image Captioning)



Matching using Global Image Features (GIST + Color)

Millions of samples

Smallest house in paris between red (on right) and beige (on left).

Bridge to temple in Hoan Kiem lake.

A walk around the lake near our house with Abby.

The water is clear enough to see fish swimming around in it.

Hangzhou bridge in West lake.

The daintree river by boat.

. . .

Transfer Caption(s)

e.g. "The water is clear enough to see fish swimming around in it."

Im2Text: Describing Images Using 1 Million Captioned Photographs

Vicente Ordonez, Girish Kulkarni, Tamara L. Berg.

Advances in Neural Information Processing Systems. **NIPS 2011**. Granada, Spain.

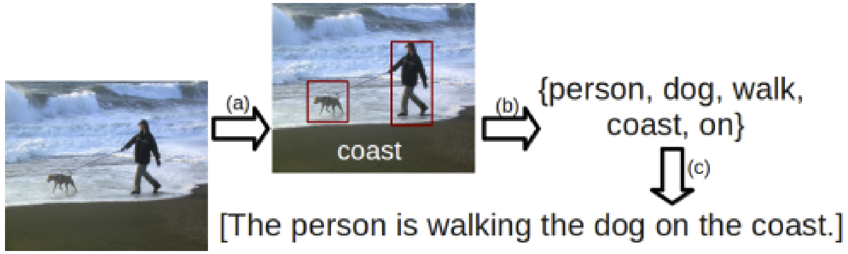

(a)
coast
(b)
{person, dog, walk, coast, on}
(c)
[The person is walking the dog on the coast.]

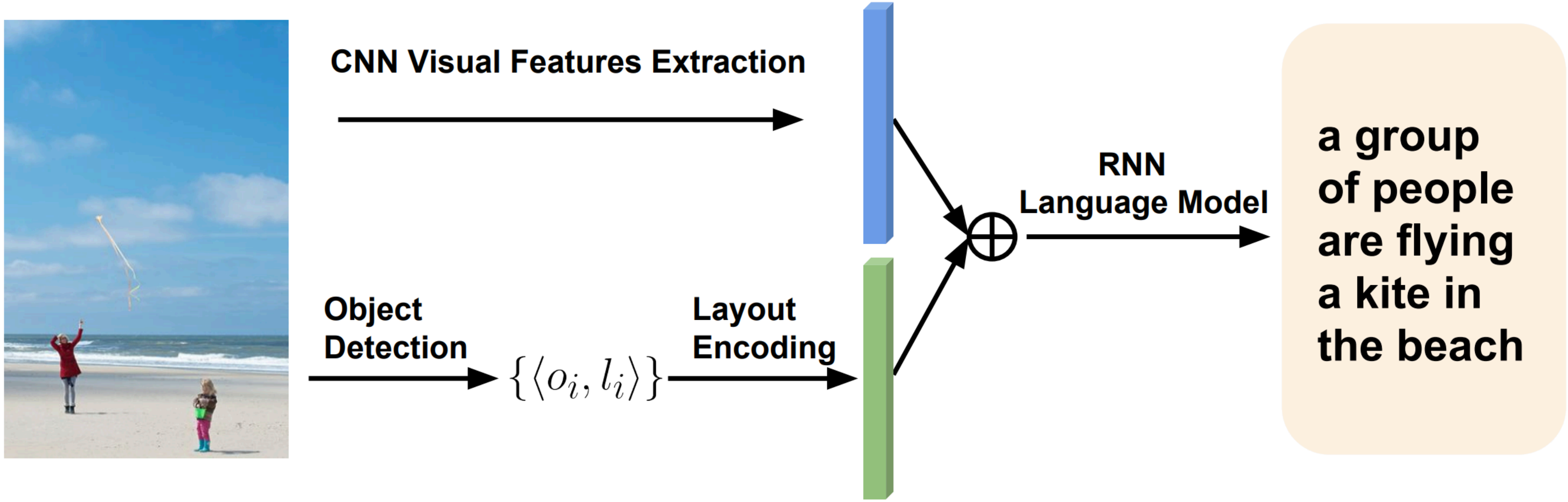
Figure 3: Overview of our approach. (a) Detect objects and scenes from input image. (b) Estimate optimal sentence structure quadruplet $\mathcal{T}^*$. (c) Generating a sentence from $\mathcal{T}^*$.

Corpus-Guided Sentence Generation of Natural Images

EMNLP 2011

Yezhou Yang [†] and **Ching Lik Teo** [†] and **Hal Daumé III** and **Yiannis Aloimonos**
University of Maryland Institute for Advanced Computer Studies
College Park, Maryland 20742, USA
{yzyang, cteo, hal, yiannis}@umiacs.umd.edu

One method for image captioning …



CNN Visual Features Extraction

Object Detection $\{\langle o_i, l_i \rangle\}$ Layout Encoding

RNN Language Model

a group of people are flying a kite in the beach

Obj2Text: Generating Visually Descriptive Language from Object Layouts
Xuwang Yin, Vicente Ordonez. Empirical Methods in Natural Language Processing.
EMNLP 2017. Copenhagen, Denmark. September 2017. [pdf] [arxiv] [code] [bibtex]
(~Oral presentation)

Enriching Video Captioning with Commonsense Descriptions

Standard Caption

A band is playing at a concert

Generated Commonsense Descriptions

Intention

to entertain the audience

Effect

will get standing ovation

Video2Commonsense Dataset

- Videos of agents doing actions
- Annotations for intentions of agents, effect of actions

Benchmarking Video Captioning

- Existing models found lacking
- Guidance from commonsense knowledge bases required

V2C

VIDEO TO COMMONSENSE

Fang*, Gokhale* Banerjee, Yang, Baral. "Generating Commonsense Descriptions to Enrich Video Captioning" *(EMNLP 2020)*

Video2Commonsense
Enriching Video Captioning with Commonsense Descriptions

Conventional Caption

Group of runners get prepared to run a race.

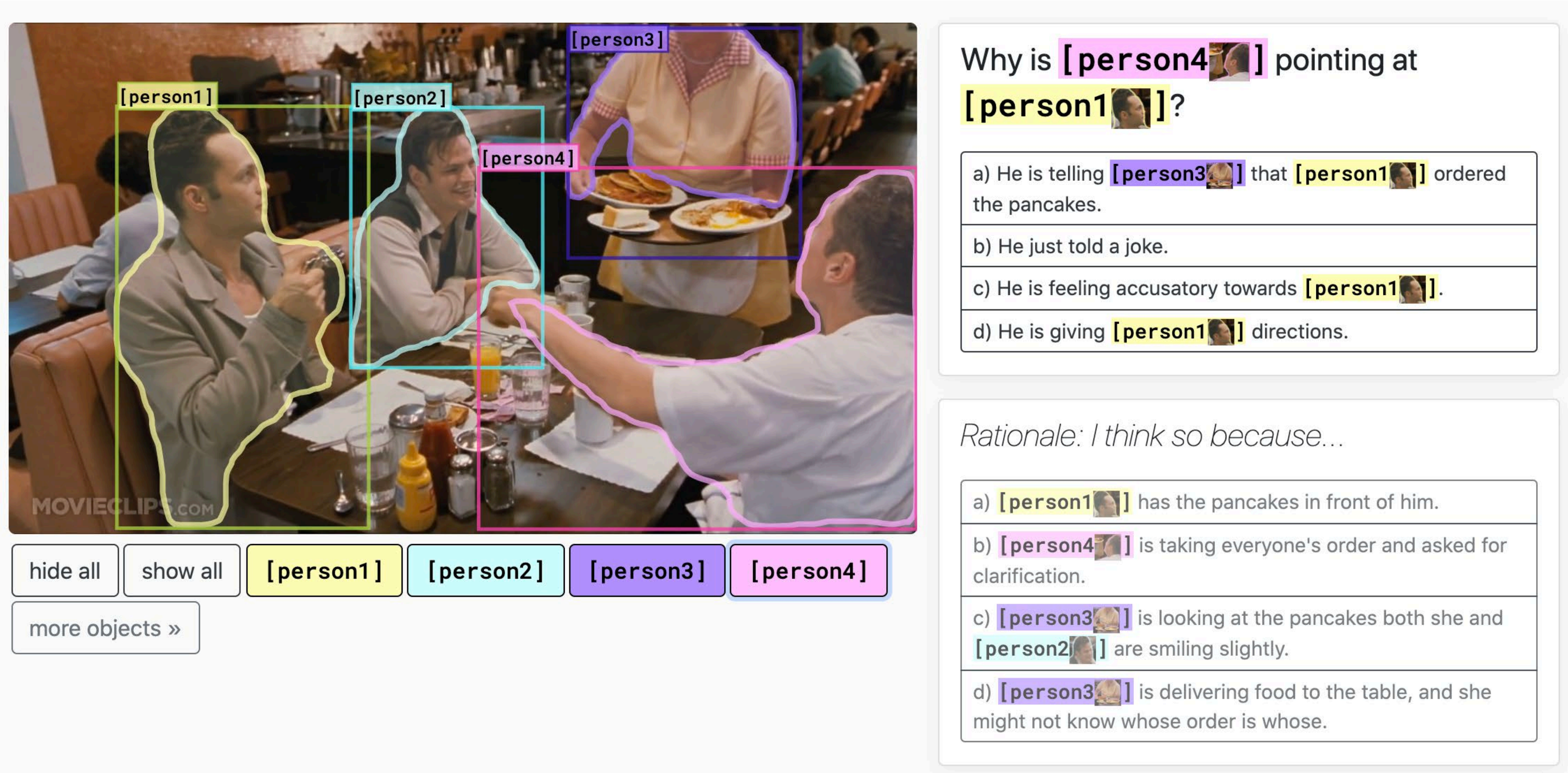
Commonsense-Enriched Caption

In order to win a medal, a group of runners get prepared to run a race. As a result they are congratulated at the finish line. They are athletic.

Commonsense Question Answering

What happens next to the runners? { Are congratulated at the finish line
become tired

Visual Common Sense Reasoning



Why is [person4] pointing at [person1]?

a) He is telling [person3] that [person1] ordered the pancakes.

b) He just told a joke.

c) He is feeling accusatory towards [person1].

d) He is giving [person1] directions.

Rationale: I think so because...

a) [person1] has the pancakes in front of him.

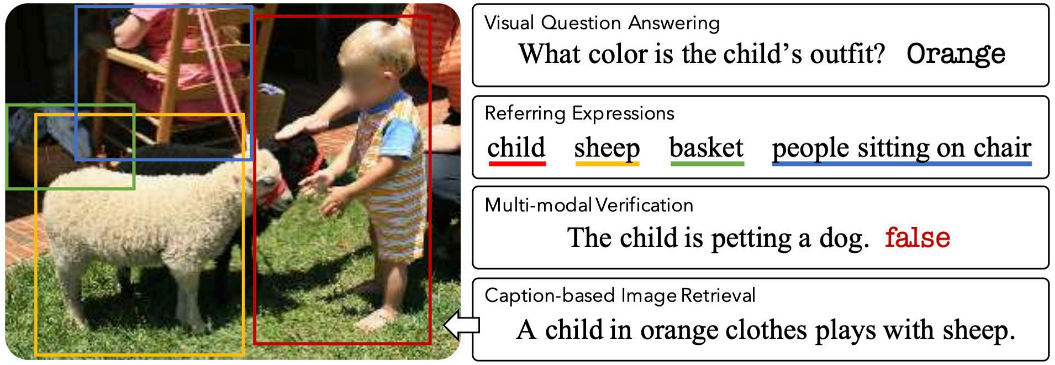
b) [person4] is taking everyone's order and asked for clarification.

c) [person3] is looking at the pancakes both she and [person2] are smiling slightly.

d) [person3] is delivering food to the table, and she might not know whose order is whose.

https://visualcommonsense.com/

Multi-task Learning / More General Models



Visual Question Answering
What color is the child's outfit? Orange

Referring Expressions
child sheep basket people sitting on chair

Multi-modal Verification
The child is petting a dog. false

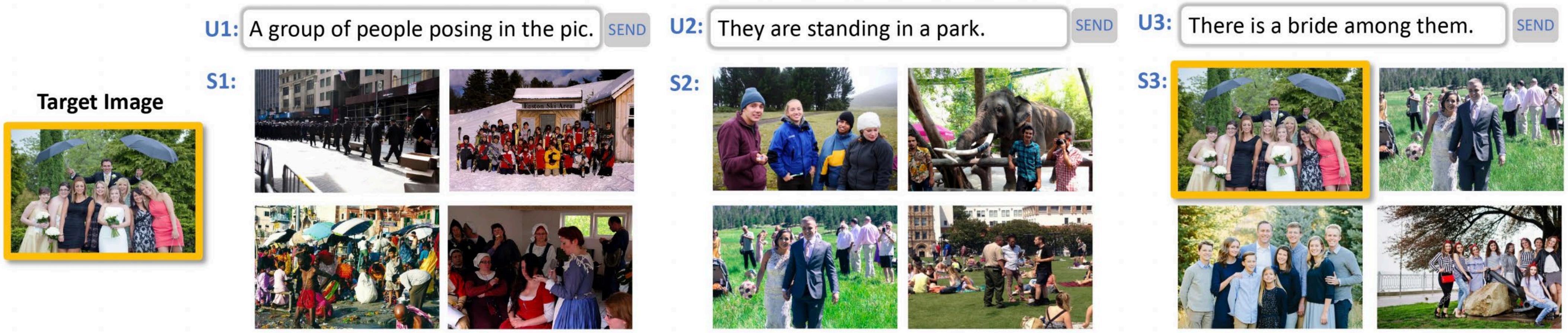
Caption-based Image Retrieval
A child in orange clothes plays with sheep.

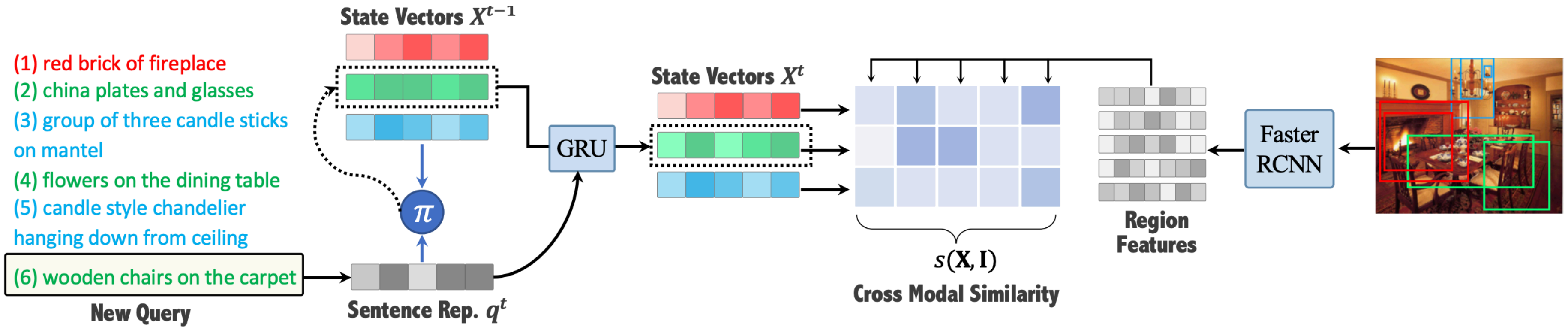
12-in-1: Multi-task Vision and Language
https://arxiv.org/abs/1912.02315

Salesforce DecaNLP
https://arxiv.org/pdf/1806.08730.pdf

Question	Context	Answer
What is a major importance of Southern California in relation to California and the US?	...Southern California is a major economic center for the state of California and the US....	major economic center
What is the translation from English to German?	Most of the planet is ocean water.	Der Großteil der Erde ist Meerwasser
What is the summary?	Harry Potter star Daniel Radcliffe gains access to a reported £320 million fortune...	Harry Potter star Daniel Radcliffe gets £320M fortune...
Hypothesis: Product and geography are what make cream skimming work. Entailment, neutral, or contradiction?	Premise: Conceptually cream skimming has two basic dimensions – product and geography.	Entailment
Is this sentence positive or negative?	A stirring, funny and finally transporting re-imagining of Beauty and the Beast and 1930s horror film.	positive

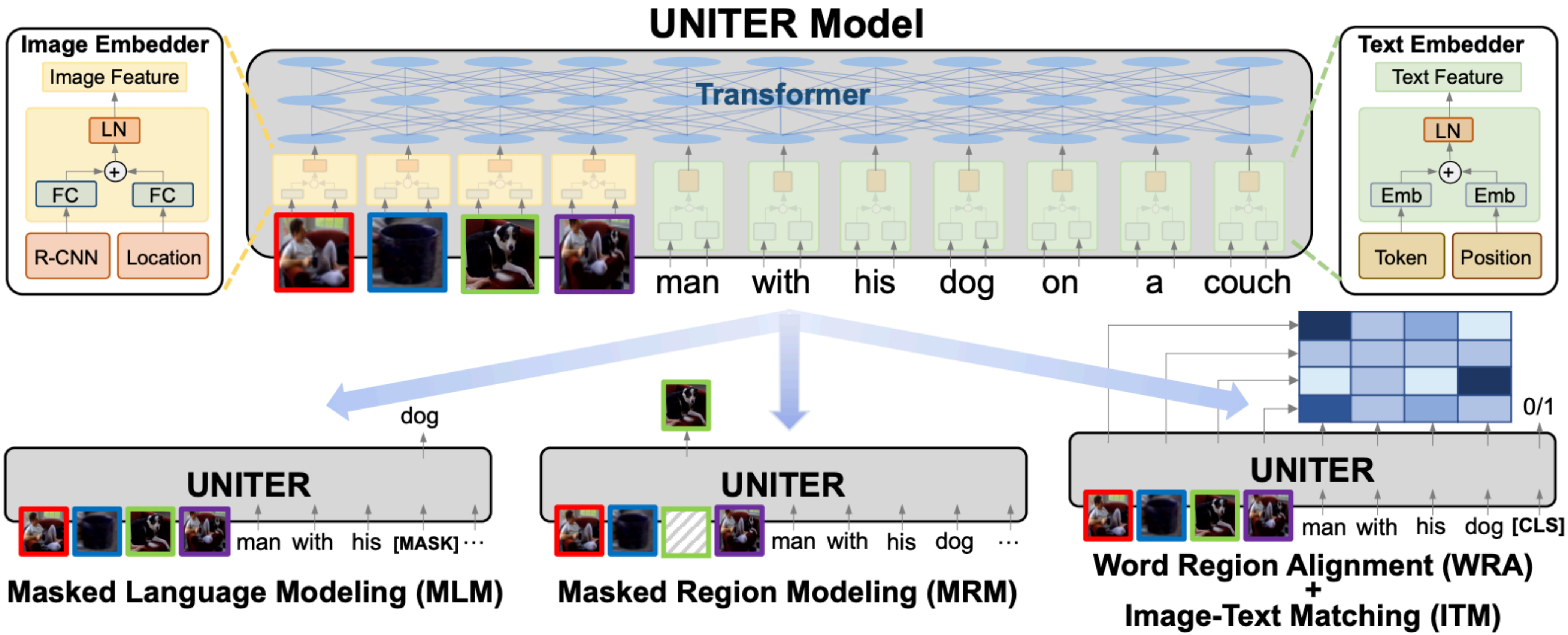
Interactivity + Language and Vision


Target Image
U1: A group of people posing in the pic. SEND
S1:
U2: They are standing in a park. SEND
S2:
U3: There is a bride among them. SEND
S3:

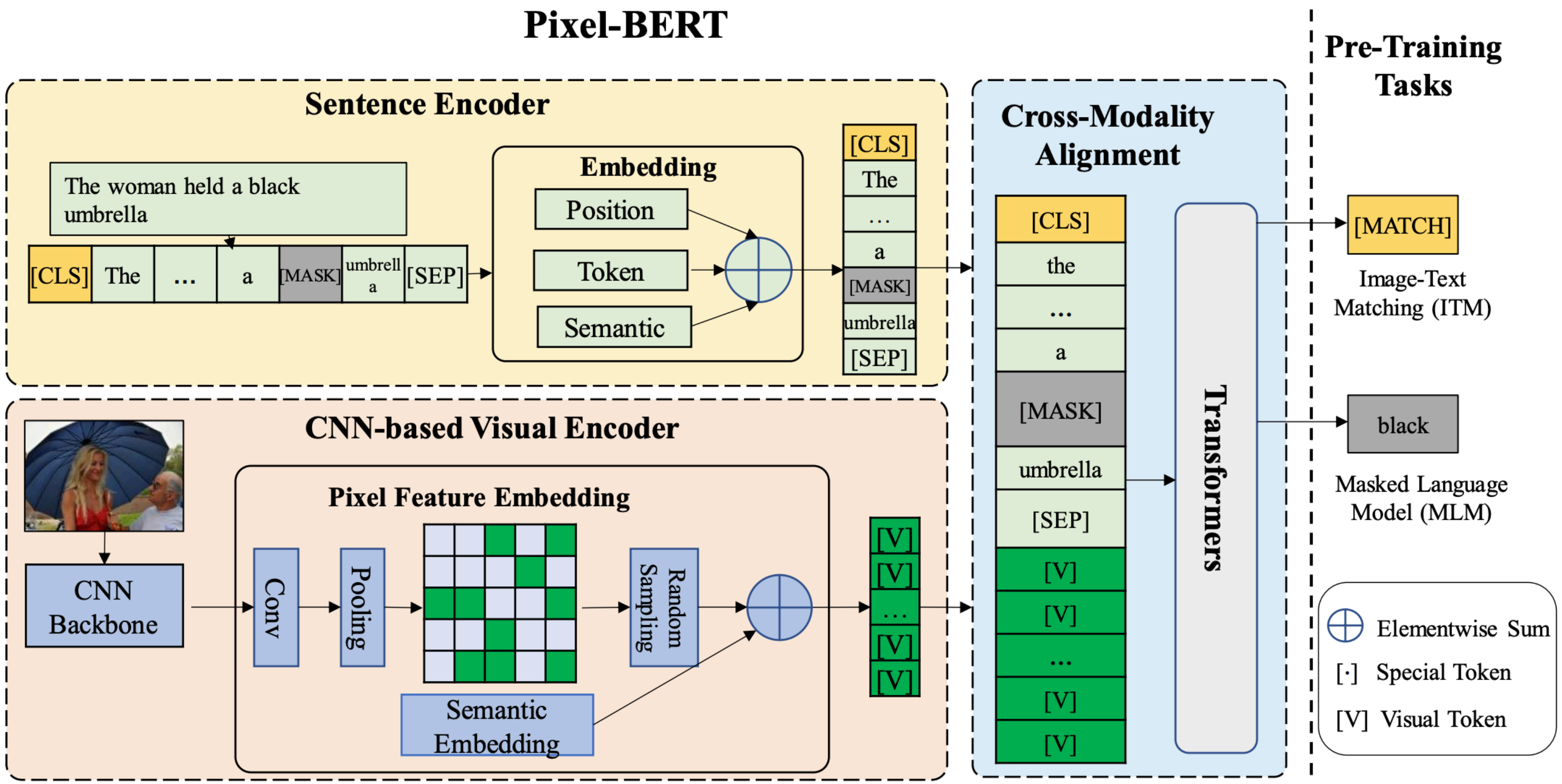

(1) red brick of fireplace
(2) china plates and glasses
(3) group of three candle sticks on mantel
(4) flowers on the dining table
(5) candle style chandelier hanging down from ceiling
(6) wooden chairs on the carpet
New Query
State Vectors X^{t-1}
π
Sentence Rep. q^t
GRU
State Vectors X^t
$s(\mathbf{X}, \mathbf{I})$
Cross Modal Similarity
Region Features
Faster RCNN

https://arxiv.org/abs/1911.03826

General models for Vision and Language - UNITER

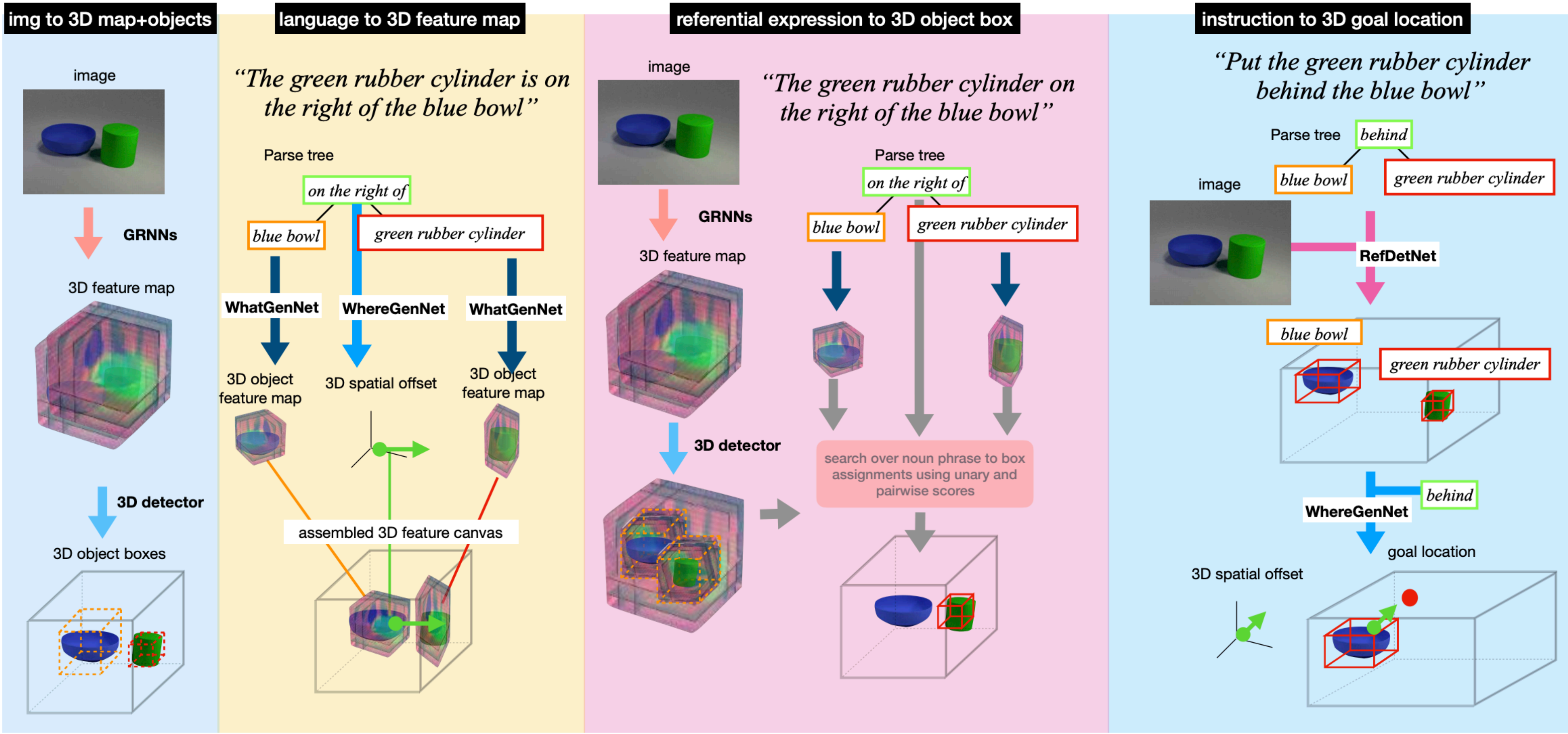


Grid Features – Pixel BERT



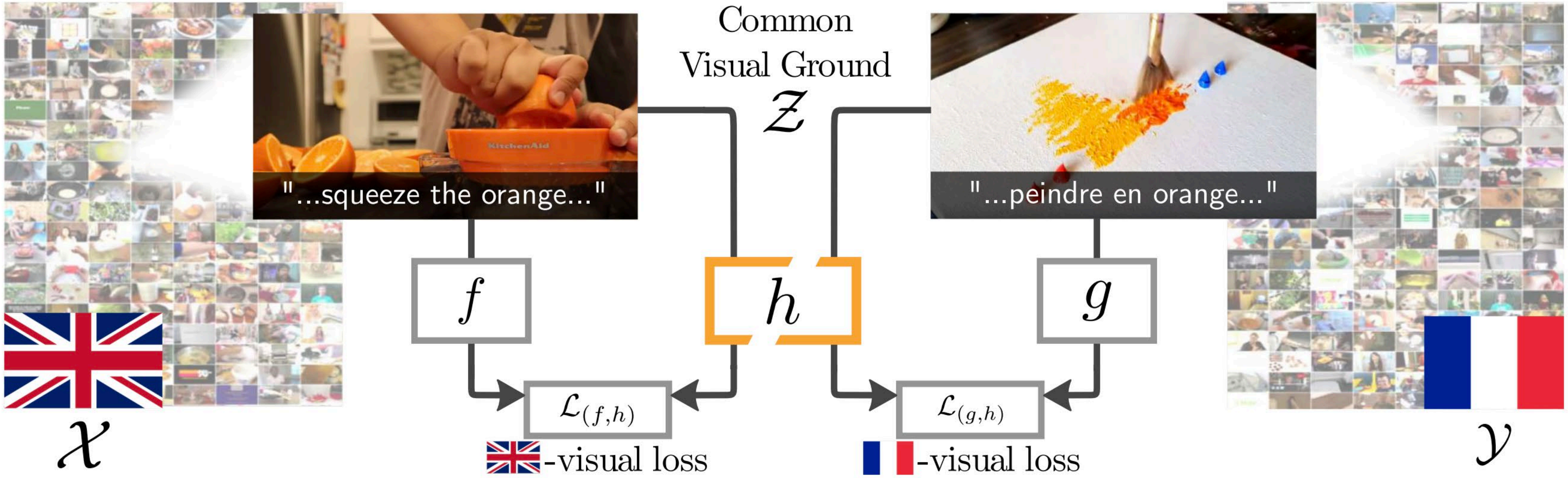
https://arxiv.org/pdf/2004.00849.pdf

Vision + Language + 3D



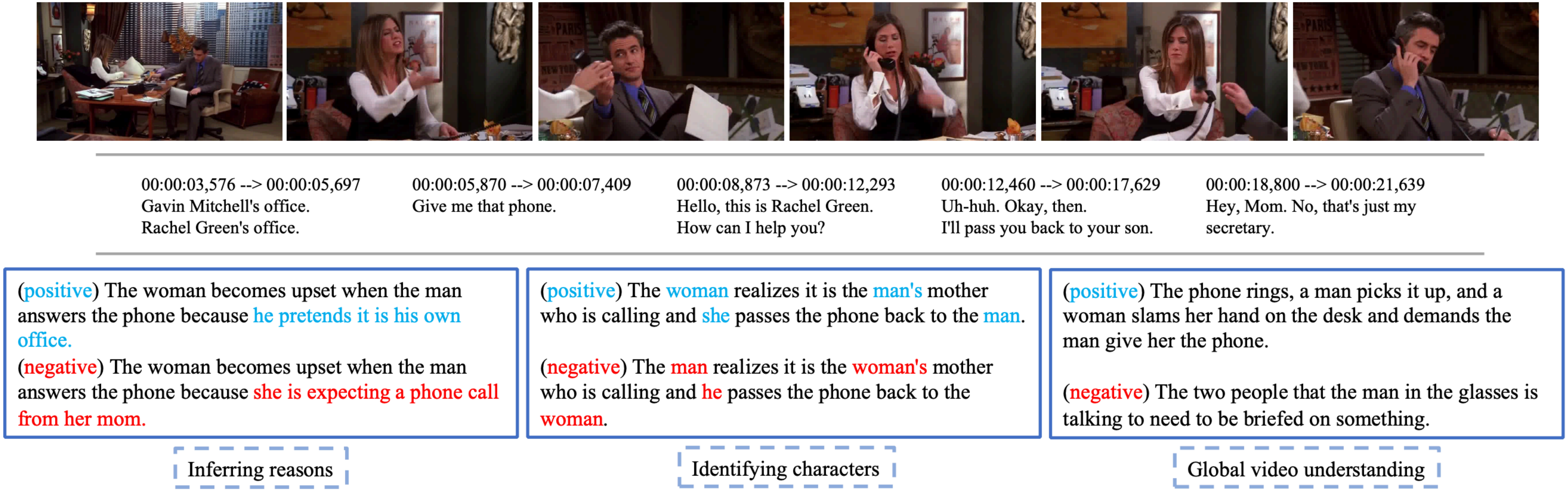
https://arxiv.org/abs/1910.01210

Multiple Languages and Vision



https://arxiv.org/abs/2003.05078

Video + Language Tasks



00:00:03,576 --> 00:00:05,697
Gavin Mitchell's office.
Rachel Green's office.

00:00:05,870 --> 00:00:07,409
Give me that phone.

00:00:08,873 --> 00:00:12,293
Hello, this is Rachel Green.
How can I help you?

00:00:12,460 --> 00:00:17,629
Uh-huh. Okay, then.
I'll pass you back to your son.

00:00:18,800 --> 00:00:21,639
Hey, Mom. No, that's just my
secretary.

(positive) The woman becomes upset when the man answers the phone because he pretends it is his own office.
(negative) The woman becomes upset when the man answers the phone because she is expecting a phone call from her mom.

Inferring reasons

(positive) The woman realizes it is the man's mother who is calling and she passes the phone back to the man.

(negative) The man realizes it is the woman's mother who is calling and he passes the phone back to the woman.

Identifying characters

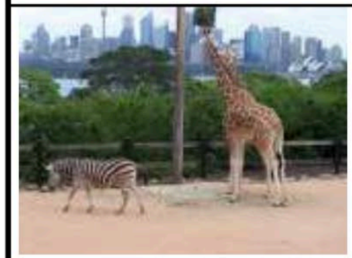
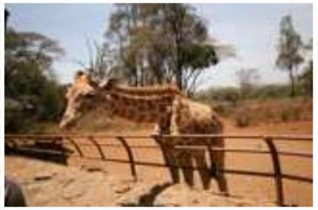
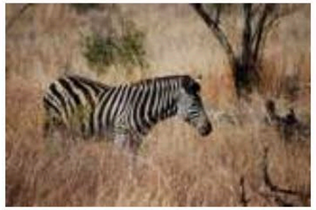
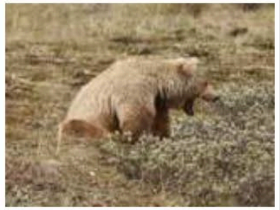
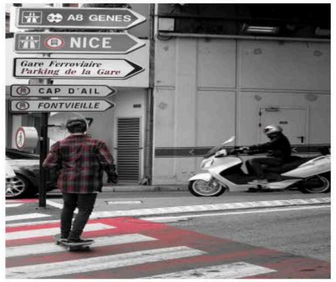
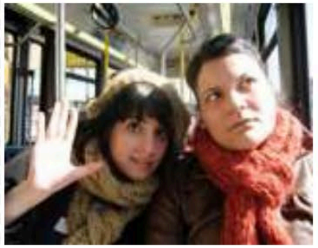
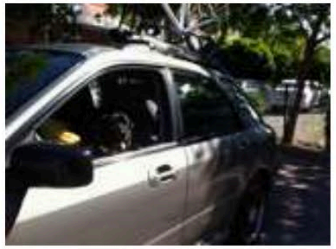
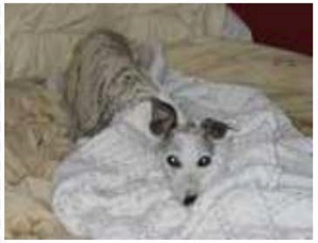
(positive) The phone rings, a man picks it up, and a woman slams her hand on the desk and demands the man give her the phone.

(negative) The two people that the man in the glasses is talking to need to be briefed on something.

Global video understanding

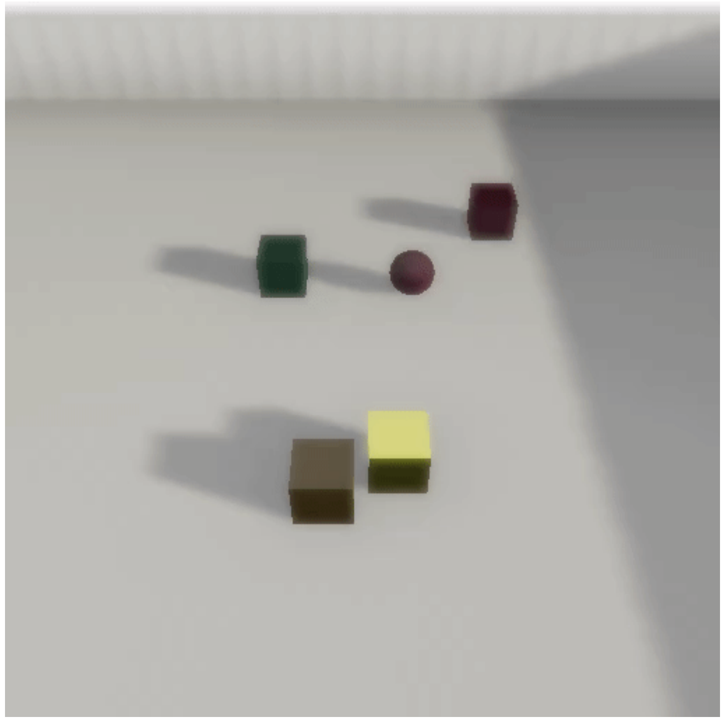
https://openaccess.thecvf.com/content_CVPR_2020/papers/Liu_Violin_A_Large-Scale_Dataset_for_Video-and-Language_Inference_CVPR_2020_paper.pdf

Counterfactuals in Vision and Language

Question Image	Counterfactual Questions	Counterfactual Images
 Is this in Australia?	1. Is the grass green? 2. Is there grass on the ground? 3. Are they standing on a green grass field? 4. Is the stop light green?	  
 What color is the person's helmet?	1. What color jacket is the girl wearing? 2. What color jacket is the person wearing? 3. What color is the jacket? 4. What color is the woman's jacket?	
 Where did the shadow on the car come from?	1. What kind of dog is this? 2. What type of dog is this? 3. What kind of dog is shown? 4. What is the breed of dog?	

https://openaccess.thecvf.com/content_CVPR_2020/papers/Abbasnejad_Counterfactual_Vision_and_Language_Learning_CVPR_2020_paper.pdf

Asking Counterfactual Questions to Reason about Physical Properties



Input Video

Counterfactual Question

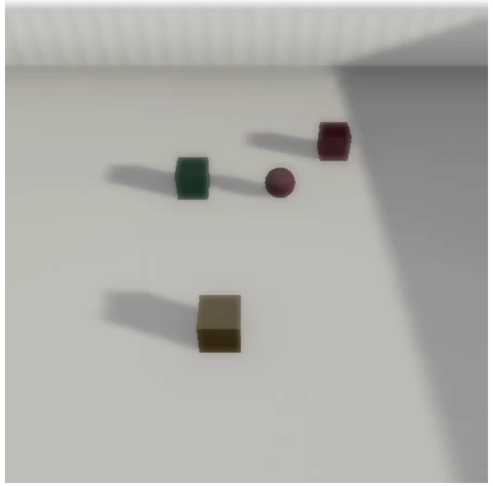
What will happen if the yellow cube is **removed** ?

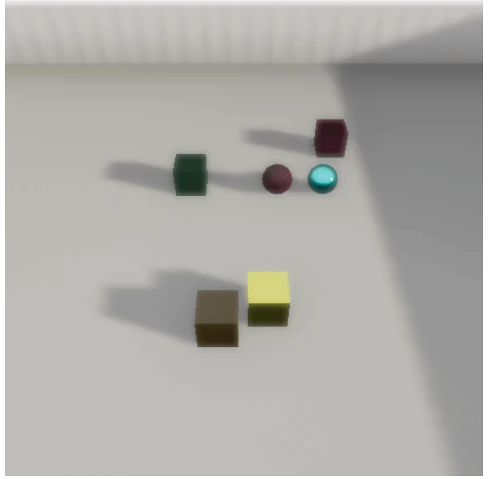
(A) Purple Cube will collide with brown cube

Planning Question

How can the collision between yellow and purple cube be stopped?

(A) **Add** teal sphere to the right of purple sphere





Effect of Action

My lab's focus: Perception & Reasoning with Robustness

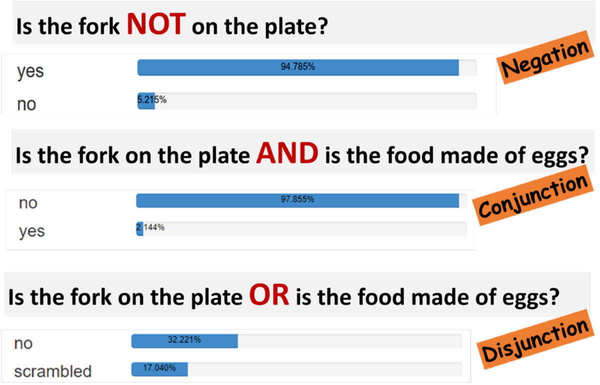
Robust Visual Reasoning (Visual QA, Video Captioning, V&L Inference)

V&L Robustness: Logical, Semantic, Spatial (use additional knowledge sources and sensors)

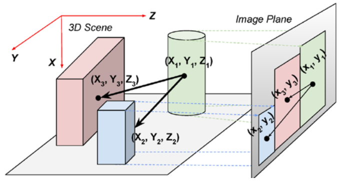
Is the fork **NOT** on the plate?

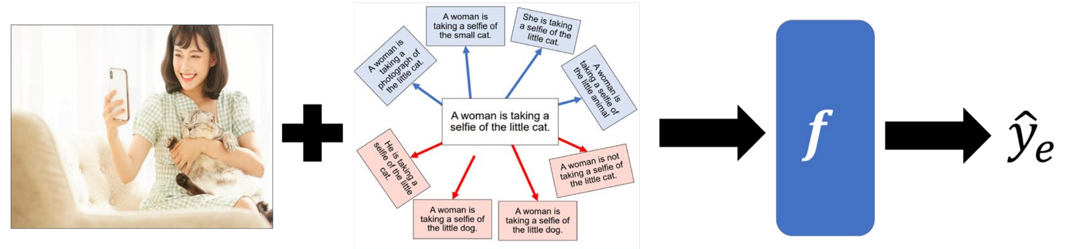
Is the fork on the plate **AND** is the food made of eggs?

Is the fork on the plate **OR** is the food made of eggs?



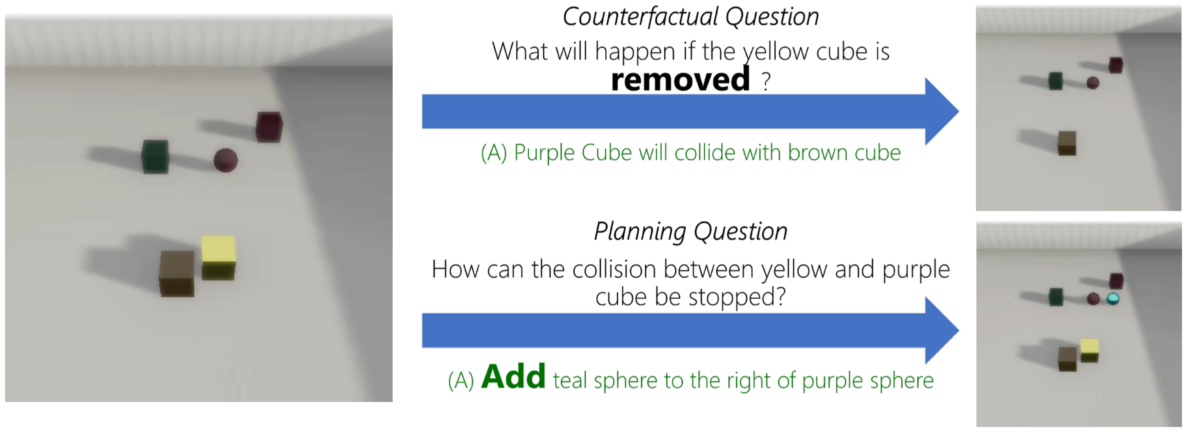
Question	Answer
Is that a giraffe or an elephant?	Giraffe
Who is feeding the giraffe *behind* the man?	Lady
Is there a fence *near* the animal *behind* the man?	Yes
On which side of the image is the man?	*Right*
Is the giraffe *behind* the man?	Yes





A woman is taking a selfie of the little cat.
A woman is taking a photograph of the little cat.
A woman is taking a selfie of the small cat.
She is taking a selfie of the little cat.
A woman is taking a selfie of the little animal
He is taking a selfie of the little cat.
A woman is taking a selfie of the little dog.
A woman is taking a selfie of the little dog.
A woman is not taking a selfie of the little cat.
f
$\hat{y}_e$

Understanding Agent Actions in Videos with Commonsense, Counterfactual and Physics-Based Reasoning



Counterfactual Question

What will happen if the yellow cube is **removed** ?

(A) Purple Cube will collide with brown cube

Planning Question

How can the collision between yellow and purple cube be stopped?

(A) **Add** teal sphere to the right of purple sphere

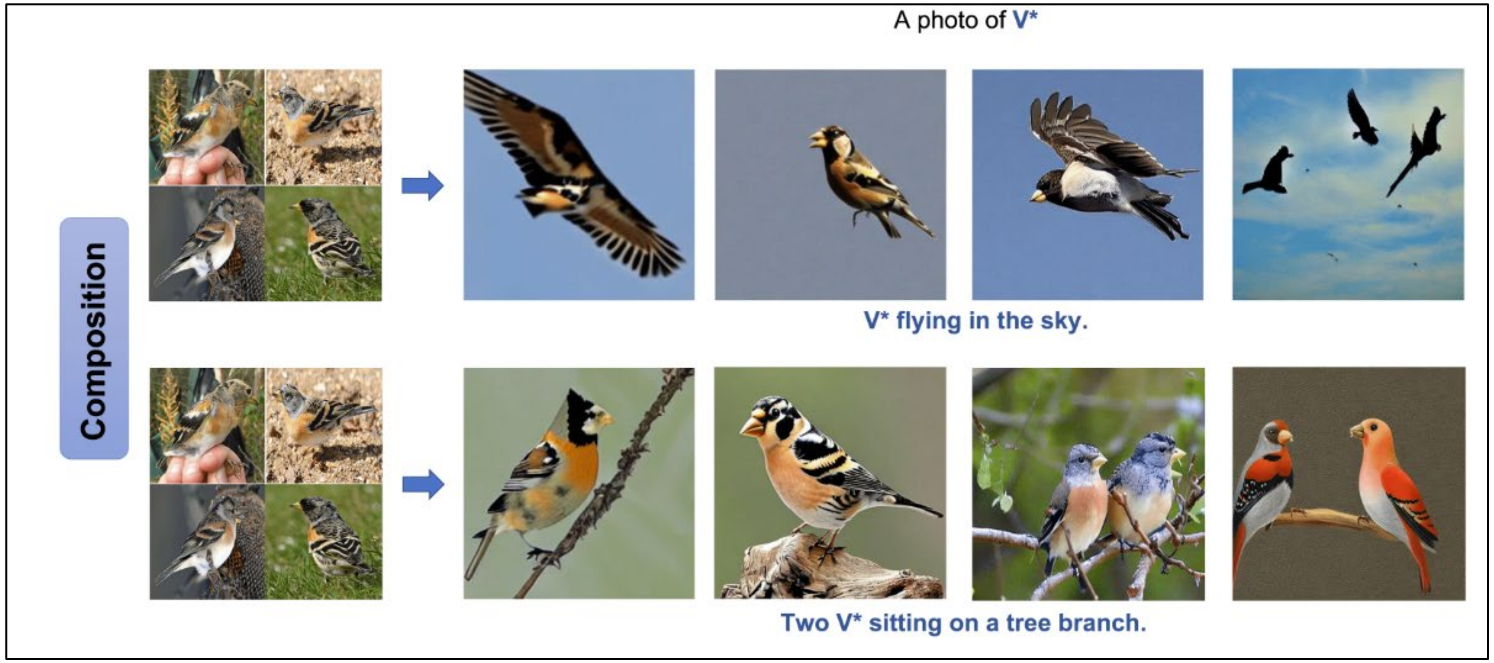
Conventional Caption	Group of runners get prepared to run a race.
Commonsense-Enriched Caption	In order to win a medal, a group of runners get prepared to run a race. As a result they are congratulated at the finish line. They are athletic.
Commonsense Question Answering	What happens next to the runners? { Are congratulated at the finish line become tired

Gokhale ECCV '20; Gokhale EMNLP'20; Gokhale ACL'21; Fang EMNLP'20; Banerjee ICCV'21; Patel EMNLP'22

Novel Vision+Language Concept Description

- OOD detection: detect novel (unseen / unknown) objects in videos

- Few-Shot Concept Learning
  - learn that concept
  - assign semantic meaning (in latent space)
  - Reproduce the concept (novel view synthesis)



Patel et al. AAAI 2024

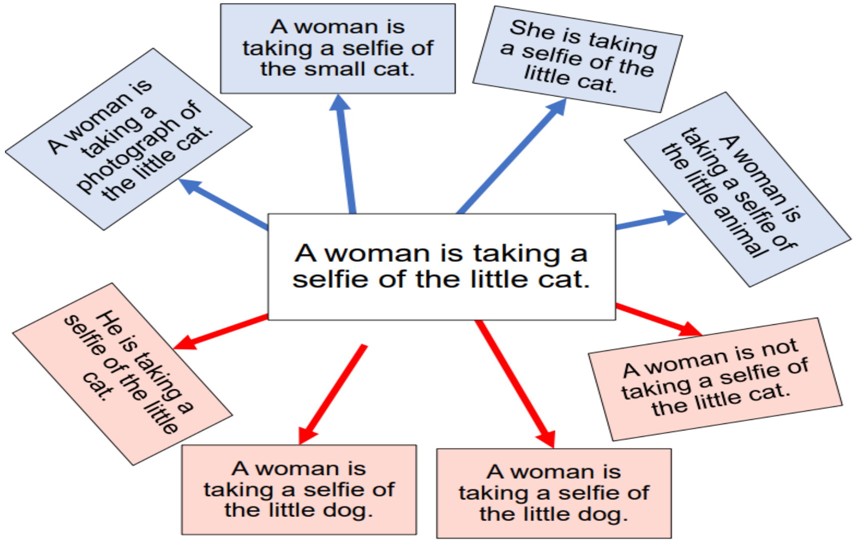
My lab's focus: Perception & Reasoning with Robustness

Natural Language as a Visual "Sensor"

Humans (ordinary/domain-expert) describe visual scenes in natural language
(e.g. English, Hindi, Chinese, Arabic)

Vision-Language Alignment helps for reasoning "beyond pixels"

Commonsense inferences crucial when some sensors malfunction/uncertain/compromised



A woman is taking a selfie of the little cat.

A woman is taking a photograph of the little cat.

A woman is taking a selfie of the small cat.

She is taking a selfie of the little cat.

A woman is taking a selfie of the little animal

A woman is not taking a selfie of the little cat.

A woman is taking a selfie of the little dog.

A woman is taking a selfie of the little dog.

He is taking a selfie of the little cat.

Conventional Caption	Group of runners get prepared to run a race.
Commonsense-Enriched Caption	In order to win a medal, a group of runners get prepared to run a race. As a result they are congratulated at the finish line. They are athletic.
Commonsense Question Answering	What happens next to the runners? { Are congratulated at the finish line become tired